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Guide for Inspection of Refinery Equipment

Chapter III—Inspection Planning

THIRD EDITION, DECEMBER 1985



American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005



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Refining Department

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American
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PREFACE

This chapter is one of a series that 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, 1220 L Street, N.W., Washington, D.C. 20005.

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 this 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	Inspection Planning
Chapter IV	Inspection Tools
Chapter V	Preparation of Equipment for Safe Entry and Work
Chapter VI	Pressure Vessels (Towers, Drums, and Reactors)
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
Appendix	Inspection of Welding

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Guide for Inspection of Refinery Equipment

CHAPTER III—INSPECTION PLANNING

3.1 General Information

3.1.1 SCOPE

Inspection is a primary aid in reducing the number of process interruptions, maintaining a safe operation, and lowering the cost of maintenance and repair. Thus inspection is a vital part of the maintenance program. A successful inspection program hinges on good planning, knowledge of the deterioration of equipment and the conditions causing deterioration, and the ability to work closely with others in the refinery organization. The inspector must have a good understanding of the process operations, a comprehensive knowledge of the equipment, and the ability to locate and identify the potential forms of deterioration within the equipment. This chapter focuses on the development of thorough inspection plans, keyed to ongoing operations, and the effective scheduling of inspection both while units are operating and during shutdowns.

3.1.2 REFERENCED PUBLICATIONS

Readers of this chapter should supplement its contents by reference to the latest edition or revision of the following documents cited in the text.

API

510 *Pressure Vessel Inspection Code*

2015A *A Guide for Controlling the Lead Hazard Associated with Tank Entry and Cleaning*

3.2 Inspection Procedures

Refinery runs and unit operations are based on anticipated demands for specific products, and inspections should be planned to complement unit operations. Operating units cannot remain in service continuously and still retain optimum process and mechanical efficiency. Shutdowns at predetermined intervals for cleaning, maintenance, and repair are required to ensure safe, reliable, and efficient operation. Many inspection tasks can be accomplished while units are onstream or during a short process turnaround. Other tasks can only be accomplished while units are shutdown. A thorough review of the process flow and operations may reveal that the total inspection of a unit is unnecessary at any one shutdown. Performing all possible inspection tasks while units are in operation will minimize downtime.

The inspector should prepare an inspection procedure or outline based on the next expected unit run length. This outline is actually an inspection guide. It should be reviewed, and possibly revised, both prior to and immediately following each inspection. In preparing the outline, the inspector must determine the extent and type of inspection required for each unit and each piece of equipment, including pressure-relieving devices. Additions or corrections should be made based upon interim replacements and repairs, recommendations resulting from previous inspections, and any physical changes made during the operating periods or during any shutdown that may have occurred. Consideration should also be given to the possible benefit of special tests.

A well prepared, detailed procedure tells the inspector what to examine and what the inspection requirements are, provides assurance that nothing will be overlooked, and ensures a thorough job of planning the inspection work. The written procedure assists him in determining locations that may require surface preparation or the availability of special tools or equipment. He can better predict the areas where the work load will be the heaviest, and he can concentrate the inspection effort on potential trouble spots.

The success of any inspection program is dependent not only upon the extent of the inspection planning, but also on how the actual inspection is conducted and the quality of the inspection data obtained. Inspection plans should address the personal safety of all inspectors and the availability and serviceability of protective clothing, tools, equipment, and signs (see Chapter V).

Conferences with other departments (operations, maintenance, safety, and others) are valuable in planning for inspections that will take place during shutdowns.

3.3 Scheduling

Scheduling is defined as the planning and tabulating of refinery operations and maintenance projected over a period of time. Scheduling is used to achieve the most efficient and profitable utilization of the equipment that is consistent with safety, available manpower, material, and time necessary to direct, control, and evaluate not only the individual unit but also the overall refinery operation. A realistic operating schedule must be prepared and combined with an effective maintenance and inspection schedule for each process, utility, and individual piece of equipment.

