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A S S I S T A N C E

TO FOUNDRY AND FORGE WORKS OF HEAVY MECHANICAL COMPLEX AT TAXILA

PAKISTAN

DP/PAK/86/025

Final Report

Prepared for

The Government of the Islamic Republic of Pakistan

by the

United Nations Industrial Development Organization

Based on the work of UNIDO experts, and the sub-contracted HPH Expert Team.

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Table of Contents

Explanatory Note

CI Foundry	-	Cast Iron Foundry
FFW	-	Foundry and Forge Works
F. Shop	-	Fettling Shop
HFF	-	Heavy Foundry and Forge, former name of FFW
HMC	-	Heavy Mechanical Complex
HPH	-	Hutmaszprojekt-Hapeko, Polish subcontractor
HP Shop	-	Hydraulic Press Shop
NDT	-	Non-Destructive Testing
NPD	-	National Project Director
PakSteel	-	Pakistan Steel Corporation in Karachi
QA	-	Quality Assurance
SEC	-	State Engineering Corporation
SM Shop	-	Steel Melting Shop
TOR	-	Terms Of Reference

ACKNOWLEDGEMENT

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Sincere thanks are addressed to Mr. Olivier Bovet, the Programme Officer of UNIDO Islamabad whose valuable support of and substantial assistance in execution of the Project were of such great help to the team in the achievement of the project objectives.

ABSTRACT

The Foundry and Forge Works (FFW) of the Heavy Mechanical Complex Ltd. located at Taxila was designed to produce large forgings and castings beyond the capability of existing operations within Pakistan , and also to undertake the complete local manufacture of certain heavy capital goods as well as essential spare parts for both public and private sector companies. Development of the current range of products has significantly reduced import and foreign exchange requirements.

Although much has been achieved. there are a number of areas within the production facilities which need upgrading in production technology in order to secure further development of the Company. Also, the reject rates and quality standards , in some instances, have been poor resulting in high costs and unreliable delivery performance.

The government of the Islamic Republic of Pakistan is keen to improve the working efficiency of its engineering units in the public sector. With this aim, a technical assistance project for the Foundry and Forge Works was approved by UNDP/UNIDO in May, 1990.

The main objectives of the project were:
- improvement in quality of forged and cast products,
- improvement in the supply of a large range of forged and cast products at specified quality level.

The main components of the project were:
- foreign expert services in various fields of foundry and forge operation,
- overseas fellowship programmes for FFW engineers,
- provision of essential quality equipment.

At the completion of the project, the following benefits to the Foundry and Forge have been noted:
- the current reject rate of finished products have been decreased by 7%, this corresponds to roughly estimated value of 700,000 US$ (related with present European prices),
- the material yield has been improved by 5% and this corresponds to estimated value of 400,000 US$,
- manufacturing technologies for various processes have been implemented and/or improved,
- technical capabilities of FFW personnel have been reinforced through intensive training at the shop-floor level.

This report presents the results of the activities of six experts, assigned to the project as the team representing the UNIDO subcontractor - the Polish Hutmaszprojekt-Hapeko S.A., (HpH).

A. INTRODUCTION

1. Background.

Heavy Foundry and Forge Ltd., (HFF) was recently absorbed by the Heavy Mechanical Complex (HMC) at Taxila as its Foundry and Forge Works (FFW). It began production as a commercial enterprise in 1978. The design, equipment, installation and technology were established with the assistance of the People's Republic of China.

After 15 years, the Foundry and Forge Works is still the only supplier within the country of large castings and forgings and it does not offer any substantial competition to other private and public plants. Nevertheless, the Government of Pakistan emphasizes the need for the manufacturing sector to become more technically competent, improving the quality of products and increasing efficiency and profitability.

The processes of the diversification of production into more complex products demanded by the manufacturing sector with a simultaneous increase in the supply of domestically produced goods is directly focused on reduction of the import costs, as well as on the development of the export of some end-products. In the last years, HMC/FFW accumulated significant knowledge and experience on the production technologies of various cast and forged products. However, the existing gap between present manufacturing techniques, as well as operational practices, and those in developed industrial countries seems to be very serious, limiting the end-product quality and development of the technical staff. Also it becomes evident that such situation may have serious implications on the output and financial performance of the Company.

2. Organization of FFW.

The present organization scheme of Foundry and Forge Works covers the following substantive productions departments:

- Steel Foundry - with electric arc and induction furnaces, hand and machine moulding along with heat treatment and finishing sections for the production of steel casting and ingots.
- Cast Iron Foundry - with induction and cupola furnaces, machine and hand moulding, producing castings up to 27 tons weight.
  Small non-ferrous castings are also produced at the Cast Iron Foundry.
- Hydraulic Press Shop - with 3150 tons capacity press for open die forgings along with a 10 ton manipulator and furnaces for preheating and heat treatment.
- Forge Shop - with equipment for both open and closed die forging, heat treatment and finishing facilities for the production of parts for the automobile industry, and grinding media for cement plants.

- Service facilities - such as Pattern Shop, Machining and Fabrication Shops, Maintenance Section and Materials Testing Laboratory.

The designed annual capacity is:

- Steel castings	- 6500 tons
- Steel ingots	- 38000 tons
- Cast iron castings	- 5000 tons
- Non-ferrous castings	- 80 tons
- Forgings	- 4600 tons

- Grinding media - 2500 tons

At present, the two-strand continuous caster for square billets is being installed at the Steel Foundry. A possibility to add some modern secondary metallurgy equipment including a ladle furnace, vacuum degassing unit and electro-slag remelting plant has been recently taken into consideration by HMC/FFW management.

3. Situation at FFW before implementation of the project.

Owing to the total lack of financial data concerning either the production cost or product scrap rates, it has not been possible to quantify the earlier achieved results and thus the situation has been described in qualitative form only.
The main areas, requiring prompt improvement have been identified namely:

- **Steel open die forgings:** high evidence of surface and internal defects, low ingot/forging yields, excessive machining allowances, high reject rates and customer complaints caused by poor steelmaking process control, inadequate practice of ingot pouring, poor forging and heat treatment control, inappropriate raw materials.
- **Steel castings:** high rate of casting defects, poor surface conditions, excessive machining allowances, remedial operations and long delivery periods, defective weld repairs and defective heat treatment operations caused by poor steelmaking process control, inappropriate quality of raw materials, particularly moulding sands, inexperience in certain casting and moulding design and practices, incorrect heat treatment and weld repair procedure applications.
- **Die forgings:** inconsistent product quality and customer complaints caused by poor quality of steel and inaccurate control of heat treatment processes.
- **Quality assurance:** lack of quality performance data, erratic product quality and inconsistent product acceptance caused by lack of overall integrated quality system , lack of detailed process standards, imprecise acceptance standards for raw materials and finished products.

Additionally, the modification and development of the company cost control systems as well as the production of certain non-ferrous castings designed for the sugar industry have been identified as the areas requiring comprehensive advisory services and consultations in order to streamline and consolidate the measures taken by FFW so far.

