Order No. 132P

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Defense Threat Reduction Agency

DTIRP Outreach Program

8725 John J. Kingman Road, MSC 6201

Fort Belvoir, VA 22060-6201

1.800.419.2899

Email: dtirpoutreach@dtra.mil

Web: http://dtirp.dtra.mil

Quick Reference Guide to Chemical Equipment

Order No. 132P

June 2004

This pamphlet is part of a series about the Chemical Weapons Convention and its potential security impact on DoD facilities and chemical plants. It was prepared by the Defense Treaty Inspection Readiness Program (DTIRP) to increase ***Readiness Through Awareness*** within the U.S. Government and defense contractor community. Additional copies of this pamphlet, as well as other information about arms control treaties and the application of security countermeasures, are available through the DTIRP Outreach Program.

Prepared for:
Defense Threat Reduction Agency
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8725 John J. Kingman Road, MSC 6201
Fort Belvoir, VA 22060-6201
1-800-419-2899
http://dtirp.dtra.mil

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INTRODUCTION

HOW TO USE THIS GUIDE

This reference guide is intended to serve as a tool to provide national escorts and other United States personnel supporting Chemical Weapons Convention (CWC) inspections at U.S. industrial facilities with basic information about industrial chemical processing and production equipment and the identifying characteristics of these various types of equipment. The guide provides a foundation for chemical production equipment familiarization and may serve as an aid to discussions between program managers and engineers during site preparation, training, and inspection activities.

The CWC is an international arms control treaty banning the development, production, stockpiling, acquisition, transfer, or use of chemical weapons (CW). The Convention achieves this goal by monitoring certain chemicals listed on three "schedules" and those identified as discrete organic chemicals. Many of these chemicals are dual-use, meaning they have legitimate industrial applications but can also be used for illegitimate purposes. Although they may be used in the development of certain types of CWs, dual-use chemicals are also widely used for various industrial, pharmaceutical, and other peaceful purposes. For this reason, the CWC monitors these chemicals and does not seek to eliminate their commercial use. The Convention not only affects private industrial facilities engaged in activities above treaty-monitored thresholds, but government and government contractor facilities as well. As a result, more facilities in the United States are affected by the CWC than any previous arms control treaty or agreement.

Multinational inspection teams (IT) employed by the Technical Secretariat (TS) of the Convention's implementing body, the Organization for the Prohibition of Chemical Weapons (OPCW), execute the verification regime. During on-site visits, the IT travels to a specified site to gather information related to the facility's data declaration or, in the event of a challenge inspection, to clarify and resolve questions concerning a possible non-compliance concern. OPCW TS inspectors are highly-trained and skilled professionals. In addition to their knowledge of the Convention and its provisions, all OPCW TS production specialists are required to possess a Bachelor of Science degree in chemical engineering or chemistry, as well as 6 years of practical, in-plant experience. Inspectors are employed with the OPCW through multi-year contracts.

What features of a chemical plant might arouse concern during a CWC inspection? Indicators of potential CW activity generally fall into one of six areas: chemicals, process/production equipment (the main focus of this reference guide), facility construction, safety and health equipment/procedures, security measures, and miscellaneous systems. Because there is no standard facility construction identical to every chemical facility, the identification of chemical processing or production equipment is a critical element of field activities during a

CWC inspection. Chemical processing may involve the separation of chemicals, the alteration of a chemical's physical characteristics, or the removal of chemicals from a mixture. Chemical production involves a reaction between two or more chemicals resulting in another product, as well as possible by-products. Common chemical equipment is used to support both types of activities.

During an inspection of a declared facility, inspectors will focus on the types, capacity, convertibility, and location of industrial chemical equipment and verify that it is consistent with the data declaration. These declarations form the basis of the CWC's inspection regime. During an initial inspection, the inspectors will also assess the risk posed by a facility's activities to the object and purpose of the Convention. This assessment will be used to determine the frequency and scope of subsequent, "routine" inspections and is required by the inspection mandate, an official OPCW document guiding the inspection.

In assessing the risk posed by the characteristics of a chemical plant site, the following characteristics of the process/production area may be considered:

- production capacity of the plant;
- the presence of processing equipment capable of handling highly toxic and/or corrosive materials to include: high alloy, corrosion resistant equipment; welded pipelines; double or triple pipes; canned pumps; and special seals on pumps or valves;
- the presence of individual items of process equipment that are enclosed or have hoods over them; and
- the physical plant layout to include: air locks; large capacity ventilation systems sufficient to maintain negative pressure; alarms designed to indicate the loss of negative pressure; air treatment systems (cyclones, charcoal filters, and scrubbers on the ventilation systems); enclosed process areas; isolated control rooms; air monitoring systems; and a laboratory suitable for toxic work.