The arrangement of the various operating schedules and their respective maintenance and inspection schedules into a flexible and workable composite master schedule requires the coordinated effort of the process, maintenance, and inspection groups. Depending upon the type of units and the size of the refinery, the composite schedule may be projected to cover a period of several years. The schedule may be reviewed and updated on a monthly basis so that it will always project shutdowns over the next 12 months.

Figure 1 provides an example of a composite schedule. It is a typical schedule for a medium-sized refinery that utilizes periodic, continuous, run-to-run, and onstream methods of inspection. All units are listed, and the shutdown intervals and 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 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 shutdown. Considerable variation between the blocked-in areas and the crosshatched areas might indicate either a planned change in schedule or an unscheduled emergency shutdown occurring before the scheduled shutdown. Unscheduled shutdowns should alert inspectors that unusual operating conditions may have existed or that operating errors may have occurred.

The frequency of shutdowns, as well as the downtime scheduled for each unit, will vary. 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 refinery flow; and the manpower requirements for shutdown are but a few of the many factors affecting shutdown intervals and lengths. The determination of shutdown intervals (and conversely, the length of time a unit may be operated safely) is one of the most important aspects of scheduling. The frequency of inspection is covered in the chapters of the *Guide for Inspection of Refinery Equipment* covering specific classes of equipment and in API 510, *Pressure Vessel Inspection Code*. Computerizing inspection data has been useful in helping to determine shutdown intervals and lengths.

Generally, the downtime scheduled for a shutdown is governed by the amount of time required to complete one or two major jobs (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 timing of 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, a revamp of the unit, safety considerations, manpower requirements, jurisdictional requirements, or remaining service life.

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.

Preparing the next unit shutdown schedule begins with the current shutdown. Inspection data should be analyzed as soon as possible. The inspector uses this data to advise management and others of the condition of the equipment and of what repairs and replacements might be expected. The sooner all concerned know what major repairs and replacements are necessary, the more adequate the planning job will be.

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

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

Most refineries hold preshutdown meetings 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. Supervisory personnel from process, maintenance, and inspection departments who attend these meetings 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 should attend since the meetings present an excellent opportunity to gain experience and to become familiar with overall shutdown operations.

As soon as possible after a unit has been returned to service, a postshutdown meeting is helpful to evaluate performance and to consider ways of improving future inspection scheduling and work.