4. UNIDO's input.

The project entitled "Assistance to Foundry and Forge Works of Heavy Mechanical Complex Ltd. at Taxila" was approved by UNDP/UNIDO in May, 1990.
The main components of the project included:

- Foreign expert services	US$ 421.700
- Overseas training of FFW engineers (Annex 4)	US$ 87.600
- Expendable and non-expendable equipment for quality control (Annex 5)	US$ 180.000
- Sundries	US$ 5.000
TOTAL	US$ 694.300

All the quality control equipment envisaged to be supplied has been received at FFW.

The details regarding experts' services are given below:

POST	FIELD	man/months
11-01	Steelmaking	6
11-02	Moulding and coremaking practice	6
11-03	Methods engineering for medium/heavy steel castings	6
11-04	Heat treatment and weld repairs of forgings and castings	4
11-05	Free forging	4
11-06	Non-destructive testing techniques of forgings and castings	2
11-07	Quality assurance system, standards and data recording	6
11-08	Manufacture of cast iron rolls for steel re-rolling industry	2
11-09	Modification and development of cost control system	6
11-10	Manufacture of non-ferrous castings	1

The experts against the posts 11-02, 11-03 and 11-09 were selected through standard UNIDO procedures and were fielded in the Project Site independently of the sub-contractor. The results of their work have been presented in the separate terminal reports.

The expert against the post 11-10 was appointed by UNIDO in a result of FFW request, agreed during the Tripartite Review Meeting of the project held in Islamabad in November,1992.

Six experts (posts 11-01, 11-04, 11-05, 11-06, 11-07 and 11-08), subcontracted through the Polish Hutmaszprojekt-Hapeko S.A (HPH) were fielded simultaneously as a team but all the project expert missions were properly co-ordinated irrespective of the contractual modality.

The initiation of expert activities had been preceded by a short mission to the Project Area undertaken by the Contractor Team Leader and UNIDO Chief Technical Advisor in December, 1991. The objective of their mission was to formulate - in consultation with the counterparts - a detailed work-plan and time table for the experts' services.

The experts' work programmes which had been earlier agreed with the Team Leader suffered modification after the arrival of the team to the Project Site and by the end of each mission. In fact, some changes consisted in re-setting the priorities of subjects of experts' services considered by FFW as of special importance.
The programme of experts' activities was completely implemented in the

course of three split missions which took place between 15 February, 1992 and 11 April, 1993. The revised project schedule is attached as Annex No.6. The project objectives were achieved thanks to the effective collaboration with and logistic support of the counterpart staff.

B. PROJECT OBJECTIVES.

The immediate objective of the project was to improve the quality and increase the output and reliability of supply of open die forgings and medium/heavy steel castings through the introduction of improved technology and the training of the personnel at the shop-floor level.
Special attention was required for the manufacturing technologies for essential spare parts for Pakistan Steel Corporation (PakSteel). It was expected, at the termination of the project, that rejections would be below 5% and production would no longer be substandard and would meet the requirements of the clients. It was further expected that the yield of ingots/forgings/finished products would be improved up to generally acceptable limits. The above mentioned aims had to be supported by formulation and installation of integrated quality assurance systems, incorporating quality assurance procedures in all the manufacturing processes within FFW with the relevant manuals, standards for testing and acceptance of raw materials and major products as well as suitable data recording systems.

A supplementary problem, considered to be of special importance for FFW, was to put into operation the manufacture of chilled cast iron rolls for the steel re-rolling industry. It was required to recommend production methods, define requirements regarding production inputs and provide detailed manufacturing instructions for an agreed range of products.

C. DUTIES OF PROJECT PERSONNEL

The experts assigned to the project represented a multidisciplinary team , consisting of six engineers having a very comprehensive industrial experience and relevant educational background. The posts of experts, as defined by the job descriptions, were corresponding to the following fields of specialization:

- steelmaking technology,
- heat treatment of metals,
- forging of steel,
- non-destructive testing techniques of metal parts and pieces,
- quality assurance and control in steel industry,
- manufacture of rolls for steel works.

The final version of the duties of the project personnel was agreed upon consultation with the National Project Director, the General Manager of FFW and conversations with the counterparts. The duties, presented in the form of detailed work-plans have been drafted in accordance with the priorities defined by FFW and specialization of each individual expert. Consequently, the six work-plans presented by the team have been based on the specific subjects of services/consultations assigned to each of experts namely:

- Team Leader: Expert in steelmaking
  - melting and refining of various steel grades,
  - pouring of ingots/castings,
  - implementation of improved steelmaking techniques/practices,
  - improvement of ingot moulds design,
  - recommendation of specifications regarding steelmaking inputs,
  - elaboration of technological instructions,
  - co-ordination of the team activities,
  - final reporting.

- Expert in heat treatment
  - elaboration of heat treatment technologies for achieving required mechanical properties and microstructural specifications for different end-products,
  - supervision of heat treatment of forgings and castings,
  - elaboration of technology for weld repairs of casting defects,
  - improvement of the heat treatment processes for parts for automobile related industry.

- Expert in forging
  - supervision of forging operations,
  - introduction of more efficient forging technologies to achieve improved end-product quality, increased material yield and reduced production costs,
  - recommendations regarding temperature ranges, indicating heating rates, holding times etc. for forging processes of various steel grades,
  - elaboration of adequate heat treatment to reduce hydrogen content in steel (cooling after forging).
  - design of new, improved tooling in order to increase the efficiency of the forging operations.

- Expert in non-destructive testing
  - evaluation of current non-destructive testing (NDT) techniques for steel castings and forgings and implementation of necessary improvements,
  - elaboration of NDT acceptance standards for major end-products,
  - assistance to the counterpart staff in the commissioning of the NDT equipment supplied under the project.

- Expert in quality assurance
  - preparation of detailed quality assurance procedures related to all the manufacturing processes within FFW,
  - recommendation of standards and specifications for production inputs (in conjunction with other experts),
  - recommendation of acceptance specifications for major cast and forged products,
  - assistance in drafting the quality assurance manuals,
  - design of a 'quality data recording and information report' system.

- Expert in rollmaking

  - estimation of the market demand for chilled cast iron rolls of weight 500-2000 kgs,
  - recommendations for appropriate manufacturing methods,
  - selection of production inputs.
  - preparation of technological instructions,
  - assistance/supervision during the start-up period of roll manufacture.

D. SCOPE OF TECHNICAL SERVICES

The services provided in accordance with the project document were directly or indirectly aimed at improvement of the FFW product quality and at strengthening of the capabilities of technical personnel. A triple function of the services was designed to be achieved, namely:

- technical, due to its inter-relation with various aspects of manufacturing processes,
- financial, because of its impact on the lowering the cost of production,
- complementary, to consolidate the measures already taken by FFW before implementation of the project.

