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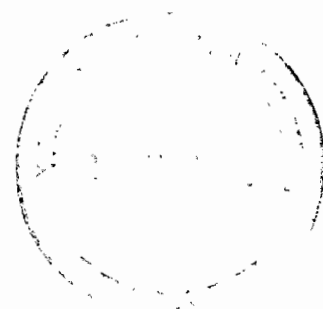
SUPERSEDED

GUIDE
FOR
INSPECTION OF REFINERY EQUIPMENT

CHAPTER III
GENERAL PRELIMINARY AND PREPARATORY WORK

SECOND EDITION

1976



AMERICAN PETROLEUM INSTITUTE

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PREFACE

This chapter is one of a series which make up the manual, *Guide for Inspection of Refinery Equipment*. It is based on the accumulated knowledge and experience of engineers of the petroleum industry. All users are invited to submit suggested revisions to the director of the Refining Department, American Petroleum Institute, 2101 L Street, Northwest, Washington, D.C. 20037.

The information contained in this publication has been arranged in its present form as a means of facilitating continuity of presentation and convenience of reference. It does not constitute, and should not be construed to be, a code of rules, regulations, or minimum safe practices. It is not intended that the practices described in this publication supplant practices that have proven satisfactory. Nor is it intended that this publication discourage innovation and originality in the inspection of refineries. Users of the publication are reminded that no book or manual is a substitute for good judgment.

The *Guide for Inspection of Refinery Equipment* is subdivided as follows:

Chapter I	Introduction
Chapter II	Conditions Causing Deterioration or Failures
Chapter III	General Preliminary and Preparatory Work
Chapter IV	Inspection Tools
Chapter V	Preparation of Equipment for Safe Entry and Work
Chapter VI	Unfired Pressure Vessels
Chapter VII	Heat Exchangers, Condensers, and Coolers
Chapter VIII	Direct-Fired Boilers and Auxiliary Equipment
Chapter IX	Fired Heaters and Stacks
Chapter X	Pumps, Compressors, and Blowers, and Their Drivers
Chapter XI	Pipe, Valves, and Fittings
Chapter XII	Foundations, Structures, and Buildings
Chapter XIII	Atmospheric and Low-Pressure Storage Tanks
Chapter XIV	Electrical Systems
Chapter XV	Instruments and Control Equipment
Chapter XVI	Pressure-Relieving Devices
Chapter XVII	Auxiliary and Miscellaneous Equipment
Chapter XVIII	Protection of Idle Equipment
Chapter XIX	Inspection for Accident Prevention
Chapter XX	Inspection for Fire Protection
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CHAPTER III

GENERAL PRELIMINARY AND PREPARATORY WORK

3.1 General

Refinery runs and unit operations are planned to meet the anticipated demand for specific products. However, a refinery or operating unit cannot remain in service continuously and still retain its optimum process and mechanical efficiency. Some pieces of equipment or parts thereof will cease to perform satisfactorily as a result of an accumulation of dirt, coke, sludge, and so forth. Some items will deteriorate; others will fail or wear out.

In order to assure a maximum onstream efficiency, it is desirable to shut down at predetermined intervals for cleaning, maintenance, and repair.

Many inspection operations on major operating equipment must be made while the units are shut down; some other inspections are made preferably while the units are in operation. To minimize downtime, all possible inspection operations should be performed while the units are in operation, and preparations for inspection of major operating equipment should be made prior to the shutdown.

Much of the inspection work can be accomplished while the units are onstream or during a short process turnaround. A thorough review of the process flow and operations may reveal that the total inspection of a unit is unnecessary at any one shutdown.

Inspection that contributes to the maintenance of the desired level of process and mechanical efficiency and augments the safe operation of the refinery equipment is necessary. It should be considered as an aid in bringing about a reduction in the number of process interruptions and in lessening the cost of maintenance and repair. These and other considerations make inspection a vital part of the maintenance program and give added assurance of a safe, continuous, economical operation.

A successful inspection program hinges on the work done in planning future inspections, knowledge of the deterioration of the equipment and the conditions causing the change, and ability to work closely with others in the refinery organization. The inspector must have a good understanding of the process operations and a comprehensive knowledge of the equipment, and he

must be able to locate and identify the form of deterioration within the equipment.

Information relative to planning an inspection of a new unit can be obtained by consulting the designer or personnel in other refineries that have similar units. Guided by his own knowledge and the experience of others, the inspector should be able to pinpoint the areas that are subject to certain types of deterioration and metal loss.

It is desirable that the inspector prepare an inspection procedure or outline. In preparing the outline, the inspector must exercise sound judgment to determine the extent and type of inspection required for each unit and each piece of equipment. This outline is actually an inspection guide. It should be reviewed, and possibly revised, both prior to and immediately following each inspection. Additions or corrections should be made based upon the interim replacements and repairs, the recommendations resulting from the current inspection, and the physical changes made during the operating periods or at the current shutdown.

A well-prepared, detailed procedure tells the inspector what to examine and what the inspection requirements are; it provides assurance that nothing will be overlooked. It enables the inspector to do a better and more thorough job of planning the inspection work. It assists him in the determination of the locations that may require special surface preparation, tools, or inspection equipment. Also, he can better predict the areas wherein the work load is heaviest, and he can concentrate the inspection effort on these potential trouble spots; thus an extension of the shutdown can be avoided.

The success of any inspection program is dependent not only upon the extent of the preliminary and preparatory work but on how the actual inspection is conducted and the inspection data obtained. The inspector should make certain that he has provided for his own personal safety and for that of other personnel. He should see that serviceable protective clothing, tools, equipment, and signs are available. (Refer to IRE Guide, Chapter V.)

Conferences with concerned personnel are valuable in planning for the shutdown inspections.

3.2 Scheduling

3.2.1 FORMULATION OF SCHEDULE

Scheduling is the planning and setting forth, in tabular form, of refinery operations and maintenance projected over a period of time. This is done to achieve the most efficient and profitable utilization of the equipment that is consistent with safety, available manpower, material, and time. This is necessary in order to direct, control, and evaluate not only the individual unit but the overall refinery operation. To accomplish this, it is essential that a realistic operating schedule be prepared and combined with an effective maintenance and inspection schedule for each process, utility, and non-operating unit or individual piece of equipment. In addition, each schedule must be tailored to fit into management's plan of not only the refining operation but the overall plant operation.

The arrangement of the various operating schedules and their respective maintenance and inspection schedules into a flexible and workable composite master schedule that covers the entire refinery becomes a formidable task. The formulation of this composite schedule requires the coordinated effort of the process, maintenance, and inspection groups. Depending upon the type of the units and the size of the refinery, the composite schedule may be projected to cover a period of at least five years.

Table 1 is an example of this type of schedule. It is a typical composite schedule for a medium-sized refinery that utilizes the periodic, continuous, run-to-run, and on-stream methods of inspection. All units are listed and the shutdown intervals, as well as the downtime scheduled for each unit, are plotted in terms of weeks. The blocked-in area opposite the name of each unit indicates the tentative shutdown date for that particular unit and the length of time required for the shutdown. The spaces below the blocked-in areas, when crosshatched, show the actual dates and time required for each inspection. Considerable variation between the blocked-in areas and the crosshatched spaces might indicate either a planned change in schedule or an unscheduled emergency shutdown occurring prior to the scheduled shutdown. The latter would indicate that a better or more thorough planning, scheduling, or inspection job could have been done, or that unusual operating conditions may have existed, or that operating errors may have occurred.

