CONFERENCE OMAINTEC 2005 EXHIBITION
بيروت ٢٠-٢٣/٦/٢٠٠٥
Beirut 20-23/6/2005

الملتقى الدولي السنوي الرابع
للتشغيل والصيانة في البلدان العربية
The 4thInternational Operation and Maintenance
Conference in the Arab Countries OMAINTEC 2005

Industrial Maintenance Education and Training

In the New Millennium

Mohammad Othman Al Nais
EdD, College Dean,
Hail College of Technology.
Email : dr_alnais@hotmail.com

Mohamed AICHOUNI
PhD, Assistant Professor
Hail College of Technology
Email : m_aichouni@yahoo.co.uk

Abstract

There is no doubt that plant maintenance is among the most crucial operations in industry; Even more ***`there is gold on those Reliability and maintenance Practices`*** . Proper maintenance training can help companies save money, increase product quality, and improve employee morale. In recent years, the subject of industrial maintenance training has become a hot subject. Many US technical colleges, community colleges, technical universities, professional organizations and consultancy firms have developed and implemented successful training programs. The present paper is dedicated to address this important issue from economical, technical and managerial standpoints. The analysis led the authors to make a proposal for a training program in this specific technical area at the Technical Education and Vocational Training level to support real and urgent need of Arab industrial companies. The training if implemented at technical or community colleges of the region would lead to an associate degree in industrial maintenance. The development of this training program is believed to be original since there is no academic training institution offering such a program in the Arab world.

KEY WORDS: *Industrial Maintenance, Competency-based Education, Vocational Training, Quality , Technical, DACUM, ABET.*

1 - INTRODUCTION

As we enter the 21st century, economy and manufacturing industry are becoming increasingly competitive. Three major forces have contributed to these important fact; These are:

- the globalization of trade, investment and manufacturing;
- the development of international standards for all kinds of goods and services; and
- the explosive growth of High-Tech in almost every sector of the economy.

Engineering education and technical training have reached a level of unprecedented strategic importance to the industry, to the economy and to society as a whole. Demand for advanced technical skills and high requirements on the qualifications of persons working in the many different areas of industrial activity are continuously increasing to ensure competitiveness and product quality. In plant operation, the production equipment and machinery is one of the few areas where significant economic gains can be made. This is true, when the machinery are kept running smoothly and without serious failures. Such an activity has been allocated to skilled maintenance technician and craftsman at the production plant. Their work is vital to the success of the industrial facility, not only because an idle machine will delay production, but also because a machine that is not properly maintained would affect the quality of the final product and may cause serious injuries to operators.

The US Department of Education conducted a survey aiming to determine the major factors leading to an increase in manufacturing productivity. The results of the survey are as follows:

- Increasing capital stock by 10% increases productivity by 3.2%.
- Increasing an individual's work hours by 10% increases productivity by 6.0%.
- Increasing an individual's educational level by 10% increases productivity by 8.6%;

The survey shows clearly the vital impact of education and training on the overall plant productivity. The study also showed that skill level of maintenance personnel in the US and Canada is well below what the industry would judge acceptable; (80 percent are bellow the required level). A properly designed and developed maintenance skills assessment and training programs would be the solution. A thorough analysis of the industrial situation in Arab countries would certainly give even poorer figures.

Maintenance training, properly developed and implemented, can help companies save money, increase product quality, and improve employee morale. The subject of industrial maintenance training has become a hot subject. Many US technical colleges, community colleges, technical universities, professional organizations and consultancy firms have developed and implemented successful training programs. Outstanding educators, industrial engineers and managers have been working together to implement recent educational concepts such as `Competency-based education`, DACUM curriculum analysis and Web-Based Training to design and develop industrial maintenance training programs. Major skills needed by industry have been identified by the Accreditation Board of Engineering and Technology Programs (ABET). Industrial Maintenance Technician programs developed by Cameron University, Western Oklahoma State College, Madison area Technical College and Wisconsin Indianhead Technical College have been declared by industrial and professional organizations to be exemplary and promising technical programs.

