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ASSISTANCE IN THE ESTABLISHMENT OF A TESTING AND QUALITY CONTROL LABORATORY AT THE HOMS REFINERY

IS/SYR/75/003

SYRIAN ARAB REPUBLIC.

TERMINAL REPORT

Prepared for the Government of the Syrian Arab Republic by the
United Nations Industrial Development Organization,
executing agency for the
United Nations Development Programme

United Nations Industrial Development Organization

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United Nations Development Programme

ASSISTANCE IN THE ESTABLISHMENT OF A TESTING AND QUALITY CONTROL LABORATORY AT THE HOMS REFINERY

IS/SYR/75/003

SYRIAN ARAB REPUBLIC

Project findings and recommendations

Prepared for the Government of the Syrian Arab Republic
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Sabri A. Aglan, quality control expert

United Nations Industrial Development Organization
Vienna, 1977

Explanatory notes

References to dollars ($) are to United Staes dollars, unless otherwise stated.

The monetary unit in the Syrian Arab Republic is the Syrian pound (LS). During the period covered by the report (1976), the value of the Syrian pound in relation to the United States dollar was $US 1 = LS 3.90.

The following abbreviations are used in the report:

API American Petroleum Institute

ASTM American Society for Testing and Materials

LPG liquefied petroleum gas

ABSTRACT

This is the terminal report of the project "Assistance in the Establishment of a Testing and Quality Control Laboratory at the Homs Refinery"(IS/SYR/75/003). The project was requested by the Government of the Syrian Arab Republic in February 1974. The project which called for the supply of analytical equipment and the services of an expert for six months, was originally approved by UNIDO for financing under the General Trust Fund (VC/SYR/74/068). It was later agreed that the entire original amount of $US 105,000 should be used to purchase equipment and that the assistance of the expert ($US 25,300) should be financed under the programme for Special Industrial Services (SIS).

The Homs Refinery laboratory is a medium-sized laboratory which was enlarged after the October 1973 war. The expert found that the present building is sufficient for the activities performed.

Equipment

The equipment that was ordered by the Refinery and that was supplied by UNIDO can well cover the present requirements. The expert suggests the acquisition of additional items in his recommendations. Most of the equipment received is at present operating; a few items are not working because of lack of accessories, chemicals and operating manuals. Over 80% of the equipment ordered by UNIDO was received by the Refinery in good order. A few items (not more than 5%) were found defective and the matter is being handled by UNIDO authorities with the insurance companies.

Laboratory personnel

The number of laboratory personnel is adequate, except for chemists. The quality of laboratory technicians is promising and with continuous training and encouragement they will be able to handle most of the laboratory routine activities. In the area of training the expert includes suggestions for training new personnel and on-the-job training in his recommendations. Special work and the operation of complicated equipment require a number of chemists who are not available at present.

A proposed laboratory organisation covering number, posts and job

descriptions was submitted to the management of the Refinery. Annexes contain information on analytical procedures, safety and fire-fighting activities and a follow-up report on an earlier UNIDO assistance project on preventive maintenance and mechanical inspection.

CONTENTS

Annexes

INTRODUCTION

Background

As the Homs Refinery laboratory was severely affected during the war of October 1973, the Government of the Syrian Arab Republic in February 1974 requested assistance for the establishment of a testing and quality control laboratory at the Refinery. In July 1974 UNIDO approved the project for financing under the General Trust Fund in the amount of $US 105,000 for equipment and the services of an expert for six months. On the request of the Government the expert's arrival was postponed until the bulk of the equipment had arrived.

The project, which was entitled "Establishment of a testing and quality-control Laboratory at the Homs Refinery"; was originally given project No. VC/SYR/74/068. Later in July 1975 it was agreed that the expert assistance would be financed by Special Industrial Services (SIS) (IS/SYR/75/003) and that the original project budget would be fully utilized for the purchase and supply of analytical equipment.

Quality-control concepts

In the oil industry, as in most of the chemical industries, quality control is becoming an essential part of the industrial process (see analytical procedures detailed in annex I). It is a good and indispensable tool in the production stages. Samples from the different streams are periodically collected and tested for certain key properties. The results obtained help the operations engineer to adjust the operating units.

Quality control is carried out on finished products through determination of specified physical and chemical properties to meet sales contracts, state specifications and in all cases to ensure safe application of products.

Another important function of quality control sections is the services given to other departments of the refinery helping them to offer the required technical services in the following fields:

(a) Water treatment and industrial water conditioning;

(b) Corrosion minimization through analytical measurements;

(c) Trouble-shooting and modifications studies etc.

In short, quality control ensures efficient, economic and safe operation.

Objectives of the project

According to the project document, the goals of the project were:

(a) To supply certain analytical equipment as requested by the Government that was needed for quality-control activities;

(b) To provide the Refinery with a quality-control expert for six months who could assist in the following fields:

(i) Advising on and planning the layout and installation of equipment for the purpose of establishing a laboratory suitable for testing and quality control of refinery products and raw materials;

(ii) Training the refinery personnel in the use of the equipment and in modern techniques of petroleum testing;

(iii) Making recommendations on the long-term planning and organization of the laboratory including further requirements for training.

The counterpart laboratory senior staff were: Maged Hossamy, Laboratory Chief; Khalid Soliman, Supervisor of the Analytical Laboratory Section; and Mohamed B. Abdulgalid, Supervisor of the Gas Laboratory Section.

I. FINDINGS

Homs Refinery operations

The Refinery started operations in 1959 with a small capacity. Since then it has been expanded and the present facilities comprise various types of units, a coker complex and utilities.

Crude distillation units

There are four distillation units with an annual capacity of more than 5 million tons. Different types of crude oils are processed and, accordingly, the pattern of yields (quantity and quality) varies. Products obtained are processed further to achieve the following objectives:

(a) Separation and treatment of hydrocarbon gases to produce liquid petroleum gases;

(b) Hydrogenation and desulphurization of naphtha before platforming;

(c) Hydrogenation and desulphurization of kerosine to produce jet fuel;

(d) Hydrogenation and desulphurization of gas-oil to reduce sulphur and to improve combustion properties.

The residue from atmospheric distillation is handled as follows:

(a) Used as fuel oil (if sulphur content is acceptable);

(b) Distilled under reduced pressure for bitumen production;

(c) Used as feedstock for the delayed coker complex.

Vacuum distillation units

One unit has an annual capacity of about 100,000 tons. The bitumen produced represents 70% from feed.

The coker complex

Annual capacity is about one million tons of atmospheric residue. Major equipment includes:

Coking heaters

Coking drums

Fractionating tower

The main objectives of the complex are:

(a) Maximization of middle distillates;

(b) Minimisation of residue which is converted into petroleum coke;

(c) Production of appreciable quantities of hydrocarbon gases rich in H_2S

The gases produced are further separated and treated to give the following products:

H_2S-rich stream for sulphur recovery unit

LPG for bottling

Fuel gas for refinery heaters

The distillates obtained are unstable and should be hydrogenated and desulphurised.

