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ESTABLISHMENT OF PREVENTIVE MAINTENANCE SYSTEMS TO INCREASE PRODUCTIVITY OF PHILIPPINE INDUSTRIES

DP/PHI/87/008

PHILIPPINES

Technical report: Development of condition monitoring and failure analysis for preventive maintenance project in national engineering centre *

Prepared for the Government of the Philippines
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Richard F. Vogl,
expert in condition monitoring and failure analysis

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Industrial Management and Rehabilitation Branch

United Nations Industrial Development Organization

Vienna

* This document has not been edited.

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INTRODUCTION

In response to a request from the Government of the Philippines in establishing an institutionalized Preventive Maintenance System to increase industrial productivity within the National Engineering Center (NEC) at the University of the Philippines Campus, Diliman, Quezon City, an UNIDO Expert Mr. R.F. Vogl, undertook a two-months mission to NEC from 11 July - 10 September, 1990.

In support of the project UNIDO had provided the NEC with equipment and non-destructive testing (NDT) instruments to create a Preventive Maintenance Diagnostic Laboratory and a Preventive Maintenance Information and Promotion Service.

I. EXPERT'S ACTIVITIES AT THE NEC

The work of the Expert has been divided in two principal categories:

At first to carry out actual plant consultancy/technical service work and laboratory analysis with the use of condition monitoring instruments and secondly to develop a manual and procedure in condition monitoring and failure analysis which are specifically suitable to local industries.

I1 INDUSTRIAL PLANT VISITS

Several plant visits were carried out as follows:

A. Resins Inc. Manila

Several visits were made to this Company. There are many product lines in the Resins Inc. - supplying the paint, soap, detergent industry, etc. Among other things following plant wings could be seen.

1. ALUM Plant produces Aluminum-Sulfate in liquid and solid form. The plant, machinery equipment looks very old.

The plant is designed for 60 mt/day - at the present time they are producing only 12 mt/day - although a big demand is available for such products (peaktime)

Wear has taken place, especially on grinding rolls (components) secondary crusher mill (bottleneck) - pulverizing bauxit.

The grinding components where wear has taken place are builded up by manual welding method, hardfacing, etc.

This is the main problem in this plant.

2. SULPHURIC ACID PLANT

The plant is designed for a capacity of 40 mt/day - Monsanto process.

The plant looks corroded. A lot of provisional respective temporare devices are employed in order to protect pipeline-parts, valves etc. against to the atmosphere. Some untightness and leakage in the piping system could be seen, especially on cooling loops and hot gas filter (450°C).

Samples has been taken (corroded pipes) for metallographic examination - and some (lubricating oil) for wear debris monitoring.

3. PROPOSALS FOR CONDITION MONITORING (CM)

It is a rule of thumb that chemical plants which are older than 12-15 years - are running uneconomically. But nevertheless CM should be applied as the following:

- Wall thickness measurement, especially on piping systems, pipe narrowing, pipes - especially in contact with etching liquids, high temperature/pressure piping - for measuring wall thickness reduction. Calculation of minimum pipe wall thickness against standards (ANSI)

- Some metallographic testing could be applied, investigate embrittlement, etc. (sample)

- Wear debris monitoring (sample)

- Vibration monitoring should be applied on some specific points like vertical pumps, blower, etc especially on bearing caps.

- Hardness testing (grinding rolls) welded surfaces, welding procedures, etc.

All these kinds of CM and testing methods should be applied periodically, to see if deterioration is growing up.

There would be a need for some more plant informations, like drawings, pamphlets, process charts, flow diagrams, for better understanding.

B. <u>ARMCO Marsteel Corporation, Manila</u>

Some visits were paid to Armco Steel Mill. Raw materials are mostly scrap. During my stay the Electric Power/Demand Analyser (DRANETZ) and the Optalign Equipment for alignment of shaft-coupled rotating machines were introduced.

Furthermore, according to the wish list of the maintenance engineer they want to install leak detectors, vibration meter/analysis, laser-optic alignment (Optalign), shock pulse meter - SPM, etc.

By the way it should be mentioned that a shredder plant would be a good, economical investment for Armco Marsteel.