Assistance and advisory services have been rendered through and at various managerial levels so as to secure an effective exchange of information and to formulate proper conclusions. Day-by-day consultations, interviews and discussions were commonly applied. Whenever possible, demonstration of the techniques recommended by the experts has been utilized for better understanding of the 'know-hows' presented. Discussions and consultations on specific manufacturing methods were immediately complemented with the relevant documentation prepared by the experts.

The documentation, of which a complete set is an integrated part of this report, was produced in the form of information sheets consisting of various consecutive sections, such as:

- information or comments on some "ad-hoc" identified issues,
- guidelines on newly modified techniques, technologies, procedures etc., and/or concrete technological processes recommended to be employed,
- theses for discussions covering deficiencies or critical factors affecting the course of production processes, functioning of equipment etc...

Engineering drawings, simple sketches, diagrams, lay-outs etc., have been also included into the materials deposited with the technical staff of FFW. Upon the request of the counterparts, a set of specifications together with detailed technical offers regarding the equipment suggested to be installed within the production departments of the Company have been presented by the experts.

E. PROJECT ACTIVITIES

Irrespective of the detailed description of technical services rendered by the team, the activities carried out within the project framework can be summarized as follows:

1. General and individual meetings.

An introductory meeting with the counterpart staff was called by the NPD upon the arrival of the team to the Project Site. Extensive discussion on the scope and substance of services took place during the meeting. Similar meetings were held every week, in order to review the results of the experts' activities and, to exchange views on follow-up actions recommended to be taken by FFW.

2. On-the-job training.

This type of training was arranged particulary for the group of foremen/workers directly involved with essential manufacturing processes, i.e. steelmaking and forging.

3. Discussions

Discussions on the draft documentation produced by the team, as well as on some common technical problems, were held individually by each of the experts. Practical conclusions for follow-up actions have been formulated based on these discussions.

SUBSTANCE OF TECHNICAL ACTIVITIES

The technical activities of the subcontracted team have been based on an urgent demand for consultations on specific questions in the areas within which the possibilities of upgrading of the Plant performance have been early identified by the counterparts. Both the substance of activities undertaken and the nature of UNIDO assistance to FFW are reflected in the "Monthly Progress Reports" and in the documents (i.e. "Information Sheets" and other relevant enclosures) attached to this report. In order to highlight the multi-disciplinary nature of the services rendered by the experts, some of the problems analyzed are briefly reported below:

Quality of steel

The improvement of steel cleanness was the most important factor influencing the quality of forged and cast products. The changes implemented within existing steelmaking practices have been supported by an appropriate theoretical background together with the respective operational instructions and expert activity on the shop-floor-level. Guidelines for the melting of various steel grades have been prepared for each particular case.

Forgeable ingots

After a close examination, a set of recommended ingot types, ensuring correct properties of steel, has been selected from all the ingots used so far. A number of the ingot moulds has been re-designed in order to improve their geometry. The problem of an appropriate ingot choice as related to the required forging reduction ratio, and to better material utilization has been emphasised with reference to each newly elaborated technology.

Anti-hydrogen heat treatment

A procedure for hydrogen removal by means of a thermal diffusion process carried out after forging has been elaborated and successfully implemented. Heating times and temperatures have been established separately for different cross-section areas of forged parts, with reference to the chemical composition of the steel and its sensitivity to hydrogen content. The importance of this practice has been clearly demonstrated by the number of forgings rejected in the past due to flakes and the improvement obtained by using the correct procedures.

Heating of ingots/forgings

The procedures for heating forging ingots and for the re-heating of forged material, as related to the different steel compositions have been established. In view of difficulties detected, an examination of the operating conditions of the heating furnaces at the HP Shop was carried out. This has resulted in a number of recommendations focused on improving gas burner efficiency; the necessary repairs of refractory linings; the modification of waste gas exhaustion systems; the establishment of an appropriate furnace atmosphere etc.. As a consequence, the efforts taken towards obtaining a better control of the re-heating operations have given very positive results.

Medium/heavy steel castings

The co-operation of the team with UNIDO experts under posts 11-02 (moulding and coremaking - Mr. Kazimierz Pniewski) and 11-03 (foundry methods engineering - Mr. Tadeusz Ryterski) fielded at FFW at the same time, was aimed at obtaining the improvement of steel quality through the modification and supervision of steel refining and mould pouring operations.

Specifications of raw materials

A complete set of recommended specifications, based on the international standards which may be applicable for FFW, has been prepared. Useful information facilitating the choice of appropriate materials for individual production processes has been included.

Quality Assurance System

The Quality Assurance Manual, based on the ISO standards of 9000 series along with adequate procedures covering all the manufacturing processes has been drafted. The importance of the installation of the system for quality data, and the information reporting system was particularly emphasized during the discussions held on the subject matter.

Acceptance conditions for FFW forged products

Detailed outlines for acceptance of major FFW products, such as spares for sugar plants, spares for PakSteel and others, with reference to the results of ultrasonic inspections have been drafted. The documentation produced was supplemented with recommendations concerning the execution of ultrasonic tests of forgings.

Spare parts for PakSteel

The experts were directly engaged in the successful manufacture of such critical spares parts as couplings and spindle heads for rolling mills, forming rolls, pinch rolls etc.. In order to meet the requirements of rollers for the continuous slab casters, the documentation describing the whole manufacturing process in detail, and indicating all critical points which may have an influence on the final result has been prepared and talked over with the counterpart staff. However, the manufacture of the rollers could not be carried out during the experts' stay in the Project Area due to the lack of confirmed job orders which were expected be obtained from PakSteel.

Quality control equipment

Assistance was provided for the commissioning of the equipment supplied under the project. Amongst others, a method of steel sampling for the analyzers of gases dissolved in steel has been proposed and implemented. Calibration of the crack depth measuring instrument has been carried out. On-the-job training of the technical staff for the work with a new ultrasonic flaw detector was arranged. Additionally, necessary repairs and maintenance of NDT equipment have been executed by the expert.

Die forgings for automobile industry

The expertise concerning the review of existing heat treatment practices for production of gear wheels and pinions as well as evaluation of raw material input (imported low carbon, and low alloy case-hardening steel) quality have been carried out. This led to useful conclusions to be formulated, together with a number of recommendations as to the future actions to be taken..

Production programme for HP Shop

This information has been prepared for the Sales & Marketing Department of HMC in order to facilitate a selection of job orders for hydraulic press-3150 tons. The scope of this programme is as follows:

- dimensions and geometry of forgings,
- division of steel grades according to their content of alloying elements and forgeability classes,
- state of delivery and kind of required heat treatment,
- the range of acceptance examinations required to be carried out.

Precise dependencies between the technical equipment of HP Shop and the existing production facilities of Steel Melting Shop at the present time have been stressed.

Improved tools and tackles for production

A number of sketches, drawings etc., including tools for shaping and other equipment for free forging, hand tools for steelmaking as well as all necessary equipment for the chilled cast iron rolls production has been prepared and supplied to the counterparts. A solution to a problem concerned with upgrading the shaft type heat treatment furnaces at HP Shop has been suggested. The replacement of existing furnace covers with a less complicated system has been proposed. Guidelines for a general overhaul of the electric arc furnaces at the Steel Foundry have been prepared. Action to be taken, regarding the ways of modifying the furnaces along with possibilities for the installation of modern ladle metallurgy equipment have been discussed in detail with the concerned staff.