3.4 Inspection During Periods While Units Are in Operation

3.4.1 EXTERNAL INSPECTION

API 510, *Pressure Vessel Inspection Code*, calls for all

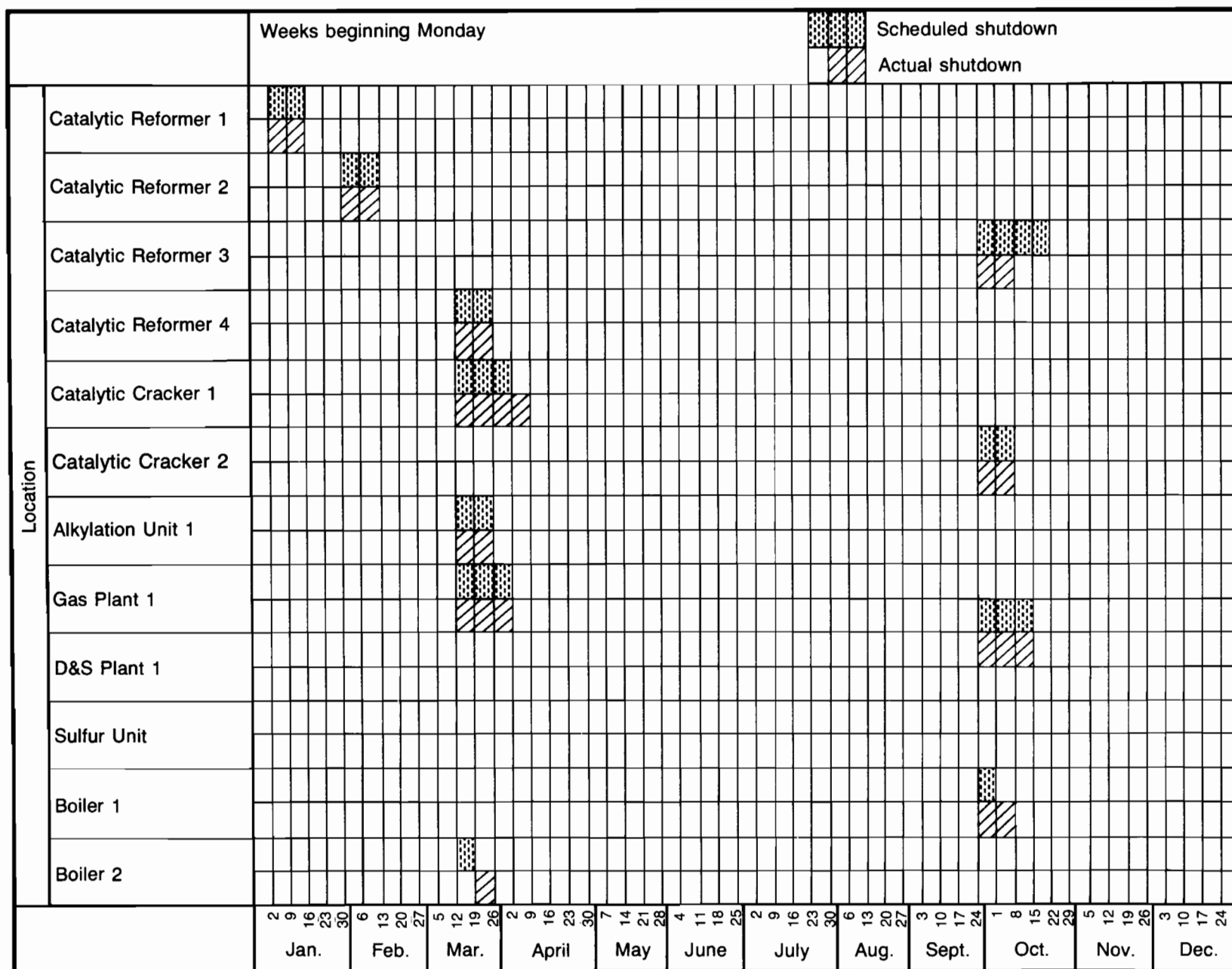


Figure 1—Shutdown Schedule

vessels to receive an external inspection at least every 5 years. This inspection of the vessel's setting is conducted preferably while the vessel is in operation so that operation's influence on any problems can be detected.

3.4.2 INSPECTION OF EQUIPMENT IN OPERATION

Inspection of equipment in operation may reveal conditions that require more detailed investigation when the unit is shut down. In addition, certain conditions can be observed while the unit is in operation that are difficult or impossible to observe when the unit is shut down. The following phenomena and particular equipment types should be routinely monitored.

1. Corrosion rate, by means of probes or coupons.
2. pH values, by use of onstream monitoring instruments and analysis of receiving waters.
3. Operational changes (feedstock, throughput, temperature, and others).
4. Heater tube metal temperature.
5. Rotating equipment.

As a preliminary step in making inspections while a unit is in operation, prepare a checklist of the various items of equipment and indicate under each the parts to be inspected. This checklist will ensure that items are not overlooked during the inspection. Table 1 provides an example of a checklist.

Before beginning a major shutdown, anticipated problems or problem areas, described in 3.4.2.1 through 3.4.2.9, should be examined since they may indicate places that require further detailed inspection or more repair work than anticipated.

3.4.2.1 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 and are caused by leaking valves, screwed fittings, pump packing, and gaskets at flanged joints. The discoloration or wetting of the area adjacent to the leak may make it readily apparent. If the oil is hot, yet below its ignition temperature, a smoke-like cloud usually accompanies the oil seepage or drip.