Hydrogenation and desulphurisation units

There are three units, the main features of which are as follows:

Naphtha-kerosine hydrogenation unit. Annual capacity is about 250,000 tons. Through catalytic reactions, S is converted to H_2S.

Light gas-oil hydrogenation unit. Annual capacity is about 700,000 tons. Catalytic desulphurisation and hydrogenation reactions take place, and S is converted to H_2S.

Heavy gas-oil hydrogenation unit. Annual capacity is about 150,000 tons. The same reactions take place as in the preceding unit.

Hydrogen-producing unit

Naphtha is steam-reformed to produce about 16,000 NM^3/h of hydrogen. Purity is over 97%.

Platforming unit

Naphtha is reformed over platinum catalyst to produce reformate of more than 86 octane number. Hydrogen and hydrocarbon gases are produced as by-products.

Utilities

Water is pumped from the Al-Assy River. Water treatment facilities include coagulation, filtration and softening.

Demineralised and soft water are produced for different applications.

Cooling water is circulated in a closed system which is replenished from time to time with treated water.

Steam is generated through a number of high-pressure boilers. Different steam pressures can be obtained through reduction facilities.

Waste water is treated through an API separator as well as through other facilities for chemical treatment.

Existing quality-control facilities

The quality control laboratory is a section under the operations department. The activity is carried out by the main laboratory which is located beside the administration building. Available facilities consist of a two-floor building which has been recently repaired and enlarged. It includes the following laboratory sections:

On the first floor:

- Day laboratory
- Octane laboratory
- Analytical laboratory
- Special laboratory

On the second floor:

- Shift laboratory
- Gas laboratory
- Titrations laboratory
- Jet-fuel laboratory

The building was found adequate; it needed only a few modifications in equipment layout and in the distribution of activities carried out by each laboratory section.

The first report of the expert to the management of the Refinery, in September 1976, proposed new laboratory functions and some modifications in the activities performed by each laboratory section. According to this study, laboratory functions cover the following analytical activities.

Refinery units quality control

Quality control in the Refinery units consists of routine analysis carried out on samples collected from the streams of the different units according to a certain sample schedule. These samples are tested for some critical properties, and results are immediately reported either verbally or in writing. Based on these results, the operating conditions are readjusted.

Samples collected include:

(a) Liquid petroleum samples (feedstocks and streams);
(b) Gas samples (gas streams and end-products);
(c) Water samples (from boilers and cooling water circuit);
(d) Solid samples (such as petroleum coke and sulphur).

This activity is carried out by the control and gas laboratory sections, which are working on a shift basis 24 hours a day, 7 days a week.

Finished products quality control

Usually, finished products are prepared through blending the base-stock tanks to meet the required sales specifications. Blending ratios can be determined very well by laboratory experiments. When blending is completed and the tank is ready for marketing, representative samples are collected according to standard sampling procedures and are then tested.
Quality certificates are issued and the final status of the tank is approved by the chief chemist. In case of deviations from the specifications, the material is corrected, if possible, or the management of the Refinery is consulted. This activity is usually carried out by the finished products, jet-fuel and octane laboratory sections, which operate on a day-shift basis.

Refinery technical services

The technical services of the Refinery consist of several analytical activities essential to its operations, and concern modifications and long-term studies. Such activities include:

Evaluation of crude oils
Corrosion control
Water conditioning

Evaluation and control of chemical additives used in the different refinery operations

Details of each activity are given later in this report. These activities are to be carried out by the analytical and investigations laboratory section.

Laboratory equipment

Laboratory equipment was severely affected during the October 1973 war. In the last three years authorities of the Refinéry have replaced this equipment with the local purchase of simple material, purchases from several European sources, and equipment supplied by UNIDO.

The following table gives the purchase orders for equipment supplied by UNIDO.

Purchase order	Value in US dollars	Supplier	Status
15-4-00785	7,214	Labimex	Delivered
15-4-00791	21,071	Kovo	Delivered
15-5-00956	4,972	Radiometer	Delivered
15-5-01032	15,053	Analis	Delivered
15-5-01032	16,663	Analis	Delivered

The following major equipment supplied by UNIDO has been received, installed and is in operation or is ready for operation:

(a) A potentiometric recordomatic titrator, used at present for the quality control of jet fuel and other products;

(b) A Reid vapour pressure apparatus, used at present to determine vapour pressure of gasoline-naphtha and LPG;

(c) ASTM distillation apparatus (double-unit), used at present to determine the boiling ranges of light petroleum distillates;

(d) Colorimetric-spectrophotometers (2 units), used at present for the quality control of industrial water samples as well as other applications;

(e) Abbee refractometer (with automatic water bath), used at present for refractive index determinations;

(f) Conductivity meter, used in the quality control of industrial water;

(g) Raney-nickel apparatus, used for trace sulphur analysis;

(h) Standard ASTM equipment, such as several units of carbon-residue apparatus, several units of flash-point testers, several units of standard viscometers and several units of water determination apparatus;

(i) Bitumen-testing equipment, which includes one penetrometer, softening point apparatus and ASTM distillation of cut-backs;

(j) Several general items, such as water baths (with automatic temperature control), hot plates, heating equipment, water stills, centrifuge etc.

(k) Nitrogen determination equipment (Kjeldahl method), used at present to determine nitrogen in feedstocks of the different refinery units;

(l) About 50 items of glassware, used at present by the different laboratory sections;

(m) A large number of standard hydrometers, used to determine gravity of crude oils and petroleum distillates;

(n) A variety of ASTM thermometers covering different ranges.

The following major equipment ordered by UNIDO was delivered in March 1977 as the last consignment:

(a) Equipment for reduced-pressure distillation;

(b) Apparatus to determine gasoline stability;

(c) Equipment to determine calorimetric value of liquid fuels;

(d) Multi-unit, three refrigerated compartments for pour and cloud-point testing;

(e) Ductilometer for bitumen testing and another 15 different items.

Laboratory personnel

Laboratory personnel numbers about 80. The academic qualifications of the personnel assigned to various posts are:

(a) BSc in chemistry or chemical engineering (3);

(b) BA and other university graduates (3);

(c) High school certificate (a small number of technicians);

(d) Intermediate and preparatory school certificate (the majority of technicians and testers);

(e) Manual workers (sample men).

Shortcomings

The lack of chemists and supervisory staff may result in:

(a) Poor communications (the chief chemist has to communicate with all levels, a situation which is physically impossible and leads to centralization of authority and inefficient supervision);

(b) Poor technical follow-up of work progress which may result in inaccurate work and poor reporting;

(c) Work procedures are not well established and poorly kept. This also applies to other laboratory documents, e.g., analysis reports, quality certificates, agreement specifications etc.

(d) No planned or efficient training of new personnel or follow-up of their development.