The two key pieces of processing/production equipment required to manufacture chemical agents are a batch reactor and a distillation column. Since chemical equipment often serves dual or multiple functions, one cannot completely discount the possibility that a legitimate reactor or other piece of equipment has other, illegitimate uses. By the same token, the presence of such equipment alone would not identify a chemical plant as a CW production facility. A combination of characteristics and observations must be used to determine whether a chemical plant is capable of producing CW.

This guide will assist you in developing a general knowledge about the most common pieces of processing/production equipment found in chemical plants including reactors, columns, dryers, filters, and storage tanks/bins. There are a few important things to remember when using the guide. First, equipment with the same generic name does not always look or appear the same. Second, equipment with the same generic function does not always have the same generic name. Third, it is usually difficult to recognize processing equipment unless the product and process for which such equipment is being used are also known. Fourth, because of the high cost of new equipment, used equipment is often reused for new purposes. Equipment utilizing used components often appears dilapidated. Also, chemical equipment may be located outside and appear weathered because of exposure to the elements. This appearance may lead to the assumption that the equipment is not operational, when in fact it remains fully functional. Finally, poor appearance may also lead to identification problems.

Because of variations in the use, appearance, and configuration of chemical equipment, this guide is organized according to major equipment types. Each equipment section includes a brief and general definition of the equipment and bulleted "observables" which are identifying features that enable the user to distinguish a particular equipment type from other similar equipment. Each section also includes visual aids, such as photographs or diagrams depicting the equipment or its function. Although not the focus of this guide, illustrative examples of indicators of potential CW activity related to facility construction, safety and health equipment/procedures, security measures, and miscellaneous systems are included in the Appendix.

REACTORS

Generic Function: Chemical Reaction

Chemical reactors are vessels in which two or more chemicals are reacted to produce another product while controlling such parameters as pressure and temperature. A wide variety of reactors are found in industrial chemical facilities. A reactor's size and type vary according to the reaction it facilitates (i.e., applying or removing heat to control a reaction, reacting gases and/or liquids, or physically mixing the reactants to aid the reaction). Unique identifying components include jackets used to adjust heating and cooling temperatures of tank contents, and motors/agitators used to mix contents. Reactors may also be bioreactors involving organic chemical processes.

Observables

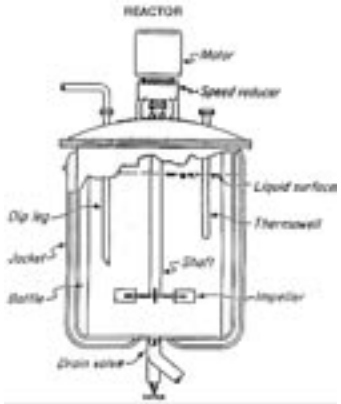
- The size of the reactor indicates its capacity.
- Flanged connectors (flow tubes attached to the reactor) may indicate the complexity of the reaction being conducted and the number of reactants or catalysts to be introduced.
- Note the specific operation a reactor is performing. Some reactors do not function as reactors, they merely serve as containers for mixing two chemicals or are used as storage tanks for chemicals in processing.
- The presence of impellers and motors connected to a reactor indicate the type of activity of the reactor.
- Note interior materials of construction (i.e., glass-lined, stainless steel, etc.).
- Reactors go by many names according to function. At an industrial plant site, they may be referred to as storage tanks, mix tanks, crystallizers, batch reactors, surge tanks, and dissolvers.
- Data-plates may provide some information identified above.