Liquid materials, which are vapors 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 a leak is suspected and the vapor is both odorless and invisible and 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 (condenser, cooler, and reboiler) is the entry of flammable liquids into steam and cooling-water systems, particularly where cooling towers are used. High-pressure process systems that employ acids and light hydrocarbons, such as alkylation units, are particularly susceptible. 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, sampling points on water lines from all separate cooling units are desirable. 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. Hydrocarbon alarms for installation in cooling towers are also available.

Leaks may occur in tubular reboiler systems and can introduce process materials into the steam-condensate systems. Generally, an explosimeter is used to detect the presence of flammable vapors. The existence of substantial quantities of flammable vapors indicates reboiler leakage.

In general, tubular equipment is routinely checked (such as once a shift) for leaks. 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.

3.4.2.2 External Corrosion

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

The causes of external corrosion are covered in detail in Chapter II. In addition, detailed information concerning inspection for external corrosion is provided in the various chapters of the *Guide for Inspection of Refinery Equipment* on specific types of equipment and in API 510.

When corrosion appears to have materially reduced the

Table 1—Checklist for On-Stream Inspection

PRESSURE VESSELS**Inspect for:**

Externally visible defects, such as external corrosion, external weld defects, unsatisfactory condition of rivets, and hydrogen blistering.
 Deformities attributable to excessive pipeline strains or other causes.
 Leakage at manholes, connections, and reinforcing pads.
 High-temperature spots on internally insulated vessels.
 Condition of structural members, such as platforms, walkways, ladders, and davits.
 Condition of insulation, insulation covering, and banding.
 Performance, from discussion with operators or from operators' reports.

Obtain:

Thickness measurements (possible on some vessels with ultrasonic-type instruments).

SHELL-AND-TUBE EXCHANGERS**Inspect for:**

Externally visible defects.
 Leakage at connections, shell cover, channel or bonnet, channel cover, and so forth.
 Condition of supports or supporting structure.
 Condition of insulation and fireproofing of supporting structure.
 Performance, from discussion with operators or operators' reports.

Obtain:

Thickness measurements (possible on some exchangers with ultrasonic-type instruments).

AIR-COOLED EXCHANGERS**Inspect for:**

Externally visible defects.
 Leakage at connections.
 Condition of supporting structure (including any fireproofing, bolts, and clamps) and hood.
 Condition of motor, reduction gears, and fan blades.
 Performance, from discussion with operators or from operators' reports.

Obtain:

Thickness measurements using ultrasonic or radiographic equipment.

FIRED STEAM BOILERS**Inspect for:**

Signs of overheating of boiler tubes, superheaters, and water walls.
 Condition of refractory walls in firebox.
 Proper operation of burners.
 Proper operation and tightness of blowdown valves and equipment.
 Operation of relief valves.
 Operation of dampers.
 Condition of external walls, structural members, and insulation.
 Condition of water columns and gage glasses.
 Condition of deaerator, internal and external (in some instances this is possible).
 Adequacy of fuel supply facilities.

FURNACES AND STACKS**Inspect for:**

Readily observable defective conditions.
 Heat distribution, overheating, bulging, sagging, or bowing of furnace tubes.
 Proper temperature of tubes, using optical or infrared pyrometers.
 Indications of deterioration of tube supports.
 Proper operation of burners and correct flame distribution.
 Indication of failure in refractory linings.
 Condition of casing, structural members, breeching, and so forth.
 Condition of external insulation and fireproofing.
 Out-of-plumbness, vibration, or swaying of stack.
 Performance, from discussion with operators and from operators' reports.

PIPING**Inspect for:**

Leaks at joints, external corrosion, cracked welds, and so forth.
 Vibration, swaying of lines, position of movable supports, wear at pipe supports, or excessive deformation.
 Condition of insulation or other covering.
 Condition of pipe supports and brackets.
 Proper alignment of expansion joints.
 Condition of valves and valve packing.
 General condition, from discussion with operators.