In this paper we address the important issue of industrial maintenance training from economical, technical and managerial standpoints. The analysis leads us to make a proposal for a training program in this specific technical area at the Technical Education and Vocational Training level to support real and urgent need of our industrial companies. The training if implemented at technical or community colleges of the region would lead to a an associate degree in industrial maintenance. The development of this training program is believed to be original since there is no academic training institution offering such a program in the Arab world.

2 – Brief Overview on Maintenance in the past, present and the future

In this section, we will present an overview of maintenance industry from the past, the present and then we discuss what would be the future of maintenance with the advent of the Information and Communication Technologies which are the most important fact of modern societies.

2.1 - The maintenance industry in the past

Few decades ago, maintenance was thought to be the wicked-surgeon department in a company or plant. Most operations asked for immediate undertaking without preparation. Inventiveness and good hammering were two of the core competences needed to be a good maintenance technician. Thirty years ago maintenance costs in U.S. companies were between 0.4% and 0.8% of the total sales. The proportion is now significantly higher. In 1992 a typical manufacturer operated using approximately 55% reactive maintenance and 31% preventive maintenance practices (White 2004). Most industrial companies are embracing these new technologies and working methods. Maintenance activity typology for typical industrial plant is presented in table 1 and figure1.

Table 1 - Maintenance Activity typologies

Maintenance type	Percentage of Usage in plant
Reactive Maintenance	55
Preventive Maintenance	31
Predictive Maintenance	12
Other	2

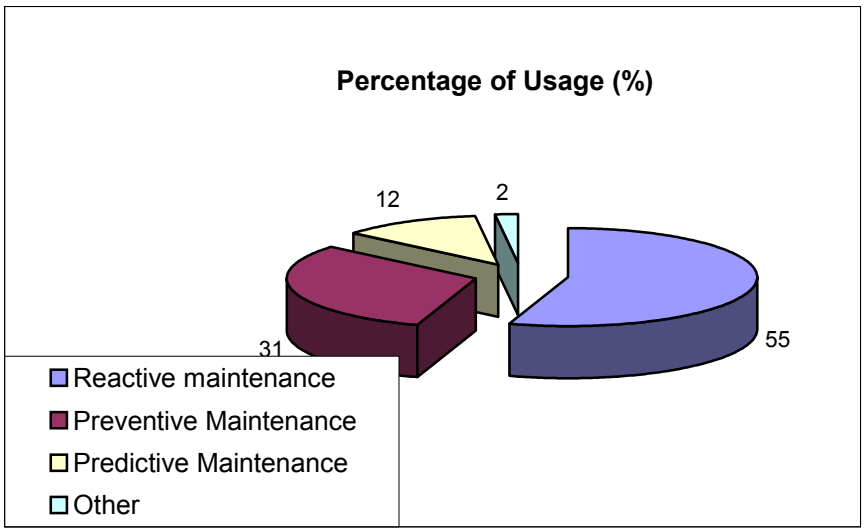
Overtime, another key indicator, constituted on average 15% of the total working time in maintenance organizations. This figure is relatively high. Since maintenance is putting in so much overtime, it confirms the reactive approach that is usual in industry. Reducing overtime is essential if a maintenance organization is to be truly cost-effective.

2.2 - Maintenance today

Today, maintenance costs range from 3% to 15% of total sales and from 2 to 12% of product costs and are probably the largest, most out-of-control "controllable" cost in the plant. This clearly indicates that the importance of reliability and maintenance practices has been changing. A few years ago, most organizations were often reacting to failures and the best practice was preventive maintenance programs designed to maintain equipment in good

condition. Today's environment has shifted focus to predictive and proactive maintenance approaches. Programs such as Total Productive Maintenance (TPM) and Reliability Centered Maintenance (RCM) are being implemented. Best practices involve monitoring the condition of equipment, performing failure modes effects analysis (FMEA) to determine root causes of failure, and training, developing, and involving operators to lower equipment-related costs and to increase the value added in production. Most of modern companies including those in the Arab world are embracing these techniques and working methods.