It is to be noted that the frequency of the shutdowns, as well as the downtime scheduled for the different units, varies to a great extent. The size, type, and age of a particular unit; the severity of the process operations; the tie-in with other units or the complexity of the re-

finery flow; and the manpower requirements for the shutdown are but a few of the many factors affecting the shutdown interval and length. The determination of that interval, the length of time a unit may be operated safely, is one of the most important phases in scheduling. Information as to the frequency of inspection is contained in the chapters covering specific classes of equipment. Computerization of inspection data has been useful in helping to determine shutdown interval and length. Generally, the downtime scheduled for the shutdown is governed by the amount of time required to complete one or two major jobs—either repairs, replacements, or a revamp. In some instances, the determining factor may be the time required to restore the equipment to a state of cleanliness that is satisfactory for the next period of operation.

The actual timing of the shutdowns is determined, for the most part, by the length of time a unit is in operation. Quite often the length of a run is restricted or influenced by factors outside the scope of work of the inspection group; for example, process cleaning, product demand, major repairs and replacements, physical changes, the revamp of the unit, safety considerations, manpower requirements, and the like.

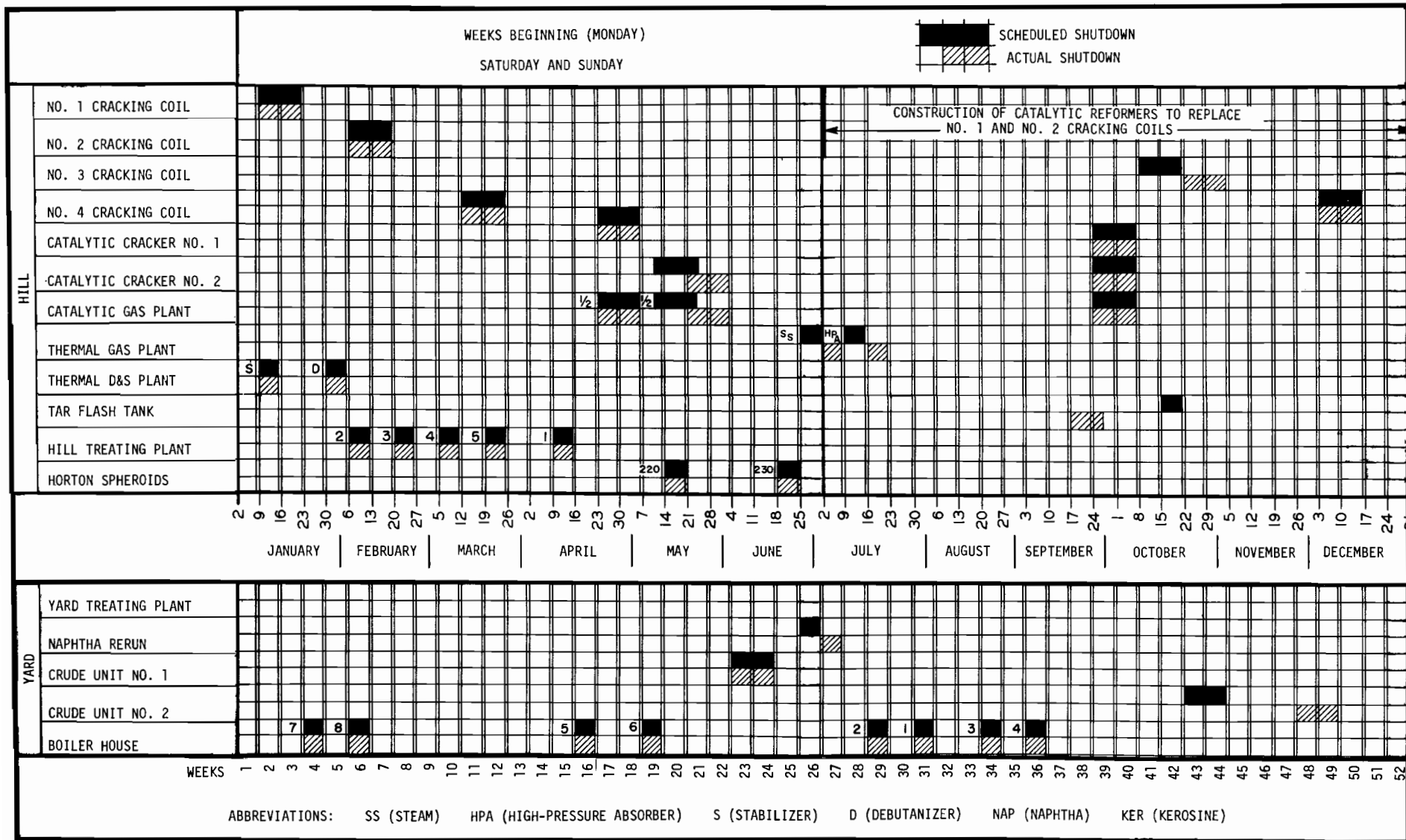
Weather may be a factor in the timing of a shutdown. Manpower productivity decreases under adverse weather conditions. The freezing of water in equipment is troublesome in cold weather. Timing a shutdown to avoid inclement weather may be advisable.

There are times when the scheduling of the shutdown hinges upon the maximum permissible period of operation, based upon laws or upon the service life remaining for a particular piece of equipment. In such cases, the length of run may not be determined solely on the basis of the inspection group's recommendations.

Preparing a unit shutdown schedule begins with a current shutdown. It is desirable that the inspection data be analyzed as soon as possible since the information gathered during a current shutdown is the basis for planning the next shutdown. The inspector uses these data to advise management and others concerned of the condition of the equipment and of what future repairs and replacements might be expected. The sooner all concerned know what future major repairs and replacements are necessary, the more adequate will be the planning job.

In preparing the unit shutdown or work schedule, the various shutdown operations or activities should be organized so that one operation or activity complements or supplements the other. Similarly, the various job assignments should be planned so that one job does not interfere with another. An effort should be made to schedule work in order to coincide with shutdown and

TABLE 1—Composite Shutdown Schedule



startup. One method is to use critical path scheduling. This involves sequence job planning to arrive at an optimum period for the shutdown.

Some refiners hold a pre-shutdown meeting to discuss the actual shutting down of the unit, maintenance and repair work to be completed during the shutdown, inspection work planned, and startup of the unit. All work contemplated is enumerated, discussed, and arranged in proper sequence. (At this time the inspector can request that additional equipment be made available or that special cleaning and preparation work be done.) As soon as possible after the unit has been returned to service, a post-shutdown meeting is held to evaluate the performance and consider ways and means of improving the schedule.

The supervisory personnel of the process, maintenance, and inspection groups attend these meetings and are directly involved in planning, directing, and coordinating the various shutdown activities and operations. In the event of a revamp, someone from the refinery engineering department may attend. New inspectors are advised to attend since the meetings present an excellent opportunity to gain experience and to become familiar with overall shutdown operations.

In preparing for the unit inspection, all equipment subject to corrosion or erosion and other forms of deterioration should be listed for inspection, excluding the inspection of nonoperating equipment and any other inspection work that can be performed while the unit is in operation. The inspector can then assign a priority to each item and formulate a realistic or workable inspection schedule. Specific items can only be inspected when available during a shutdown. It is often necessary to spread these items over two or more shutdowns to shorten downtime.

Some refinery maintenance forces may not be equipped with enough tools, equipment, and supervisory personnel to do all the work in a reasonable length of time. In such cases, part or all of the job may be contracted to an outside concern specializing in this type of work.

3.2.2 WORK DURING PERIODS WHILE MAIN UNITS ARE IN OPERATION

Inasmuch as the major part of the inspection effort at the scheduled shutdowns is concentrated on the operating equipment and the auxiliaries, it is desirable, and sometimes necessary, that as many of the inspection operations as possible be performed while the main units are in operation.

