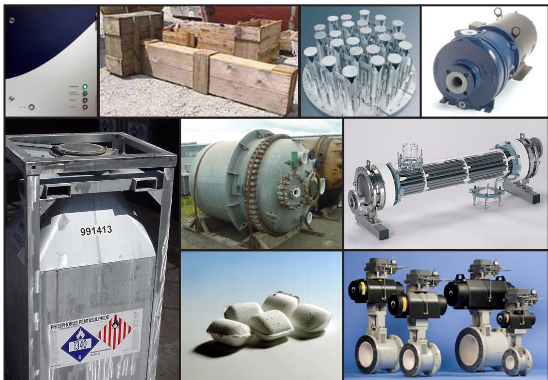
Australia Group
Common Control List Handbook

Volume I: Chemical Weapons-Related Common Control Lists



On the cover:

Top left: Toxic gas monitoring system (Figure II.A)

Top centre left: Crate for a glass-lined agitator impeller and shaft (Figure 1.2.F)

Top centre right: Zirconium liquid distributor (Figure 4.D)

Top right: Fluoropolymer-lined magnetic drive pump (Figure 8.B)

Middle centre: Glass-lined chemical reaction vessel (Figure 1.1.C)

Middle right: Heat exchanger with silicon carbide tube bundle and glass shell (Figure 3.B)

Bottom left: Tote bin containing phosphorus pentasulphide (Figure 2)

Bottom centre: Bricks of sodium cyanide (Figure 45.A)

Bottom right: Zirconia-lined butterfly valves (Figure 6.C)

Table of Contents

Volume I: Chemical Weapons-Related Common Control Lists

Dual-Use Chemical Manufacturing Facilities and Equipment and Related Technology and Software

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Foreword

The Australia Group (AG) is an informal arrangement of countries which, through the harmonisation of export control measures, seeks to ensure that exports of materials, equipment, and technology do not contribute to the development of chemical or biological weapons.[1] Founded in 1985 in response to chemical weapons use in the Iran-Iraq War and the lack of uniformity in different countries' export controls, the AG since has grown to encompass 41 participating countries and the European Commission. From an initial focus on chemical weapons precursors, it has expanded its scope to include not only dual-use chemicals, but also biological materials, chemical and biological equipment, and related technology and software.

Since its founding, the AG has played an important role in hindering the spread of chemical and biological weapons. The AG Common Control Lists of dual-use materials, equipment, technology, and software – and guidelines for their responsible transfer – provide a framework for effective chemical and biological trade controls. While the AG has established sound lists of strategic chemical and biological goods, there remains a need for commodity-oriented training materials to enhance the capabilities of enforcement officers to identify dual-use materials and equipment in cargo shipments. Such resources also can assist other trade control officials in evaluating the legitimacy of transfers of these items.

The *Australia Group Common Control List Handbook* aims to serve as such a resource. The Handbook covers commodities found on each Common Control List and is divided into two volumes according to the threat posed by items on a particular list:

- Volume I: Chemical Weapons-Related Common Control Lists
  - Chemical Weapons Precursors
  - Dual-Use Chemical Manufacturing Facilities and Equipment and Related Technology and Software
- Volume II: Biological Weapons-Related Common Control Lists
  - Human and Animal Pathogens and Toxins
  - Plant Pathogens
  - Dual-Use Biological Equipment and Related Technology and Software

Chapters within each section provide an overview of the appearance, key features, uses, and global producers of each item on each control list. Brief introductions to dual-use technology are also included to provide context for the chemicals, pathogens, and equipment discussed, and additional supporting information can be found in the appendices to both volumes. We intend and hope that this Handbook will be a practical resource for personnel engaged in chemical- and biological-related trade controls – from enforcement officials working in the field and license analysts desiring a better understanding of controlled items, to those responsible for training such personnel on dual-use commodities.

The AG Handbook is produced by the United States Government for the purpose of facilitating effective export controls on AG-controlled items. Unlike the AG Guidelines and the AG Common Control Lists, the AG Handbook itself is not an official Australia Group publication of record.

The images, websites, and other references included in this Handbook are intended to give examples of materials and equipment with features similar to those that the AG Common Control Lists describe. It is important to note that presence of certain items or equipment in a photograph, on a website, or in a reference does not necessarily mean that the pictured or referenced item meets AG control specifications. Decisions on the control status of an item are made by considering the technical specifications of a specific product on a case-by-case basis.

June 2014

[1] See the AG website at http://www.australiagroup.net and the Introduction to the Australia Group in both volumes of the Handbook.

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Introduction – The Australia Group (AG)

The Australia Group: Origins, Objectives, and Activities[1]

The Australia Group (AG) is an informal arrangement that aims to minimise the risk of assisting chemical and biological weapons (CBW) proliferation through the harmonisation of export control measures. The AG meets annually to discuss ways to increase the effectiveness of participating countries' national export licensing systems in an effort to prevent proliferators from obtaining materials, equipment, and technology for CBW programs. AG participants do not undertake any legally binding obligations; the effectiveness of their collaboration depends solely on a shared commitment to CBW nonproliferation goals and the strength of their respective national measures.

When formulating control lists and guidelines for adoption by participants, the AG considers the following key characteristics of effective export licensing measures:

- they should be effective in impeding the production of CBW;
- they should be practical and reasonably easy to implement; and
- they should not impede the normal trade of materials and equipment used for legitimate purposes.

