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

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

FAIR USE POLICY

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

CONTACT

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

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

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

22097

11p.

PARAGON

ENGINEERING LIMITED

REPORT ON THE

MAINTENANCE MANAGEMENT WORKSHOP

for ENGINEERS

from METALLURGICAL AND ENGINEERING INDUSTRIES IN COMESA

16 NOVEMBER - 11 DECEMBER 1998

KITWE, ZAMBIA

Contract No.98/268P

1.00 INTRODUCTION

The United Nations Industrial Development Organisation (UNIDO) contracted Paragon Engineering Limited to provide services related to the Maintenance Management Workshop for Engineers from Metallurgical and Engineering Industries in COMESA Countries. The scope of services to be provided was as follows:-

- Premises (venue, lunch, morning and afternoon tea and snacks)
- All necessary facilities such as secretarial and typing services, photocopying, stationery, supply of PC equipment (computer, printer, overhead projector, flip chart, TV/video, public address), transport for participants(to and from airports, to and from hotels and venue of workshop - daily).

- Management of Workshop and support staff as well as public relations
- Ten (10) national experts (from its staff and independent consultants from Zambia)

This report covers the work executed and all the services provided during the workshop as per the above requirements.

2.00 SERVICES PROVIDED

The following were the services provided:-

2.01 Premises

The venue of the Workshop was at Klub XTC, Parklands which is a quiet part of the City of Kitwe. The workshop accommodation comprised a lecture lounge, a dining room and an office for secretarial services.

The lecture lounge was equipment with an overhead projector, computer projector, slide projector, TV/video, and flip chart.

The secretarial services equipment included a computer, printer, photocopier, fax and telephone. In total 21 handouts were photocopied and given to workshop participants.

The dining room served morning tea and snacks, lunch, and afternoon tea/soft drink and snack to all participants, resource persons and supporting staff.

2.02 Transport

Transport was provided to and from the two airports serving the City of Kitwe for resource persons as well as for daily commuting. In addition, transport was provided for industrial tours within and outside Kitwe.

2.03 Management/Public Relations

Mr Kennedy Nyirenda was available on full time basis for the duration of the workshop as per contract. In addition to ensuring that all services required for the Workshop were in place, Mr Nyirenda coordinated the following:-

a) Publicity of the workshop in both the print and electronic media.

The opening of the workshop was covered by the national television network and the two main daily newspapers. Banners announcing the Workshop were put up at various points in the city.

The Workshop was officially opened by the Deputy Minister of Commerce, Trade and Industry and closed by the General Manager of Zambia Consolidated Copper Mines Ltd - Nkana Division.

b) Arrangement for Industrial Tours

Four industrial tours were arranged.

c) Coordination of the Presentations

Ensuring that lectures were presented at the allocated times and that the programme run according to schedule.

2.04 Hire of Local Resource Persons

The following national experts were hired to give lectures on various subjects as follows:-

Name	Subject(s)
T Chanda	Maintenance Strategies
E Mwela	Systematic Failure Analysis
N Malisa	Condition Monitoring Concept and Principles/Lubrication and Lubricants testing
G Kabaso	Condition based maintenance/Machine based vibration monitoring and fault Diagnosis
E Banda	Non Destructive Testing Maintenance Applications/Weld Specification and Inspection
F D Yamba (Prof)	Energy Management
S Chipeta	Wear Debris Analysis/Oil Based Condition Monitoring Applications
A Ng'andu (Dr)	Lubrication - Maintenance Perspective/Plant Reliability/Quality Mgt
K Nyirenda	Finance and Man Management
G Kapeso	Heat Treatment for Wear Resistance
C D Mwila (Dr)	Occupational Health, Safety & Environment

All the resource persons carried out their assignments as required.

3.00 PARTICIPANTS

A total of twenty six participants from industry in Zambia and Zimbabwe attended the workshop. A full list is given in Appendix 1.