Dimpled Reactors



Full Jacket Reactors


Generic Reactor



Internal Coil Reactor

Half Pipe Reactors

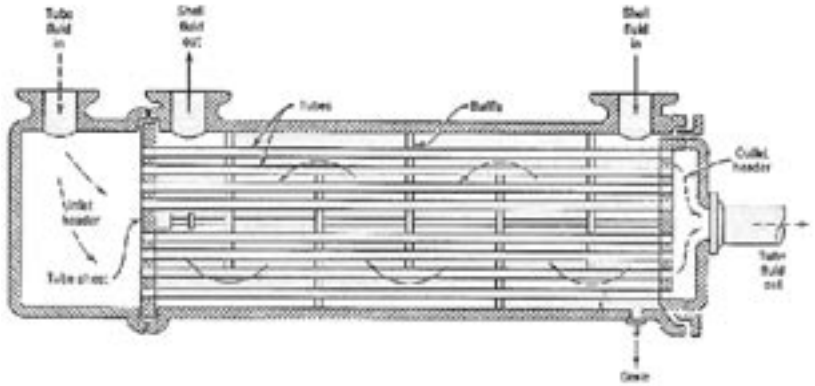
Generic Function: Heating/Cooling

The purpose of heat exchangers is to cool a hot liquid or in some cases, to heat a liquid. Heat exchangers are containers in which outgoing hot liquid or vapor transfers heat to an incoming cool liquid. In shell and tube exchangers, hot liquid vapor is contained in the shell while the cool liquid passes through the tubes, which usually are arranged in coils for maximum contact with the heat source. Heat exchangers are very common and are used in many chemical operations. Shell and tube heat exchangers, the most commonly used, are the easiest to spot—they always have four openings. Inspectors will typically want to verify the physical state of material being pushed through the exchanger (gas, liquid, slurry, or solid).

Observables

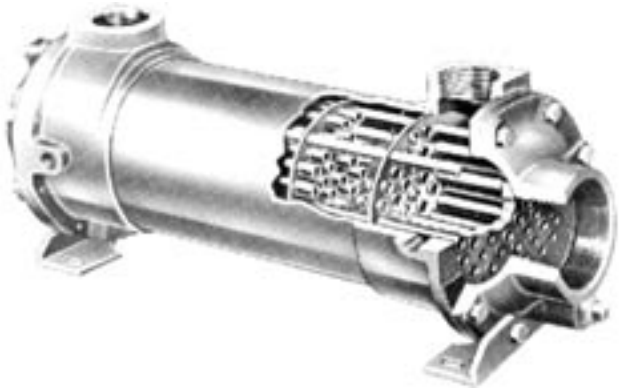
- The size of the heat exchanger indicates its capacity.
- Features include external connections leading into and out of the exchanger, as well as nearby visible temperature gauges and/or safety guidelines.
- Although the object may generically be referred to as a heat exchanger, an industrial plant manager, a program manager , or a chemical engineer may also refer to it as a condenser, re-boiler, evaporator, or reactor, depending on its current use.

Shell and Tube Heat Exchangers



Shell and Tube Heat Exchangers

Shell and Tube Heat Exchangers (Single Pass)



Shell and Tube Heat Exchangers (Multiple Pass)

DISTILLATION COLUMNS

Generic Function: Material Separation

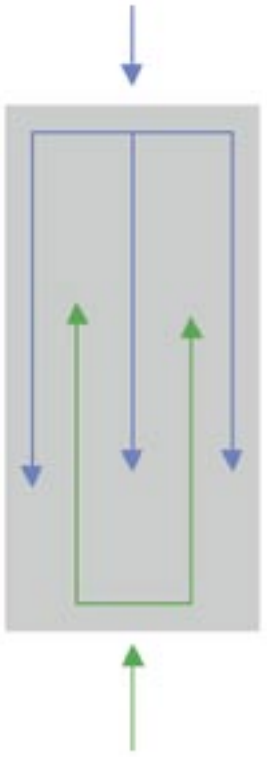
The purpose of a distillation column is to separate chemicals through heat or chemical reaction. Distillation columns consist of various-sized tubes that boil liquid and condense vapor in order to purify liquids or separate components of a liquid mixture. Distillation columns depend on gravity to work and stand upright. The difference between the several types of distillation columns lies in their internal composition. Packed columns are filled with objects, called packing material, which the vapor rises through. In tray columns, the vapor is purified by rising through small holes bored into a number of levels or plates.

Observables

- The size of the column or tower indicates its capacity, and its height may indicate the relative difference in boiling points of the chemicals being separated.
- The number of connectors and the configuration of the distillation column indicate the process being conducted.
- Posted safety guidelines or Hazardous Materials (HAZMAT) signs may indicate the types of chemicals being distilled.
- The re-boiler and condenser are essential elements of distillation columns. Their absence may indicate an extraction column.
- Data-plates may provide some information identified above.

Liquid Mixture Falling Through Column

The key is to maintain close contact between rising and falling components



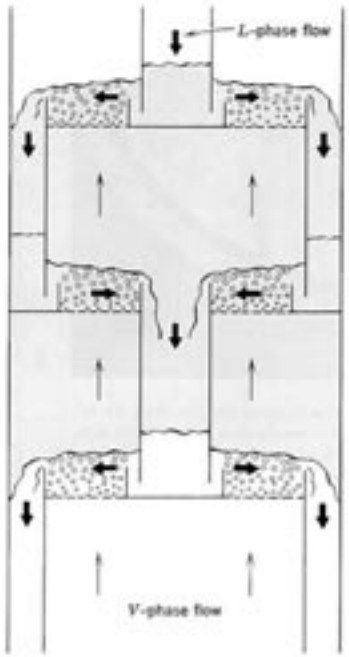
Material is transferred between rising and falling components