Figure 1 – Maintenance Activity Typologies in Plants



The principal players on the maintenance market have also been changing. This change highlights the strategic importance maintenance activity has gained within industrial manufacturing processes. The most important players are: industrial manufacturers, machinery manufacturers, spare parts suppliers, consultants, maintenance professional organizations and software manufacturers. The advents of Information and Communications Technologies (ICT) in general and the Wide World Web (www) have completely changed our maintenance philosophy and practices. The huge capabilities offered by these new technologies are shaping industrial technology and management. Figure 2 shows how maintenance has evolved into a real asset management discipline with the deployment of successive waves of technology especially, ICT and the World Wide Web (www). In his recent paper White (2004), discussed thoroughly how can the new ICT technologies improve maintenance practices in industrial plants.

2.3 - Maintenance Issues in the New Millennium

It is well agreed that the new millennium is characterized by globalization of trade, investment, manufacturing and the development of International Quality Management Standards (ISO 9000 series) associated with an explosive growth of high-Tech technologies in all the possible areas of our modern economy. These three major forces have pushed hard the old hammering activity to reshape it self within industrial plant organizations. Completely new issues have evolved; These are:

- Remote Maintenance
- Knowledge Management
- Computer based training, Web based Training.

As predictive maintenance uses data, which is transmittable by a network, it offers the opportunity to keep an eye on machinery from a distance. Though costs can be seen at the beginning to be higher, it will normally drop as wireless technology comes online. Internet tools are very powerful in remote consulting and obtaining information about accreditations and norms related to maintenance activity. It certainly saves time and money.

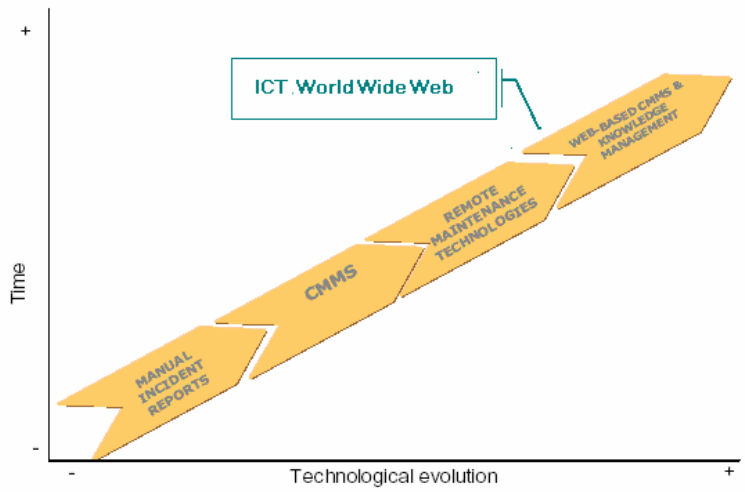


Figure 2 – Evolution of Maintenance Management with Technology (White 2004)

Knowledge management is referred to as the accumulation of experience and tacit knowledge that goes beyond the simple quantitative indicators that are generated by information systems such as CMMS. Maintenance engineers and technicians can now register information related to their activities in a computerized format. Even the data from predictive maintenance can be brought into the system and elaborated upon.

The concepts of e-markets and e-Commerce which came too soon and too fast to industry can be the most appropriate way to provide added value by using the internet in maintenance. More and more suppliers are contacted through email. Technical drawings on plant situations are sent in digital format to suppliers. This allows significant time-saving. There is more and more internet usage to find information through search engines (Yahoo and Google). Normally, catalogues are consulted to compare price, afterwards an offer is requested through email. Internet use is still variable between different plants in the industrial groups concerned. Some maintenance professionals are regular users of internet technology while there are some factories that are not even connected yet.

3 - Job Opportunities for Industrial Maintenance Technician

Industrial Maintenance Technicians are responsible for keeping things running in a variety of organizations. They are in demand in all types of industries and services. Industrial machinery installation, repair and maintenance are critical operations for manufacturing, petrochemicals, water desalination, power generation, food processing, pharmaceutical, textiles industries. Such operations have also a great importance for air and maritime transport companies,

telecommunications, health services, military and armed forces, and many more civil services. Typical careers available after graduation would include:

- Maintenance Technician Assistant
- Maintenance Technician Foreperson
- Maintenance Machinist
- Maintenance Technician
- Maintenance Welding
- Multi-craft Industrial Maintenance Technician.