4.00 SUMMARY OF TRAINING MATERIALS

Abstracts of the training materials given to participants is given in Appendix 2. All the lectures were well received and generated a lot of discussion. That the participants had found the Workshop useful was reflected in the "Back to Office Action Plans" they presented at the end of the programme.

5.00 DETAILS OF INDUSTRIAL TOURS

The aim of the visits was to get an appreciation of operations vis-a-vis maintenance management and practical demonstrations on condition based maintenance.
The following study tours were undertaken to metallurgical and allied engineering industries:-

5.01 Nkana Smelter and Power Plant - Zambia Consolidated Copper Mines (ZCCM) Limited, Kitwe

Nkana Smelter produces anode copper from copper concentrate using reverberatory furnaces. The Power Plant generates electricity using the waste heat from the Smelter.

5.02 Group Engineering Services - ZCCM - Technical Services, Kalulushi

Group Engineering Services houses laboratories for condition based maintenance, physical metallurgy and non - destructive testing.

5.03 Nchanga Open Pit - Zambia Consolidated Copper Limited, Chingola

The Nchanga Open Pit contributes about 60% of Zambia'a copper production.

5.04 Boart Longyear - Ndola

Boart Longyear has a gas carburising heat treatment plant which it uses to treat mining tools it manufactures.

5.04 Zambia Metal Fabricators (ZAMEFA), Luanshya

ZAMEFA main line of business is the production of copper wire.

6.00 CONCLUSION

Paragon Engineering Limited executed the work and provided the required services as per contract.

APPENDIX 1:

LIST OF PARTICIPANTS TO THE MAINTENANCE MANAGEMENT WORKSHOP FOR ENGINEERS FROM METALLURGICAL AND ENGINEERING INDUSTRIES IN COMESA

	Name	Job Title	Organisation
1.	Jewell Mbambara	Plant Engineer	BP Zambia Plc
2.	Peter Daka	Snr Asst Engineer (Transport)	ZCCM Mufulira Division
3.	Crispin C Nkonde	Section Engineer (Hoists)	ZCCM Mufulira Division
4.	Ernest M Chipalo	Section Engineer (Transmission)	CB Energy Corporation
5.	Wilson Rutsate	Bar Rod Mill Manager	Zimbabwe Iron and Steel Works
6.	Francis R Zirobwa	Divisional Manager Mills	Zimbabwe Iron and Steel Works
7.	Charles Danha	Mechanical Services Engineer	Zimbabwe Iron and Steel Works
8.	Benjamin Bwalya	Mechanical Workshop Head	Indeni Petroleum Refinery Co
9.	Joseph Mwila (Dr)	Engineer	BP Zambia Plc
10	George Mumba	Mechanical Fitter	BP Zambia Plc
11	Bilson Bwalya	Electrical Technologist	BP Zambia Plc
12	Yotham Chimbala	Engineer Switch Tlx Exchange	Zambia Telecommunications Co
13	Amon Sakala	Assistant Workshop Foreman	Kitwe City Council
14	Terry Ngweshe	Electrical Engineer	Ndola City Council
15	Mengo Siwale	Senior Assistant Engineer	ZCCM Nchanga Division
16	Paul Bilima	Snr Asst Engineer - Mechanical	ZCCM Nchanga Division
17	Gladio M'hango	Foreman	ZCCM Nchanga Division
18	Alfred Mushingo	Section Engineer - QA	ZCCM Nchanga Division
19	Wilson Banda	Engineer	Zambia Electricity Supply Corporation
20	Chofya Mwale	Section Engineer	ZCCM Nkana Division
21	Nzwalo Sikaluzwe	Section Engineer	ZCCM Nkana Division
22	Patrick Akayombokwa	Section Engineer	ZCCM Nkana Division
23	Ferdinard Menzu	Senior Assistant Engineer	ZCCM Nkana Division
24	Kasompe O Chola	Maintenance Engineer	Zambia National Broadcasting Corporation
25	Emmanuel Bwalya	Maintenance Engineer	Zambia Natioanl Broadcasting Corporation
26	Raphael Chomba	Maintenance Engineer	Zambia Natioanl Broadcasting Corporation

APPENDIX 2.00:

ABSTRACTS OF TRAINING MATERIALS GIVEN TO THE WORKSHOP PARTICIPANTS

A2.01 NON - DESTRUCTIVE TESTING MAINTENANCE APPLICATIONS - By E BANDA

Non-destructive testing (NDT) forms a critical part of the maintenance function as it helps in predicting maintenance resource needs, improve safety and check for quality in certain types of maintenance work.