Liquid or Gas Mixture Rising Through Column

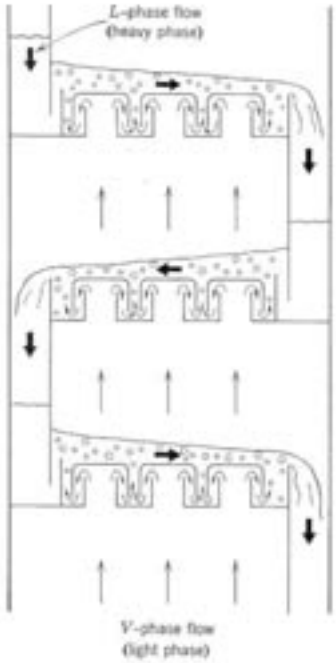
Distillation Column Types

Tray Columns

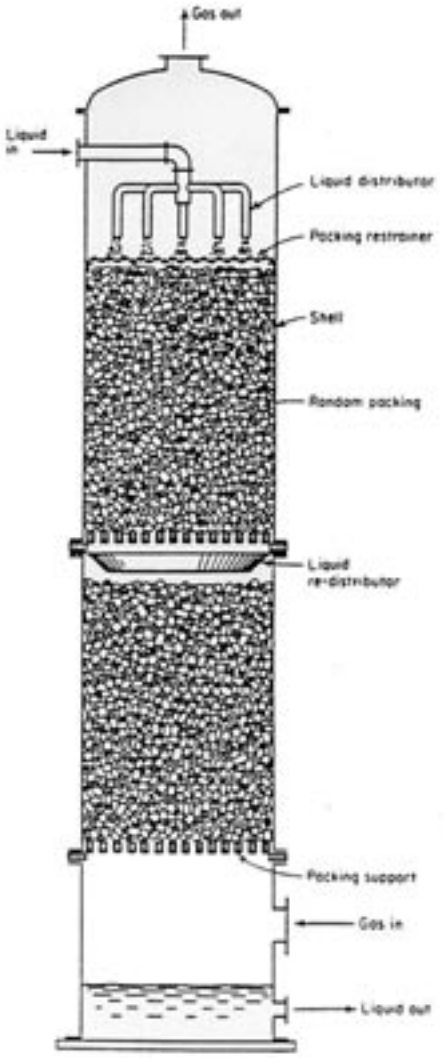
Axial Flow



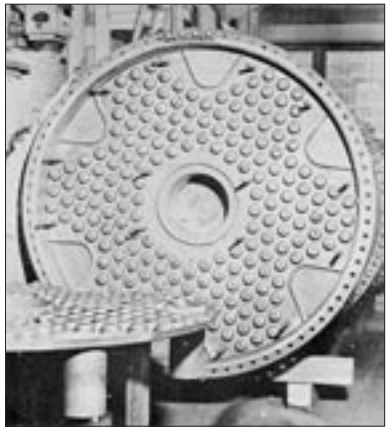
Cross-Flow

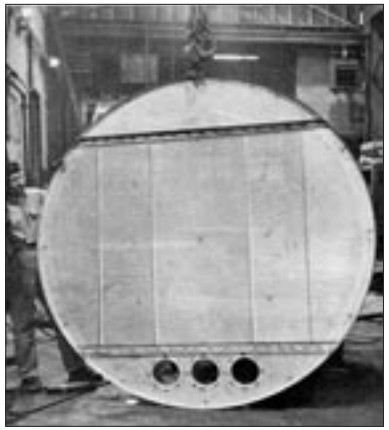


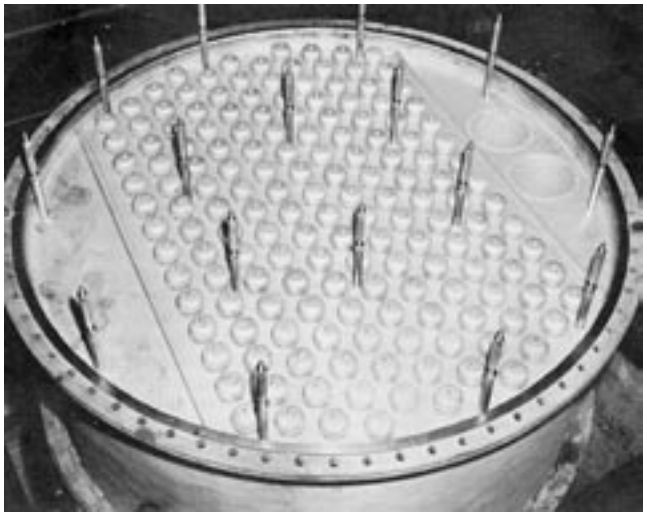
Distillation Column Types
Packed Column



Distillation Column – Trays







Distillation Column – Packing Materials

Raschig Rings

Intalox Saddle

Pall Rings

Berl Saddle

Cyclohelix Spiral Ring

Lessing Ring

Cross-Partition Ring

EXTRACTION/ADSORPTION/ ABSORPTION COLUMNS

Distillation Column – Examples

Generic Function: Material Separation

Like distillation columns, the purpose of extraction/adsorption/absorption columns is to separate chemicals by using their characteristics. Like distillation columns, they stand upright and depend on gravity to work.

Extraction/adsorption/absorption columns have the same configuration as distillation columns except there are no bubble cap trays and no re-boiler or condenser.

Extraction columns are often called wash columns. They rely on differences in solubility and density and usually involve two liquids.

Adsorption/absorption columns usually involve two gases. Those used for the waste treatment of gases are called scrubbers.

Adsorption columns have different names. In some cases, they are called wash columns. Adsorption columns are normally used to remove solid particulate matter from gases or to remove hazardous gases. In some adsorption columns, a chemical reaction occurs.

Observables

- The size of the column or tower indicates its capacity. Its height may indicate the relative disparity in boiling points of the chemicals being separated.