Obtain:

Thickness readings (possible on some lines with ultrasonic or radiographic instruments).

PRESSURE-RELIEVING DEVICES**Inspect for:**

Leakage.
 Proper operation of steam, air, and other utility relief valves. Should be checked by increasing pressure until valve relieves or by lifting disk off the seat with the lifting device for pressure up to 200 pounds per square inch gage.

PUMPS AND COMPRESSORS¹**Inspect for:**

Externally visible defects, unusual noise, vibration, and so forth.
 Temperature and pressure of lubricating-oil and cooling water.
 Leakage at packing glands and mechanical seals and at oil or water lines.
 Performance, pressure gages and flow meters as evidence of performance and from discussion with operators and from operators' reports.
 Condition of standby equipment, if operating equipment is in good running condition.

INSTRUMENTS AND CONTROL EQUIPMENT¹**Inspect for:**

Proper functioning.
 Operation of pressure- and temperature-indicating and recording instruments.
 Operation of flow control valves and orifice meters.
 Deterioration or damage to instrument tubing (especially on unit).

ELECTRICAL SYSTEMS¹**Inspect for:**

Condition of power line supports and insulation.
 Overheating of transformers.
 Hot spots caused by high resistance (using infrared thermal imaging cameras) in switchgear, disconnects and cable splices.
 Overloading of motors.
 Condition and operation of motor starting equipment.
 Operation of motors, including coupling to driven part, and motor bearings.
 Grounding connections of certain equipment.

GENERAL**Inspect:**

Blowdown systems.
 Cooling towers.
 Sewers in unit area, for proper seals.
 Inventory or storehouse items.
 Materials-handling facilities.
 Oil separators, incinerators, disposal equipment, and so forth.
 Quality of general housekeeping.
 Inspection tools and equipment.

¹This equipment may or may not be a direct responsibility of the inspector.

metal thickness and thickness measurements cannot be obtained, notation should be made to take thickness measurements when the equipment is out of operation.

3.4.2.3 Defective Insulation and Fireproofing

Insulation and fireproofing should be inspected for breaks and cracks that might permit corrosion of the protected surface. The presence of rust, scale, or other corrosion products indicates defective protective coverings or weatherproofing. Inspection of protected surfaces beneath defective protective coverings should be made to determine the extent of corrosion. 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.

3.4.2.4 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.

3.4.2.5 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.

3.4.2.6 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 profile thickness radiography (see Chapter V). 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 oil, grease, or plastic couplants. The inspector must establish standards for each line in service governing the use of ultrasonic and radiographic instruments. Initially a line index should be prepared identifying each line by size, product, and temperature.

3.4.2.7 Improper Operation of Mechanical Equipment

Both the process operators and maintenance personnel performing routine maintenance on an operating unit can point

out mechanical equipment that is operating improperly. Any malfunction of the equipment should be brought to the attention of the appropriate inspector so that he can assess the cause of the difficulties and determine whether a more thorough examination should be made.

3.4.2.8 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 and may be desirable to do so, thereby reducing manpower requirements and inspection time during scheduled shutdowns.

3.4.2.9 Standby Equipment

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

3.4.3 INSPECTION OF NONOPERATING EQUIPMENT

All nonoperating equipment should be inspected while the units are in operation. Items considered in this category and covered in other chapters are:

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

Generally, most major replacement items are inspected at the fabricator's shop before shipment. 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. In addition, many stock items (such as mechanical filters, replacement pumps or parts, valves, gaskets, and bolting) require inspection before being placed in stores.

Other items that may be inspected while the main units are on stream include:

1. Painting and protective coatings.
2. Guy lines to stacks and flares.

3. Painters' trolleys (sheaves and pulleys used for hoisting).
4. Materials-handling equipment, such as elevators and conveyors.
5. Coal pulverizers, water and oil separators (combination gravity and mechanical skimmer type), and silos.
6. Fire-protection equipment, such as pumps, hydrants, water lines, and foam systems.