The presentation explained the principle behind the major NDT techniques in use for maintenance purposes today with the object of presenting them as tools which can be used by maintenance personnel to help solve problems and make decisions. The application of each technique and the contrasts between them were also discussed. Other techniques, which are less common but also useful, be it rarely, were mentioned.

The presentation was further illustrated by case studies from industry which not only highlighted the practical application of these techniques but their interdependence.

A2.02: WELDING INSPECTION AND SPECIFICATIONS - By E BANDA

Welding is one of the most important operations in engineering production and maintenance today. Due to the fact that in most welding operations, a large factor affecting its quality relates to operator skill, welding quality has been associated with elaborate inspection procedures and systems to ensure and verify the quality of important welding work.

The presentation explained some of the important aspects of welding inspection namely, characteristics of welded joints, defects present in welded joints (their cause and prevention) and methods used for the detection of these defects. Reference was also made to the approval testing of welders in terms of the philosophy behind this testing and how it is carried out, by referring to excerpts from standard specifications. Case studies to illustrate the use of welding inspection in conjunction with specifications were made again with reference to API 1104.

The presentation was aimed at enlightening participants in the area of a much misunderstood engineering tool and the systems which can improve the quality welding be it for maintenance purposes or otherwise.

A2.03: HEAT TREATMENT FOR WEAR RESISTANCE - By G B KAPESO

Heat treatment involves heating of a metal to a definite temperature followed by cooling at a suitable rate in order to obtain certain physical properties. Heat treatment for wear is carried out by surface hardening which involves treating the surface layer only. Components hardened in this way combine a hard surface for wear resistance and a tough core to withstand impact loads.

This presentation discussed the various techniques used for surface hardening and how the choice of technique is influenced by the application the component will be subjected to.

A2.04: **ENERGY - A CRITICAL FACTOR IN ATTAINING COMPETITIVENESS - By Prof. F D YAMBA**

Energy consideration is one of the factors influencing total management strategy and hence competitiveness. Energy management is not an event but a process. The presentation described this process and discussed the basics of energy systems, the need for energy efficiency and opportunities for energy efficiency improvements in industry. Examples of energy efficient technologies and process improvements were given.
The presentation also discussed energy audits and energy conservation opportunities in detail

A2.05: **LUBRICATION; A MAINTENANCE PERSPECTIVE - By Dr A N NG'ANDU**

When two surfaces rub together, power is lost to friction, heat is developed, and wear takes place. The purpose of lubrication is to separate the two rubbing surfaces somewhat and to reduce the abrasion. In more general terms, the object of lubrication is to reduce friction, wear and heating of machine parts which move relative to each other. Lubrication can therefore be defined as the control of friction by the introduction of a film between rubbing surfaces.

The presentation gave the main considerations in the effective and efficient use of lubricants to ensure longetivity of operation of machines which require lubrication; i.e. a maintenance perspective.

A2.06: **PLANT RELIABILITY - By Dr A N NG'NDU**

The emerging world economy is escalating the demand to improve the performance of products and systems while at the same time reducing their cost. The concomitant requirement to minimise the probability of failures, whether those failures simply increase costs and irritation or gravely threaten the public safety, is also placing increased emphasis on reliability. The formal body of knowledge that has been developed for analysing such failures and minimising their occurrence cuts across virtually all engineering disciplines, providing the rich variety of contexts in which reliability considerations appear. Indeed, deeper insight into failures and their prevention is to be gained by comparing and contrasting the reliability characteristics of the systems of differing characteristics: computers, electromechanical machinery, energy conversion systems, chemical and materials processing plants, and structures, to name a few.