3.2.2.1 Inspection of Equipment in Operation

Inspection of equipment in operation may reveal

certain conditions that indicate the necessity for a particular detailed investigation when the unit is shut down. Also, there are certain conditions that can be observed while the unit is in operation that are difficult or impossible to observe when the unit is shut down. Such conditions that should be routinely monitored are:

1. Corrosion rate by means of probes.
2. pH control by use of onstream monitoring instruments and analysis of receiver waters.
3. Review of operations for changes in feedstock, throughput, temperature, and so forth.
4. Heater tube metal temperature survey.
5. Analysis of rotating equipment.

As a preliminary step in making inspections while a unit is in operation, it is desirable to prepare a schedule by listing the various items of equipment and indicating under each the parts to be inspected. Having a checklist of this kind will avoid the possibility of overlooking important items. Table 2 is an example of the type of schedule that may be used.

It is particularly important to consider the problems discussed in Paragraphs 3.2.2.1,a through 3.2.2.1,i prior to a major shutdown as they may indicate places that require further detailed inspection or more repair work than anticipated.

a. LEAKS

Leaks of any type are undesirable and should be investigated to determine their origin or source, as well as their cause. If sufficiently serious, a leak may cause an emergency or unscheduled shutdown.

The majority of oil leaks are found in operational bleeders caused by leaking valves, screwed fittings, pump packing, and gaskets at flanged joints. Usually the leaks are noticed readily by the discoloration or wetting of the adjacent area. If the oil is hot, yet below its ignition temperature, a smokelike cloud usually accompanies the oil seepage or drip.

Liquid materials, which are vaporous at atmospheric pressures and temperatures, are potentially the most hazardous and often the most difficult to detect. Some leaks can be recognized by a wavy appearance of the air (similar to the so-called heat waves on a highway), by odor, by sound, by frosting at the point of leakage, or by a visible cloud caused by condensation of moisture along with droplets of unvaporized material. When the vapor is both odorless and invisible and a suspected leak cannot be detected audibly, by ultrasonic leak detection, or by a soap test, regular gas-analysis equipment should be employed.

One of the principal hazards in connection with shell-and-tube equipment (condensing, cooling, and re-

TABLE 2—Inspection of Equipment During Operation

PRESSURE VESSELS

Inspection:

General, for any externally visible defects such as external corrosion, external weld defects, unsatisfactory condition of rivets, and hydrogen blistering.
 For deformation attributable to excessive pipeline strains or other causes.
 For leakage at manholes, connections, and reinforcing pads.
 For high-temperature spots on internally insulated vessels.
 Of condition of structural members such as platforms, walkways, ladders, and davits.
 Of condition of insulation, insulation covering, and banding.
 Of performance, from discussion with operators or from operators' reports.
 To obtain thickness measurements (possible on some vessels with ultrasonic-type instruments).

SHELL AND TUBE EXCHANGERS

Inspection:

General, for any externally visible defects.
 For leakage at connections, shell cover, channel or bonnet, channel cover, and so forth.
 Of condition of supports or supporting structure.
 Of condition of insulation and fireproofing of supporting structure.
 Of performance, from discussion with operators or from operators' reports.
 To obtain thickness measurements (possible on some exchangers with ultrasonic-type instruments).

AIR-COOLED EXCHANGERS

Inspection:

General, for any externally visible defects.
 For leakage at connections.
 Of condition of supporting structure (including any fireproofing, bolts, and clamps) and hood.
 Of condition of motor, reduction gears, fan blades.
 Of performance, from discussion with operators or from operators' reports.
 To obtain thickness measurements using ultrasonics or radiography.

FIRED STEAM BOILERS

Inspection:

Visual, of boiler tubes, superheaters, and water walls, for signs of overheating.
 To observe refractory walls in firebox.
 Of burners, to ascertain proper operation.
 Of operation and tightness of blowdown valves and equipment.
 Of operation of relief valves.
 Of operation of dampers.
 Of general condition of external walls, structural members, insulation.
 Of general condition of water columns and gage glasses.
 Of deaerator, complete internal and external (in some instances this is possible).
 Of fuel supply facilities.

FURNACES AND STACKS

Inspection.

General, for any readily observable defective conditions.
 To observe furnace tubes for heat distribution, overheating, bulging, sagging, or bowing.
 To measure the temperature of tubes using optical or infrared pyrometers.
 To observe tube supports for any indication of deterioration and to ensure proper support of tubes.
 Of burners, for proper operation and flame distribution.
 Of refractory linings, for indication of failure.
 Of condition of casing, structural members, breeching, and so forth.
 Of condition of external insulation, fireproofing, or paint.

Of condition of stack, guy wires, and anchors.

For out-of-plumbness, vibration, or swaying of stack.

Of performance, from discussion with operators or from operators' reports.

PIPING

Inspection:

General, for leaks at joints, external corrosion, cracked welds, and so forth.
 Visual, for vibration, swaying of lines, position of movable supports, wear at pipe supports, or excessive deformation.
 Of condition of insulation or other covering.
 Of condition of pipe supports and brackets.
 Of expansion joints, for proper alignment.
 Of condition of valves and valve packing.
 Of general condition, from discussion with operators.
 To obtain thickness readings (possible on some lines with ultrasonic-type instruments or radiography).

PRESSURE-RELIEVING DEVICES

Inspection:

General, for leakage.
 For proper operation of steam, air, and other utility relief valves, should be checked by increasing pressure until valve relieves or by lifting the disc off the seat with the lifting device for pressure up to 200 psig.

PUMPS AND COMPRESSORS*

Inspection:

General, for any externally visible defects, unusual noise, vibration, and so forth.
 Of lubricating-oil temperatures and cooling-water temperatures and pressure.
 For leakage at packing glands and mechanical seals and at oil or water lines.
 Of pressure gages and flow meters, as evidence of performance; also of performance, from discussion with operators or from operators' reports.
 Of standby equipment, if operating equipment is in good running condition.

INSTRUMENT AND CONTROL EQUIPMENT*

Inspection:

General, to assure proper functioning.
 Of pressure- and temperature-indicating and recording instruments.
 Of flow control valves and orifice meters.
 For deterioration or damage to instrument tubing (especially on unit).

ELECTRICAL SYSTEMS*

Inspection:

Of power lines, for condition of supports and insulation.
 Of transformers, for overheating.
 Of switch gear, disconnects, and cable splices for hot spots caused by high resistance (using infrared thermal imaging cameras).
 Of motors, for overload.
 Of motor-starting equipment.
 Of motors, for operation (including coupling to driven part); also of motor bearings.
 Of grounding connections of certain equipment.

GENERAL

Inspection:

Of blowdown systems.
 Of cooling towers.
 Of sewers in unit area, for proper seals.
 Of inventory items or storehouse items.
 Of materials-handling facilities.
 Of oil separators, incinerators, disposal equipment, and so forth.
 For condition of general housekeeping.
 Of inspection tools and equipment.

* This equipment may or may not be a direct responsibility of the inspector.

boiler) is the entry of flammable liquids into steam and cooling-water systems, particularly where cooling towers are used. This is especially important on high-pressure process systems that employ acids and light hydrocarbons, such as alkylation units. Localized corrosion, or any kind of failure of the condensing or reboiler equipment, may permit both corrosive and flammable material to enter the lower pressure cooling-water system.

The flammable material may be released at the cooling tower and the corrosive material may permeate the entire cooling system. Under these conditions it is desirable to have sampling points on water lines from all separate cooling units; pH recorders and alarms may be employed for immediate acid detection. To detect leakage of hydrocarbons in the cooling system, periodic inspection of the top part of the cooling tower for hydrocarbon odors or use of a gas detector is required.