Manufacture of cast iron rolls

Recommended production methods have been supplemented with a set of detailed technological instructions.

F. PROGRESS MADE

1. Before the implementation of the project, the Foundry and Forge Works of HMC was facing serious problems of rejection of open die forgings caused by internal and surface defects, these being mostly of metallurgical origin.

   The reject rate was 10% with a further 5% passed conditionally (forgings re-classified for less important products).

   The distribution of defects, as observed at that time, is found in the Annex. No.8 of this report.

   Changes implemented by the experts within steelmaking, forging and heat treatment practices have reduced the reject rate to the internationally accepted limit.

   Till the date of the UNIDO/HPH team departure, about 3000 tons of liquid steel have been produced for making of forgeable ingots. 135 melts of various steel grades, carbon and alloy construction steels, hot work tool steels and high manganese steels were directly supervised by the steelmaking expert on the shop floor.

   Out of the total production of forged products, to the date of departure of the team some 60% have been processed into finished products.

   The current reject rate of finished products is below 3%. As compared with the Annex No.8, the current distribution of the forging defects is as follows:

   - 80% - surface defects resulting in losses due to additional machining operations (observed mostly in July, August and early in September, 1992),
   - 15% - porosity,
   - 5% - non-metallic inclusions.

Internal cracks, caused by an excessive hydrogen content have not been observed. Thus the newly recommended practice of heat treatment has reduced hydrogen dissolved in the steel below 2 ppm. The regular tests concerning the determination of oxygen and nitrogen contents in steel has indicated satisfactory results, i.e. below 70 ppm of (O) and about 100 ppm of (N).

2. The forging technology transferred to FFW has also resulted in an improvement of 5% in the ingot to forging material yield. However, this cannot be determined precisely since the yield for individual forgings may vary within the range 40-70% and the individual value depends on the actual forging production programme. Further improvement is expected after full implementation of the recommendations related to the ingot moulds.

3. The forged products made under supervision of the experts team were the following:

   - sugar mill shafts of diameter up to 600 mm,
   - spindle heads and couplings for rolling mills (PakSteel),
   - pinch rolls (PakSteel),
   - forming rolls for hot strip rolling mill (PakSteel).
   - rollers of various diameters (PakSteel),
   - drive shafts,
   - intermediate shafts,
   - pinion shafts,
   - pressure feeder shafts,
   - pump blocks,
   - die blocks,
   - tail bars,
   - punches,
   - flanges,
   - sprockets,
   - railway axles,
   - forged bars of various dimensions.

4. The manufacture of the slab caster rollers for PakSteel was considered to be of special importance for FFW in view of future co-operation between the two companies.
   In November 1992, PakSteel was visited by the NPD and the Team Leader with the aim of revising the manufacturing technology for the rollers as proposed by the team. During the discussion, the quantity of rollers to be produced in January, 1993 had been precisely determined.
   Unfortunately, PakSteel had not ordered the rollers before the end of the last experts' mission and in view of anticipated production costs, the Management of HMC/FFW did not agree to start the production without a firm order.

   The production of shearing knives for PakSteel has not been started because of the same reason, as mentioned above.

5. Along with improvement of steel quality, that of medium/heavy castings has also been improved.

   The frequency of castings defects such as porosity and shrinkage as well as surface cracks has been reduced.

The experts participated in melting and refining of steel, pouring-in of moulds, heat treatment and weld repairs of castings.

The following castings (of weight up to 25 tons) were produced within the reported period:
- gear wheels,
- supporting rollers for cement kilns,
- ladles for the copper industry.
- mill cheeks for sugar mills.
- various pinions.

6. In spite of significant delays regarding preparatory stage of chilled roll production, two rolls with dimensions ϕ255x460 mm for finishing rolling stands, were cast before the team departure from the Project Area.

   The rolls with indefinite chilled layer are made of cast iron prepared in an induction furnace. As the optimum grade of foundry pig iron (SORELL Metal) was not available, a pig iron previously refined in electric arc furnace has been used as a charge material.
   The microstructure of the rolls, as tested on production samples taken during the pouring of moulds, has been found to be correct.
   Thickness of the chilled layer is about 35-40 mm.
   Hardness of the roll barrel was not been tested, since the machining was still in process at the end of the mission.
   Manufacture of rolls made of SG iron could not be undertaken, because the master alloys for cast iron modification were not available during the mission.

G. CONCLUSIONS

A number of observations and "ad-hoc" studies on the operation of the Foundry & Forge Works have been made, based on which several conclusions were drawn. Most of the conclusions refer to the specific topics discussed in detail in the attached documents/annex'. Others have been drafted in the context of studies of the production techniques and are contained in the suggested modifications, others cover the improvement of the production disciplines both on the shop-floor and at supervisory levels, others concern the increasing expenditures on materials and equipment anticipated in a near future, and the problems related to implementation of expert services etc..
For the purpose of presentation only some of the conclusions were selected and grouped as per subject of services, and the results of observations made by each of the team members.

The conclusions presented below are considered to be those best reflecting importance of problems identified by the expert team. Others of a very specific and technically narrow character are included into the "Information Sheets" and other attachments to this report.

Steelmaking

1. Steelmaking is an important production process, having the most definitive influence on the quality of final products and hence requires to have initial priority over other manufacturing processes.

The measures applied by FFW to secure day-by-day operation of the equipment, availability of production inputs, manpower etc. are insufficient.

2. The Technological Design Office does not employ any specialist in metallurgy. This creates a number of problems for the SM Shop supervisory staff vis-a-vis an increasing demand for manufacture of new steel grades of complex nature. Their production cannot be improvised on an "ad-hoc" basis due to very strictly applied quality requirements.

3. Contrary to the comment in the Terms of Reference, the quality of raw materials used for steelmaking in SM Shop of FFW seems to be sufficient; the quality of steel has been significantly improved without a change of major raw materials used for the process. Nevertheless, periodical shortages, together with irregular supplies of certain important materials and a necessity to employ substitutes of lower quality and suspect value have a very negative impact, not only on the quality of steel. This fact cannot be neglected.

4. Worn out ingot moulds have not been replaced with the new ones with improved design, requested since April, 1992 i.e. when relevant documentation concerning the manufacture of new moulds was handed over to the counterpart staff.

   The total number of moulds in use is insufficient to secure a trouble-free production of forgeable ingots.

5. The service life of the ingot moulds is very short when compared with acceptable standards, this is due to the improper chemical composition of the pig iron used for mould manufacture, particularly a too high sulphur content . which cannot be reduced through cupola melting.

6. Only one immersion thermocouple portable stand is used for measuring the liquid steel temperature. This is insufficient for regular control of steel refining. The exact determination of steel temperature, which is particularly important before the pouring of heavy castings, is rarely done.