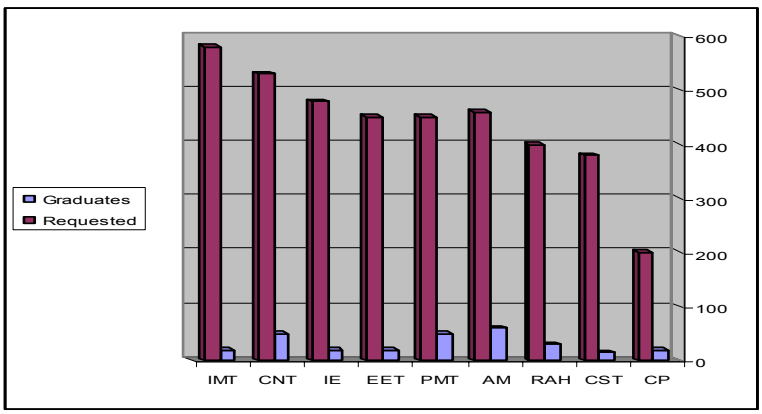
The graduate can enter the private business of Machine Repair, Machine Rebuilder, and Millwright. He can advance to such positions as Maintenance Leadperson, Maintenance or Millwright Apprentice, Foreman, or Maintenance Superintendent.

In a recent study conducted by Ranken Technical College at St Louis, USA, it has been shown that there is a strong demand at both national and international levels for Industrial Maintenance Technician. The results presented in table 2 and figure 3 show clearly there is a real need to this technical specialty and that the requested number of technicians by the industry in one area is far to be satisfied by the graduates from the technical college of that area.

Table 2 – Job Opportunities for IMT (Results from a typical technical college (Ranken TC, St Louis, MO) for the period June,1, 1999 to May , 31, 2000)

Industry		Graduates	Requested
CP	Carpentry / Building and Construction	**20**	**200**
CST	Control Systems Technology	**15**	**380**
RAH	Refrigeration , Air Conditioning	**30**	**400**
AM	Automotive Maintenance	**60**	**460**
PMT	Precision Machining Technology	**50**	**450**
EET	Electronics Technology	**20**	**450**
IE	Industrial Electricity? Electronics	**20**	**480**
CNT	Computer Networking	**50**	**530**
IMT	**Industrial Maintenance**	**20**	**580**

Figure 3 – Workforce demand on Industrial Maintenance Technician



Another important argument concerning this training program is that pay rates for people in industrial maintenance field are among the highest of all trades and businesses. Table 3 summarizes the results of the 2004 salary survey in USA published by the Plant Maintenance Resources Center.

Table 3 – Annual Salary by Position (2004)

Position		Salary (US $)
MC	Management Consultant	107.143
CE	Consulting Engineer	78.333
MMS	Maintenance Manager/Superintendent	64.213
MP	Maintenance Planner	56.583
MFS	Maintenance Foreman / Supervisor	53.405
PME	Plant Maintenance Engineer	53.333
MCT	Maintenance crafts / tradesperson	52.400
CIT	Computer / IT Consultant	50.000
PIE	Process / Industrial Engineer	47.500
IMT	Industrial Maintenance Technician	46.250
Other	Other	52.042