The underqualification of working personnel may result in:

(a) Inaccurate analytical results;

(b) Poor handling of equipment which results in breakages and short lifetime;

(c) Poor estimation of the value of their work and its effect on the Refinery operations;

(d) Unsafe operation, which may lead to accidents.

The above factors should be borne in mind although they do not strictly apply to the present laboratory situation, since there are a good number of sincere, efficient personnel with long experience.

To avoid such a shortcoming in the future, the situation was discussed and studied in detail with the counterpart, and its importance was clarified. Accordingly, a detailed laboratory organisation was proposed to management in October 1976. This proposed organization is described later in this report.

Achievement of goals

During the assignment period the following goals were achieved:

Concerning the building

(a) The analytical and investigation laboratory was expanded and the working space in this section has been nearly doubled;

(b) The titrations laboratory section was expanded because of the volume of work with the installation of modern equipment;

(c) It was agreed to establish a separate section for the evaluation of crude oils. The necessary action was taken with the engineering department;

(d) New extension of the utilities piping systems was studied and is under implementation. All laboratory sections will be provided with water, steam and compressed-air connections;

(e) Gas cylinders will be located outside the building for safety. Suitable internal connections will be installed. The project is still under study because of some physical difficulties.

Concerning the equipment

Equipment supplied by UNIDO was inspected and either installed or stored for future needs.

Most of the items of equipment ordered by the Homs Refinery were inspected, installed or stored. This equipment included the following major items:

(a) A recordomatic DB spectrophotometer with digital reading facilities. The recorder is slightly defective and the supplier was requested to send a replacement of the defective part by air-freight;

(b) Recordomatic potentiometric titrators (3 units): one is installed and the other two are stored for future needs;

(c) An automatic nitrogen distillation apparatus. The apparatus is operating at present and has proved to be very efficient and useful;

(d) An additional Raney-nickel apparatus to determine trace sulphur;

(e) A modified Orsat gas analyser for determination of hydrogen, carbon dioxide, carbon monoxide and methane in reformers and flue-gases;

(f) On-line oxygen analyser (portable) to determine oxygen in platformer streams;

(g) Most of the equipment needed for hydrocarbons type analysis (PONA) of light petroleum distillates;

(h) More than 50 other miscellaneous items.

Since October 1976 action has been taken to start up most of the Refinery units, including:

The coker complex

The three hydro-desulphurisation units

The sulphur recovery plant

The gas-treating units

The hydrogen plant

These units require an extensive quality-control scheme. Requirements were studied and new requisitions covering equipment needed were prepared, approved by the management of the Refinery and forwaded to the foreign purchasing section for action.

Major items covered by these requisitions include:

(a) Atomic absorption spectrophotometer. This major equipment will be used to determine elements in water streams, petroleum distillates, catalysts and other metallic materials;

(b) An additional gas chromatograph for routine gas analysis;

(c) A number of portable gas analysers which will be used by laboratory technicians in the units to determine several gaseous components;

(d) Karl Fisher analyser to determine moisture in gas and liquid streams;

(e) A new model of Burell gas analyser provided with catalytic chamber for H_2 and CH_4 analysis in the different hydrogen unit streams;

(f) Pure hydrogen generators to generate hydrogen used as carrier gas in gas chromatographs;

(g) Special gas-sampling containers suitable for high-pressure gas lines and corrosive mixtures;

(h) Additional equipment needed for water analysis;

(i) Distillation facilities which are required for crude-oil evaluation programmes;

(j) Other general laboratory items used by the different laboratory sections, such as glassware, heaters, ovens, furnaces, balances etc.

All these requisitions are expected to be delivered during 1977.

Concerning quality control in refinery units

In normal operations. Several meetings were held with the operations engineers to study and discuss quality control requirements for each unit. Based on these studies a complete sampling and testing schedule covering the needs of the whole refinery operating units was established. The schedule includes information on the following:

Operating unit number

Number of unit stream to be tested

Location of sampling point

Time of sampling (indicated in hours)

Type of analysis needed

Frequency of testing

This schedule can also be used by laboratory management as a good tool for planning since it can give the following information:

Total working hours per shift

Total manpower needed per shift

Number of equipment required for each test in the control laboratory

Types and quantities of chemicals and materials needed by the control laboratory

Vacations schedule of the control laboratory personnel

Quality control cost for each refinery unit

In short, it can help in manpower planning, materials requisitions and cost estimation.

In the case of operating troubles. The normal testing schedule may be temporarily changed to meet an unusual situation. Frequency of testing as well as type of analysis will be according to the unit supervisor's request.

In case of planned test-runs. Before starting a test-run in any of the refinery units, the operations engineer informs the laboratory about its objective and the time it will take. Accordingly, a test-run sampling schedule is established by the laboratory. At the end of the test-run, results are reported to the operations department to be included in the final test-run report.

Concerning test methods and work procedures

Many test methods and work procedures were prepared in Arabic and explained to laboratory chemists and technicians, including the following:

(a) Raney+nickel method of trace sulphur analysis;
(b) Wickbold method of trace sulphur analysis;
(c) Distillation of petroleum distillates under reduced pressure;
(d) Trace oxygen analysis in high pressure boilers;
(e) Density by Lipkins pyknometer method;
(f) Refractive index and refractive intercept;
(g) Water separation index of jet fuels;

(h) Hydrogen sulphide and mercaptans determination by potentiometric methods;

(i) Separation of saturated hydrocarbons from light petroleum distillates;

(j) Hydrocarbons type of analysis of gasoline and naphtha.

In addition, the following operating manuals were translated:

Orsat gas analyser

Portable oxygen gas analyser

Water separometer analyser

Beckman spectrophotometer

Saybolt chromometer

Abbee refractometer

Radiometer potentiometric titrator

Concerning laboratory administration

The chief chemist of the Refinery was briefed on the importance of the following subjects:

(a) Decentralization of authority through a better communications system and delegation of authority;

(b) Training of laboratory personnel, especially newly appointed members. Two training programmes for laboratory chemists and technicians were proposed;

(c) Planning of manpower, taking into consideration the normal annual personnel turnover, the refinery expansion programmes and the continuous development of laboratory personnel through introduction of new test methods and application of modern analytical techniques;

(d) Pre-planning for laboratory requirements of equipment, spare parts and chemicals, taking into consideration delay in deliveries;

(e) Establishing a periodic checking programme to ensure accuracy of results and to take corrective action in case of deviations;

(f) Development and encouragement of good relations between workers and supervisors;

(g) Close contact between laboratory personnel and other refinery personnel who receive laboratory services for better understanding and co-operation.

Concerning laboratory organization

The following is a brief outline of the main aspects of the proposed organization (submitted to counterpart in October 1976).