AG Participants (as of June 2014)

- Argentina
- Australia
- Austria
- Belgium
- Bulgaria
- Canada
- Croatia
- Republic of Cyprus
- Czech Republic
- Denmark
- Estonia
- European Commission
- Finland
- France
- Germany
- Greece
- Hungary
- Iceland
- Ireland
- Italy
- Japan
- Latvia
- Lithuania
- Luxembourg
- Malta
- Mexico
- The Netherlands
- New Zealand
- Norway
- Poland
- Portugal
- Republic of Korea
- Republic of Turkey
- Romania
- Slovak Republic
- Slovenia
- Spain
- Sweden
- Switzerland
- Ukraine
- United Kingdom
- United States

All countries participating in the AG are States Parties to the Chemical Weapons Convention (CWC) and the Biological and Toxin Weapons Convention (BTWC), and they strongly support efforts under those treaties to rid the world of CBW. As of June 2014, the AG includes 41 participating countries plus the European Commission.

This section provides an overview of the AG's history, its objectives, and the activities it undertakes to strengthen nonproliferation export controls on CBW-related goods and technologies.

Origins of the Australia Group

As noted on the AG website,[2] a United Nations investigation team found in 1984 that Iraq had used chemical weapons (CW) in the Iran-Iraq war in violation of the 1925 Geneva Protocol, and that at least some of the precursor chemicals and materials for its CW program had been sourced through legitimate trade channels. In response, several countries introduced export controls on certain chemicals that could be used to manufacture CW.

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[1] The text of this section is taken largely from the AG website; http://www.australiagroup.net/en/index.html

[2] AG, The Origins of the Australia Group; http://www.australiagroup.net/en/origins.html

However, these controls suffered from a lack of uniformity, and it soon became apparent that attempts were being made to circumvent them. This led Australia to propose a meeting of countries with export controls with the aim of harmonising their national licensing measures and enhancing cooperation. The first meeting of what subsequently became known as the Australia Group took place in Brussels in June 1985. At that meeting, 15 participating countries and the European Commission agreed that there was value in exploring how existing export controls might be made more effective to prevent the spread of CW.[3]

The AG has met regularly since then, with plenary meetings currently held annually in Paris and intersessional meetings held on an as-needed basis. The scope of the controls discussed by the AG has evolved to address emerging threats and challenges. Evidence of the diversion of dual-use materials to biological weapons (BW) programs in the early 1990s led to development of control lists on specific pathogens and toxins. Over time, the control lists have expanded to include certain equipment, technology, and software that can be used in the manufacturing or disposal of CBW.

Australia Group Objectives

The primary objective of AG participants is to use licensing measures to ensure that transfers of certain chemicals, pathogens, toxins, dual-use chemical and biological facilities and equipment, and related technologies do not contribute to the proliferation of CBW. The AG achieves this by harmonising participating countries' national export licensing measures. The AG's activities are especially important because chemical and biotechnology sectors worldwide are targeted by proliferators as sources of materials, equipment, and technology that can be used to support CBW programs.

Participants have recognised from the beginning of the AG that export licensing measures are not a substitute for the strict and universal observance of the Geneva Protocol, the BTWC, and the CWC. All participants in the AG are States Parties to both the BTWC and the CWC. Support for these treaties and their objectives remains the overriding aim of AG participants. Export licensing measures instituted by individual member countries assist in implementing key obligations under the CWC [Article I, 1 (a) and (d)] and the BTWC [Articles I and III].

Export licensing measures also demonstrate participants' resolve to avoid not only direct but also inadvertent involvement in the proliferation of CBW, and to express their opposition to the use of these weapons. It is also in the interests of commercial firms and research institutes and of their governments to ensure that they do not inadvertently supply dual-use materials, equipment, technology, or software for use in the manufacture of CBW. Chemical and biological industries worldwide have firmly supported this principle.

Australia Group Activities

As previously mentioned, the AG is an informal arrangement. The purpose of AG meetings is to explore ways to increase the effectiveness of existing controls through exchange of information, harmonisation of national control measures and, where necessary, changes to the scope of controls. All AG decisions are made by consensus.

All AG participants agree to require licenses for the export of specific:

- Chemical weapons precursors;
- Dual-use chemical manufacturing facilities and equipment and related technology and software;
- Human and animal pathogens and toxins;
- Plant pathogens; and
- Dual-use biological equipment and related technology and software.

[3] AG, The Origins of the Australia Group; Ibid.

The above items form the basis for the AG's "Common Control Lists," which have been developed through AG consultations and are adjusted periodically to ensure their continued effectiveness in the face of technological advancements. Measures agreed upon by AG participants are applied on a national basis. Under these measures, exports are denied only if there is a well-founded concern about potential diversion for CBW purposes.

AG participants encourage all countries to take the necessary steps to ensure that they and their industries are not contributing to the proliferation of CBW. Controls will be more effective if similar measures are introduced by all potential exporters of listed items, as well as by potential transshipment countries. Export licensing measures demonstrate the determination of AG countries to avoid involvement in the proliferation of these weapons, which would be a violation of international law and norms. In addition to being consistent with the nonproliferation provisions of the CWC and BTWC, such measures are required of all states to ensure compliance with UN Security Council Resolution 1540 and its extensions.

The Australia Group Common Control List Handbook

This Handbook is designed to assist officials in implementing controls on AG Common Control List (CCL) items. It provides basic descriptions of and information on the notable features, packaging, and typical applications of AG-listed CW precursors, pathogens, toxins, and dual-use chemical manufacturing and biological processing equipment. In addition, it discusses CCL entries on related technology and software. The Handbook is based on the AG CCLs as of March 2014. The most current version of the AG CCLs can be accessed via the AG website at http://www.australiagroup.net.