7. Scrap returned from the Fettling Shop is often mixed-up (e.g. high Cr scrap with high Mn scrap) and, apart from melting problems, full recovery of expensive alloying elements is impossible.

   The recommended system of scrap segregation has not been implemented as yet. The Fettling Shop personnel does not appear to be interested in the proper handling of scrap, which is shifted to the scrap yard (which is unfortunately an integral part of Fettling Shop) without any treatment or classification.

   The idea to establish a joint management for Fettling Shop and scrap yard, in common with clearly defined areas of personal responsibility should be pursued

8. Correction of the SM Shop equipment failures, and routine repairs are seldom executed due to the pressure on the continuous production operation which is apparently for the purpose of increasing the output.

The operation of the SM Shop is badly affected by numerous breakdowns of furnaces, cranes, etc., and this has a very serious influence on the course of the production processes which clearly cannot be carried out in a full compliance with the applicable instructions and procedures which are known by the staff.

Forging

1. As certain ingot moulds are not available it is not possible to follow the specific production technologies which are based on a careful choice of ingots for each particular forging operation. The appropriate forging reduction ratio and thus a complete and adequate transformation of "as cast" ingot structure is far more important than merely obtaining a required forging shape. The technical staff is applying far from sufficient attention to this very critical matter.

2. Substantive assistance provided by the technical staff to the shop-floor-level personnel is desired but not given. This relates to the direct support to be given during the introduction of newly designed technologies and is indispensable in order to avoid unnecessary misunderstandings and costly errors in production.

3. The anti-hydrogen heat treatment is based on the assumed content of hydrogen in steel. This system is not so precise, but has to be followed in view of delays in the commissioning of the hydrogen content determinator.

4. The breakdown of the forging manipulator significantly complicates forging of smaller ingots (4,6 and 8 tons), particularly those made of alloy steels with narrow range of forging temperatures.

5. Leakages of the hydraulic systems of the press reduces its designed capacity 3150 tons to about 2500 tons. For this reason, serious difficulties are observed during forging of heavy ingots. This refers to the situation when important operations cannot be carried out or completed (e.g upsetting).

6. Inspection of heating furnaces at HP Shop has indicated the necessity for major overhauls. Improvements made "ad-hoc" during the furnace campaign have only decreased the number of problems related to improper heating of ingots/forgings.

7. Application of a flame cleaning blowpipe for re-conditioning of ingot/forging surface has been found the best option to reduce the evidence of surface defects (e.g. hot tears).

8. Scrap arising during forging production cannot be fully utilized because the recommended, simple method for its segregation and storage has not been implemented so far. Only a technological discard is equal to 30% of each ingot weight. The scarp is clean (so called "blue scarp") and may be used for melting of special steel grades.

Heat treatment

1. Heat treatment processes are badly affected by numerous deficiencies related either to technological discipline or lack of repeatability of process parameters.

2. The instrumentation for temperature control of heat treatment is partly out of order and the maintenance of the required, narrow temperature ranges is difficult. Usually, in case of a single furnace, 2-3 (of total 6-8) thermocouples are not working. The positioning of the thermocouples is done in a casual way.

3. The quality of die forgings is directly influenced by the quality of steel. Tests of low carbon case-hardening steel imported from Italy have been carried out by the UNIDO expert. The microstructure and cleanness of the steel, as determined by the tests, were found unsatisfactory with reference to the technically permissible limit. Such steel may be used for local production in the SM Shop of FFW.

4. The heat treatment of castings is carried out rather in an 'accidental' manner. The supervisory staff of the Fettling Shop operates without clearly and personally addressing their responsibilities.

5. The shaft type heat-treating furnaces at the HP Shop have not been operated for a long time due to maintenance problems.
In the case of heavy forgings, bogie hearth furnaces do not allow an uniform temperature distribution. This results in excessive quenching stresses and cracks as well as an objectionable hardness distribution range of heat treated material.

6. At present, the Forge Shop is not equipped with a zone-fired heating furnace. In view of this, the trials to undertake the manufacture of forgings made of alloy tool steels (high C and Cr contents) as well as high speed steels are not feasible.

Non-destructive testing

1. The presently available equipment for non-destructive testing such as portable ultrasonic testers, crack depth measuring instrument, magnetic flaw detector etc., are quite sufficient for the scope of inspections required for major FFW products.

2. It is felt that the problem of maintenance of the said equipment cannot be solved at the Plant level and probably not in the country scale. Extensive use of such instruments requires their frequent checking along with calibration of control circuits.
The measures to secure availability of spare parts as well as to strengthen the capacities of the Instrumentation Maintenance Section should be applied, since the services rendered through local dealers have not proven to be effective and useful.

3. NDT inspections are carried out in a correct way at FFW. Either scope of inspections or test methods are precisely known to the NDT Section personnel.
Relevant documentation is kept properly.

4. Forgings are seldom marked (with reference to ingot bottom and riser parts). Some of them are marked incorrectly, although the importance of this operation was particularly emphasized during the discussions with the counterpart staff. Calibration of an ultrasonic head should be always done on the bottom (i.e. clean part of forging), otherwise correct results of a test cannot be assured. Also, the evaluation of

ultrasonic test results becomes more difficult.

5. In the light of diversified FFW production programme, the experience of the NDT Section personnel in proper evaluation of test results with reference to the importance of end-products, their application and working conditions has been identified as the priority matter. In this regard, the capacities of the personnel have to be reinforced through further intensive on-the-job training.

Quality assurance

1. Presently, the FFW quality policy is limited to resolving theoretical problems; more radical measures are required to be taken with regard to the "on-line" activities.

2. So far, FFW has not implemented any system which clearly directs the responsibility for quality of production to each employee and/or groups of employees, sections, shifts, departments etc.. This makes it difficult to enforce the duties of the personnel which are supposed to be aimed at assurance of quality.

3. Co-ordination and co-operation between the technical design and quality assurance/control sectors is not defined precisely. It happens that production of certain items is commenced before testing methods and acceptance conditions are defined and cleared by the QA staff.

4. Raw materials procured from various sources of supply are of different properties and compositions and are not strictly related to the standards and requirements of each specific method of production. This make it difficult to implement standardized inspection procedures. Efforts concentrated on the separation of substandard materials are not followed by appropriate practice of their storage.

Rollmaking

1. A hardness, measured on a barrel surface of a chilled roll is dependent on chemical composition of a cast iron. In order to achieve a required hardness and thickness of the chilled layer, the composition has to be kept within a very narrow range.
   The lack of proper (i.e. quick and accurate) facilities for the testing of chemical composition of cast iron does not allow the attainment of the required quality level.

2. The manufacture of rolls is based on appropriate raw materials with strictly specified properties; the general application of "substitutes" should not be a common practice.

3. Orders for rolls usually specify only their dimensions and required hardness. The problem of material and production method choice is expected to be solved by a manufacturer. Before the commencement of production of any type of rolls, the rolling mill which placed an order should be visited with the aim to assess the "on-site" working conditions and to collect all necessary information, as has been clearly demonstrated in practice during the visit paid to six steel rolling mills located in Lahore.