C. <u>Polyphosphates, Inc., Manila</u>

Several visits were carried out to this company. Different condition monitoring instruments had been introduced to the maintenance department as follows:

- Optalign, for shaft alignment.

- Thermovision, for measuring hot spots on different plant components.

- Electric power analyzer, measuring power demand.

Some explanations were given regarding different welding procedures, especially Tungsten Inert Gas (TIG) welding machines, automatic, semi-automatic.

III DEVELOPMENT OF A MANUAL IN CONDITION MONITORING, NDT AND FAILURE ANALYSIS

Some pages were prepared especially in vibration analysing and balancing, explanation of vibration, what is vibration, explanation of instruments for vibration measurements, how vibration is measured, where to measure, what measurements to make, interpretation of vibration measurements, correction of the most common mecnanical problems uncovered through vibration analysis especially unbalance misalignment, defective bearings, defective gear teeth and so on.

Another topic of the manual shows the periodical wall-thickness measurement on chemical plants by the ultrasonic method and some aspects regarding material testing by the Dye Penetrant Method.

Some further pages deal with the use of industrial radiography by x-ray tube and artificial radioactive sources, some explanation of advantages and disadvantages of radio-isotopes against x-ray tube. Attention must be paid to the radiation protection rules, dose rate measuring device, pocket dosimeter for direct reading of the radiation dose. Some explanations has been described regarding interpretation of exposed x-ray film, especially defects in welding joints and castings, cracks, lack of fusion, etc. Please see Annex II.

IV RECOMMENDATIONS

1. To impart comprehensive training at the NEC it is imperative that for the grasp of theory like audio visual aids, the practical skills be not left to imagination only. For that purpose it should be intend to display in the center a wide variety of built-up models and actual components like pumps, valves seals and bearings, etc.

   These may not be absolutely functional by their mere presence in the centre. A pump having gone out of order in the plant may be of little use there but the same will serve a useful purpose in the NEC, especially when the new building for the diagnostic laboratory is finished.

   The maintenance heads of various local factories are therefore requested to afford assistance to this engineering centre by providing models as before mentioned and other components/assemblies which they feel, can be used for training.

2. In a further stage an industrial radiography unit (x-ray) should be applied at the NEC.

   Industrial radiography is a very useful instrument in the field of NDT, especially for Quality Control of welds and castings.

3. Emphasis should be made in obtaining more contacts with local industries so that all NDT equipment is in use. Some instruments should be used not only in the maintenance field but also for inspection activities, e.g. for progress inspections during the manufacturing process of industrial plant components, and under construction and erection sites.

ANNEX I

20 November 1989

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

PROJECT OF THE GOVERNMENT OF THE

REPUBLIC OF THE PHILIPPINES

JOB DESCRIPTION

DP/PHI/87/008/11-04/J.12206

Post Title:	Expert in Condition Monitoring and Failure Analysis
Duration:	Three months
Duty Station:	Manila, Republic of the Philippines
Purpose of Project:	To assist the Government of the Philippines in establishing an institutionalized Preventive Maintenance System to increase industrial productivity.
Duties:	The expert will be attached to the National Engineering Centre (NEC) at the University of the Philippines. He will specifically be expected to:

1. Develop a manual of guideline for evaluating and improving failure analysis methods and practices in local industries.

2. Develop or provide manuals and procedures in condition monitoring and failure analysis which are specifically suitable to Philippine Industries.

3. Carry out actual plant consultancy/ technical service work and laboratory analysis with the use of condition monitoring instruments.

4. Submit a training programme in condition monitoring and failure analysis, and conduct this training for project staff and related participants.

5. Submit a list of technical literature and information materials on condition monitoring and failure analysis, indicating priority of usefulness, sources and approximate cost.

The expert will also serve as a resource person on condition monitoring and failures analysis in other project activities and will also be expected to prepare a final report, setting out his findings and recommendations to the Government on further action which might have to be taken.