- The number of connectors and the configuration of the extraction/adsorption/absorption column indicate the process being conducted.
- Posted safety guidelines or HAZMAT signs may indicate the types of chemicals being distilled.
- Data-plates may provide some information identified above.

Distillation Column – Examples

FILTERS

Generic Function: Material Separation

A filter is a porous material through which fluids or gases may pass removing suspended solids. Almost any water-insoluble, porous material with a reasonable degree of rigidity can serve as a filter. In industrial operations, cotton duck, woven wire cloth, nylon cloth, and glass cloth are often used.

Observables

- Filters are best identified by the type of material being used and its porosity.
- Note the destination of both outputs (solid particles and purified liquid/gas).
- Data-plates may provide some information identified above.

Industrial Filters

DRYERS

Generic Function: Material Separation

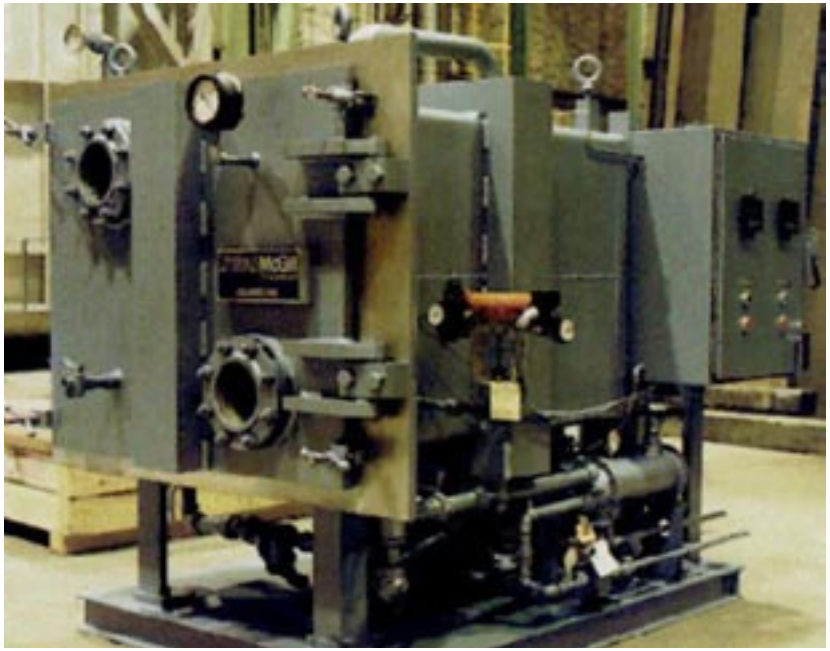
Dryers are used in chemical processes to remove liquids from solids through evaporation. Industrial drying is performed by both continuous and batch methods. There are a wide variety of dryers used in industry, including belt, centrifugal, convection, conveyor, flash, fluid-bed, freeze, pan, rotary drum/tray/vacuums, screw, spray tubular, tunnel, truck tray, and vibrating dryers. Dryers have few unique identifying features, and closely resemble other types of industrial equipment. Inspectors will typically want to verify the physical state of the material being dried.