H. RECOMMENDATIONS

Detailed recommendations on specific issues provided by the experts have been handed over to the counterpart staff. The recommendations, together with relevant outlines, operational procedures, technical guidelines etc., all presented in the documentation annexed to this report provide a solid basis and justification for the actions suggested by the experts, to be taken by FFW in the future. Towards the end of the second mission of the expert team, a review was made concerning the implementation of the experts' recommendations.

A report containing a synthesis of the implementation status was prepared for the TPR meeting held on the premises of the SEC in Islamabad on 25 November, 1992. In this report, the recommendations have been classified as "implemented", "partly implemented or being implemented" and "not implemented". Due to relatively short time intervals between the individual missions of the team and to the FFW budget constraints, many recommendations have not been fully implemented as yet.

A general observation of the team is, that there have been no difficulties as regards the implementation of recommendations directly related either to technology transfer or overall direct improvement of product quality. Nevertheless, there have been a number of recommendations focused on the better utilization of production inputs, the application of improved tooling, the overhaul of installed equipment etc.. Some of them have been only partly implemented, the others requiring either investments or changes within the existing organization of labour, have not yet been considered to be implemented. The FFW management understands the implications of the recommendations and taking these into consideration, attempts to find a way for their practical realization. The actual problems were highlighted during the final discussion held before the departure of the team.

The following principal recommendations are offered:

1. FFW should not depart from established production practices which have proved to be successful after the implementation of experts' advice during their missions.
   This relates mainly to the strict observance of technological instructions. It is highly recommended to concentrate efforts to ensure that these instructions are known and properly used by technical staff concerned.

2. The need for the further upgrading of the skill of workers, foremen, operators etc. and of the qualifications of supervisory staff is stressed by this report and recommended to be on of the priorities for future technical assistance to FFW.
   The training facilities existing in FFW as well as the opportunities of fellowship programmes should be utilized to a maximum extent. Bilateral contacts with foreign companies capable of offering appropriate training and consultations should be sought by FFW.
   The possibility of direct collaboration between FFW and HPH has been already taken into consideration by both parties.

3. The proposals of HPH addressed to FFW to jointly discuss the areas of mutual interest and the possibilities of utilizing further technical services of the Polish experts are recommended to be taken into

consideration by the SEC authorities.
This particularly refers to the offers of equipment supply, the overhaul of basic production units accompanied by adequate maintenance programmes. the supply of spare parts and contractual services of experts in various fields of manufacturing technologies.

4. Poor testing facilities available for "on-site" inspection are proposed to be improved by the acquisition of more appropriate modern equipment.
This particularly concerns the determination of chemical composition of metals by spectrometers (e.g. SPECTROTEST M, SPECTROLAB) and carbon/sulphur determinators (e.g. LECO).
Such equipment should be installed first in the CI Foundry, where wet methods of chemical analysis and the use of the carbon equivalent measuring instrument are quite insufficient, when related to the production programme, which includes high alloy cast irons.
The spectrometer employed at the Steel Foundry is not in good condition and its frequent breakdowns create a serious bottleneck which influences the performance of the whole department. Under such circumstances, the procurement of a new instrument would be desired.

5. The interest for the integrated quality assurance systems, as it was often expressed by the QA management with regard to the ISO standards of 9000 series, should be considered as a healthy symptom.
However, it is strongly felt that keen interest on efforts to implement already established system cannot be converted into practice via theoretical deliberations. Only if properly planned, radical measures are applied to ensure the implementation of the procedures for quality in production. can useful results be obtained.

As long as quality assurance is not the principal duty of the whole management and of each employee, the QA system cannot be effectively used.A more active participation of QA inspectors in the manufacturing processes is required in order to secure their correctness and full compliance with the approved procedures.
The computer available at the QA Department, seldom used, and applied mainly to "desk-top publishing" should be a solid basis for implementation of the recommended quality data recording and information report system.

6. After the successful trials of production of cast iron rolls with indefinite chilled layer, it is recommended to concentrate efforts towards an introduction of new material for rolls i.e. nodular (SG) cast iron inoculated with Ni-Mg-Ce and Ni-Cu-Mg-Ce master alloys. Presently, this material is widely used by the leading roll manufacturers in Europe and the USA. A technical description of the production method has been provided for the counterpart staff.

Also, it would be beneficial for FFW to establish close contacts with producers of rolls for steel re-rolling. Comprehensive training, guidance on production methods and transfer of know-how may be provided, among others. by the BUCZEK Steel Works - the main supplier of rolls for the Polish steel industry.

7. In view of the satisfactory results of pig iron refining carried out in the electric arc furnace, it is suggested to locate the production of

ingot moulds in the Steel Foundry.
The cupola melting at the CI Foundry cannot secure required low content of sulphur in the material for ingot moulds and this is the reason that their service life is far from expectations, seriously increasing the cost of steel ingot production. Moreover, the CI Foundry is overloaded with important production tasks and, therefore, is not able to meet the demand for ingot moulds of the SM Shop.

8. The prompt introduction of a competent supervisory/control system for the proper management of production inputs should be considered as imperative for the proper functioning of the production departments of FFW.

Particular attention should be paid to the Steel Foundry, where both the diversity and the consumption of various materials is the largest. Radical measures are recommended to be taken by the HMC/FFW authorities in order to establish an appropriate information system co-ordinating the activities of stock management. For this purpose, the application of a computer along with relevant software is considered to be reliable and economically acceptable.

9. The process of further strengthening the FFW capabilities is envisaged to be achieved also through an establishment of a preventive maintenance programme. At present, the equipment installed in the Plant is rarely made available for preventive inspection and regular maintenance services. Breakdown repairs have become a common practice. It is pertinent to mention that after 13 years of operation, most of the installed equipment is significantly worn out and thus requires an extensive maintenance. An effective maintenance programme will, without doubt result in the reduction of overall production cost. It means, that the cost of said programme including scheduling, inspections, repairs etc., is lower than the cost of breakdowns and repairs together with the lost profits caused by the lower production.

In view of the importance and urgency of the action required by this critical area, "on-the-spot" consultations through services of two consultants (one in industrial management and one in preventive maintenance) are suggested to be arranged either through bilateral agreement of FFW with internationally recognized companies or based on further technical assistance by UNIDO.

The consultants would be expected to draft a detailed check-list of regular and systematic "on-line" inspections and preventive services.

10 Taking into consideration the 'jobbing' nature of the operations of the Foundry & Forge Works, which receives orders of diverse design, material specifications and quality requirements, it is obvious that completion of the current project does not assure an instant solution to all the identified problems. The idea introduced by FFW management to continue technical assistance in the form of foreign expert services was widely consulted with UNIDO experts. Recently, the company has entered into the manufacture of high-tech equipment for the power generation sector. A number of problems related to the lack of experience in production techniques of a complex nature are expected to be solved through comprehensive advisory services. However, it is suggested to limit the scope of services to the following areas of a very specific

importance:

- **steelmaking**: production of new, mostly high alloy steel grades, implementation of modern steelmaking practices such as continuous casting and ladle metallurgy,
- **foundry methods engineering**: production of heavy duty steel castings,
- **moulding techniques**: necessity of introduction of new moulding materials and practices.