The items listed above are but a few of the many items that need to be checked and maintained, for each is in some way related to safety, operability, or reliability of the refinery.

3.5 Preparation for a Major Inspection Before a Shutdown While Equipment Is in Operation

Certain preparations for a major inspection to be conducted during a shutdown 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.

A tour of the unit will help the inspector locate points where scaffolding or platforms may be required for access to certain equipment or areas. Scaffolding may be erected in advance if it will not interfere with current operations. Accessibility to piping should be a primary consideration since the selection of one location over another may cut down the carpenter's or pipefitter's time and reduce the duration of the 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. If operations permit, insulation may be removed before the shutdown.

Additional preparation work that may be helpful and time saving includes:

1. Locating benchmarks and reference lines.
2. Checking inspection tools and equipment for readiness.
3. Reviewing drawings, inspection reports, records, procedures, and the like.
4. Discussing the condition of equipment and various job assignments with other inspection personnel.

3.5.1 INSPECTION PROCEDURE

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 should also 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.

The inspector should be aware, before the actual inspection begins, of the type of information that should be collected during the inspection and included in the inspection report. It is essential that the report contain the information necessary to determine the following:

1. The date of the next inspection.
2. The repairs that will be needed, or are likely to be needed, at the next unit shutdown.
3. At a subsequent inspection of the equipment, the amount of deterioration that has occurred since the current inspection.

If it is the responsibility of the inspector, the report should also include full details of any repairs or alterations that have been carried out.

After the operations and maintenance departments 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 plan their work. The inspector should also advise them of any special cleaning, surface preparation, or preparatory work.

Table 2 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 types of deterioration may have been overlooked. Constant revision is necessary to keep the procedure up to date with the current condition of the equipment. As a unit ages, the maintenance and repair generally increase. Conversely, inspection requirements may be reduced if a particular type of deterioration is slow and predictable.

3.5.2 MANPOWER

The person in charge of the inspection should discuss the conditions that may be expected with all personnel who will be involved. At that time he may assign jobs to individuals according to their 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, jobs may be interchanged to broaden the knowledge and experience of all inspectors.

Occasionally, it may be necessary to recruit extra help outside of the regular inspection personnel. Inexperienced help should assist or work under the supervision of a regular or trained inspector. Contract inspection companies can often provide experienced inspectors if the inspection work force needs to be augmented during a shutdown.

Extra inspection help 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.

3.5.3 DISCUSSING THE CONDITION OF EQUIPMENT WITH OPERATORS

The inspector is responsible for informing the operations supervisors and other personnel concerning the condition of the equipment. He should be alert to deviations from safe

operating and equipment conditions. He should also be aware of changes in operating methods and materials that are handled, since they will have an effect on the frequency and extent of the inspection.

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

The improper operation of mechanical equipment may indicate that it is in need of repair or replacement. When a

Table 2—Inspection Procedure for a Unit Shutdown

FURNACE AND COIL

1. Inspect exterior of tubes for excess oxidation and bulges. Obtain wall thickness by ultrasonic or other means and caliper tube outside diameter.
2. Inspect headers, seats, plugs, and holding members for cracks, scored seats, and other defects. Obtain wall thickness in thin sections.
3. Inspect damper warpage, corrosion, and proper operation.
4. Inspect tube supports for cracks, sagging, and 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.
9. Inspect burners.

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 average and maximum 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 average and maximum 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 measurements 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 the 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 the 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 pop, clean, repair, test, and reset all pressure-relieving devices, as shown on the attached list. Record pretest pop 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 ensure that all connections are tight. Test vacuum part of unit to ensure tightness at 29 inches of mercury vacuum.

product is off-specification, inspectors should direct their 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 requires his immediate attention at the scheduled shutdown.

In some instances, the process group may have initiated certain minor interim replacements and repairs or physical changes. For example, valves may have been replaced because of malfunctions. The inspector should be informed of or discuss with operators any physical changes and the extent of repairs or replacements made during the operating periods, since they will affect the planning of the scheduled inspection. He should note these changes so that the inspection records can be kept up to date.