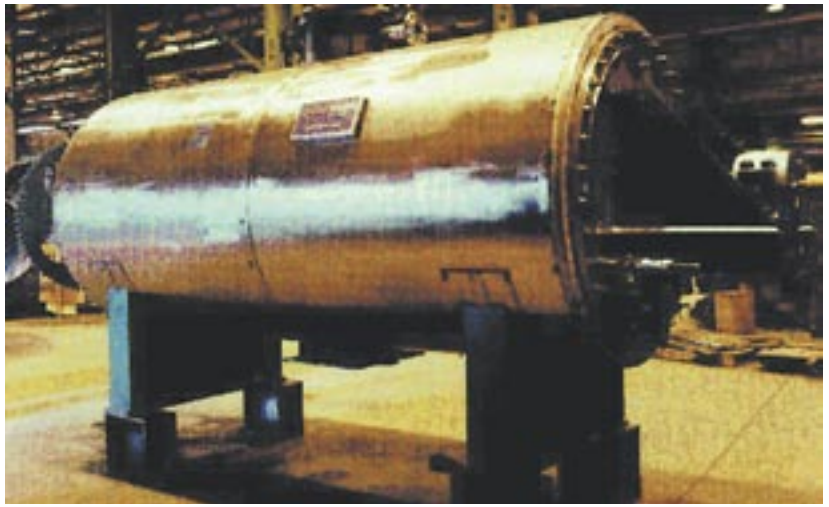
Observables

- Identify the process as a batch or continuous drying process.
- Data-plates may provide some information identified above.

Dryer

Dryers





DUST COLLECTORS

Generic Function: Material Separation

Dust collectors eliminate dust and particulate matter from areas where chemical processing or manufacturing is occurring, improving visibility and safety in industrial chemical environments.

Observables

- The frequency or density of dust collectors for areas in which chemical processing is occurring indicates the environmental and safety levels associated with a particular process or operation.
- Look for dust collectors in “clean” rooms or operation areas.
- Data-plates may provide some information identified above.

Dust Collectors

Internal

External

EVAPORATORS

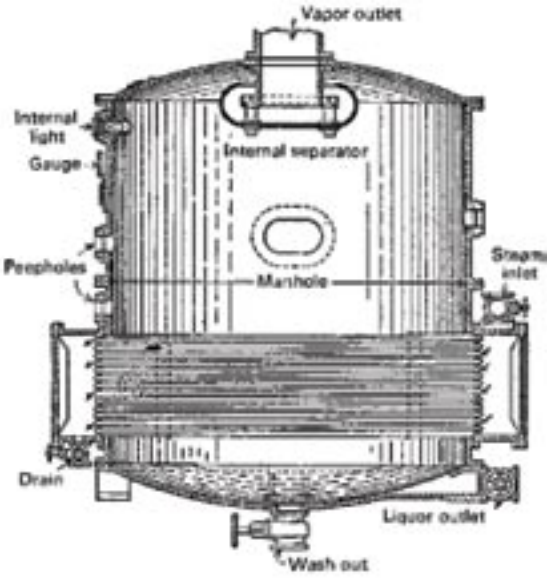
Generic Function: Material Separation

Evaporators are containers used to capture escaping vapors from an evaporating liquid. They are a major chemical engineering unit operation for generating the separation of liquids and solids and, in particular, to recover the solute (such as dissolved salt) from solvents (such as water). Evaporators may be referred to as film, flash, or submerged-tube types, each differing in the process used to evaporate the liquid. Evaporators often are used instead of boiling to avoid setting off a chemical reaction.

Observables

- Note the type of solvent and solutes being manipulated or captured.
- Data-plates may provide some information identified above.

Evaporator



CENTRIFUGES

Generic Function: Material Separation

Centrifuges apply centrifugal force to a mixture or suspension of materials of similar densities. The equipment revolves at high speed to impart great force to separate materials. Materials of higher density are thrown toward the outer portion of the chamber, while those of lower density are concentrated in the inner portion. This technique is used in several industrial operations.

Observables

- Note the association and location of the centrifuge to the chemical process or operation (attached or separate).
- Data-plates may provide some information identified above.

Centrifuges

GRINDING MILLS

Generic Function: Particle Size Reduction

Grinding mills have several names, such as ball or pebble mills, but essentially conduct the same operation despite the differing identifiers. They are generally steel cylinders rotating on a horizontal axis and contain steel or ceramic balls of varying diameters. They are used for grinding and mixing dry chemicals, pigments, food products, and other dry materials.

Observables

- Size and input/output equipment are the best indicators of activity.
- Data-plates may provide some information identified above.