Qualification: University degree in engineering (mechanical, electrical or electronics) and extensive training in condition-based maintenance. At least 5 years of industry or consultancy services experience in condition monitoring, failure analysis and predictive maintenance. Adept in the use of condition monitoring instruments such as leak detectors, eddy current meters, ultrasonic detectors, radiographic, ferrographic and spectrographic equipment.

Language: English

Background Information: The institutionalization of preventive maintenance in Philippine industries is anticipated to increase industrial productivity.

At present planned maintenance is wanting in many industries of the country. This current state is brought about by the general lack of appreciation of the benefits of planned maintenance by management and the lack of sufficient expertise to conduct maintenance activities.

The National Engineering Center (NEC), counterpart of this project, is an agency taking the lead in promoting preventive maintenance in the Philippines. It serves as a focal point to pool engineering expertise for maintenance, providing technical surveys, disseminating information and conducting training courses. However, it is necessary to upgrade and improve the skills of the core staff of the Centre in specialized fields of preventive maintenance and in utilisation of measuring and detecting equipment.

For this purpose UNIDO provides for short term expertise (2-3 m/m) in corrosion and materials engineering, condition monitoring, lubrication, instrumentation control, reconditioning of equipment, computerized maintenance management, as well as training and acquisition of equipment.

The project was started in 1988. It is expected that by the end of it (approximately 4 years duration) a Preventive Maintenance Centre will be established within the NEC to provide systematic preventive maintenance assistance and consultancy services for industry and conduct appropriate training courses for maintenance managers and technical staff. It is also envisaged to create a Preventive Maintenance Diagnostic Laboratory and a Preventive Maintenance Information and Promotion Service.

ANNEX II

MANUAL ON CONDITION MONITORING, NDT AND FAILURE ANALYSIS

It is very seldom for a machine to fail suddenly, abrupt, without any pre-warning. There is usually some weakness of machinery performances, vibration, noise or leakage, which indicates -everything is not allright.

The importance of the condition monitoring activity is to achieve an advanced warning of failure with the purpose to replacing items before their failure - in a planned matter. This has the effect of minimizing the interruptions to production.

In the event of component failure under service conditions, failure analysis of the damage should be investigated as follows:

- clarification of damage causes.
- examination of in-service components and analysis of the plant operating conditions, as well as
- lifetime analysis.

Much of the work of preventive maintenance, condition monitoring consists primarily of NDT examination to ensure that certain components are fit for further operational services. Even if it is found that their condition is satisfactory, costs can often be reduced by the use of condition monitoring instruments or other diagnostic aids which make it possible to examine the machinery without dismantling and while the plant is actually in operation. There are many, various condition monitoring instruments, NDT methods and devices described as follows:

VIBRATION MONITORING

Vibration analysis is a non-destructive testing method in which the mechanical and operating conditions of machines are checked. There are a number of ways where vibration analysis can be used, especially for periodic routine vibration measurements of machines to check their postover-

haul or repair check to ascertain that machines have been returned to good operating conditions, and check of machines prior to plant shutdown for annual maintenance as an aid to planning overhaul work.

Explanation of Vibration

If a mass is set in motion, it will move back and forth between some upper and lower limits. This movement of a mass through all its positions is defined as one cycle of vibration.

The number of these cycles in a certain time is the frequency of vibration - as one of the basic characteristics.

Cycles per minute (cpm), cycles per second (cps).

There are some other characteristics like displacement, velocity and acceleration, where measurement of vibration severity can be taken.

Portable Instruments for Vibration Measurement

a. Vibration Meter

A number of different portable instruments are available for making vibration measurements. The basic instrument for a machinery vibration preventive-maintenance program, however, is a small hand-held vibration meter, which measures overall displacement or overall velocity. A vibration meter is used for checking the mechanical conditions of machines at periodic intervals; it can also be used for noise measurement. A vibration meter consists of an amplitude-range selector, a displacement/velocity/ noise (A,B,C,) selector and a meter for reading the amplitude. A velocity pick up is connected to it by a cable.

b. Vibration Analyzer

When a mechanical defect is detected, however the vibration meter is not capable of pinpointing the specific cause. This is the purpose of the vibration analyzer.