Leakage sometimes occurs in tubular reboiler systems which could introduce process materials into the steam-condensate systems. Generally, an explosimeter is used to detect the presence of flammable vapors; if they are in substantial quantities, reboiler leakage is denoted.

In general, the check for leakage in tubular equipment is made on a regular schedule (such as once a shift). Consequently, the discovery and location of a leak is usually made by a process operator. In the event of a leak, the equipment is usually removed from service for inspection.

b. EXTERNAL CORROSION

A survey should be made of all equipment where external corrosion may occur. Commonly, these pieces of equipment are in areas subject to wetting or condensation, particularly under insulation. Cooling towers and spray ponds eject a considerable amount of water into the surrounding atmosphere and in the winter evolve into considerable amounts of steam and fog. In plants with marine atmospheres, the salt spray can over a period of time be highly damaging to nearby equipment, including metallic, concrete, and other materials of construction. The inspector should be alert to and regularly check for corrosion in these areas, particularly if salt is present.

Information on all causes of external corrosion is covered in detail in IRE Guide, Chapter II. In addition, detailed information concerning inspection for external corrosion is covered in the various chapters on specific types of equipment.

When corrosion appears to have materially reduced the metal thickness and thickness measurements cannot be obtained, notation should be made to take thick-

ness measurements when the equipment is out of operation.

c. DEFECTIVE INSULATION AND FIREPROOFING

Insulation and fireproofing should be inspected for breaks and cracks that might permit corrosion of the protected surface. Evidences of rust, scale, or other corrosion products indicate defective protective coverings. Inspection of protected surfaces beneath defective protective coverings should be made for the extent of corrosion that may have occurred. If the defective insulation or fireproofing cannot be repaired or replaced during operation, notation should be made to repair the defective covering when the equipment is out of operation.

d. STRUCTURAL ELEMENTS

Structural elements should be inspected during operation for corrosion and distortion. If defective elements cannot be repaired or replaced during operation, notation should be made to do the necessary work when the equipment is out of operation.

e. PIPING

Piping should be inspected during operation for vibration, distortion, leaks, strains, or other defects. If repairs cannot be made during operation or other corrective measures cannot be taken, notation should be made to do the necessary work when the equipment is out of operation.

f. THICKNESS MEASUREMENTS

Downtime can be shortened by checking the wall thickness of some piping items while they are in service with ultrasonic-type instruments or radiography. Thickness measurements taken by ultrasonic instruments are not affected significantly by slight pitting or light scaling; they may, however, be impaired by severe pitting and heavy scaling. The ordinary head used to send and receive the signals being transmitted through the pipe wall can be damaged by high temperatures. However, there are high temperature ultrasonic transducers and high temperature oils, greases, or plastic couplants. The inspector must establish for each line in service standards for the use of ultrasonic-type instruments and radiography. Initially this will require that a line index be made wherein each line is identified by size, product, and temperature.

g. IMPROPER OPERATION OF MECHANICAL EQUIPMENT

Both the process operators and the maintenance men performing the routine maintenance on the operating unit can point out mechanical equipment that is operating improperly. Any malfunction of the equipment

should be brought to the attention of the inspector so that he can assess the cause of the difficulties and determine whether a more thorough examination should be made.

h. EXCHANGERS AND CONDENSERS

Frequently several heat exchangers or condensers are employed to provide the necessary heat transfer for a particular stream or service. Sometimes individual or stacked units are grouped together and are so manifolded that it is possible to take a single or stacked unit out of service. There may be times when the maximum heating or cooling capacity is not required. Therefore, it is possible to inspect certain exchangers and condensers while the unit is in operation; furthermore, it may be desirable to do this to realize a saving in mechanical manpower and inspection time at the scheduled shutdown.

i. STANDBY EQUIPMENT

The complete detailed inspection and repair of standby equipment may be performed provided the regular operating equipment is in good condition. If it is evident that extensive repairs and possibly replacement to the regular equipment will be required at the scheduled shutdown, it is desirable that the spare or standby equipment be in good operating condition. Emergency generators, spare pumps, motors, compressors, and so forth should be checked and operated regularly.

3.2.2.2 Inspection of Nonoperating Equipment

To the greatest possible extent, all nonoperating equipment should be inspected while the units are in operation because of the better availability of time. In general, all inspections of foundations, structures, and buildings, and safety inspections, as described in detail in IRE Guide, Chapter XIX may be conducted while the unit is in operation. And, as mentioned in the foregoing paragraph, the complete detailed inspection and repair of standby equipment may be performed provided the regular operating equipment is in good condition. Items considered in this category and covered in the respective chapters are:

1. Structures.
2. Foundations.
3. Tankage.
4. Loading racks.

Generally, most of the major replacement equipment items are inspected at the fabricator's shop before they are shipped to the refinery. In some instances, however, this may not be possible and the inspector will have to make the initial inspection when the material is received at the refinery. Also, there are many standard off-the-

shelf and stock items (such as mechanical filters, replacement pumps or parts, valves, gaskets, and bolting) that require inspection before being placed in stores.

The following are other types of inspection work that may be performed while the main units are on stream.

Painting and protective coatings should be examined because of possible atmospheric corrosion or deterioration resulting from the elements. Guy lines to stacks and flares are another example of items that should be inspected. Others would be the painters' trolleys (sheaves and pulleys used for hoisting), wire rope as found on power winches, air hoists, and cranes, and certain materials-handling equipment such as elevators and conveyors. Many other types of equipment such as coal pulverizers, water and oil separators (combination gravity and mechanical skimmer type), and silos are essential to the operation of the refinery and should not be overlooked. Fire-protection equipment, such as pumps, hydrants, water lines, and foam systems, should also be inspected periodically and tested for operability.

The aforementioned are but a few of the many items that need to be checked and maintained, for each is in some way related to either the safety, operability, or appearance of the refinery. (See IRE Guide, Chapters XVII, XIX, and XX.)

3.2.3 PREPARATION FOR MAJOR INSPECTION WHILE EQUIPMENT IS IN OPERATION

Certain preparations for a major inspection may be made while units are in operation. The condition of the unit, and more specifically the individual equipment items that have not been functioning properly, can be discussed with the operators. A study of the inspection reports and records, plus information gained from the process operators, should determine the extent of the inspection contemplated for each item of equipment. With this knowledge, the inspector can plan and organize his work.

A tour of the unit will help the inspector locate the points where scaffolding or platforms may be required for access to certain equipment or areas. It may be advisable to check piping at this time to determine whether or not the location is the most desirable from the standpoint of accessibility. By selecting another location, a saving may be realized in the carpenter's or pipefitter's time and in inspection. Also, the inspector can pinpoint areas where insulation may have to be removed or where special surface preparation may be required for a detailed visual examination and can make arrangements for such works.

Other items may be found helpful and time saving. Bench marks and reference lines may be located. Inspection tools and equipment may be checked and

made ready. Time may be allotted to review drawings, inspection reports, records, procedures, and the like and to discuss conditions of equipment and various job assignments with other inspection personnel.

3.2.3.1 Scheduling Work

An inspection procedure or guide should be prepared after all data from previous inspections have been thoroughly reviewed, as well as data that may have been developed by periodic or partial inspections while the unit was in operation. Consideration also should be given to any completed inspection and repair work that may have been accomplished during the current period of operation. This guide will enable the inspector to plan his inspection work for the current shutdown. In turn, he can notify others concerning what he plans to inspect.

After the mechanical department and the various crafts have been informed of the scope of the inspection work contemplated and know the extent of the normal maintenance and repair work to be done at the unit shutdown, they can then plan their work. The inspector should also advise them of any special cleaning surface preparation or preparatory work.