The laboratory is divided into three main sections:

Control section

Gas section

Analytical and investigation section

Under the chief chemist are three senior chemists who are supervising the three sections. The control section includes the following laboratories:

Shift laboratory

Finished products laboratory

Octane laboratory

The gas section includes:

Gas laboratory

Crude oil evaluation laboratory

Titrations laboratory

The analytical and investigation section includes:

General analysis laboratory

Instrumental laboratory

Water analysis laboratory

Corrosion control laboratory

The shift supervisor post will be strengthened so that he can supervise the entire operations of the laboratory during his shift.

Qualifications requirements:

Chief chemist: BSc in chemistry or chemical engineering with 10 years experience minimum

Senior chemists : same degree but with 8 years experience minimum

Laboratory supervisor - shift supervisor:

BSc chemistry or equivalent with 4 years experience minimum or

High school certificate with 10 years experience minimum

Junior chemists: BS in chemistry (new graduates)

Laboratory technicians:

High school with 6 years experience

Intermediate school with 10 years experience

Laboratory assistants:

High school (new graduates)

Intermediate school with 4 years experience

Sample men:

Intermediate school

Without degree but knowing reading and writing

In both cases they should be physically fit.

The laboratory at present is short of chemists and technicians, although the total number of personnel is higher than the number needed in the new proposed organization.

Follow up of activities relating to safety, preventive maintenance and mechanical inspection (IS/SYR/71/806)

At the request of UNIDO the expert carried out an investigation to determine to what extent the recommendations made by the experts assigned to the previous UNIDO project (IS/SYR/71/806) had been adopted at the Homs Refinery. The recommendations related to the work of the expert on safety and fire fighting, S. Maruthappa, and to the work of experts from Engineer India Ltd. who carried out preventive maintenance and mechanical inspection under contract to UNIDO.

The expert's findings are given in annexes II and III.

II. CONCLUSIONS

Based on the preceding review, the following conclusions may be reached:

The building

The existing building is suitable and sufficient for the present activities. A number of facilities as mentioned before should be considered.

Equipment

The present available equipment covers most of the analytical work needed. Few additions are listed under recommendations.

Equipment obtained through UNIDO as well as the other items newly purchased by the Refinery are operating in good condition. Exceptions are items that were either defective when received (reparable) or lacked some accessories.

Personnel

There is a notable shortage of chemists and qualified laboratory supervisors which affects laboratory operations, training and administration.

Training and personnel development

This subject has to be seriously considered by the Refinery. Certain action is suggested in the expert's recommendations.

Documentation and reporting

It is weak owing to the lack of supervisors and the unavailability of a typist or a secretary.

Laboratory operations

Available facilities can cover routine work as well as activities of an investigative nature; most of the work done at present is routine and the field of investigations should be strengthened to include several technical studies which can be very useful to the refinery operations.

Equipment maintenance

Maintenance is weak at present owing to lack of spare parts and shortage of instruments technicians. The only alternative at present is to rely more on suppliers' representatives.

III. RECOMMENDATIONS

Laboratory equipment

In addition to the present equipment the following major items should be acquired:

(a) Atomic absorption spectrophotometer. This is a very useful analytical tool and can be used to determine concentration of additives in industrial water streams; to analyse and determine corrosion products in various streams; and to make a general analysis of elements;

(b) C.F.R. engine for gasoline testing. Only one engine is available now in the Homs Refinery and it is the only reliable engine for octane number determination in the Syrian Arab Republic. The situation will become critical in case of long maintenance periods or unexpected operational problems. It is highly recommended that an additional one, preferably of the same model (Waukesha, serial No. 295037), be ordered. The laboratory should also be provided with lead addition facilities to gasoline and reference fuel blends. These facilities which include a special fume-hood, glassware and safety equipment, have been ordered by the Refinery;

(c) Infra-red spectrophotometer. It is very useful to have a medium-sized instrument of this type. It can be used to determine additives in water (to check possible leaks in cooling water systems) and other analytical applications;

(d) Corrosimeter. This is a useful tool for corrosion control studies. It can check the effect of different refinery fluids on metals, and it can evaluate the performance of corrosion inhibitors and their optimum concentrations when used.

In addition to these major items of equipment the expert has recommended other necessary laboratory facilities which have been ordered.

On-line analysers

The refinery operating units should be supplied with a number of additional on-line analysers, to provide the operating personnel with continuous recording of certain key properties. In some cases the time consumed in sampling and analysis in the laboratory may result in risky operations or notable production losses.

Examples of on-line analysers are:

(a) Chromatographs, which can give continuous analysis of hydrocarbon gas streams in several refinery units;

(b) H_2S and sulphur oxides gas analysers in the acid gas-treating units and in the sulphur recovery plant;

(c) Oxygen gas analysers on the feed lines of high pressure boilers;

(d) Viscosity analysers in the fuel-oil blending stations.

A good supplier in this field is the Beckman Instruments Corporation United States of America. It would be worthwhile to contact this firm for consultation.

Training

Training should be given special attention since methods of testing and analytical techniques are improving constantly and accuracy is essential in quality control.

Two types of training are always carried out: training of newly appointed personnel and on-the-job training.

Training of newly appointed personnel

A three-month training programme for laboratory assistants is recommended. Subjects of interest include:

Safety and fire fighting (few days)
Refinery operating units (few days)
Stocks and shipping (few days)
Two weeks in each laboratory section where they can be trained in methods of sampling, work procedures and equipment used

After completing their training programme successfully they can be given simple assignments. Follow-up progress reports covering their performance, capabilities and shortcomings, if any, should be forwarded by their direct supervisors to the laboratory administration.

A six-to-eight-month training period is recommended for laboratory chemists according to the following programme:

One week in safety department
One week in stocks and shipping
Two months in the operations department where they would become familiar with the different units, production streams and sample points

One month in each laboratory section where they would be trained in laboratory test methods, operation of analytical equipment, methods of reporting and safety

After completing this training programme they can be assigned to specific jobs. Their performance should be followed up through periodical progress reports given by their direct supervisors to the chief chemist.

On-the-job training

It is always a good practice to transfer laboratory personnel from one section to the other. This inspires more interest, gives more experience and creates better communications among them. It would also help in case of a sudden personnel shortage in any section.

Senior chemists and laboratory supervisors should have short periodic meetings with their staff, in which they review present work procedures, explain new techniques or demonstrate how to operate new analytical equipment. Similar meetings are also recommended between the chief chemist and the senior chemists.

For staff with high academic qualifications, it is highly recommended that they spend suitable training periods in the Development and Industrial Research Centre at Damascus. The Centre is very well equipped with modern analytical facilities and it has a good scientific documentation centre. This sort of training would update their knowledge and keep them acquainted with new trends in the analytical field.

Attendance and participation in the various scientific conferences arranged by the Arab League and by international agencies is also recommended for the chief and senior chemists.