The inspector, to successfully perform his duties, must create and maintain a harmonious working relationship with operations, 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.

3.6 Work During Periods While Main Units Are Shutdown

Although a considerable amount of inspection work may be accomplished while the main units are in operation, the bulk 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 operating equipment and auxiliaries and to complete any of the partial inspections made during operating periods or during previous short shutdowns.

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. Certain areas requiring the routine attention of inspection personnel are discussed in 3.6.1 through 3.6.4.

3.6.1 DISCONNECTING OR BLANKING OF EQUIPMENT

The requirements for making equipment safe for entry and for various classes of work are discussed in Chapter V. 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 (feed lines, product lines, and other piping undergoing maintenance and inspection work) be blinded off. When workers 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 before beginning the work. 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, the process and utility piping connected to the vessel from other sources must 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. Discharge from the line near the vessel, even when the line is disconnected, may have serious consequences.

With the exception of cold water lines in some cases, utility lines should be blinded or disconnected. Fuel lines to fired heaters, boilers, and other furnaces should be blinded so 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 dismantled. Similar blinding is recommended for work on piping systems.

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

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. Portions that are not gas free must be adequately blinded.

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 type. They consist of a solid disk on one end of a handle and a filler ring on the other end. Temporary slip blinds or a solid disk with a protruding handle are another type. Steel-plate blind thickness must be adequate to withstand 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 checklist 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 to eliminate a complete resurvey of these procedures

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 instrumentation, Nuclear Regulatory Commission (NRC) requirements should be strictly followed. Applicable procedures also should be employed for instruments that contain other radioactive materials.

3.6.2 VENTING, DRAINING, AND CLEANING

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

In purging prior to shutting down, steam is the most satisfactory purging medium in wide use; however, it is not suitable for 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, but systems containing austenitic stainless steel materials should be evaluated thoroughly before steam is selected as the purging medium. Because of its temperature and partial-pressure effect, steam assists in vaporizing and removing volatile materials. 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. Flue gas has been used as another method of purging equipment.

When making inspections during the winter months in cold climates, care should be exercised in the use of steam or water for purging or testing because it may freeze in lines and in other areas. If allowed to remain until operation begins, ice may collect in vessels and eventually flash into steam with damaging results. On occasion, the 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 F (93 C) or 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; water may be introduced when they are at or above temperatures of 800 F (425 C) for cooling the coke, provided the vapor outlets are properly opened.

The use of air for cooling should be reviewed carefully. Air is normally satisfactory for purging and cooling boiler

and furnace fireboxes. However, it is likely to ignite coke, iron sulfide, and other combustible materials in process equipment 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. The internals of large process units may be melted down by the careless and improper use of air.

Vacuum purging is sometimes employed for cleaning equipment of toxic or flammable materials before maintenance and inspection. The operation of such systems usually involves pumping out the 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 used.

To prepare equipment for maintenance and inspection, pressure vessels and other important parts of operating systems are frequently 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, tar, coke, or similar material has collected inside a manway or a drain, precautions should be taken when opening the vessel or drain, since 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. 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 if there is sufficient oxygen to support life. This may be done by using the appropriate type of oxygen content 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 an open-flame, metallic-arc welding, or other source of ignition, 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 carried out according to the provisions of Chapter V.

3.6.3 CAUTION SIGNS AND PROTECTIVE EQUIPMENT

In the execution of inspection work, certain precautions should be taken to protect inspectors and workers, to avoid damage to equipment, and to maintain general safety in the inspection area.

The inspectors, 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 the presence of flammable or toxic vapors and other materials. Entrance should be avoided until the area or equipment has been gas tested or checked and declared safe for entry. If it is necessary to enter a tank or vessel that contains hydrogen sulfide, toxic vapors, or insufficient oxygen, a mask designed for the specific atmosphere should be used.