The programme of future advisory services should be based on short-term visits of experts and "ad-hoc" consultations on specific issues and currently identified problems. Priority should be given to supplementary on-the-job training of FFW engineers through carefully prepared fellowship programmes.

11 It is suggested that the UNIDO Backstopping Officer pay a short visit to the Project Site in order to assess the expected results of the follow-up actions and to review the status of implemented recommendations.
Additionally, UNIDO may wish to assist in the preparation of a programme of further technical assistance to FFW.

Annex No.1

List of reference documents

1. UNIDO Project Documents DP/PAK/86/025
2. Job Descriptions of the UNIDO Experts
3. Informative Materials on the Heavy Mechanical Complex Ltd. issued in Pakistan (in English).
4. Chief Technical Adviser's Manual - UNIDO publication.
5. Monthly Progress Reports and Experts' Activity Reports prepared during execution of the project.

Annex No.2

Members of UNIDO Sub-Contractor Team

1. Adam Partyka, the Team Leader, Expert in Steelmaking.

2. Roman Twardoch, Expert in Free Forging.

3. Bohdan Krahelski, Expert in Heat Treatment.

4. Janusz Sobczak, Expert in Non-Destructive Testing
   (during the 2nd mission of the Team).

5. Jozef Kaperczak, Expert in Non-Destructive Testing
   (during the 3rd mission of the Team).

6. Waldemar Malek, Expert in Quality Assurance.

7. Zbigniew Sikora, Expert in Rollmaking.
   (during the 1st mission of the Team).

8. Marek Szulinski, Expert in Rollmaking
   (during the 3rd mission of the Team).

Annex No.3

Senior Counterpart Staff

1. Dr. Saeed Akhtar	- National Project Manager
2. Mr. Mehboob Ali Forge)	- General Manager (Foundry &
3. Dr. Imtiaz Saeed	- Head of HMC Quality Assurance
4. Mr. Doost Mohammad	- Gen. Manager (Quality Assurance)
5. Mr. M. Siddique Javed	- Dy. General Manager (QA)
6. Mr. Mohammad Tufail	- Manager (Steel Melting)
7. Mr. Misbah-ul Haq	- Manager (Steel Moulding)
8. Mr. Zahid Aziz Khan	- Manager (Quality Assurance)
9. Mr. Riaz Awan	- Manager (Cast Iron Foundry)
10. Mr. Mohammad Nabi	- Manager (Forgings)
11. Mr. Abdul Raziq Qureshi	- Manager (Technology)
12. Mr. Manzoor Ahmed	- Manager (Fettling Shop)
13. Mr. Moatassin Mirza	- Manager (Quick Analysis Lab.)
14. Mr. Mohammad Mohsin	- Dy. Manager (Steel Melting)
15. Mr. Abdul Munian	- Dy. Manager (Steel Melting)
16. Mr. M. Arif Khan	- Dy. Manager (Technology)
17. Mr. I. M. Choudhry	- Dy. Manager (Steel Moulding)
18. Mr. M. Daud Khan	- Dy. Manager (Steel Moulding)
19. Mr. Abdul Waheed	- Dy. Manager (Cast Iron Foundry)
20. Mr. Haji M. Iqbal	- Dy. Manager (Quality Assurance)
21. Mr. Azar Attique	- Dy. Manager (Forgings)
22. Mr. Frederick Gill	- Asstt. Manager (Steel Melting)
23. Mr. Asfund Yar	- Asstt. Manager (Steel moulding)
24. Mr. Kamran Qureshi	- Asstt. Manager (H. Press Shop)
25. Mr. Abdul Hameed	- Asstt. Manager (ND Testing)
26. Mr. Abid Hussein	- Foreman (Heat Treatment)
27. Mr. Mohammad Siddique	- Foreman (Steel Moulding)

Annex No.4

OVERSEAS FELLOWSHIPS

Post	Field	No. of persons	Duration months
31-01	Basic electric arc melting practice for production of carbon and alloy steel for ingots and castings.	1	3
31-02	Moulding and coremaking technologies and sand control with the production of heavy steel castings produced by the carbon dioxide process.	1	3
31-03	Steel casting methods technology by application of directional feeding techniques	1	3
31-04	Production of SG iron castings.	1	2
31-05	Pattern-making techniques for steel iron castings in wood and polystyrene	1	2
31-06	Production techniques and control of die forgings for the automobile related industries	1	2
31-07	Application and economics of advanced steel refining techniques - vacuum degassing, ladle and electroslag refining	1	2*
31-08	Maintenance of instrumentation for steelmaking and heat treatment furnaces (specific instruction on instruments supplied under the project)	1	3
31-09	Computerization of foundry and forge costing systems.	1	3

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* This fellowship has been recently converted into a study tour (two weeks) with the purpose of visiting the leading European steel plants which use modern metallurgical equipment.

Annex No.5

EQUIPMENT

Post	Description	Value US $
41-00	Expendable Equipment	10,000
	Various foundry and forge publications covering international standards and specifications, operational and management practices, quality and cost control and other publications useful during and after the project	
42-00	Non-expendable Equipment	
	- Ultrasonic equipment for testing of forge shafts before machining (Krautkramer model USM3S and accessories).	13,000
	- Magnetic flaw detector for testing of steel castings and forgings.	4,800
	- Crack depth meter to measure depth of surface defects of steel forgings.	11,200
	- Radiation pyrometer for range up to 1550°C for control of process parameters of forging.	2,400
	- Carbon equivalent measuring equipment.	5,500
	- Two immersion thermocouples with digital read-out suitable for liquid iron steel.	1,600
	- Sand testing equipment comprising one set of mechanical sieves - British Standard CO2 gassing equipment for standard AFS compression testpieces, two mould hardness testers for green sand, two mould hardness testers for CO2 sand.	1,500
	- One Jominy end-quench test machine	1,000
	- Equipment for determination of dissolved hydrogen, nitrogen and oxygen in steel	129,000
	TOTAL EQUIPMENT	**180,000**

TIME SCHEDULE

FOR SUB-CONTRACTED EXPERT ACTIVITIES OF HPH TEAM

Assistance to Foundry & Forge Works of Heavy Mechanical Complex Ltd. at TAXILA

UNIDO Contract No. 91/251

ACTIVITY / EXPERT SERVICES	1992 FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	1993 JAN	FEB	MAR	APR	MAY	JUN	JUL	DURATION OF ASSIGNMENT M/M PRODOC	CONTRACT	EXERCISED
11-01 STEELMAKING																			7	9	9 1/3
11-04 HEAT TREATMENT																			5	5	5 1/3
11-05 FORGING																			7	7	7 1/3
11-06 N-D TESTING																			3	3	4
11-09 QUALITY ASSURANCE																			7	7	5
11-08 ROLLMAKING																			3	3	3
	1st MISSION							2nd MISSION				3rd MISSION							TOTAL M/M 32	TOTAL M/M 34	TOTAL M/M 34