Laboratory safety

Laboratory safety should be taken seriously by the management as well as by all laboratory personnel. Areas of danger in laboratory operations are as follows:

(a) Presence of large quantities of inflammable materials in every place in the building, such as oil and oil products, solvents used for analysis, hydrocarbon gases and chemicals;

(b) A number of compressed-gas cylinders are found in different laboratory sections, some of which represent a real hazard, such as hydrogen-gas cylinders, oxygen-gas cylinders and other inflammable gases. The danger of explosion also exists;

(c) Many chemicals used for analysis are toxic. Some are extremely poisonous, such as arsenic, mercury and lead;

(d) Working with tetra-ethyl lead requires observance of strict safety regulations;

(e) Laboratoratory atmosphere becomes contaminated with hydrocarbon gases and other materials unless ventilation is efficient.

The following safety manual practices are recommended:

(a) Concerning work conditions:

(i) Gas cylinders should be kept outside the building and connected to the different sections with a suitable piping system;

(ii) Laboratory drainage must always be maintained and checked for possible leaks since electrical connections are also located in the same duct;

(iii) Fume-hoods should be provided with efficient suction motors and safety glass screen;

(iv) Oil samples which are retained for different periods must be stored outside the building in a well-ventilated place;

(v) It is always a good practice to store solvents and highly volatile materials in a cold room which has a special design with an automatic alarm system and pressure release facilities;

(vi) Hazardous and poisonous chemicals should be kept under the direct control and supervision of chemists and supervisors. It is better to keep them in a locked place;

(vii) In the control and the gas laboratory sections, air contamination should always be checked with suitable gas detectors. Hydrogen sulphide detectors are recommended for the gas laboratory;

(viii) Electrical connections must be explosion-proof especially in places where hydrocarbon gases are concentrated;

(ix) Suitable safety facilities must be available to the laboratory supervisors in case of need;

(x) The laboratory should be provided with a sufficient number of fire extinguishers which must be well distributed and periodically checked;

(b) Concerning laboratory personnel:

(i) Supervisors should explain very new experiments in detail with special attention to the hazards involved and safety regulations. Technicians should not be allowed to proceed with these new experiments unless their supervisors are sure of their capability and full understanding;

(ii) Handling of toxic chemicals must be done only by authorised personnel, and in case a technician is going to handle them for the first time he should be fully aware of their nature and the regulations that he has to follow;

(iii) All hazardous analytical work should be done in the fume-hoods while hood windows are closed and ventilation motors are on;

(iv) Laboratory personnel must be provided with safety facilities, clothes or equipment in case of need. They should be trained in the proper application of these facilities;

(v) Training in using fire extinguishers is essential. Suitable types of extinguishers must be located in proper places; empty ones should be replaced at once;

(c) Concerning sample men:

When collecting samples from refinery units and tanks sample men should observe the following regulations:

(i) In the units, they should collect samples in the presence of the operators who guide them;

(ii) When opening the sample line they should be careful, and should keep their faces away from the material sampled especially in case of gas samples;

(iii) They should put on suitable safety clothes depending on the type of sample and the location of sampling;

(iv) When sampling volatile products from tanks, two should go together; while one is sampling, the other is watching him.

<u>Refinery technical services</u>

Because of the complexity, automation and advance technology of refining operations, the operating group should be supported by a group of technologists who can handle the following technical subjects:

<u>Optimisation studies</u>. These studies should be carried out on each refinery unit to find out the optimum operating conditions, the best feedstock properties and the most acceptable products. This is usually done through a series of planned and technically oriented test-runs.

Studies of bottle-necks. Such studies may be carried out on each unit or on the whole refinery to define bottle-necks which limit production capacity or product quality. As a result of these studies, short- or long-term solutions, modifications or projects are proposed.

Trouble shooting. These are day-to-day activities through which investigations of unexpected operational problems are carried out and solutions are proposed to overcome the existing troubles.

Technical recommendations. These are given in the following areas:

(a) Choice of catalysts and chemicals required for refinery operations;

(b) The most effective and economic additives used in water treatment, corrosion control and product performance through a series of laboratory and field experiments;

(c) The most suitable metals and alloys used in the Refinery and advice on any other metallurgical problems.

Project evaluation studies (technical side). This involves preparation of the following documents:

Scope of the project

Input-output tables

Choice of processes

Unit layout

Engineering and technical data

These activities can be carried out through efficient co-ordination between the following technical groups:

Process engineering

Corrosion and inspection engineering

Quality control section

Data-processing section

The role of the laboratory in the performance of such activities is essential. The most closely related laboratory sections are:

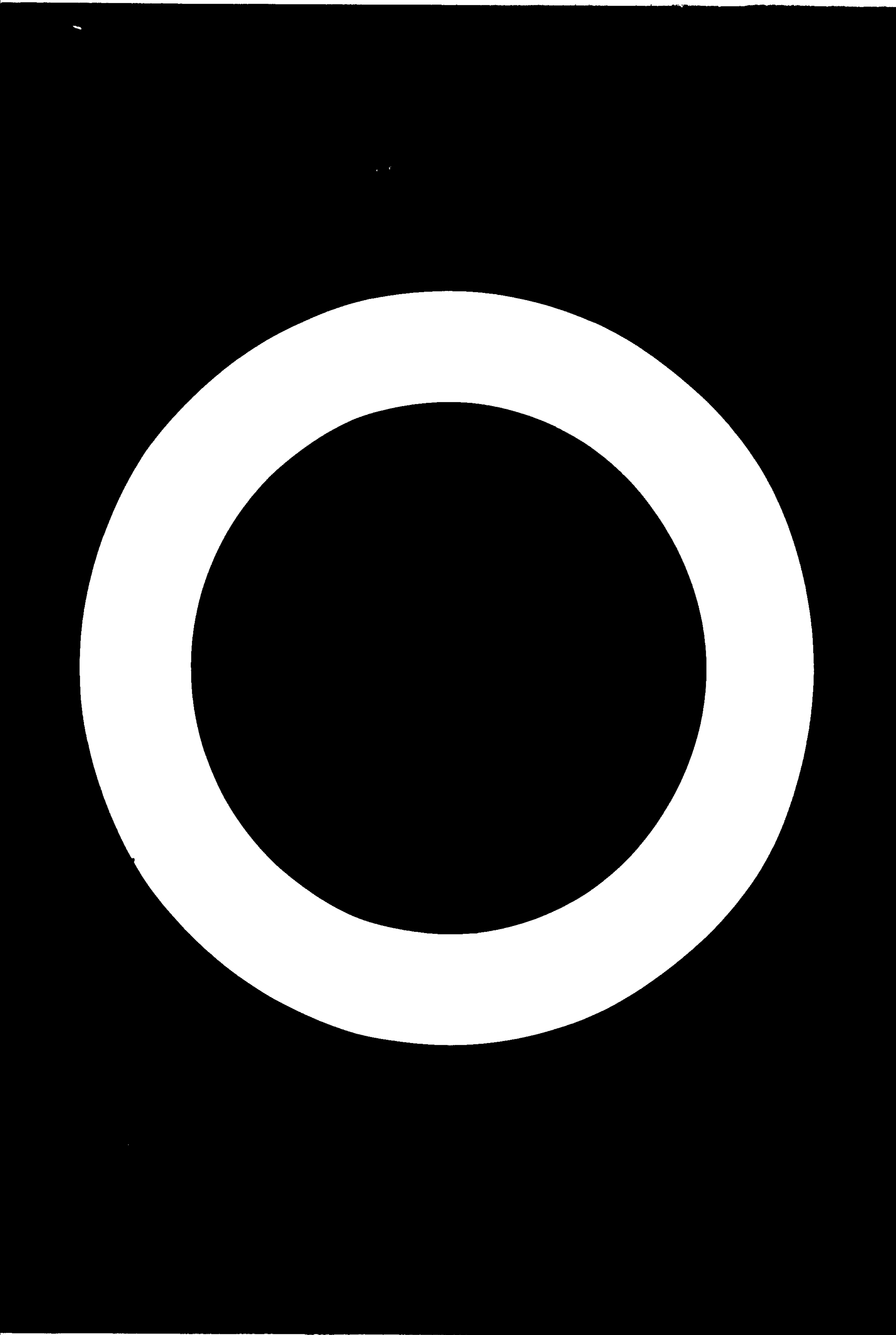
The analytical and investigation section