The AG Handbook is produced by the United States Government for the purpose of facilitating effective export controls on AG-controlled items. Unlike the AG Guidelines and the AG CCLs, the AG Handbook itself is not an official Australia Group publication of record.

The Handbook is organised like the AG CCLs, with additional sections providing background information pertinent to understanding the controls. Each section on materials and equipment follows the same format: the AG control language is reproduced in a highlighted text box, followed by a basic description of the item, its notable features, packaging, and typical applications, as well as illustrative images. The images, websites, and other references included in this Handbook are intended to give examples of materials and equipment with features similar to those that the AG CCLs describe. It is important to note that presence of certain items or equipment in a photograph, on a website, or in a reference does not necessarily mean that the pictured or referenced item meets AG control specifications. Decisions on the control status of an item are made by considering the technical specifications of a specific product on a case-by-case basis.

Any AG control "Notes" relevant to a particular item have been included with the actual control text. Each listed item is discussed separately. Where applicable, side boxes identifying the headquarters locations of companies that can produce particular items accompany the text. These lists of countries that might produce specific items are representative and not necessarily exhaustive, since subsidiaries or trading companies in other countries may be capable of supplying such items.

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Australia Group Guidelines

Guidelines for Transfers of Sensitive Chemical or Biological Items[4]

June 2012

The Government of xxx has, after careful consideration and consistent with its obligations under the BTWC and the CWC, decided that, when considering the transfer of equipment, materials, technology and software that could contribute to chemical and biological weapons activities, it will act in accordance with the following Guidelines.

1. The purpose of these Guidelines is to limit the risks of proliferation and terrorism involving chemical and biological weapons (CBW) by controlling tangible and intangible transfers that could contribute to CBW activities by states or non-state actors, consistent with Article III of the Biological Weapons Convention, Article I of the Chemical Weapons Convention, and all relevant United Nations Security Council Resolutions. In accordance with Article X of the Biological Weapons Convention and Article XI of the Chemical Weapons Convention, these Guidelines are not intended to impede chemical or biological trade or international cooperation that could not contribute to CBW activities or terrorism. These Guidelines, including the attached Australia Group (AG) control lists and subsequent amendments thereto, form the basis for controlling transfers to any destination beyond the Government's national jurisdiction or control of materials, equipment, technology and software that could contribute to CBW activities. The Government will implement these Guidelines in accordance with its national legislation.

2. These Guidelines will be applied to each transfer of any item in the AG control lists. However, it is a matter for the Government's discretion to determine whether and to what extent to apply expedited licensing measures in the case of transfers to destinations it judges possess consistently excellent non proliferation credentials. Vigilance will be exercised in the consideration of all transfers of items on the AG control lists. Transfers will be denied if the Government judges, on the basis of all available, persuasive information, evaluated according to factors including those in paragraph 3, that the controlled items are intended to be used in a chemical weapons or biological weapons program, or for CBW terrorism, or that a significant risk of diversion exists. It is understood that the decision to transfer remains the sole and sovereign judgment of the Government.

3. In fulfilling the purposes of these Guidelines, national export control legislation, including enforcement and sanctions for violations, plays an important role.

4. To fulfil the purposes of these Guidelines, the evaluation of export applications will take into account the following non-exhaustive list of factors:

   a. Information about proliferation and terrorism involving CBW, including any proliferation or terrorism-related activity, or about involvement in clandestine or illegal procurement activities, of the parties to the transaction;

   b. The capabilities and objectives of the chemical and biological activities of the recipient state;

   c. The significance of the transfer in terms of (1) the appropriateness of the stated end-use, including any relevant assurances submitted by the recipient state or end-user, and (2) the potential development of CBW;

   d. The role of distributors, brokers or other intermediaries in the transfer, including, where appropriate, their ability to provide an authenticated end-user certificate specifying both the importer and ultimate end-user of the item to be transferred, as well as the credibility of assurances that the item will reach the stated end-user;

[4] Text of the Guidelines is reproduced from http://www.australiagroup.net/en/guidelines.html.

e. The assessment of the end-use of the transfer, including whether a transfer has been previously denied to the end-user, whether the end-user has diverted for unauthorised purposes any transfer previously authorised, and, to the extent possible, whether the end-user is capable of securely handling and storing the item transferred;

f. The extent and effectiveness of the export control system in the recipient state as well as any intermediary states;

g. The applicability of relevant multilateral agreements, including the BTWC and CWC.

5. In a manner consistent with its national legislation and practices, the Government should, before authorising a transfer of an AG-controlled item, either (a) satisfy itself that goods are not intended for reexport; (b) satisfy itself that, if reexported, the goods would be controlled by the recipient government pursuant to these guidelines; or (c) obtain satisfactory assurances that its consent will be secured prior to any retransfer to a third country.

6. The objective of these Guidelines should not be defeated by the transfer of any non-controlled item containing one or more controlled components where the controlled component(s) are the principal element of the item and can feasibly be removed or used for other purposes. (In judging whether the controlled component(s) are to be considered the principal element, the Government will weigh the factors of quantity, value, and technological know-how involved and other special circumstances that might establish the controlled component or components as the principal element of the item being procured.) The objective of these Guidelines also should not be defeated by the transfer of a whole plant, on any scale, that has been designed to produce any CBW agent or AG-controlled precursor chemical.

7. The Government reserves the discretion to: (a) apply additional conditions for transfer that it may consider necessary; (b) apply these guidelines to items not on the AG control lists; and (c) apply measure to restrict exports for other reasons of public policy consistent with its treaty obligations.