Grinding Mill

MIXERS/BLENDERS

Generic Function: Material Mixing

Mixers and blenders may be similar to reactors in appearance. However, the difference is they are not designed to house chemical reactions. Although they may be used to apply or remove heat and have impellers and motors installed, they are not structured to control the contents in a sealed-reaction environment. Often, they may look like tubs or other storage containers. While mixers and blenders are not designed to function as reactors, often reactors may be found being used as a mixer or a blender. This is common practice in industry, where convertibility of equipment allows greater range of use and increased cost-efficiency.

Observables

- Data-plates may provide some information identified above.

Mixers/Blenders

PUMPS/BLOWERS

Generic Function: Material Transfer

Pumps and blowers are commonly used for the transportation of fluids and/or gases around a chemical plant. They typically "push" the fluids/gases through the process tubes. Pumps push fluids, while blowers push gases.

Observables

- Identify the use of a pump or blower in the process.
- Note additional connectors or housings for pumps/blowers.
- Data-plates may provide some information identified above.

Pumps

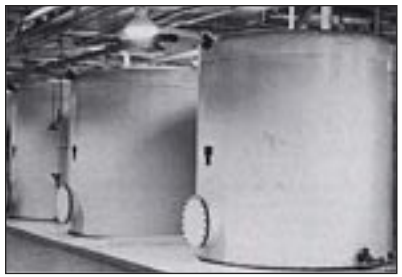
Generic Function: Material Storage

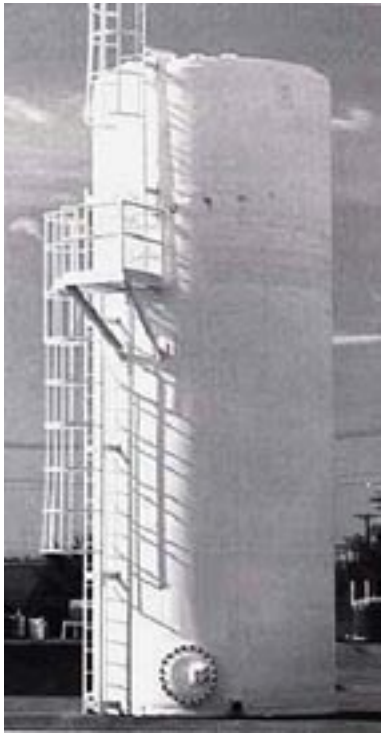
Chemical tanks and bins store chemicals and/or other process components at industrial facilities. They may also be used to store safety and environmental agents associated with chemicals used in the process. Often pieces of equipment, such as reactors not being used for processing, are used to store compounds to improve equipment versatility and facility cost-efficiency.

Observables

- Note whether the tank is capable of performing as a reactor, mixer, or blender.
- Note the location of the tank or bin (close to process, transportation areas, etc.).
- Note piping connections.
- Data-plates may provide some information identified above.

Tanks and Bins





Potentially Ambiguous Plant Characteristics

Chemical processing/production equipment is just one of several categories of indicators or "flags" of potential CW activity which could arouse concern during an inspection of a chemical plant site. Some additional categories include chemicals, facility construction, safety and health equipment/procedures, security measures, and miscellaneous systems.

The most obvious sign of potential CW activity is the presence of CWC scheduled chemicals. The presence of nonscheduled precursors to CWC scheduled chemicals, catalysts, agent decontamination chemicals, and degradation product signatures could also be seen as indicators.

Elements of facility construction, which may be flags of potential CW activity include:

- location of facilities in remote, isolated areas (chemical plants are generally not found in remote areas—i.e., those lacking a key transportation system such as a rail spur or a port);
- location of a facility in, adjacent to, or near government or military facilities;
- enclosed processing/production areas and laboratories;
- large industrial complexes;
- diked buildings;
- underground or earth-covered buildings or storage bunkers;
- unique changing facilities and showers; and
- unusual facility construction.

An enclosed facility in the United States handling highly toxic chemicals such as Schedule 1 chemicals would be equipped with features such as exhaust hoods, negative pressure rooms/systems, air locks, self-contained modular areas, sophisticated ventilation systems, and incineration, scrubbing, or filtration systems (including activated carbon filters).