There are many different types of vibration analyzer available. The largest number in use are the tunable filter type with vibration pick up and strobe light. A vibration analyzer has the capability to measure vibration amplitude, frequency, and phase, the three characteristics needed to describe and identify any vibration.

The tunable filter is a device to separate many individual vibrations at different frequencies as shown at most machinery vibrations so that an individual amplitude, frequency, and phase can be measured.

Points of Measurement

The bearing caps of machinery are usually the best locations for vibration measurements, since these are the points through which the forces of vibration are transmitted, - and they are accessible for measurements.

For periodic vibration checks a single measurement in the horizontal or vertical direction is often sufficient, but a complete analysis should include horizontal, vertical, - and axial measurements at each bearing cap. Periodic vibration checks are carried out at regular intervals.

Strobe Light

One of the basic vibration diagnostic instruments is the stroboscope. A stroboscope is a light source that can be adjusted to flash at a desired rate. It may be used to illuminate the vibrating surface in a fixed reference system to be analysed. When the stroboscope flash is aimed at a revolving object or moving parts and the flash rate is set to the same frequency (rpm) or a harmonic multiple of it, the moving object will appear motionless due to persistence of vision. If the flashing frequency is slightly different from the vibration frequency, the vibration displacement appears in slow motion.

Common Causes of Vibration

Unbalance is the most common cause of vibration. Unbalance is recognized by vibration occuring at rotational frequency whose amplitude in the radial direction is more than twice the axial amplitude.

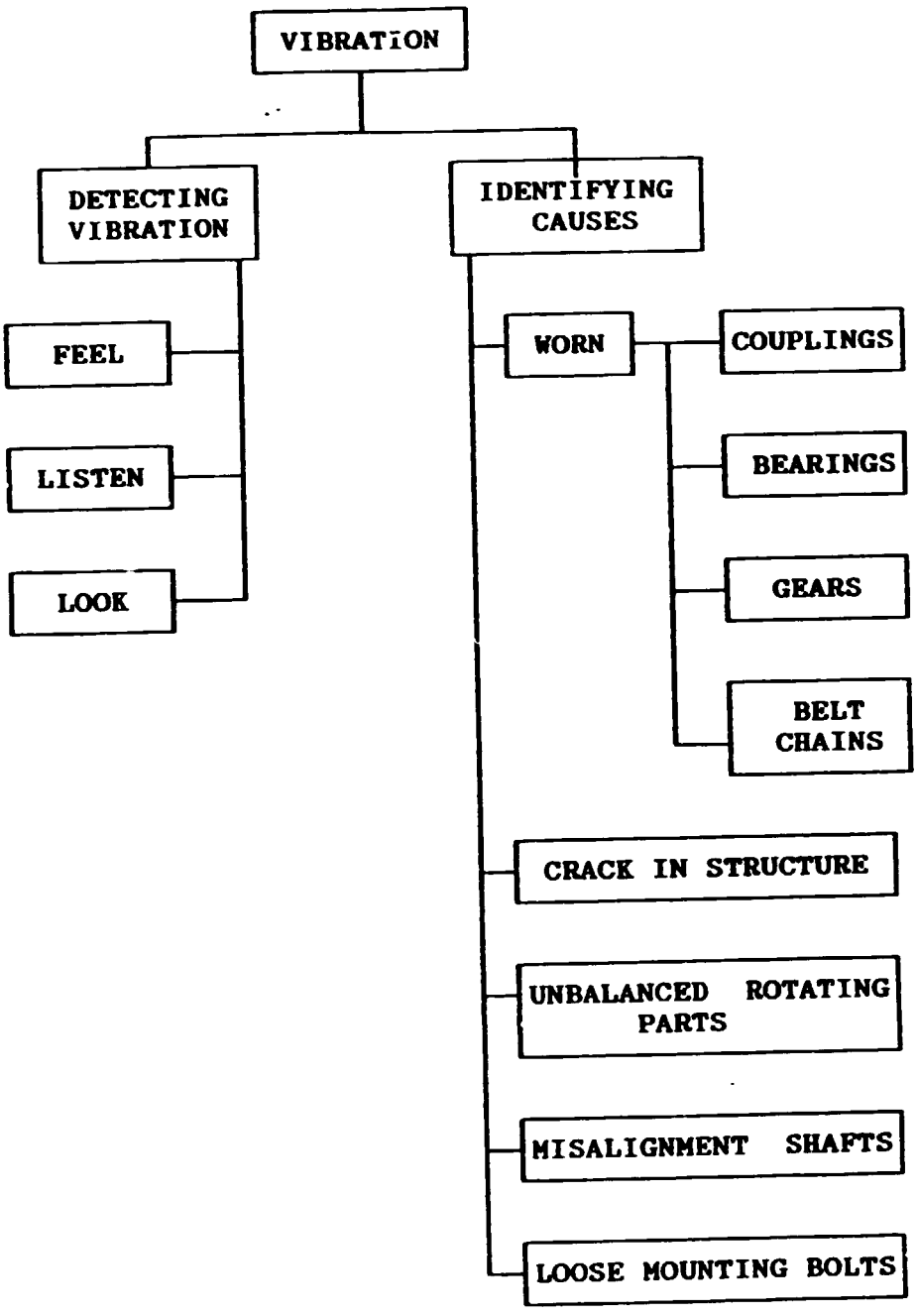
Misalignment on shafts, couplings, sleeve bearings is the second largest cause of vibration even when self-aligning bearings and flexible couplings are used.