EXPLANATION

- As per PRODOC - work-plan dated 31 DEC'91
- As per work-plan revised during TPR Meeting in November '92
- Actual time of experts' services - 3rd mission delayed by one month upon the request of the counterparts

Annex No. 6

Annex No.7

LIST OF ATTACHMENTS

I. Information Sheets:

1. Blue fracture test.
2. The diagram for the anti-hydrogen heat treatment.
3. Argumentation for applying of the preliminary heat treatment of forgings.
4. The rules of proper choice of the weight and the format of the forgeable ingots during manufacture of different grades of steel free forgings.
5. The deoxidation of steel. Sedimentary deoxidation process.
6. The instruction concerning the technical conditions of acceptance of refractory materials.
7. Major alloying elements. Proposal of the recommended specifications.
8. Fluxes. Recommended specifications.
9. The manufacturing technology for thin-walled cylinder - the roll body for the hot strip mill of Pakistan Steel Co.
10. The instruction concerning the application of refractory materials being in use for electric arc furnaces and the required standards of their acceptance.
11. Preheating of ingots prior to and between forging operations.
12. The forgeable ingots and the respective ingot moulds. Analysis of the present situation and recommended changes.
13. The technology of manufacturing couplings for PakSteel.
14. The technological instruction concerning the manufacture of forging inserts and die blocks.
15. Carbon containing materials. Recommended specifications.
16. Steelmaking in basic electric arc furnaces. Technological instructions.
17. Cored wire injections. A general guideline.
18. The effect of vacuous steel treatment on the quality of the products working in particular (special) conditions.
19. Provisional acceptance conditions of the steel forgings of the coupling H5M-0597.
20. Provisional (facultative) non-destructive testing conditions of forgings.
21. The procedure of Quality Assurance within HMC/FFW production processes. The basis of the elaboration : International Standards ISO 9002 and ISO 9003.
22. QA procedure within production processes where the special processes are required. The basis of the elaboration: International Standard ISO 9001
23. QA procedure within Foundry production processes.
24. QA procedure within Forging production processes.
25. The instruction concerning quality data recording and information report system.
26. Steel scrap.Basic information.Standards and specifications. The use of alloy scrap, the manner of its segregation and circulation within the Plant.
27. Technical conditions of examinations and acceptances for free forgings and forged bars.
28. Quality Assurance procedure within steelmaking.
29. Technical conditions of examinations and acceptance for die forgings of general assignment.

Annex No.8

TABULATION OF THE FORGING DEFECTS AND THEIR CAUSES

DEFECT	CAUSE
Large non-metallic inclusions	-carbide slag replaced by white slag too late -dense slag before tapping -too low tapping temperature -improper ladle preparation -inappropriate (too intensive) argon blowing into a ladle -too high steel refining temperature -too long steel refining time
Dense, fine non-metallic inclusions	-inadequate steel refining practice -inefficient deoxidation of steel -unfavourable (solid) products of deoxidation -insufficient separation of deoxidation products -too low tapping temperature -too short time of steel holding in a ladle before casting
Unfavourable distribution of inclusions within ingot volume	-unfavourable geometrical parameters of ingot mould -inadequate pouring rates -improper temperature of ingot mould prior to pouring
Secondary pipes porosities	-insufficient addition of an exothermic powder -too low temperature of hot top lining -insufficient amount of steel poured into riser -unfavourable ingot geometry (slenderness) -re-oxidation of steel during tapping -high content of gases dissolved in steel -low temperature of steel being poured -inappropriate pouring rates
Surface cracks	-cold shuts during pouring -defective ingot mould internal surface -hanging and tearing of ingot during solidification -intercristalline microcracks and further penetration of oxygen during ingot heating -wrapping of metal during forging
Internal cracks	-"snow-flakes" -forging cross -improper heating of ingot prior to forging -microstructure heterogeneity

DISTRIBUTION OF DEFECTS (50 examined forgings)

- 72% - non-metallic inclusions
- 8% - surface cracks
- 14% - central porosity
- 2% - internal cracks

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

_____
(fund)

TERMINAL SMALL-SCALE PROJECT EVALUATION REPORT (TPER)
(UNIDO-administered funds: projects up to $US 150,000)

I. **Identifying data** (please attach copy of the cover page of the project document)

A. Project number: ../.../../...

B. Total UNIDO budget at the start of the project (exclusive support cost): $US _____

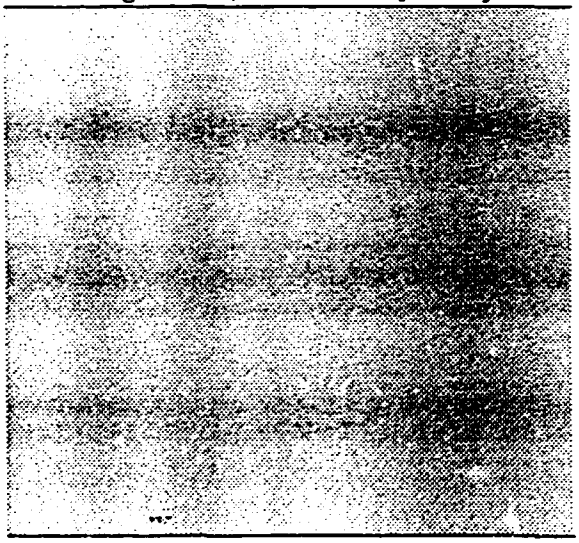
Actual expenditure: $US _____

C. Actual starting date: _____ Actual duration: _____

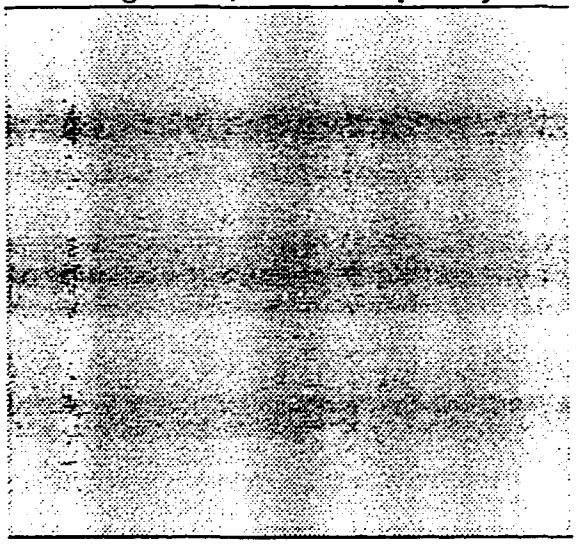
II. **Performance**

For each output given in the project document, please describe:

A. Planned outputs in terms of magnitude, kind and quality



B. Outputs achieved in terms of magnitude, kind and quality



C. Problems, if any, encountered in producing the outputs:
(please describe in detail)