The presentation gave a definition of reliability and went on to discuss reliability design guidelines, redundancy and quality management.

A2.07: **ZIMBABWE IRON AND STEEL COMPANY (ZISCO) - MAINTENANCE MANAGEMENT MANUAL - VOLUME 1 - By N M MASHANYARE**

The maintenance manual's objective is:-

a) To maintain the optimum level of availability performance of the plant and to meet the budgeted production output and the customer quality requirements at the lowest possible cost and within a safe working environment.

b) To standardise the approach to maintenance and ensure that engineering, operational, purchasing, training, projects and stores personnel focus on the correct maintenance activities at all times.

c) To ensure that everybody in the Company understands the maintenance concept and speak the same maintenance language.

The presentation used the ZISCO manual as a basis for drawing up a maintenance management system.

A2.08: **WELDING DESIGN - By Dr SADEK**

This presentation was on welding design. Welding was defined as a process of joining or uniting metals. The metal pieces are either heated until they are molten and then fused together or they are heated to a temperature below their melting point and bonded by a molten filler metal. Another method is to heat them until they are soft enough to hammer or press together.

The presentation highlighted factors affecting weld design as materials, welding process, welding preparation, residual stresses and distortion, fixtures and positioners, joint strength and efficiency, and welding costs. Principles of sound welding design was given.

A2.09: **MATERIALS SELECTION - By Dr J K BYARUHANGA**

The objective of this presentation was to give the participants:-

a) An understanding of the roles of cost, availability, and properties in material selection

b) Guidelines on how to screen candidate materials and arrive at the proper choice.

It was pointed out that the importance of material selection is increasing due to many reasons such as decreasing availability, new materials, problems associated with pollution and recycling, necessity for weight reduction and energy savings, domestic and foreign competition, more severe and critical service and customer requirements. Consequently, recognising the interdependent relationship between materials and their processing will continue.

Both design and manufacturing engineers need to exercise knowledgeable care in selecting, specifying and utilizing materials in order to achieve desired satisfactory results at reasonable cost and with assured quality. Most modern products are relatively complex. To achieve a proper balance among functional fulfilment, pleasing appearance and reasonable cost, it is almost always necessary to utilize a variety of materials. Further, with new materials almost constantly coming on the market, manaufactureres of exsisting products have a continuous task of re-evaluating the materials currently in use to assure that progress does not pass them by.

A2.10: **SYSTEMATIC ANALYSIS OF ENGINEERING COMPONENT SERVICE FAILURES - By E M MWELA**

Systematic failure analysis is the "thoughtful review of product and environmental facts which leads to identification of root causes of product problems". An engineering component or assembly is considered to have failed:-

a) When it becomes completely inoperable
b) When it still operable but is no longer able to perform its intended function satisfactorily
c) When serious deterioration has made it unreliable or unsafe for continued use

Failures are caused; they do not just happen. Efficient maintenance of plant and machinery requires that each failure be systematically investigated and the recommendations integrated in the maintenance system.

The presentation gave details of the process of systematic component failure analyisis. A number of case studies were presented.

A2.11: CLEANER PRODUCTION - By L D MANYAMA

Cleaner production (CP), which is a broadly defined technical term, can be applied to the whole industrial sector; from oil refineries to handicraft manufacturing and steel mills. Pollution controll has become an increasingly expensive, tedious, and difficult goal to achieve. The rising cost of waste treatment and pollution control is no longer a viable alternative for traditional end-of-pipe treatment. Searching for the most feasible strategy for industry to alleviate pollution is priority concern.

In recent years, a shift has occurred in solving pollution problems from a technical basis to diverse scientific one. This trend accounts for why Cleaner Production has become a mainstream application. The tenets of Cleaner Production can be summed up in the three words: Continuity, Prevention, and Integration.

This presentation covered the cleaner production concept, who should be involved, and how cleaner production and environmental management system are inter-related in promoting better environmental management. The presentation ended with a profile on how to undertake cleaner production.