Safety and health equipment/procedures which may be flags of potential CW activity include:

- HAZMAT detection systems (e.g., audible alarm systems for evacuation of surrounding work areas, color change badges, or air samplers);
- emergency decontamination systems (e.g., emergency eyewash/shower stations, holding ponds, sump drainage/containment, and large tanks containing decontamination chemicals);
- emergency protective gear stations;
- routine wearing of respirators, self-contained suits, or non-reusable protective clothing;
- signs warning of toxic chemicals;
- posted emergency evacuation plans/routes;
- emergency vehicles within close proximity;
- chemical release monitoring equipment, deluge systems, and spray systems;
- emergency shelters (including established shelter-in-place locations and emergency operations centers);
- blast/overpressure protection to prevent damage from vapor cloud or other explosions; and
- a clinic/dispensary, chemical emergency treatment areas, or other medical facilities prepared to respond to injuries resulting from exposure to high toxicity chemicals due to accidents, spills, and inhalation (especially if capabilities exist for Cholinesterase analysis and administration of medical treatment and antidotes for nerve and other agents).

Security measures which may be flags of potential CW activity include:

- antipersonnel wire enclosures (you should never find concertina wire in a commercial facility);
- high security or double fences;
- electronic surveillance/intrusion detection devices;
- armed guards at security checkpoints;
- guard dogs;
- specialized entry procedures for storage areas;
- excessive restrictions of access to raw material storage or waste/treatment areas or records during an inspection;
- restricted contact for inspectors with operating personnel; and
- a military presence.

Such measures could be construed as inappropriate and excessive for normal chemical production activities.

Other miscellaneous indicators of potential CW activity include:

- specialized process/production equipment metallurgy and materials of construction (processing and production of toxic and/or corrosive chemicals may require advanced metallurgy and/or secondary containment);
- the absence of common transportation systems;
- proximity to plants manufacturing precursor chemicals;
- batch processes;
- equipment capable of being easily reconfigured;
- hazardous waste areas;
- underground/intricate chemical piping systems; and
- multipurpose plants. A multipurpose plant may be a cause for concern simply because this type of plant is designed to manufacture a variety of products and generally has a wide array of process/production equipment and a wide span of technical expertise.

Also, note specialized materials of construction such as hastelloy, stainless steel, monel, glass, lead, and enamel all may be found in legitimate chemical industry, and not all CW agents or precursors require special materials of construction.

Finally, it is important to remember that nearly all of the previously discussed indicators of potential CW activity may be seen in legitimate industrial facilities, including pesticide, pharmaceutical, specialty chemical, fine chemical, multipurpose, and universal pilot plants. Universal pilot plants are smaller than a multipurpose plant, possess many additional features, and are usually capable of manufacturing virtually any chemical.

LIST OF ABBREVIATIONS

CW	Chemical Weapons
CWC	Chemical Weapons Convention
DTIRP	Defense Treaty Inspection Readiness Program
DTRA	Defense Threat Reduction Agency
HAZMAT	Hazardous Materials
IT	Inspection Team
OPCW	Organization for the Prohibition of Chemical Weapons
TS	Technical Secretariat

RELATED MATERIALS

Order through DTIRP Outreach Program Coordinator
1-800-419-2899

101B Challenge Inspections under the Chemical Weapons Convention
Bulletin

102P Chemical Weapons Convention—The Impact
Pamphlet

104V Chemical Weapons Convention—The Impact
Video

107V Managed Access under the Chemical Weapons Convention
Video

108P CWC - Questions Facing the U.S. Defense Industry
Pamphlet

112P Managed Access under the Chemical Weapons Convention
Pamphlet

114P Features of Chemical Facilities
Pamphlet

115P Routine Inspections under the Chemical Weapons Convention
Pamphlet

117P Guide for Challenge Inspections under the Chemical Weapons Convention
Pamphlet

118P Guide for Initial and Routine Inspections under the Chemical Weapons Convention
Pamphlet

119P CWC Challenge Inspection Planning Considerations
Pamphlet

122P Guide to Managed Access under the Chemical Weapons Convention
Pamphlet

123A Development of a Chemical Weapons Convention Pre-Inspection Briefing
Article

125P CWC Inspection Preparation Guide
Pamphlet

127C Chemical Weapons Agreements Information
CD-ROM

129P Guide to Scheduled Chemicals
Pamphlet

131P Rights & Obligations of the Inspection Team & the Inspected State Party under the Chemical Weapons Convention
Pamphlet

133B Role of the Requesting State Party Observer in CWC Challenge Inspection
Bulletin

152P CWC Inspector's Privileges and Immunities
Pamphlet

407C Arms Control Treaties Information
CD-ROM

408P Arms Control Agreements Synopses
Pamphlet

410P Quick Reference Guide to Arms Control Inspection Timelines
Pamphlet

907P DTIRP Arms Control Outreach Catalog
Pamphlet

908V Facility Protection Through Shrouding
Video

930C The Arms Control OPSEC Process
CD-ROM

936V Verification Provisions—Point and Counterpoint
Video

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Video

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