8. In furtherance of the effective operation of the Guidelines, the Government will, as necessary and appropriate, exchange relevant information with other governments applying the same Guidelines.

9. The Government encourages the adherence of all states to these Guidelines in the interest of international peace and security.

(Latest versions of Control Lists to be attached)[5]

[5] This parenthetical remark is reproduced from the Guidelines on the AG website. The complete Common Control Lists can be found at http://www.australiagroup.net/en/controllists.html.

Further Provisions Applicable to Australia Group Participants

In addition, participants in the Australia Group, consistent with their obligations under the BTWC and CWC and in accordance with their national legislation have, after careful consideration, decided also to give equal respect to the following provisions.

Catch-All

1. Participant states will ensure that their regulations require the following:

   a. an authorisation for the transfer of non-listed items where the exporter is informed by the competent authorities of the Participant State in which it is established that the items in question may be intended, in their entirety or part, for use in connection with chemical or biological weapons activities;

   b. that if the exporter is aware that non-listed items are intended to contribute to such activities it must notify the authorities referred to above, which will decide whether or not it is expedient to make the export concerned subject to authorisation.

2. Participant states are encouraged to share information on these measures on a regular basis, and to exchange information on catch-all denials relevant for the purpose of the AG.

No Undercut Policy

In accordance with the Group's agreed procedures, a license for an export that is essentially identical to one denied by another AG participant will only be granted after consultations with that participant, provided it has not expired or been rescinded. Essentially identical is defined as being the same biological agent or chemical or, in the case of dual-use equipment, equipment which has the same or similar specifications and performance being sold to the same consignee. The terms of the Group's 'no undercut policy' do not apply to denials of items under national catch-all provisions.

Common Approaches

AG participants implement these Guidelines in accordance with the Group's agreed common approaches on end-user undertakings and chemical mixtures.

Intra EU Trade

So far as trade within the European Union is concerned, each member State of the European Union will implement the Guidelines in the light of its commitments as a member of the Union.

Brokering Services

AG members should have in place or establish measures against illicit activities that allow them to act upon brokering services related to items mentioned in the AG control lists which could contribute to CBW activities. AG members will make every effort to implement those measures in accordance with their domestic legal framework and practices.

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Introduction to Chemical Weapons and Dual-Use Chemical Technology

Chemical Weapons: An Overview

CW-Related Terminology

Traditionally, a chemical weapon (CW) is thought of as a toxic chemical loaded into a delivery system such as a munition – i.e., a complete device for exposing a population to a substance that can cause death or other injuries through its chemical action. The Chemical Weapons Convention (CWC) broadens this traditional definition significantly,[1] for the purpose of achieving the treaty's goal of "complete and effective prohibition of the development, production, acquisition, stockpiling, retention, transfer and use of chemical weapons, and their destruction."[2] According to the CWC, "Chemical Weapons" means the following, together or separately:[3]

a. Toxic chemicals and their precursors, except where intended for purposes not prohibited under this Convention, as long as the types and quantities are consistent with such purposes;

b. Munitions and devices, specifically designed to cause death or other harm through the toxic properties of those toxic chemicals specified in subparagraph (a), which would be released as a result of the employment of such munitions and devices;

c. Any equipment specifically designed for use directly in connection with the employment of munitions and devices specified in subparagraph (b).

A "toxic chemical" is further defined as "any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals. This includes all such chemicals, regardless of their origin or of their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere." The CWC Schedules of Chemicals identify certain toxic chemicals and precursors for application of the verification measures called for in the treaty.

These definitions are familiar to CWC National Authorities and are well-suited for successful implementation of the treaty and achievement of its goals. They further address the fact that many toxic chemicals and precursors have legitimate, peaceful uses. The CWC recognises that such chemicals should not be considered to be CW when they are (1) used for purposes not prohibited under the CWC (e.g., industrial, agricultural, research, medical, pharmaceutical, or protective purposes) and (2) are of the types and quantities that would be consistent with these peaceful purposes.

However, for the objectives of this Handbook, a more traditional approach to CW-related terminology is taken in order to succinctly describe the potential roles of various chemicals (and equipment) in a CW program. In this Handbook, a toxic chemical that *could* be used as a CW will be simply referred to as a CW agent; precursors to CW agents are not considered to be CW in the context of this Handook, but rather chemicals that can be used to produce CW agents.

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1 For further explanation of the rationale behind the CWC's definitions, see the OPCW's "Brief Description of Chemical Weapons"; http://www.opcw.org/about-chemical-weapons/what-is-a-chemical-weapon

2 Chemical Weapons Convention, Preamble; http://www.opcw.org/chemical-weapons-convention/preamble/

3 Chemical Weapons Convention, Article II, Paragraph 1; http://www.opcw.org/chemical-weapons-convention/articles/article-ii-definitions-and-criteria/

[CW agents](#) typically are grouped into classes based upon their effect on living organisms. These biochemical effects are directly related to the structure and reactivity of the agent molecules; therefore, substances in a given agent category frequently have similar chemical structures – i.e., the same types of atoms connected in similar ways. This section gives a very brief overview of the agent classes and their relationship to chemical structure. Information on the effects of agent exposure is found widely in the open literature[4] and is summarised in the paragraphs below.