A2.12: FINANCIAL AND MAN MANAGEMENT - By K NYIRENDA

Businesses operate in a number of forms but in all cases the goal is the same - to make money. The financial performance of a business, that is whether it is making money or not is measured and reported, usually, annually. This presentation looked at some of these reports; Profit and Loss Account, Balance Sheet and Sources and Application of Funds..

Every organisation, whether private or public, manufacturing or service has an operations function which transports inputs into finished goods which are in turn sold for money. Inputs to the system can be human resources, capital, materials, land, energy, etc. The human resource input is the organisation's most valuable asset and its management can mean the difference between success or failure. The presentation attempted to show that human resource management centres around self management, managing the boss and the subordinates. It then went on to show how this can be successfully achieved.

A2.13: MACHINERY FAILURE MODES AND PATTERNS - By G KABASO

Having covered the historical background to maintenance management, an introduction was made on identification, assessment and classification of plant, machinery or component failures.

A plant or piece of machinery may fail in any one of the following modes :

- can't function as intended, i.e. if it can't meet a desired standard of performance.
- wears out e.g. wear in a gearbox which is manifested in high gearbox temperature
- breakdown, i.e. stops functioning completely e.g. a shaft breakage

The possible causes and effects of such failure should be well understood so that maintenance decisions are put in place to prevent failure and meet the desired standard of performance.

The presentation was made with illustrations of failure patterns summarised as random, infant mortality and wear out failures.

A2:14: MAINTENANCE STRATEGIES - By G KABASO

The presentation covered a short history of the maintenance role leading up to the evolution of Maintenance Management Systems. With the proliferation of industrialisation, competition became a driving force in efforts to reduce operating production costs. At this stage maintenance was identified as a major contributor to the production cost. The presentation discussed the findings from studies carried out by Industrial and Management Scientists which provided ways of analysing the maintenance costs and their distribution in an industrial activity. These studies conclude that maintenance has an optimum cost, and that maintenance strategies are aimed at achieving this optimum cost.

Work creation advises that all maintenance may fall into four categories viz preventive(scheduled periodic overhauls), predictive(condition-based maintenance), breakdown (fix it when it breaks) and proactive(root cause correction). These are the maintenance strategies that can be used to achieve a maintenance departments objectives. Breakdown maintenance is the most expensive and least desirable.

A successful maintenance strategy will use the mix of the available maintenance strategies. Initially the equipment vendor's proposed preventive maintenance programme will be reviewed to incorporate the peculiarities of the environment in which the plant/equipment is being operated in.

The resulting preventive maintenance programme is then used to determine predictive maintenance, corrective or proactive maintenance staffing levels.

A2.15: VIBRATION MONITORING AND FAULT DIAGNOSIS By G KABASO

This presentation was covered as an introduction to one of the fundamental techniques in condition based maintenance of most industrial plants, with rotating machinery.

Vibration monitoring and analysis, as a condition monitoring technique, is the continuous or periodic measurement, trending and analysis of mechanical vibrations of a machine for the purposes of diagnosing the machine's health.

Mechanical vibrations arise as a result of normal transmission of cyclic forces within the machine structure. Initially these forces are due to inherent design factors, but as machine components begin to wear and defects develop and deteriorate this causes changes in the vibration characteristics. These changes can be measured, monitored and defects rectified to avoid failures.

Vibration monitoring and fault diagnosis case studies from the mining and mineral processing industry were presented to illustrate the application and cost effectiveness of a vibration based predictive maintenance programme.

A2.16: CAUSES AND CORRECTION OF MACHINERY IMBALANCE - By G KABASO

This was a practical presentation on the various causes and effects of mechanical imbalance on rotating machines such as pumps, compressors, blowers, fans, generators, motors, etc. in a process plant.