The water analysis section

The corrosion control section

The crude-oil evaluation section

Accordingly, these sections must be strengthened and provided with qualified and well-trained personnel. The existing equipment along with the other items recommended would be adequate for this type of work.



Annex I

ANALYTICAL PROCEDURES

Crude oil evaluation

This programme is applied for crude oils or crude-oil blends so that some useful information is obtained before actual refining. These collected data help in predicting the quantity and quality of products as well as the effect of the crude oil on refinery equipment.

There are several procedures, but the most simple and practical one may be summarized as follows:

General characteristics

This procedure includes determination of certain properties such as density, pour point, viscosity, sulphur, asphaltenes (%) and salt and water content.

Fractional distillation

About 10 litres of the crude oil is fractionally distilled in highly efficient distillation columns. Distillation is usually carried out in three steps:

(a) Distillation under atmospheric pressure up to a bottom temperature of less than 350°C (to avoid cracking);

(b) Distillation under reduced pressure (about 10 mm) up to the same bottom temperature;

(c) Claisen distillation under high vacuum (about 1 mm) until bitumen is left in the distillation flask.

During distillation successive fractions are collected in separate containers for further investigation, and operating data are tabulated as follows:

Cut umber	Cut temp. (°C)	Distillation pressure	Corrected cut temp. (°C)	Volume (%)	Weight (%)	Cumulative yield
1-						
2-						
3-						
4-						
5-						
Residue						

Analysis of cuts

For each individual cut several physioal and chemical tests are carried out. Using the results obtained, some useful relations oan be established such as:

(a) True boiling point curve, which presents the relation between yield (%) and boiling points;

(b) Sulphur distribution curve which gives the sulphur content at any cut point;

(c) Pour point curve, which presents the pour point at different cut points.

Many other correlations can be established depending on the tests carried out on each cut.

Product investigation

Successive cuts are blended in the same ratios of their presenoe in the crude oil to give the following products:

Liquified petroleum gases

Naphtha with different cut points

Kerosene with different cut points

Kerosene with different boiling ranges

Gas-oil with different viscosities

The following key properties are determined for each product:

(a) Liquified petroleum gases:

(i) Percentage in crude oil;
(ii) Composition;
(iii) H_2S and RSH (%);

(b) Naphtha:

(i) Percentage in crude oil at different points;
(ii) Octane number of naphtha with different end points;
(iii) Hydrocarbons type analysis at different cut points to find out behaviour on platforming;
(iv) Sulphur compounds present;

(c) Kerosene:

Critical properties include sulphur content, freezing point at different boiling ranges and aromatic content. These latter properties give an indication of the possibility of jet-fuel production and of the degree of hydro-desulphurisation required;

(d) Gas oil:

Important properties include pour point, viscosity, sulphur content and cetane number. The last two properties give an indication of the degree of hydro-desulphurisation required;

(e) Fuel oil:

Establish viscosity yield curve through viscosity measurements of different fuel oils obtained at different yield percentage. Also sulphur content is measured on the same samples. Additional work can be carried out if required by the operations department. This may include:

(i) Response of naphtha to tetra-ethyl lead addition;
(ii) Response of gas-oil to pour point depressants and cetane number improvers;
(iii) Effect of different sweetening processes on sulphur removal from light distillates;

(iv) Possibility of lubricating oils production from middle distillates and from residual oils;

(v) Production of blown bitumen from hard grades of bitumen.

Analytical programme for water conditioning

In refineries, industrial water is used for two main purposes:

(a) Cooling in the different refinery units;

(b) Feed for steam generation in high pressure boilers.

There are two different analytical programmes which can be applied to ensure better water conditioning.

For cooling water systems

In a closed cooling system, salts tend to concentrate or water becomes acidic owing to leakage. In both cases water becomes either scaly, resulting in poor heat transfer, or corrosive leading to metal losses. To avoid such developments, certain chemicals are added in small quantities so that they build a very thin protective film on the metal surface. Chlorine is also added to control accumulation of algae and living organisms which result in blockage of lines. Water samples are collected periodically from different locations in the system and the following analyses are carried out:

(a) pH and pHS (to indicate whether water is corrosive, scaly or neutral);

(b) Concentration of additives used to ensure the presence of certain residual quantities;

(c) Presence of metals, such as iron and copper, which indicates corrosion;

(d) Detection of oil, if any, which indicates possible leakages in the system.

Boiler feed water

In case of high pressure boilers, feed water properties must be according to the boiler design requirement, otherwise the following operational problems may occur:

(a) Foaming in the boiler drum resulting in carryover or uneconomic blow-down levels;

(b) Contamination of steam with salts thus leading to blookage and replacement of superheater tubes;

(c) Formation of hard scales in the boiler drum and other critical parts;

(d) Presence of gases such as oxygen and carbon dioxide resulting in severe corrosion in the system.

Accordingly, water control is essential and samples are collected from the different water streams to carry out the following analysis:

(a) Hardness, alkalinity, total dissolved solids, silica, pH, total suspended solids etc.;

(b) Oxygen content of feed water after de-aeration;

(c) Concentration of chemicals added such as polyphosphates, sulphites and amines.

Most of the tests carried out on water samples are simple colorimetric methods. In some cases spectrophotometric or atomic absorption techniques are applied.

Corrosion control

The following analytical approaches are usually applied.

Chemical methods

Samples are collected from different streams (water or hydrocarbon streams) and tested to find out the presence and concentration of certain metals (corrosion products).