Table 3 is an example of a procedure or guide for the inspection of a unit. Although an attempt has been made to develop a realistic example, the reader should keep in mind that this is a typical procedure and some particular type of deterioration may have been overlooked. Constant revision is necessary to keep the procedure up to date with the current condition of the equipment because as a unit ages the maintenance and repair generally increase. Conversely, there may be a decline in the inspection requirements should a particular type of deterioration be arrested or should the rate of deterioration show that some areas are being inspected too often.

If the workload requires the services of several inspectors, the person in charge of the inspection may wish to discuss with the other personnel the conditions that may be expected and to study with them drawings of the equipment. At that time he may assign jobs to individuals in accordance with experience and limitations. This is done primarily to coordinate the inspection effort and to help the inexperienced inspector become familiar with the unit. If the inspection personnel have previously worked on the unit and have become proficient in certain assignments, it may be advisable to interchange jobs to broaden knowledge and experience.

Occasionally, it may be necessary to recruit extra help outside of the regular inspection personnel. These men will have to be trained and given instructions in the particular inspection techniques associated with their

job assignments. Inexperienced help invariably assist or work under the supervision of a regular or trained inspector.

3.2.3.2 Discussion of Condition of Equipment with Operators

Inasmuch as the inspector is responsible for informing the operations supervisors and other personnel concerned as to the condition of the equipment, he should be alert to detect any deviation from safe practice with regard to equipment conditions. He should also be mindful of changes in operating methods and materials that are handled since they will have an effect on the frequency and extent of the inspection. Continuous acquaintance with prevailing conditions is especially necessary in the case of refineries processing high-sulfur crude oil or under any other conditions where deterioration of equipment is extremely rapid or of a variable nature.

To acquaint himself with prevailing conditions and to take cognizance of changes in operations and materials being processed, it is essential that the inspector maintain a close relationship with the operators. Discussion of the condition of the equipment with the operators may disclose that certain operational difficulties have occurred during the unit run. The difficulties encountered may indicate that the repair or replacement of some item of equipment may be necessary at the scheduled shutdown or the problem may indicate that a detailed examination should be made at the scheduled shutdown to determine the cause of the difficulty so that corrective action may be taken.

The improper operation of mechanical equipment would indicate that it is in need of repair or replacement. When a product is off-specification, it may direct attention to the fractionating or distillation equipment. The inspector should be prepared to examine the tower internals (trays, bubble caps, downcomers, piping, and so forth). High tube-wall temperatures suggest that a more detailed examination should be made in that area of the heater. These and many other operational difficulties serve as clues to specific types of deterioration and forewarn the inspector that a condition exists that will require his immediate attention at the scheduled shutdown.

In some instances, the process group may have initiated certain minor interim replacements and repairs of which the inspector has no knowledge or some physical changes may have been made to specific items of equipment. For example, some valves may have been replaced because of a malfunction, such as bypassing or being inoperative.

The inspector should know of any physical changes and the extent of the repairs or replacements made during the operating periods since they will affect the planning of the current scheduled inspection. He should also be informed of any changes so that the inspection records can be kept up to date. This may be achieved by establishing a friendly relationship with the operators.

The inspector, to successfully perform his duties, must create and maintain a harmonious working relationship with operating, maintenance, engineering, and management personnel in addition to satisfactorily performing inspection functions. Those responsible for the maintenance and operation of the equipment should also strive to maintain this harmonious relationship and

furnish the inspector with all of the information that will aid him in his duties.

3.2.4 WORK DURING PERIODS OF SHUTDOWN OF MAIN UNITS

Although a considerable amount of inspection work may be accomplished while the main units are in operation, the major part of the inspection work will occur during the shutdown of the operating unit. A major shutdown makes it possible for the inspector to examine the major operating equipment and auxiliaries and to complete any of the partial inspections made during the operating periods or during previous short shutdowns.

As mentioned previously, the amount of inspection

TABLE 3—Inspection Procedure for a Unit

FURNACE AND COIL

1. Inspect exterior of tubes for excess oxidation and bulges. Obtain wall thickness by ultrasonic or other means, as indicated on inspection sketch SK _____.
2. Inspect headers, seats, plugs, and holding members for cracks, scored seats, or other defects. Obtain wall thickness in thin sections, as indicated on inspection sketch SK _____.
3. Inspect damper for warpage, corrosion, and proper operation.
4. Inspect tube supports for cracks, sagging, or other defects.
5. Inspect refractory linings for spalling, fusing, or other damage.
6. Inspect inside of flue-gas ducts for damage to insulation.
7. Inspect insulation inside stack.
8. Inspect air preheater for corrosion or erosion and measure shell and head thicknesses.

FRACTIONATING TOWER

1. Visually inspect inside surfaces for corrosion or erosion. Measure thickness of shell and heads at points shown on inspection sketch SK _____. Inspect and obtain thickness of all connections. Measure or estimate and record the depth of pitting at locations where present.
2. Inspect tray plates and valves or caps for corrosion and tray packing for leakage.
3. Inspect overflows for corrosion and other defects.
4. Inspect liner at area indicated on inspection sketch SK _____ for cracked welds and bulging.

ACCUMULATOR

1. Inspect internal surfaces for corrosion or erosion. Measure thickness of shell and heads at points shown on inspection sketch SK _____. Inspect and obtain thickness of all connections. Measure or estimate and record the depth of pitting at locations where present.
2. Inspect float of liquid-level controller.

HYDROCARBON LINES AND FITTINGS

1. Measure wall thickness of all lines, as indicated on attached prints.
2. Inspect and test all valves that are tagged as leaking.

DESALTER

1. Inspect internal surfaces for corrosion or erosion. Measure thickness of shell and heads at points shown on inspection sketch SK _____. Inspect and obtain thickness of all connections.

2. Inspect electrical installation for broken insulators and short circuits.
3. Inspect insulation.

BOTTOMS TO FEED EXCHANGERS

If these exchangers were replaced with new exchangers during the last downtime, visually inspect shell, tube-bundle channel, and heads for corrosion or erosion; apply hydrostatic test for tightness at _____ psi on shell side and _____ psi on tube side.

VAPOR CONDENSERS

Inspect shell, heads, and channels for loss of thickness. If fifty tubes have been plugged because of leakage in each of these two bundles, both bundles should be replaced with spare bundles in stock. When replacements have been made, exchangers are to be hydrostatically tested for tightness at _____ psi on shell side and _____ psi on tube side.

PUMPS

1. Remove cover and inspect case of centrifugal charge pump for erosion and corrosion. Measure case thickness.
2. If the pump (a centrifugal pump) has been reported as noisy in operation, inspect bearings and impeller for misalignment.
3. If operation of the bottoms pump (a reciprocating pump) has been reported as unsatisfactory because of low capacity, inspect condition of liners and piston-wearing rings.

MOTORS

If the motor-driving main charge pump to unit has been reported as running hot, inspect for cleanliness of windings and megger windings of stator and rotor.

INSTRUMENTS

Inspect tubing for corrosion and tightness.

PRESSURE-RELIEVING DEVICES

Remove, pretest, clean, repair, test, and reset all pressure-relieving devices, as shown on the attached list. Record pretest pressure, condition, repairs, and cold set pressure for inspection records.

TEST

Upon completion of inspection and repairs, test atmospheric part of unit with 50-psi hydrostatic pressure to insure that all connections are tight. Test vacuum part of unit to insure tightness at 29 inches of mercury vacuum.

work accomplished at the scheduled shutdown is limited by the length of time the unit is shut down. It was brought out that the completion of the inspection work in the time allotted was directly related to the preliminary and preparatory work done; for example, how well all the shutdown operations were organized and coordinated. This is especially true of the inspection work during the shutdown of main units. To the greatest extent possible, the inspection work should be carried out so as to be coordinated with the regular cleaning, repair, and maintenance work; ordinarily, the inspector's work should not extend the calendar time of the shutdown.