Further common causes of vibration are bent shaft, defective antifriction bearings, eccentric rotors, defective gear teeth, mechanical looseness on sleeve bearings, bearing pedestals, foundations etc.

Correction

The most important common mechanical problem uncovered through vibration analysis is the correction of mechanical unbalance. Unbalance is the unequal distribution of the weight of a part about its rotating centerline.

The more unbalance present - the greater the force, and therefore the greater the vibration. The amount of weight at the same radius but opposite the heavy spot will balance the rotor.



LOOK, LISTEN, FEEL (LLF)

The LLF technique is commonly used for all rotating machines. Failures are mostly preceded by warning signals in the form of excessive vibration, abnormal noise, increased bearing temperatures, etc.

WEAR DEBRIS MONITORING

Parts of machines which move to each other generate wear debris from its interactions. Wear debris components are flushed with lubricating oils and debris can be extracted. By examining the quantity, type, size of wear debris that has been generated useful facts of condition can be obtained. The amount of debris generated gives an indication of the existence of a failure. This maybe local fatigue, pitting, etc. depending on the form and composition of the debris.

Two main methods for inspection are in common use:

1. Magnetic plugs method
2. Spectrographic oil analysis

Examinations should be done in regular intervals.

INDUSTRIAL RADIOGRAPHY

Sources of radiation:

The X-ray Tube consists of a glass bulb under vacuum, enclosing a positive electrode or anode and a negative electrode or cathode. The cathode comprises a filament which, when brought to incandescence by a current or a few amperes, emits electrons.

Under the effect of the electrical tension set up between the anode and cathode - these electrons from the cathode are attracted to the anode. This stream of electrons is concentrated in a beam by a cylinder or focusing cup.

Artificial Radioactive Sources (Isotopes)

Artificial radioactive substances are obtained by fission or irradiation in a nuclear reactor. It is possible in this way to obtain several isotopes in relatively large quantities and in a reasonably pure state. Among the factors deciding their value for the non-destructive testing of materials are the hardness and intensity or their radiation, their half-life and their specific activity.

Some advances and disadvances of isotopes against the x-ray tube.

- They need no electric power supply and no cooling system, so that they are very easy to use on a worksite.
- Since they give less contrast images, this means that the radiographs are less easy to interpret.
- At it is impossible to switch off the radiation emitted by radio-active sources, they penetrating or intense, the shielding needed may be quite heavy.
- The radiation from radioactive sources cannot be adjusted.

Interpretation of Radiographs

The defects found in welded joints fall naturally into several groups, especially cracks, lack of fusion, inclusions and so on.

Radiation Protection

Persons using x-ray or gamma-ray equipment must always wear a film badge and carry a pocket desimeter. The rooms in which the radiation work is done as well as the adjacent rooms must be constantly monitored with a radiation dose rate measuring device.