Coupons method

At certain locations in the system - where corrosion is expected - a standard weighed piece of material is placed having the same chemical composition as the material of construction. In periods of shutdown these pieces are collected inspected and reweighed. Loss in weight indicates corrosion and the corro ion rate is calculated.

Corrosimeter method

This method is based on measuring the electrical conductivity of metals. Metals when corroded give different conductivity values.

A standard piece of metal - called a probe - having the same composition as the material of construction is fixed at a certain location where corrosion is expected. At its free end it is connected to a cable. The corrosimeter, which is a portable instrument, when connected to these cables gives the electrical conductivity of the probe while the system is in operation.

Through periodic measurements, the following information can be collected:

(a) Start of corrosion in the system;

(b) Rate of corrosion;

(c) The comparitive effect of the different corrosion inhibitors used.

Quality control of imported and exported petroleum materials

Imported materials

Crude oils and products are imported according to contracts which include separate articles covering quality obligations. In the case of crude oils, price per barrel is always connected with the API gravity of the crude. Quantity calculations are affected by the following properties: specific gravity, salt content, water content and sediment content.

A simple procedure is usually applied in case of crude oils and can be summarized as follows:

(a) As soon as the ship is ready for discharging, representative samples are collected from the ship tanks in the presence of the captain. They are then mixed and divided into three portions;

(b) Two portions are sealed and stamped by the captain and by the buyers and each party takes one of these two portions;

(c) The third portion is analysed by the buyer's laboratory and results obtained are used for quantity calculations;

(d) In case of disagreement, the sealed-stamped samples are used for arbitration.

Exported materials

The following procedure is usually applied:

(a) Representative samples are collected from the shore tanks which will be pumped to the ship;

(b) After analysis, a quality certificate is issued and given to the captain together with a sealed-stamped sample from each tank;

(c) In case of future disagreements, these sealed samples are used for arbitration;

(d) Before pumping, ship tanks should be carefully inspected to avoid possible contamination.

Annex II

RECOMMENDATIONS
ON
REFINERY SAFETY AND FIRE-FIGHTING ACTIVITIES

Background

Homs Refinery is considered one of the most advanced and complicated refineries in the Middle East. Safety must be considered seriously since the Refinery includes, amoung other units, a hydrogen plant, a sulphur recovery plant and an LPG storing and bottling station. In addition, the Refinery is located in a windy place requiring additional precautions and facilities for safety and fire-fighting.

Importance of an effective safety programme

The objectives of an effective safety programme in any industrial organization are:

(a) To ensure the physical safety of personnel, equipment and operating units;

(b) To improve productivity through minimization of accidents and equipment failures;

(c) To discover early professional diseases and to recommend appropriate protective action;

(d) To improve work conditions and decrease pollution rates.

Recommendations covered by this report are classified into three groups:

Role of the safety department

Role of the other refinery departments

Recommended action

Role of the refinery safety department

Activities covered by the safety department include the following:

(a) To have full responsibility for and direct supervision over tasks which may be hazardous at any area in the refinery;

(b) To supervise and control fire-fighting in case of big fires or small fires in critical places;

(c) To ensure availability of safety equipment and fire-fighting facilities in places where they may be needed;

(d) To prepare requisitions, place purchase orders and follow up on deliveries of the above-mentioned materials;

(e) To train refinery personnel in fire-fighting and first aid, especially in areas where danger of fires exist;

(f) To prepare periodic statistics on safety which may include number of accidents, analysis and trends;

(g) To prepare subjects which will be discussed in the safety committee meetings and to follow up to what extent the decisions taken by the committee were fulfilled, and to define obstacles, if any.

Role of the other refinery departments

Work supervisors in the operations and engineering departments must realize the importance of safety precautions and should follow the following instructions:

(a) Before giving workers assignments they must be sure:

(i) That operating instructions are simple and easy to understand;

(ii) That workers are well trained in the equipment and work tools;

(iii) That workers know areas of danger, the hazards involved and the best way to avoid and overcome them;

(b) In case of fires or risky situations, workers should know whom to contact and where and what actions to take until the fire-fighting group reaches the place of danger;

(c) Supervisors must consider to what extent safety regulations are observed when evaluating the performance of their workers, who will then realize the importance of following such instructions;

(d) Supervisors must contact the safety department before starting any of the following tasks:

(i) Welding in gas or volatile products lines or vessels;

(ii) Welding near an operating unit or storage tanks;

(iii) Long scheduled maintenance programmes;

(iv) Using a new chemical, inhibitor or additive for the first time.

In all cases the safety supervisor will study the situation and will provide the work supervisor with the necessary facilities, regulations or safety equipment. Direct supervision by the safety department may be decided.

Recommended action

Refinery management is requested to approve the following action:

Formation of a refinery safety committee. Proposed members of such a committee would be:

Refinery manager	Chairman
Safety superintendent	Co-ordinator
Operations manager Engineering manager Medical officer Labour union representative Administrative manager	Members

During a regular monthly meeting, the committee would:

(a) Review and study the monthly safety statistics;

(b) Approve action recommended by the safety superintendent for the next month;

(c) Study any major accidents that occurred during the month and take corrective measures;

(d) Study and discuss any other subjects raised by the members.

Formation of an auxiliary fire-fighting group In order to keep the number of the fire-fighting group to a minimum and at the same time to be able to face big fires, in some refineries a few persons in each department and on different shifts are selected to form what is called "the auxiliary fire-fighting group". They are trained periodically in fire-fighting and in case of big fires they congregate and participate with the professional group in fire-fighting. They are paid a nominal monthly or annual bonus as an encouragement.

Safety training programmes. Since most of the refinery units will be starting up shortly and the processes involved are hazardous, it is suggested that a two-day condensed training programme on safety and fire-fighting be started immediately. Five per cent of the workers and operators in the operations and engineering departments should attend this programme which could be held once a week. Through this approach, the total manpower in both departments would be trained in a 20 weeks period.

Refreshment courses will be repeated every year so that it will be ensured that operators and technicians shall perform their duties safely and efficiently.

As a second priority, similar courses will be arranged for the other technical departments.

Safety booklet. Safety rules and regulations must be collected in one booklet. This information should be simple and easy to understand. The booklet should be given to every employee so that he may be aware of regulations.

Safety training of new employees. Every new employee should spend two days in the safety department before being given an assignment. During this short period he would become acquainted with refinery regulations, safety and fire-fighting activities and receive his personal safety clothes if required.

Contacts with other safety organisations. It is recommended that the refinery safety department contact other safety organizations in the area to co-ordinate and exchange knowledge and experience. Similar contacts with the state central safety organizations is essential since at present a joint project on safety is being undertaken by UNIDO and the state social insurance corporation.

Annex III

FLOW-UP REPORT ON
HOMS REFINERY INSPECTION ACTIVITIES

Background

In March 1975 experts from India, representing Engineers India Limited, started their activities with the Homs Refinery in the inspection and preventive maintenance fields.