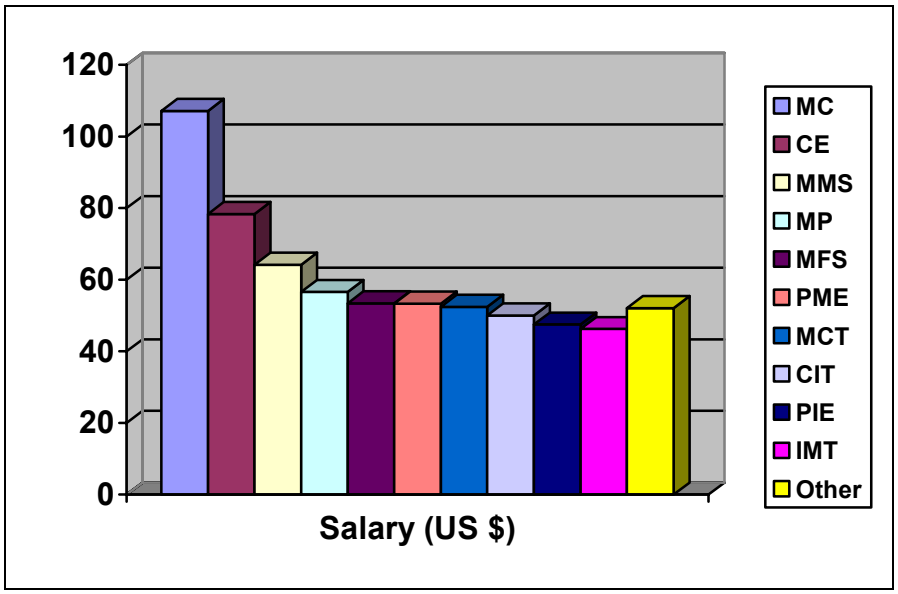


Figure 2 – Annual Salary by Position (2004)
Source : 2004 Plant Maintenance Salary Survey Results From Plant Maintenance Resources Center www.plant-maintenance.com/articles/salarysurvey04.pdf

4 – Who Offers Maintenance Training ?

Since the early 1950`s, the United States and Europe have been leaders in the efficacy and efficiency of the delivery of industrial maintenance education and training. Basically, training was all about mechanical and aviation maintenance. However, recent events indicate that industrial maintenance education is in need of a broadening of scope in order to meet the urgent needs of the 21st Century's industry. The need and importance of maintenance training

has continued to rise in the last decade as a consequence of the increased requirements of ISO 9000 and ISO 17025 quality assurance standards. Now, maintenance training, which is required to support private industry as well as the public sector, is offered by educational colleges, technical universities, commercial test equipment manufacturers, industrial consultants and professional societies such as the Society of Maintenance and Reliability Professionals. An internet research on colleges offering associate degrees in industrial maintenance and related topics such as industrial machinery mechanics and mechanical maintenance led to the following results:

- Madison Area Technical College
- Wisconsin Indianhead Technical College
- Texas State Technical College
- Ranken Technical College
- ElizabethTown Community and Technical College
- Alpenna Community College
- Western Oklahoma State College
- Prairie State College
- Cameron University
- Society of Maintenance and Reliability Professionals (www.smrp.org)

A comprehensive resources on maintenance training programs available on the net can be found on the web site of the Plant Maintenance Resources Center at:
http://www.plant-maintenance.com/training_materials.shtml
Many of these institutions offer their training programs in both on-campus and on-line formats. Hundreds of industrial companies, professional organizations and consultants implemented highly successful technical skills training programs tailored precisely to the needs of plants facilities. Computer based training (CBT) and on-line Web based training (WBT) have been adopted to deliver efficient training and education in maintenance.

In the Arab countries, to the best knowledge of the authors, the only technical college who offer similar training program is the industrial technical college of Yunbu in the Kingdom of Saudi Arabia the degree offered is Mechanical Maintenance Technician.

5 – What are the Skills an Industrial Maintenance Technician should possess Required ?

The Industrial Maintenance training program is one of the most prosperous new programs developed at several technical and community colleges in USA and Canada. Extensive analyses have been undertaken by government departments and professional organizations such as the Oklahoma Department of career and technology education and the American Society of Mechanical Engineers to identify the basic skills required by the industrial workplace partners. Industrial Maintenance technician graduate who will work in manufacturing and many other service industries should possess the following technical competencies and skills:

- Understand the basic maintenance principles and practices.
- Repair and maintain machinery in a plant or factory,
- Repair and maintain gears, chains, and belt drives on industrial equipment.
- Design, build, maintain, and troubleshoot mechanical systems.
- Perform preventive and predictive maintenance on industrial equipment.
- Use prints, schematics, diagrams, and engineering specifications.
- Repair and maintain hydraulic systems (pumps, valves, gaskets types and seals common to general industrial applications.
- Install common piping systems to industrial standards.

- Troubleshoot, repair, and maintain fluid power systems.
- Perform basic machining operations on milling, drilling, and turning machine tools.
- Perform basic welding procedures.
- Apply life skills for success in an industrial environment
- Use volt, ohm, and amp meters to perform troubleshooting on electrical systems.
- Use standard input control devices in a variety of electrical systems.
- Install, program, and troubleshoot process logic control systems.