In order to effectively coordinate the various phases of the shutdown and the work connected therewith, it is advisable that all concerned know the order in which the unit is shut down and started up. Generally, the process group prepares and issues a standard shutdown procedure for each unit, setting forth the exact order in which a unit is taken offstream and started up.

This procedure is adhered to rigidly and becomes the basis for the formulation of a unit work schedule. In planning the work schedule, all the operations or work related to the shutdown should be integrated or combined with the step-by-step procedure employed in shutting down and starting up the unit. This would include the work involved in shutting down the unit and making the equipment available and safe; the routine cleaning and maintenance work; special cleaning and preparatory work; repair work, including any replacements that may be necessary; additional work as a result of a revamp or physical change; inspection work; testing or any other special preoperational checks that may be required; and work involved in starting up the unit. By following this procedure, all shutdown activities are arranged in their proper sequence. In this way, one operation does not interfere with another and each operation may be carried out in a safe, orderly, and efficient manner. The unit work schedule is a combination of a shutdown procedure and a work schedule.

A unit work schedule or arrow diagram may be prepared and placed in the control house or some other centralized location where it may be referred to readily by process, maintenance, and inspection personnel. This diagram emphasizes the equipment where the progress of the normal cleaning and maintenance work is slow or the equipment where the work load is heaviest. Depending upon the size of the unit and the degree of coordination and control desired or necessary, the unit work schedule may be fairly simple or quite elaborate.

Inasmuch as inspection work is planned to follow

the progression of the regular cleaning and maintenance work, it usually does not interfere with these operations. However, because of major repairs and replacements or physical changes, the inspection work may of necessity be conducted prior to, during, or after the alterations. In some instances, the inspector may desire to make a cursory examination of an individual equipment item or part thereof as soon as it is made available and safe for inspection. If a particular condition that may require a considerable amount of maintenance and repair work develops shortly before the shutdown, the inspector may want to examine the equipment at the earliest opportunity to determine what repairs or replacements are necessary.

If a repair or replacement has already been scheduled, it would be desirable for the inspector to make a brief examination of the equipment to assure himself that the scope of work, as planned, adequately covers the job. At other times, it may be advisable to inspect a particular equipment item after the repair or replacement has been made, thereby obtaining the original inspection data on the replacement items or parts at the same time the current inspection data are acquired on the existing or older parts. This is especially desirable when a revamp or a physical change is made.

Quite often the inspection of larger vessels may be extended: for example, the inspection of the reactor and regenerator of a catalytic cracker or the inspection of an exceptionally large tower that may be huge in itself or may be extremely tall because a number of distillation and fractionating vessels have been stacked one on top of the other to form a single tower. It is not unusual for the inspection of one or two major vessels to be spread over the entire shutdown if an extraordinary amount of work is involved. In fact, the length of the shutdown may be determined by the amount of time required to clean and complete the maintenance work on one or two major vessels. Therefore, it is of paramount importance that all shutdown operations or activities be arranged in proper sequence and the inspection work be coordinated therewith if the unit is to be turned around and inspected in the allotted time.

Although the shutdown operations may be well organized and coordinated, including a system or method of checking progress, it is desirable for the process supervisor, maintenance supervisor, and inspector in charge to hold meetings daily during the shutdown to discuss the progress being made and any difficulties encountered. This is necessary in order to make adjustments for a lag in the performance of a particular operation or for any additional work and to review the next or subsequent operations. By keeping abreast

of the situation from day to day, an extension of the shutdown is less likely to occur. Also, everyone involved will be better prepared to handle any additional work resulting from the current inspection.

Once the shutdown is under way, a certain amount of shifting in work load or working force is to be expected, as invariably there will be conflicts of one kind or another. Consequently, adjustments must be made if the scheduled work is to be accomplished and the work on each item of equipment is to be completed at the time designated: for example, the time established by the startup. This is also true of the inspection work, as it usually follows the progression of the other work; any change made usually entails a revision in the plan or scope of the inspection work.

3.2.5 FLEXIBILITY OF SCHEDULES

Although the unit shutdown schedules generally are well adhered to, there are unpredictable factors that can cause a unit to be shut down in advance of the scheduled time. Generally, an emergency shutdown occurring prior to the scheduled shutdown results from operational difficulties. Such difficulties are sometimes caused by a mechanical failure within the equipment. Other operational difficulties may be attributed to mechanical failures of the auxiliaries. Also, the emergency or unscheduled shutdown may be the result of a leak, weld failure, valve failure, or some other difficulty that in itself may seem insignificant but in reality could be very serious.

In addition to operational difficulties that may be attributed to mechanical failures, some are the product of the operation itself. Other difficulties may be attributable to the severity of the operation, such as the coking of some vital part, a furnace-tube rupture, the rapid fouling or plugging of heat exchangers, or a decrease in catalyst activity as a result of a contaminant introduced through a change in the feedstock. Not to be overlooked are human failures. Fortunately, these types of failures are in the minority, but they do occur and may result in emergency shutdowns.

When the emergency shutdown occurs shortly after a unit has undergone a general inspection and repair, usually only the inspection and repair work necessary to return the unit to service is performed. However, if the emergency shutdown occurs near the date of the scheduled shutdown, it may be advisable to perform the scheduled general inspection and repair work while the unit is down, thus saving an extra downtime of the unit.

Because units may be shut down at a time other than that forecast or indicated on the schedule, shutdown and inspection schedules must be flexible. If oper-

ation of a unit beyond the scheduled inspection date is desired, the data taken at the previous inspection should be reviewed to determine if there is sufficient corrosion allowance remaining to permit safe operation for the extended period.

3.3 Checking Inspection Tools and Instruments

3.3.1 GENERAL

The complete examination or the partial inspection of equipment to determine its fitness for continued operation involves numerous inspection techniques, tools, and instruments. Moreover, the pertinence and reliability of the inspection data are to a large degree dependent upon the adequacy, availability, and accuracy of the inspection tools and instruments as well as the proficiency of the inspector. Each of these factors is important. The condition of the inspection tools and instruments is important because, should the tools and instruments be inoperable or inaccurate, a full or true appraisal of the deterioration of the equipment could not be made. Also, if thickness measurements are erroneous, a piece of equipment may be retired from service earlier than necessary or it may be permitted to operate after it should have been removed from service. All inspection tools and equipment should be in readiness.

In some refineries the inspection group has a trailer for the storage of inspection tools and equipment that may also serve as the inspection office during the shutdown. Prior to the shutdown, the proper tools and equipment required for the inspection are assembled and placed in the trailer. The trailer is then moved to a location within or adjacent to the unit limits. The location selected is a convenient one that does not interfere with the operation of the unit or the shutdown operations. The use of such a trailer enables the inspector to have all of his tools, records, and equipment convenient to the job site and to establish his center of operations and headquarters for the duration of the shutdown.

3.3.2 ACCURACY

The inspector should not only have the proper tools and instruments for each job but should have regular procedures and methods for checking the condition of the inspection tools and instruments. All inspection tools should always be in good adjustment to insure operability and accurate measurements. To accomplish this, they should be cleaned, checked, adjusted, and repaired immediately after their use. Cleaning and oiling most tools may be done at this time. If the inspec-

tor is unable to service and check all inspection tools or instruments immediately after their use, the slack period between shutdowns is an excellent time to do this. Measuring tools—such as micrometers, special calipers, and electronic and ultrasonic types of inspection instruments—should be checked against standards to verify their accuracy. During the shutdown, it is advisable to check these tools at least daily, before and after use, and whenever readings appear to be questionable.