PERIODICALLY WALL-THICKNESS MEASUREMENTS

An Ultrasonic wall thickness gauge is a small portable digital ultrasonic unit designed for making rapid non-destructive thickness measurements. Ultrasonic wall thickness gauges are used mainly where it is impossible to use conventional mechanical gauges or where such gauges has their accuracy owing to extend lenght of caliber arms, etc. As it requires access to only one side of the material being measured it is ideal for site work.

Chemical plants, boiler, pipes, ship-huls, and the like can be checked periodically in service in order to make preventive maintenance to determine the amount of corrosion which has taken place.

From a good local knowledge and experience with fractures and accidents, the zones of maximum stress are known in many cases. Positions where wall-thickness reduction, wear rates of corrosion normally occur. Elbows on piping system, pipe narrowing, inlet and outlet, nozzles on high pressure boilers, fittings fabricated by grey-casting especially in contact with etching liquids, all high pressure and high temperature piping systems and so on.

If it is known, e.g. in a high pressure steam pipe, where the flows normally occur, the possible dangerous wall thickness reduction can be recognized in time, and their magnitude and dangerous character assessed and prevented.

From the economic point of view it is very necessary to detect wall thickness reduction in time, in order to pre-fabricate spares, respective replacement pieces.

DYE PENETRANT METHOD

Dye penetrant method is applicable on all solid materials, such as cast steel, grey cast, alloyed or non-alloyed steel, aluminum, copper, etc. For detecting cracks, pores, and overlaps and it is free from chlorine and sulphur.

Applications:

- Test parts to be degreased and cleaned as well as other impurities removed.
- Penetrant Dye to be applied. Time of reaction depends on material, temperature, etc. and ranges on the average between 10 - 20 minutes.
- Work pieces to be cleaned from penetrant dye by special cleaner or water and to be dried.
- Developer to be applied in the thinnest possible manner. After short drying period penetrant dye penetrates on the defective spots showing a red contrast. Depth and wide of crack may be taken from width of colour mark in the white developer coat.
- Inspection - red lines in the white developer field show cracks and overlaps if present.
- It should not be smoked nearby. When working in closed rooms you should care for proper aeration.

ANNEXURE III

PERSONS MEET DURING MISSION

Mr. Ricky Rodriguez	-	Resins Inc.
Mr. Nathaniel Cultura	-	Resins Inc.
Mr. Rene Santos	-	Armco-Marsteel Alloy Corporation
Mr. Ruperth V. Ponaro	-	Polyphosphate Inc.
Dr. Francisco L. Viray	-	NEC
Mr. Edward R. Bondoc	-	NEC

WORKSHOP ON PREVENTIVE MAINTENANCE
NATIONAL ENGINEERING CENTER
U.P. Campus, Diliman, Quezon City
August 29, 1990

P R O G R A M M E

8:00 - 8:45	Registration
8:45 - 9:45	**Opening Ceremonies**

Opening Remarks

DR. ESTER A. GARCIA
Vice-Chancellor for Academic Affairs
University of the Philippines

Messages

DR. CIELITO F. HABITO
Asst. Director General
National Economic & Development Authority

MR. TURHAN K. MANGUN
Resident Representative
United Nations Development Programme

Keynote Address

DR. RICARDO T. GLORIA
Undersecretary
Dept. of Science and Technology

Master of Ceremonies

DR. FRANCISCO L. VIRAY
Executive Director
& Project Director
UP-NEC Preventive Maintenance Project

10:00 - 10:30	Paper Presentation - Current Trends in Preventive Maintenance **Mr. Tristan H. Calasanz**
10:30 - 10:45	Open Forum
10:45 - 11:15	Paper Presentation - Elements of a Successful PM Program **Mr. Henry T. Galingan**
11:15 - 11:30	Open Forum
11:30 - 12:00	Workshop Orientation/Groupings
1:00 - 1:30	Film Showing
1:30 - 3:30	Workshop Proper
4:00 - 5:00	Group Presentation (10 minutes each - 6 groups)
5:00 - 5:30	Summary