Choking Agents

Choking agents damage lung tissue, leading to pulmonary edema. The victim thereby is choked by fluid in the lungs – this is often referred to as "dry-land drowning." Choking agents frequently have reactive chlorine atoms in their structure. The most basic choking agent is chlorine gas itself (Cl_2), which was used extensively in World War I. Phosgene (Figure 1) is another example.[5]

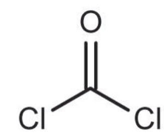


Figure 1. *Chemical structure of phosgene.*

Blood Agents

Blood agents interfere with oxygen transport from blood to body tissues. The most well-known blood agents – hydrogen cyanide and cyanogen chloride – contain a cyanide (C≡N) group. The cyanide group reacts with an enzyme called cytochrome oxidase, resulting in an inhibition of enzyme function that prevents cells from using oxygen. Therefore, oxygen is not transferred from the blood to body tissues, and the victim exposed to the agent dies. Figure 2 shows the chemical structures of hydrogen cyanide and cyanogen chloride.

H–C≡N   Cl–C≡N

Figure 2. *Chemical structures of hydrogen cyanide (left) and cyanogen chloride (right).*

Vesicants (Blister Agents)

Vesicants are also known as blister agents. As described by the Organisation for the Prohibition of Chemical Weapons (OPCW), they are oily substances that "act via inhalation and contact with skin. They affect the eyes, respiratory tract, and skin, first as an irritant and then as a cell poison. As the name suggests, blister agents cause large and often life-threatening skin blisters which resemble severe burns." Exposure to vesicants can result in blindness and permanent respiratory damage. Sulphur mustards and nitrogen mustards have a central electronegative atom (sulphur or nitrogen, respectively) bonded to carbon-chain "arms" that terminate in chlorine atoms. The arsenic-based vesicant Lewisite has a central arsenic atom bound to chlorine atoms and carbon-based groups. These three types of vesicants have reactive chlorine atoms in common; however, the symptoms of exposure to the more structurally-similar sulphur and nitrogen mustards resemble each other more closely than those of Lewisite. Examples of vesicants are "mustard gas," a type of sulphur mustard; nitrogen mustards HN-1, HN-2, and HN-3; and Lewisite. Figure 3 shows the chemical structures of some of these blister agents.

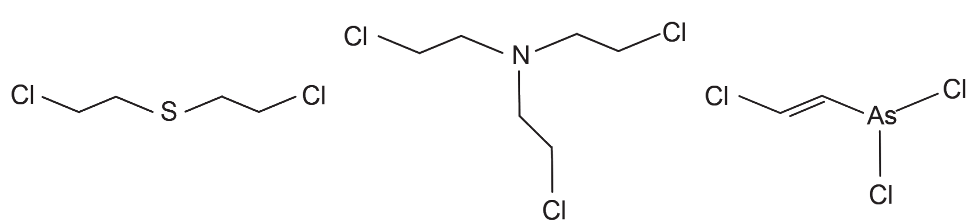


Figure 3. *Chemical structures of mustard gas (left), HN-3 (centre) and Lewisite (right).*

[4] For example, see fact sheets by the U.S. centres for Disease Control and Prevention (http://www.bt.cdc.gov/Agent/agentlistchem.asp); the OPCW's chemical agent descriptions (http://www.opcw.org/about-chemical-weapons/types-of-chemical-agent/); and D. Hank Ellison, *Handbook of Chemical and Biological Warfare Agents* (Boca Raton, FL: CRC Press), 1999.

[5] For compactness, organic chemistry shorthand is used in most of the structures shown in this Handbook. Each carbon atom is represented by the end of a line or the intersection of two lines instead of being shown explicitly as a "C." See Appendix C for more information.

Nerve Agents

Nerve agents contain a P=O group, where the phosphorus atom is also bound to three other atoms. Nerve agents bind tightly to an enzyme in the body called acetylcholinesterase. This enzyme normally destroys acetylcholine, a neurotransmitter that signals muscles to contract. When a victim is exposed to a nerve agent, acetylcholine builds up and continuously stimulates the muscles because the blocked enzyme is unable to deactivate the neurotransmitter molecules. Several physical symptoms result, from pupil constriction to muscle paralysis due to fatigue. Exposure to nerve agents ultimately can lead to death by respiratory failure – as noted by the OPCW, "muscular paralysis caused by nerve agents also affects the respiratory muscles. Nerve agents also affect the respiratory centre of the central nervous system. The combination of these two effects is the direct cause of death. Consequently, death caused by nerve agents is a kind of death by suffocation." Nerve agents include G-series agents tabun, sarin, and soman, and the V-series agents Amiton and VX. Figure 4 shows the chemical structures of tabun, sarin, and VX.

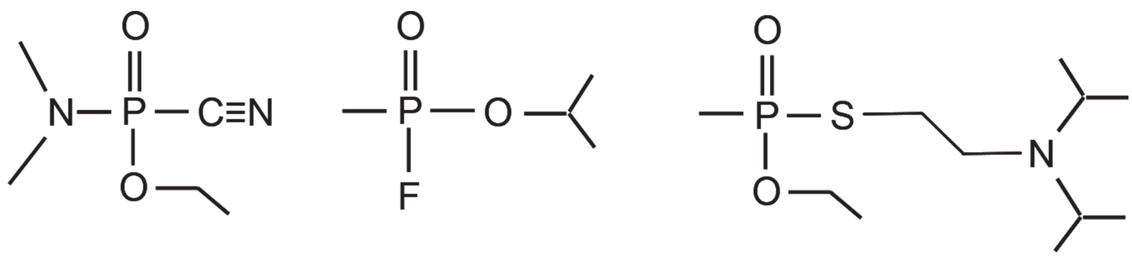


Figure 4. *Chemical structures of tabun (left), sarin (centre), and VX (right).*

Incapacitants

Incapacitants, like their name suggests, are used with the intention to incapacitate – rather than kill – a victim. This is the most diverse class of chemical substances, since different types of chemicals can cause different physiological effects that could be incapacitating. The major types of incapacitants are psychochemical, vomiting/sneezing, and tear (riot control) agents. These are also called "nonlethal" chemical agents; however, it is important to keep in mind that such agents can be lethal in sufficiently large doses. The use of these substances in war is prohibited by the CWC. BZ (Figure 5) is one example of an incapacitant.