6 – Training Program Content – The Proposal

In order to ensure that the required technical skills maintenance technician should possess, the training program leading to the degree should be carefully designed. The program should provide students and trainees with the knowledge and skills necessary to assemble, install, troubleshoot, repair and modify machinery and automated systems in manufacturing and facilities environments.
Experienced maintenance engineers from the US government departments (trade, defense and industry) and technology educators worked out together within a DACUM-National Science Foundation program to identify the competencies required of industrial maintenance technician needed by modern industry. After a careful analysis of the programs offered worldwide and thorough discussions with colleagues educators at technical colleges and industrial engineers (mainly via emails), and using benchmarking, the training program offered by Madison area technical college was decided to be the foundation of our proposal. It has to be noted here that this training program received the 2003 ASME prize of an exemplary program and was named a promising program by the US National Dissemination Center for Career and Technical Education (CTE).

The proposed program would lead to a **Diploma** in **Mechanical Technology** with a specialization in **Industrial Maintenance**. The training program which is outlined in table 4 is intended to provide students and trainees with the knowledge and skills necessary to assemble, install, troubleshoot, repair and modify machinery and automated systems in manufacturing and facilities environments. Though the training program is designed to meet Saudi industrial needs in term of maintenance technicians, it can easily implemented in any other Arab country to meet their industrial needs. As an academic and technical program, it is based on both theoretical lectures and hands-on laboratory work to prepare the trainees to successfully enter the maintenance work force.

Table 4 – Proposed Program for a *Diploma in Mechanical Technology* Specialization *Industrial Maintenance*	
First Semester 19	
Mathematics (Algebra, geometry, trigonometry, statistics)	3
Physics and Chemistry	3
English 1 (oral and written communication)	3
Engineering Drawing	3
Metal Processes 1	3
Industrial safety	2
Industrial measurements	3
Second Semester 16	
English 2	3
Islamic culture 1	2
Industrial fluid power	3
Industrial Computing	3
Industrial equipments / Industrial electricity	3
Material Testing	3

Third Semester 17	
English 3	3
Heating and air conditioning 1	3
Industrial maintenance mechanics	2
Metal Processes 2	3
Fluid Distribution systems	3
Industrial Control Systems	3
Fourth Semester 19	
Arabic language (writing technical reports)	2
Islamic culture 2	2
Heating and air conditioning 2	3
Maintenance Management	2
Welding Techniques	3
Manufacturing systems and Quality control	2
Interpersonal Relations and Professional Development	2
Electronic circuits for maintenance	3
Summer Practical (In field) Training	**4**
Total Credit hours	**74**

7 – Concluding Remarks :

To meet the needs of industry, business and government for industrial maintenance personnel, many technical and community colleges worldwide have been developing successful training programs. These have been declared to be the most promising training programs of the era among all industrial technology programs by National agencies and professional organizations.

It is the authors belief that there is a real and urgent need of industrial maintenance personnel at industrial plants in Arabic countries. Benchmarking has been used to develop a two years training program leading to an Associate degree in Industrial maintenance. The program can easily be implemented in existing technical colleges of the region.

References:

[1] `Industrial Maintenance Technology Skills Standards`, Oklahoma Department of Career and Technology Education, 2004.

[2] `Industrial machinery Installation, Repair and Maintenance Workers, Except Millwrights`, US Bureau of Labor Statistics 2004 Report, Available on internet at : www.bls.org/oco/ocos191.htm

[3] Exemplary and Promising Programs – Industrial Maintenance Technician, Available on internet at : http://www.nccte.org/exemplary/showcase/programDetail.asp?ep=66

[4] How to Develop and Implement A Successful Maintenance Skills Training Program, Richard A. Smith, Available on internet at: http://www.maintenanceresources.com/ReferenceLibrary/MaintenanceManagement/howtodesign.html

[5] Criteria for Accrediting Engineering Technology Programs, Effective for Evaluations during the 2004-2005 Accreditation Cycle. Available from Internet : www.abet.org

[6] SMRP 2000 Survey, `**There is gold in those reliability and maintenance practices**`, Society of maintenance and Reliability Professionals (www.smrp.org)

[7] Tim White, 2004, `**An Exploratory study of the role of internet technologies in the field of industrial maintenance : Is knowledge management the way forward?`,** Journal of Information Systems and Technology Management, Vol. 1 (1), pp. 94-110.