The goals of the activities were:

(a) To define existing problems;
(b) To prepare a programme for preventive maintenance;
(c) To provide and prepare manuals, standards and codes of practices;
(d) To carry out preventive maintenance and inspection programmes;
(e) To train engineers and technicians.

Achievements

Concerning inspection

The consulting oragnization established the recording system which included the following documents:

(a) Unit index scheme cards,which indicate by different colour schemes the dates of previous inspections and when the next inspection is due;

(b) History cards, covering information concerning start-up, shutdowns, emergency breakdown, scheduled shutdowns and idle periods for each piece of equipment;

(c) Field observation sheet, based on actual and periodical inspection observations;

(d) Equipment data cards in which equipment is classified into columns, vessels, coolers etc.; an individual card was prepared for each piece of equipment including an indicative sketch and the critical parts.

These systems were established for two major units of the Refinery so that they could be applied for the other units.

The following inspection activities were also undertaken:

(a) Field inspection:
(i) Established shutdown inspection procedures;

(ii) Applied thickness measurement techniques using ultrasonic and radiography methods;

(iii) Carried out full inspection programme on some units;

(b) Trained local personnel in the above-mentioned activities;

(c) Recommended a new organization for the inspection department emphasizing the need of a metallurgist and a non-destructive testing group.

Concerning preventive maintenance

The consulting group established a new preventive maintenance programme based on the following documents:

Equipment data card

History card

Check-list for each category of equipment

Unit-wide equipment inspection scheme card

In addition, the recording system for rotating equipment in most of the refinery units was introduced so that it could be applied in future for the whole refinery equipment.

Recommendations were made to ensure better performance and to update maintenance methods.

Present status

Several meetings and discussions with the chief inspection engineer were carried out with the following findings:

(a) Recording system: all cards were completed for three units. All cards are ready for the other units and will be completed in the future, although the activity is going slowly owing to the shortage of qualified personnel;

(b) Shutdown inspection procedures: at present there is always a pre-maintenance inspection programme before any shutdown; it is based on the following information:

(i) Inspection observations from the previous shutdown;

(ii) Readings collected during operation when possible;

(iii) Notes received from the operations department concerning equipment status.

When the shutdown starts, further and detailed inspection is carried out by the inspection group and, accordingly, a complete inspection report is given to the maintenance department. When maintenance is completed and before start-up the inspection department checks the equipment status. At present there is a six-month scheduled shutdown for a number of refinery units; operation of the rest depends on the actual need;

(c) Available inspection facilities: the Refinery is provided with a good number of inspection facilities which include the following major instruments:

(i) Ultrasonic machine, which is used for thickness measurements at ambient temperature and at higher termperature up to 350°C. It is also used to indicate the presence of cracks, if any, in pipes and lines;

(ii) Corrosimeter, which gives direct thickness measurements;

(iii) X-ray machine, for checking welds and welding homogeneity;

(iv) Gamovolt 100 also for checking welds and welding homogeneity. Owing to its smaller size it can be used at any place in the unit. It is based on gamma ray principle;

(v) Metascope, which is used in metallurgical applications in which different types of steels and metals can be identified; also the percentage of elements in the metal is estimated;

(d) Non-destructive testing: this method is used at present by the inspection department for identification of metals. It is also a good inspection tool when the unit is shut down or operating.

Recommendations

Based on the several discussions held with the inspection engineer as well as on the personal observations of the expert, the following recommendations would improve the present refinery inspection status:

1. Manpower:

According to the organization proposed by the consulting group, the department is short of engineers, technicians and a qualified metallurgist. The systems proposed cannot be completed with the present personnel. This also explains the delay in the completion of inspection codes, cards and forms. Management is requested to correct this situation.

2. Co-ordination:

Inspection activities can only be fruitful when concerned departments such as operations, maintenance and inspection work together and co-ordinate their activities. This can be done through periodic meetings and exchange of knowledge and documents between specialists from the said departments. Periodic status reports and follow-up reports are also important.

3. Training:

Training can be classified into two categories:

(a) Outside training, which would be very useful for inspection engineers when they can see how inspection systems are executed and followed up. They can also be trained in the different applications of inspection equipment. At present the Refinery is provided with a good number of these items of equipment, the applications of which are limited owing to the shortage of qualified and trained personnel;

(b) Local training, which can be carried out by qualified inspection engineers through lectures, meetings, publications and demonstrations. This type would be very useful for inspection technicians.

4. Corrosion studies:

At present corrosion control is carried out through the addition of inhibitors recommended by the units' suppliers. Corrosion rates are determined by some analytical methods whereby fluid streams are analysed for their metal content; also the thickness of tubes is measured ultrasonically when possible.

A good approach is to minimise corrosion rates through the application of efficient inhibitors and the continuous measurement of corrosion rates while the units are in operation and at different locations. This can be carried out by the application of the corrosimeter when probes (testing pieces) are inserted at different locations and periodic readings are taken. Through this technique the following information can be found out:

Start of corrosion

Rate of corrosion

Comparative effect of different corrosion inhibitors and different inhibitor doses

Effect of processing different feedstocks and of operating under different operating conditions

The degree of corrosion resistance offered by different metals and alloys

It is recommended that this instrument be ordered and that corrosion control studies be started in co-ordination with the laboratory and the operations department.

5. Follow-up visit by Engineers India Ltd:

The programme recommended by this consulting group in the inspection and preventive maintenance fields is very effective and impressive. It would be worthwhile to contact them in case of unfamiliar problems and to ask them for a follow-up visit. They are familiar with the local problems and conditions and can propose practical solutions in order that their recommended systems in these two fields can be completed.

Annex IV

RECOMMENDED PUBLICATIONS

ASTM publications:

- Compilation of gas chromatography data (No. 343)
- Industrial liquid lubricants - ISO viscosity classifications
- Petroleum industry vocabulary, part I
- Petroleum products - manual sampling
- Petroleum products - automatic pipeline sampling
- Petroleum products - determination of distillation characteristics
- Petroleum products - determination of viscosity index from kinematic viscosity

Publications of the Institute of Petroleum:

- ASTM/IP petroleum measurement tables
- Glossary of petroleum terms
- Institute of Petroleum review
- Modern petroleum technology
- Petroleum measurement manual

Publications on gas chromatography:

- Littlewood, A.B. Gas chromatography - principles, techniques and applications. New York, Academic Press.
- Keulemans, A.I.M. Gas chromatography. New York, Reinhold.
- Knox, J.H. Gas chromatography. New York, J. Wiley.
- Jeffrey P.G. and P.J. Kipping. Gas analysis by gas chromatography. London, Pergamon.

General publications:

- U.O.P laboratory test methods for petroleum and its products
- Nelson chemical engineering
- Safe operation manuals by the American Oil Company

Periodicals:

- Analytical chemistry
- Hydrocarbon Processing

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