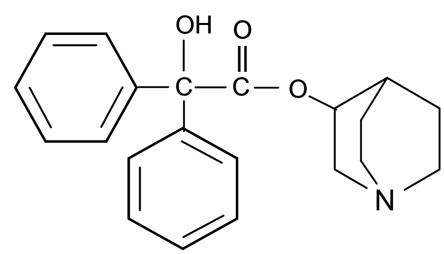


Figure 5. *Chemical structure of BZ.*

Table 1 gives LC_{50} and LD_{50} values for selected agents as derived from data in D. Hank Ellison's *Handbook of Chemical and Biological Warfare Agents* (Boca Raton: CRC Press LLC, 2000).[6] These values are shown to compare the relative lethality of the agent types.[7]

[6] These values are based on 10 minutes of exposure for a 70 kg person with a respiratory tidal volume of 15 L/minute. Values in Table 1 were converted from parts per million to mg/m^3 and grams/person to mg/kg, two more commonly used units. In general, values were rounded to whole numbers, with consideration of significant digits.

[7] The exact value of these figures may vary from one information source to another.

Table 1. *Exposure hazards posed by selected CW agents/toxic chemicals*

Agent name	Type	LC_{50} (mg/m^3)	LD_{50} (mg/kg)
BZ	Incapacitant	20000	—
Chlorine	Choking	1900	—
Phosgene	Choking	320	—
Hydrogen cyanide	Blood	200	100
Sulphur mustard	Vesicant	150	100
Nitrogen Mustard-3	Vesicant	150	10
Lewisite	Vesicant	140	30
Tabun	Nerve	13	14
Sarin	Nerve	7	24
Soman	Nerve	7	5
VX	Nerve	3	0.14

Dual-Use Chemical Technology

The chemicals and equipment employed in many sectors of the commercial chemical industry – particularly those processing toxic or corrosive chemicals – could also be used to produce CW agents. Therefore, the commodities and process operations that could be exploited to make CW agents are inherently dual-use. This section discusses the dual-use processes involved in chemical production in order to provide a context for the discussion of export-controlled chemicals and equipment in this Handbook.

The development of chemical weapons can be represented by a sequence of operations. Figure 6 shows a schematic depiction of the CW development process, starting with chemical raw materials (precursors) and ending with filled delivery systems and, eventually, waste destruction. With the exception of CW munitions and the particularly harsh, stringent conditions required to destroy them, the components of this process are found in legitimate commercial activities unrelated to CW. It should be kept in mind that the types of chemical equipment subject to export controls have characteristics that make them suitable for use in CW agent production – e.g., corrosion-resistant wetted surfaces[8] and/or design features related to safety. While equipment of concern remains dual-use in nature, these characteristics limit the number of industrial sectors in which controlled equipment would typically be used. These sectors are discussed in individual chemical equipment sections and in the section on materials of construction. The remainder of this section will be devoted to an overview of the steps depicted in Figure 6 from an industrial, dual-use perspective.

CW Precursors

Chemical weapons precursors are the chemical starting materials, or “ingredients” from which CW agents are prepared. Nearly all CW precursors are dual-use chemicals, although they vary in the extent of their legitimate use in commercial industry. Many of these chemicals are corrosive to common materials like stainless steel. This characteristic makes chemical equipment with highly corrosion-resistant wetted parts especially suitable for CW agent production; such equipment therefore is subject to export controls. Furthermore, the toxicity of CW agents and many precursors warrants special safety precautions in CW agent production, further driving the control specifications for several items on the AG chemical equipment control list. Chemicals on the AG precursor control list are discussed at length in the Chemical Weapons Precursors section in Volume I of this Handbook.

[8] Throughout this Handbook, the term “wetted surfaces” is used to denote those surfaces coming into direct contact with the processed or contained chemicals – i.e., the surfaces that must be made of corrosion-resistant materials according to AG specifications for chemical manufacturing equipment.