If it is necessary to enter a tank that has contained gasoline treated with lead antiknock compounds, the safety requirements contained in Publication 2015A, *A Guide for Controlling the Lead Hazard Associated with Tank Entry and Cleaning*, should be followed. The immediate area of tanks that have contained lead antiknock compounds 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 Nuclear Regulatory Commission procedures.

Signs, as described by the Nuclear Regulatory Commission procedures, should be placed on all vessels in which radioactive sources have been installed for 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. Goggles should be worn at all times during a shutdown. Some refineries have made this rule mandatory when a worker steps within battery limits.

In some instances, the inspector may be required to enter equipment where welding, burning, or both are being per-

formed. 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 serviceable condition at all times.

Plastic safety hats or helmets should be available. All Occupational Safety and Health Administration regulations governing safety hats should be followed. 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 close inspection of bubble caps and bolted tower trays; and Underwriters' Laboratory approved safety flashlights, safety belts, and ropes.

3.6.4 MEETING SCHEDULES AND MINIMIZING TIME OUT OF SERVICE

The amount of inspection work accomplished at the scheduled shutdown is limited by the length of time the unit is shut down. The completion of the inspection work in the time allotted is directly related to the amount of planning, scheduling, and preshutdown inspection work done and how well all the shutdown operations have been organized and coordinated. To the greatest extent possible, the inspection work should be coordinated with the regular cleaning, repair, and maintenance work. The inspector's work should not extend the duration of the shutdown.

In order to effectively coordinate the various phases of the shutdown and related work, all personnel involved should know the order in which the unit is to be 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 off stream and started up.

The inspection procedure should be adhered to rigidly and should become the basis for a unit work schedule. In planning the work schedule, all the operations 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 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, 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 shutdown procedure and 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 should emphasize equipment where the progress of normal cleaning and maintenance work is slow or 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.

Inspection work is planned to follow the progress of the regular cleaning and maintenance work, and usually does not interfere with these operations; however, if major repairs and replacements or physical changes are required, the inspection work may of necessity be conducted before, during, or after the alterations.

Quite often the inspection of larger vessels may be extensive: for example, the inspection of the reactor and regenerator of a catalytic cracker or the inspection of an exceptionally large tower. It is not unusual for the inspection of one or two major vessels to be spread over the entire shutdown period 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. It is of paramount importance that all shutdown operations or activities be arranged in proper sequence and the inspection work be coordinated if the unit is to be turned around and inspected in the allotted time. In some instances, the inspector may make a cursory examination of an individual equipment item or part 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, the inspector should make a brief examination of the equipment to assure himself that the scope of the 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, therefore 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 physical change is made.

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 and inspector in charge to hold daily meetings to discuss the progress being made and any difficulties encountered. Adjustments can then be made in the performance of a particular operation, to incorporate additional work, and to review subsequent operations. Invariably there will be conflicts of one kind or another. By keeping abreast of the situation from day to day, an extension of the shutdown is less likely to occur.

3.7 Flexibility of Schedules

Although unit shutdown schedules generally are well adhered to, there are unpredictable factors that can cause a unit to be shutdown 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 or auxiliaries. 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 could have serious consequences. Other difficulties resulting in emergency shutdowns 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 feedstock. Human failures may also occur and should not be overlooked.

When an 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. If the emergency shutdown occurs close to the date of the next scheduled shutdown, performing the scheduled general inspection and repair work while the unit is down may reduce total time out of service.

Because units may be shutdown at a time other than that forecast or indicated on the schedule, shutdown and inspection schedules must be flexible and prepared well in advance. If extended operation 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.



3.8 Checking Inspection Tools and Instruments

The complete examination or the partial inspection of equipment to determine its fitness for continued operation involves numerous inspection techniques, tools, and instruments. The pertinence and reliability of the inspection

data are dependent on the adequacy, availability, and accuracy of the inspection tools and instruments, as well as the proficiency of the inspector. All inspection tools and equipment should be in readiness. Inspection tools are covered in detail in Chapter IV.