Mechanical imbalance was identified as one common cause of vibrations on rotating machinery. Causes include geometrically uncentred rotor mass such as may be found in machining/casting inaccuracies, or fitting/assembly tolerance inaccuracies. Other cause include uneven mass distribution such as may be found in electrical windings / commutator segments, blow holes / inclusions in castings, mismatched components, etc. Service effects such as thermal dimensional changes due to stress relieving, uneven thermal growth, and displacement / settling of components such as in electrical windings and impellers cause mechanical imbalance, just like deposit build up, erosion or corrosion of rotating parts.

The effects of such vibrations can be very damaging to the integrity of plant operations and the overall life of machinery. This in condition based maintenance is overcome by in-situ or workshop balancing to standards such as ISO 1940, BS 5265 VDI 2060, etc.

A demonstration rig was used during the presentation with ten case studies from the mineral processing industry.

A2.17: CONDITION MONITORING CONCEPTS AND PRINCIPLES

The concept of condition monitoring was introduced as being based on plants or machinery that follow the wearing-out mode of failure. As a predictive maintenance strategy, the concept is based on measuring relevant and accurate data to trend wear-out and predict failure, which can then be conviniently avoided. The presentation covered an introduction to the various condition monitoring techniques available today, such as performance monitoring, vibration monitoring, oil and wear debris monitoring, thermography, non-destructive testing, etc.

Also covered was a systematic approach to setting up a condition monitoring programme, consisting of assessment of the needs, commitment of management, implementation and evaluation.

A conclusion was made on the advantages of condition monitoring in comparison to other maintenance strategies. This includes improvement in plant availability, easier maintenance resources (both material and labour) mobilisation, maintenance duly directed prioritised, shutdown optimised and cost effective which leads to improved product quality, plant safety and environmental control.

A2.18: LUBRICANT PROPERTIES, FUNCTIONS AND TESTING - By N MALISA

This was broad introduction to the chemistry of lubricants, their formulation, packaging, identification and selection

The main functions were identified as forming a fluid film between loaded surfaces, acting as a coolant in removing heat, carrying away contaminants, protect against rust, corrosion, the accumulation of sludge, varnish and similar deposits, and act as an hydraulic medium.

The single most important property was introduced as viscosity. With illustrations from the mining industry lubricants laboratory , several tests were presented that help determine the properties and characteristics of new and used lubricants. These included total acid number, total base number, flash point, pour point, etc. The emphasis however was more on testing lubricants sampled from machinery for the purposes of condition monitoring.

A2.19: WEAR DEBRIS ANALYSIS - By S CHIPETA

In this presentation the basic concept of friction and wear were introduced, covering the various types of wear in lubricated systems such as abrasive wear, adhesive wear, fretting and corrosive wear.

The methods available today for assessment of the wear debris in oil from a lubricated system were introduced with illustrations from the mining industry oils laboratory.

Spectrometric analysis helps determine both qualitative and quantitative nature of the wear debris. Common wear metals say in a diesel engine include iron, copper, chromium, aluminum, lead and tin. The most common contaminants in used lubricants include silicon, water, fuel dilution, soot, etc.

A2.20: OIL BASED MACHINE HEALTH MONITORING - By S CHIPETA

This was a presentation on the applications of lubricant testing in monitoring the health of lubricated systems such as engines, transmissions, hydraulic systems, large oil capacity bearings and gearboxes.

Based on the condition monitoring concepts, case studies were presented covering the monitoring of the condition of the oil in use and the resultant monitoring of the condition machines. This was through trending and analysing oil physical parameters, wear elements and contaminants in the oil.

Documented case studies from the mining industry ranged from prevention of machinery failure arising from wrong oil top ups to savings of as much as 70% in maintenance costs and improvement in machinery life of as much as 25% .

A2.21: OCCUPATIONAL HEALTH , SAFETY AND ENVIRONMENT - By Dr C MWILA

This was presented starting with the historical background and evolutuion of occupation health during the European industrial revolution and the legislation that followed. A local perspective was also presented on occupational diseases and the role of trade union activities in the region.

Examples were highlighted on inherent hazards such as silica, noise, process waste, effluents and other emissions, and how to handle them with protective clothing, equipment and emergency facilities paying due regard to the working environment.