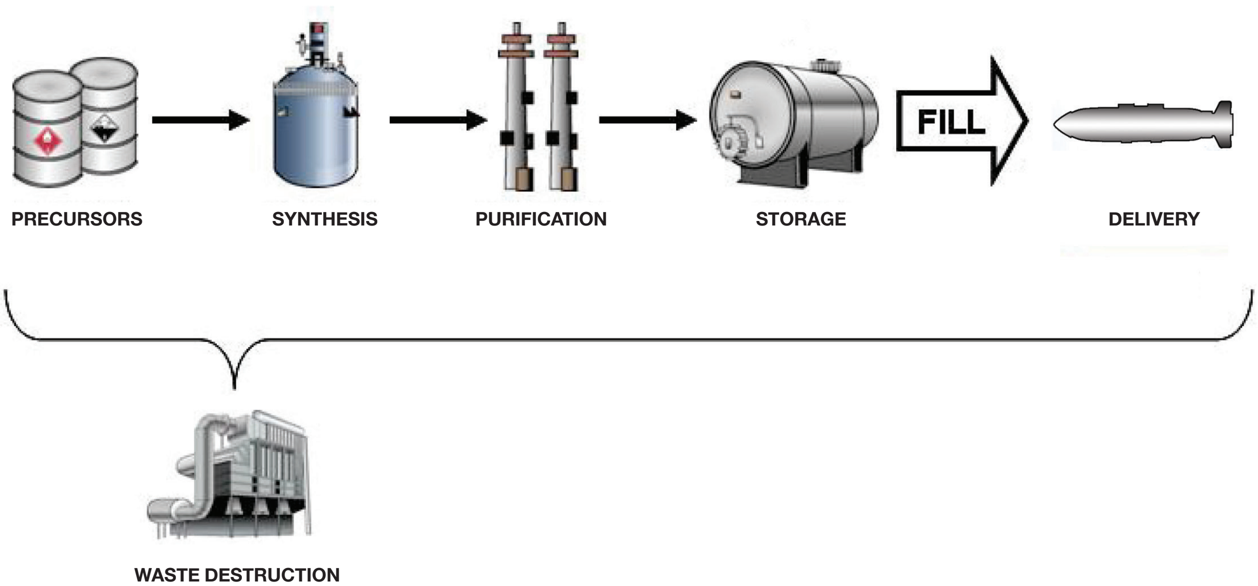


Figure 6. *Schematic of the chemical weapons development processes.*

Synthesis

Chemical synthesis is a term used for the process of making a desired chemical from other substances via one or more chemical reactions. A common industrial example of a chemical reaction is the chlor-alkali process, i.e., electrolysis of brine (salt) water to make hydrogen gas, chlorine, sodium hydroxide (caustic soda), and sodium hypochlorite (bleach). Synthesis is defined as "production" in the text of the Chemical Weapons Convention,[9] but the term synthesis is used throughout this Handbook to be in line with more common usage in the chemical sciences. With respect to the CW development process of Figure 6, this is the step in which a CW agent is actually produced.

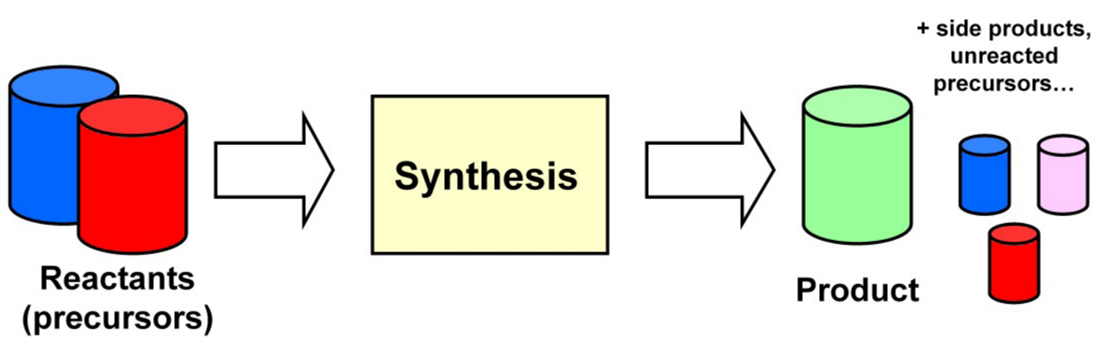


Figure 7. *Schematic depiction of the synthesis concept.*

Synthesis involves mixing chemicals under controlled conditions (such as temperature and pressure) to facilitate a chemical reaction. Figure 7 provides a schematic representation of the process. Precursors – also called reactants – are combined and undergo a chemical reaction to generate a desired chemical called the product. In the case of CW development, this product would be a CW agent. However, in reality, this process is not as simple as "chemical A reacts with chemical B to give chemical C." For example, unreacted precursors could be left in the reaction mixture, and side reactions could produce unwanted chemicals. Multiple variables therefore must be managed to maximise the success of the reaction – i.e., to maximise the amount of product created. Furthermore, multiple reaction steps will likely be required to obtain a given chemical, depending on what precursors are used.

9 Chemical Weapons Convention Article II, Definitions and Criteria; http://www.opcw.org/chemical-weapons-convention/articles/article-ii-definitions-and-criteria/

Temperature, pressure, material flow, and mixing are among the most important variables to manage in chemical synthesis. Chemical equipment used in synthesis must provide for control of these parameters, beyond simply providing containers in which the chemicals can react. Other considerations, such as the phases of the chemicals (gas, liquid, and/or solid), the hazards posed by the chemicals (e.g., corrosiveness or flammability), and the scale of the operation (laboratory scale, pilot scale, or industrial scale), as well as reliability and cost, must also be addressed. These factors influence the sizes, materials of construction, and design details of the equipment best suited for a particular synthesis operation. Key pieces of AG-listed chemical equipment relevant to the synthesis stage of CW development include reaction vessels (reactors), agitators, and heat exchangers. As with all other controlled pieces of manufacturing equipment, these items must have corrosion-resistant wetted surfaces to be eligible for control. Each reaction step may require a purification step along the pathway to make a final product.

Purification

Purification is the process of isolating a desired chemical product from a mixture of substances. Even a successful chemical synthesis will often result in a mixture of the product with other unwanted chemicals. Therefore, some additional effort must be exerted to isolate the desired product as a pure substance. This process can be referred to as purification, separation, or isolation, but purification is a blanket term that will be used in this Handbook to describe numerous methods for obtaining a pure substance from a chemical mixture. Among the most common methods for accomplishing this are distillation and affinity-based (chromatographic) methods such as extraction, adsorption, and absorption. This section provides a brief discussion of these methods due to the presence of distillation and absorption columns on the AG chemical equipment control list. Other methods used in the chemical industry to purify or isolate chemical compounds include crystallisation, filtration, evaporation, and drying.