Radiographic techniques and instruments used for measuring the wall thickness of pipe and pressure vessels, including the latest ultrasonic-type, are described and discussed in IRE Guide, Chapter IV, together with the many other nondestructive testing and measuring instruments that may be employed by the refinery inspector.

3.3.3 ADEQUACY

The many different materials used in the construction of refinery equipment, as well as the great variation in types and shapes of equipment, require that numerous measuring devices and other suitable inspection tools and equipment be provided. Because each inspection tool or instrument has certain inherent limitations, the inspector should take into consideration the suitability of a particular inspection tool for a specific application and should select a tool or instrument that is adequate for the job. For instance, magnetic-particle inspection equipment cannot be used for the detection of cracks in austenitic stainless steels and nonferrous materials; consequently, penetrant-dye or radiograph equipment should be employed. In other words, the inspector should be familiar with each tool or piece of equipment and use it only for the purpose intended.

The inspector should also bear in mind that it is desirable where possible to avoid cutting into equipment or using other destructive methods of inspection for the purpose of taking measurements since the repair may be time consuming and costly. This is especially true in light of the many suitable nondestructive measuring devices or equipment now available. Occasionally the inspector may find it necessary to obtain samples by sectioning for impact tests, microexamination, or some physical or chemical tests. However, the inspector should have a clearly defined, established, and approved repair procedure and he should see that it is rigidly adhered to when the repair is made.

3.3.4 AVAILABILITY

In selecting tools to be used during the inspection of a unit, consideration should be given to the availability

of the tools on hand.

The number of inspectors who may be working simultaneously will largely determine the number of smaller and more common tools that should be available. In the event that the more complex and expensive inspection tools or equipment are not available because the purchase thereof could not be justified, the inspector may obtain these special tools or equipment from an outside inspection agency on a rental basis. If the refinery inspection personnel is unfamiliar with the equipment, the outside inspection agency will have experienced operators whose services may be obtained on a fee basis.

The inspector should also be concerned with the availability of equipment for the protection or safety of the inspection personnel. The inspector should be provided with goggles, gas masks, protective gloves, capes, and the like used for the inspection of equipment in caustic or acid service. He should also be furnished with other protective clothing, such as may be required for the inspection of facilities that contain compounds of tetraethyllead or for the inspection of equipment handling other hazardous materials. Safety belts, bosuns' chairs, air hoists, rope (both metal and nonmetal), and radiation protection may be required to safely inspect certain items of equipment.

3.4 Preliminary Work For Major Inspections

3.4.1 GENERAL

Much of the planning and work mentioned in this section may not be the direct responsibility of the inspector. The inspector should, however, ascertain that appropriate personnel perform the necessary work preliminary to inspection and that they take into consideration his suggestions and requirements.

In the preceding sections of this chapter it was shown that much of the preliminary and preparatory work could be accomplished while the main units are in operation. Planning and scheduling maintenance and inspection work, partial inspection of equipment in operation, inspection of nonoperating equipment, discussion of conditions with the operators, and checking tools and equipment should, to the greatest extent possible, be completed during the operating periods.

It was also brought out that certain preparations for the inspection of the operating equipment may be made while the units are in operation. In addition (and as part of the preliminary work for major inspections), provision must be made for blanking or blinding off the equipment to be worked upon or inspected. The process systems must be purged and the equipment properly vented, drained, and cleaned before maintenance

nance or inspection work can be performed. Equipment items must be checked to determine if they are safe for entry before any cleaning, maintenance, or inspection work is carried out. Also, adequate means must be provided for the safety of the personnel involved in the shutdown. For safety requirements, refer to IRE Guide, Chapter V.

Extra inspection help, if needed, should be trained and instructed in the duties they are expected to fulfill. The inspector in charge should take any inexperienced personnel to the unit; point out the various items of equipment that are to be inspected; explain the details of the job together with a study of the drawings and a discussion of the conditions to be expected; show where the inspection tools and equipment are located; and specify what will be required in the way of protective clothing, what precautions should be taken, what inspection data or information is wanted, and the like. In other words, the inspector in charge should inform the inexperienced inspector of anything that will help to make the inspection job easier or safer.

3.4.2 PREPARATION OF EQUIPMENT

As suggested in Paragraph 3.2.2, it should be the constant objective of the inspector to complete as much work as possible while the main units are in operation. In particular, each piece of equipment scheduled for a major inspection should be studied and preparations made so that the inspection may be performed easily and quickly.

Scaffolding may be placed at locations where it will be required; it may be erected in advance provided the scaffolds do not interfere with current operations. In many cases, insulation may be removed from equipment or parts thereof to permit close inspection and to facilitate the maintenance or repair work. Anything that can be accomplished prior to the shutdown of the unit and that will aid in lessening the work load during the shutdown period should be completed prior to the shutdown.

3.4.3 DISCONNECTING OR BLANKING OF EQUIPMENT

IRE Guide, Chapter V should be observed since it covers the requirements for making equipment safe for entry and for various classes of work. The following is only a general statement of precautions and should not be used in lieu of the requirements of Chapter V or local refinery procedures.

When equipment is shut down, it is necessary that all connections to operating equipment (for example, feed lines, product lines, and other piping undergoing maintenance and inspection work) be blinded off.

When men are required to enter vessels or to perform maintenance work within or close to important equipment elements, the connecting piping should be closed with blind plates of adequate strength prior to beginning the work unless the hazards in particular situations have been carefully evaluated. No possibility should exist whereby a single valve could be operated in error and turn process liquids, vapors, or other hazardous or toxic materials on any members of the operating, maintenance, or inspection crews. Double valves with bleeders can be employed with safety in some cases, although blinding is the most positive protection. In the case of a vessel, this would require that process and utility piping connected to the vessel from other sources be blinded. An exception might be a vapor line from a reboiler if the bundle has been removed or a connected line has been dismantled for a considerable distance. If flammable, toxic, or otherwise dangerous liquids or gases are present, it is not sufficient that a line merely be disconnected at the vessel because discharge from the line near the vessel, even when the line is disconnected, may have serious consequences.

Utility lines should be blinded or disconnected with the exception of cold water lines in some cases. Fuel lines to fired heaters, boilers, and other furnaces should be blinded in order that no combustible liquid or gas accumulation can occur within the furnace. Heater-coil inlet and outlet piping should be blinded unless it has been extensively dismantled. Similar blinding is recommended for work on piping systems, depending upon the circumstances.

In blinding vessels, piping, and other parts, especially heat exchangers, consideration should be given to thermal expansion of fluids that may occur if a part of the confined system is heated when full of liquid. This can readily lead to major equipment failure if adequate relief valves are not provided; provision must be made to avoid heating under such circumstances.

On many occasions it is desirable to perform hot work on one portion of a process unit without making other portions gas free and suitable for the use of flames. In this event, portions that are not gas free must be blinded adequately.

To facilitate placement and checking, slip blinds with visible, brightly-painted handles are recommended. Operating blinds ordinarily referred to as spectacle or figure-eight blinds are one such type. They consist of a solid disc on one end of a handle and a filler ring on the other end. Temporary slip blinds of a solid disc with a protruding handle are another type. Steel-plate blind thickness must be adequate to withstand safely the anticipated pressure, but in no case

should blinds have less than a $\frac{3}{16}$ -inch thickness. All blinds should be installed with a gasket on each side.

A check list setting forth all blinding and similar work required for each maintenance shutdown with space for additions and exceptions should be provided on each operating unit so that a complete resurvey of these procedures does not have to be made on each occasion. Such standard lists should have the approval of responsible supervisors. Quite often the blanking or blinding operation is incorporated into and becomes part of the standard shutdown and startup procedure.

For vessels in which radioactive isotope sources have been installed for purposes of instrumentation, Energy Research and Development Administration (ERDA) procedures under which permission was granted to use the radioactive isotopes should be strictly followed. Applicable procedures also should be employed for instruments that contain other radioactive materials.

3.4.4 VENTING, DRAINING, AND CLEANING BEFORE INSPECTION

Usually, purging of a process system to clear it of previous contents is necessary (1) when operation begins and (2) at the end of operation in preparation for maintenance.

In purging preparatory to shutting down, steam is the most satisfactory general purging medium in wide use; however, it is not usable on acids and similar materials, such as the acid portions of certain alkylation units. Prior to steaming in heavy oil systems, circulation of warm, light oil may be more efficient. Steam has the advantage of being inert to hydrocarbons and most substances. Because of its temperature and partial-pressure effect, steam assists vaporization and removal of all volatile materials. Flue gas is used to an appreciable extent and is the standard purging method for at least one large refiner. The steam effluent from purging is usually directed to the blowdown system. By proper draining of the process system, the minimum amount of steam can be left as water on bubble trays, in vessels, in heater tubes, and so forth.

When making inspections during the winter months in cold climates, care should be exercised in the use of steam or water for purging and testing because it may freeze in lines and in other areas. If allowed to remain until operation begins, ice collected in vessels and elsewhere eventually may flash into steam with damaging results. On occasion, freezing of water in process lines has caused line ruptures that were undetected beneath insulation until operation was resumed.

In the final preparation of many portions of the equipment for maintenance or cleaning work, water

cooling may be necessary. Usually, water should not be introduced where temperatures are much over 200 degrees Fahrenheit nor where any substantial quantities of liquid oil are present at temperatures approaching this level. Coke drums and some reaction vessels that contain large amounts of coke and little liquid oil are exceptions to this rule, as water may be introduced when they are at or above temperatures of 800 degrees Fahrenheit for cooling the coke, provided the vapor outlets are properly opened.

Air should never be used for cooling purposes. It is likely to ignite coke, iron sulfide, and other combustible materials that may undergo spontaneous combustion under moderate heat and in the presence of air. An explosion or burning with a highly destructive flame action is likely to occur. It is readily possible to melt down the internals of large process units by the careless and improper use of air.

Vacuum purging is sometimes employed for cleaning equipment of toxic or flammable materials prior to maintenance and inspection. The operation of such systems usually involves pumping out the main contents of process fluids into other containers and the use of vacuum for removing the remaining traces of materials. Each individual system requires specific study for safe operation, especially when the introduction of air may be employed along with vacuum exhaustion to avoid oxidation of process liquids, initiation of combustion, or even the collapse of some part of the equipment if excess vacuum is employed.

In order to prepare the equipment for maintenance and inspection, pressure vessels and other important parts of operating systems frequently are equipped with drain connections for the removal of collected liquids and other materials, as well as for the blowing out of steam, inert gas, or vapor in the course of purging. Some vessels have bottom manways for the purpose of removing solids. For example, where the possibility exists that some liquid, tarry material, coke, or similar material has collected inside a manway or a drain, precaution should be exercised when opening the vessel or drain as the contents may be hot or under pressure. The unsuspected release of the contents, although not frequently a cause of property damage, has resulted in personal injury.

When a vessel or other equipment item has been purged, washed, cooled, and drained, it may be entered by workers or it may be worked upon provided it is safe to do so. A vessel entry permit should be issued and an operator should be notified prior to entry. IRE Guide, Chapter V outlines the requirements for safe entry and various types of work. If the vessel or equipment has contained flammable or toxic materials, it is

necessary after opening (and sometimes before) to test the vapors in the vessel for the content of such materials and to determine that the oxygen is sufficient for breathing. This may be done by using the appropriate type of combustible-gas indicator, explosimeter, or other device operated by a qualified person. In the event that entry into a vessel is for the purpose of conducting hot work that involves the use of open-flame or metallic-arc welding, a written hot-work permit must be obtained from the authorized source.

Procedures for gas-freeing equipment on which hot work is to be performed must be carefully carried out in accordance with the provisions of Chapter V.

3.4.5 CAUTION SIGNS AND PROTECTIVE EQUIPMENT FOR INSPECTORS

In the execution of inspection work, certain precautions should be taken for the protection of inspectors and workmen, for the avoidance of damage to the equipment, and for the maintenance of general safety in the inspection area.

The inspector, maintenance personnel, and operators should observe colored tags or signs that are used to safeguard machinery against startup. These tags or signs are applied to equipment in various ways to indicate that a switch should not be thrown or a valve should not be opened and that no other change should be made as long as the tag is affixed. Electrical equipment may be disconnected or locked out so that a switch cannot be thrown in error. Maintenance or inspection personnel should also avoid entering hot-work areas or equipment that may be hazardous as a result of flammable or toxic vapors and other materials until such time as the area or equipment has been gas tested or checked and declared safe for entry. If it is necessary for any reason to enter a tank or vessel that contains hydrogen sulfide, toxic vapors, or insufficient oxygen, a mask for the specific atmosphere involved should be used.

If it is necessary to enter a tank that has contained gasoline treated with compounds containing tetraethyllead, the safety requirements contained in *API Accident Prevention Manual 1B: Cleaning Petroleum Storage Tanks—Section B, Gasoline Tanks* should be followed.

The immediate area of tanks that have contained tetraethyllead should be posted with signs reading: **LEADED TANK, NO ONE TO ENTER WITHOUT PROPER PROTECTIVE CLOTHING and ENTER ONLY UPON OBTAINING PROPER CLEARANCE BY APPROVED AUTHORITY.**

Some refineries place signs on or adjacent to open vessels and tanks that have not been certified as gas free.

These read: **OPEN VESSEL [or TANK]. KEEP LIGHTS AND FIRES AWAY.** Caution signs should be placed at locations where men are working overhead or material is being transported to some elevation. Hot-work signs should be posted at locations where welding or burning is being performed. If the inspector or an outside inspection agency is using radiographic equipment, the area should be protected as outlined in state or ERDA procedures.

Signs, as described by the ERDA procedures, should be placed on all vessels in which radioactive sources have been installed for purposes of instrumentation.

The greatest number of injuries that require first aid treatment or medical attention are caused by foreign material lodged or embedded in the eye. It is recommended that goggles be worn at all times during the shutdown. A number of refineries make this rule mandatory when a man steps within battery limits during a shutdown.

In some instances the inspector may be required to enter equipment wherein welding, burning, or both are being performed. To avoid distress to the eyes and possible temporary blindness, the inspector should shield his eyes from the arc produced in welding. If he is to observe the welding operation, he should wear an appropriate welding shield. Approved dark-colored goggles should be worn to observe burning operations.

Occasionally the inspector may be required or may desire to inspect some part of a vessel, heater, or other piece of equipment before it has cooled down sufficiently to permit normal entry. In this case, it may be necessary for him to wear protective gloves, boots, hood, cape, or other heat-protective clothing. These and any other protective clothing that may be necessary for special jobs should be available and kept in a serviceable condition at all times.

Plastic or aluminum safety hats or helmets should be available. Normally, it is required that a safety hat be worn by all persons upon entering the turnaround area. Other protective equipment items are: safety shoes; wooden shoes for hot work in heaters, boilers, or the like; knee pads for prolonged inspection in the kneeling position; belly-boards for the close inspection of bell caps and bolted tower trays; and Underwriters' Laboratory approved safety flashlights, safety belts and ropes, and the like. This equipment is essential to the safety and welfare of the user as well as to his fellow workmen.

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