Distillation is a separation technique based on differences in boiling points between different components of a chemical mixture. The composition of a liquid mixture and the vapour formed from it will generally differ due to the different boiling points or volatilities of the component chemicals. In a basic distillation process, the liquid mixture is heated, and various components in the mixture vapourise at their different boiling temperatures. The vapours coming off at different temperatures are cooled with a condenser, condensing the vapours to liquids for collection in a receiver vessel. A collected liquid fraction will be richest in the component of the original mixture that has a boiling temperature closest to that of the temperature range collected. A different receiver can be used for each temperature range for effective separation. As this simple distillation process is repeated, the collected fractions will become increasingly richer in each of the respective components, ultimately producing pure compounds. An efficient way to repeat this process is by using a distillation column; such columns have internal trays or packings on which vapour can repeatedly condense and re-evaporate at different temperatures to effectively accomplish multiple distillation steps. Distillation can be performed in a batch or continuous fashion, and several variations on the basic process are possible (e.g., steam distillation, vacuum distillation, etc.).[10]

Figure 8 shows schematic depictions of the distillation process: on the left is a laboratory scale representation of a distillation apparatus and on the right is an industrial scale scheme. Each arrangement shares common elements: some sort of heat source to keep the liquid mixture boiling (a "reboiler" in the industrial scale apparatus, often using steam as a heat source), a distillation column, a condenser to cool and condense the vapour, and a receiver to collect the condensed product. Key AG-listed commodities relevant to distillation include distillation columns, heat exchangers, condensers, and receivers.

[10] James R. Fair, "Distillation" in *Kirk-Othmer Encyclopedia of Chemical Technology*, Volume 8 (John Wiley & Sons, Inc., 1993).

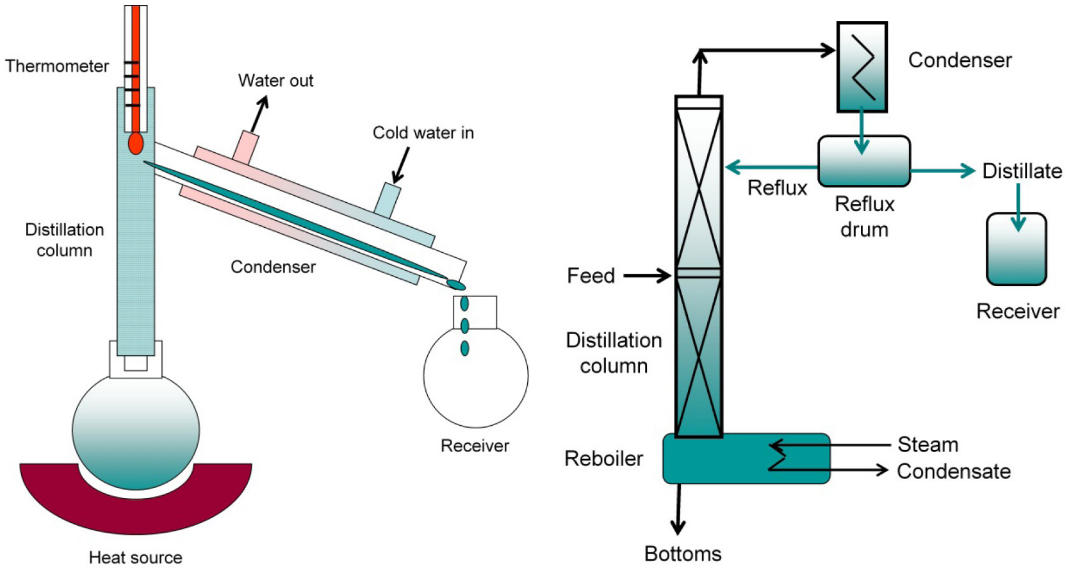


Figure 8. *Schematics of distillation apparati. Left: Laboratory scale arrangement for batch distillation. Right: Diagram for a continuous industrial scale distillation. Often a portion of the condensed vapour is returned to the column; this is referred to as reflux.*

A variety of separation processes are based on differences in the affinity of chemicals in a mixture for different media. Liquid-liquid extraction uses two immiscible liquids (like oil and water) to accomplish separation. A liquid mixture containing a dissolved chemical compound that needs to be separated is contacted with an immiscible liquid for which the dissolved chemical has greater affinity. The chemical passes into the new “extracting” liquid because it is more soluble in that liquid and will be preferentially incorporated into it. The two liquids are then physically separated, producing a separation of the dissolved components. In adsorption processes, one substance preferentially adheres to a substrate, while others are not retained. The desired component then is removed from the substrate, or “eluted,” by washing with a different solution to which it binds more strongly than the adsorbent. Conversely, the unwanted components could be adsorbed onto the substrate, leaving the desired substance in the original, now purified, solution. In contrast to adsorption – which involves binding to a surface – absorption refers to a bulk uptake of one phase into another, such as a gas into a liquid or a liquid into a solid. Absorption is often used to remove gases from a mixture for environmental reasons (i.e., scrubbing to remove air pollutants), as well as for product recovery and production of solutions of gases.[11] Absorption columns appear in the AG chemical equipment control list in the same entry as distillation columns, and, while functionally different, the two types of columns are quite similar. Both columns must be made of or lined with corrosion-resistant materials to be eligible for control.

Chemical Transfer and Storage

Chemicals, including precursors, intermediates, final products, and wastes, must be transferred between different locations throughout any chemical production facility, as well as stored at certain times. When handling CW agents or any dangerous substances, transfer and storage operations must take into account the hazardous nature of the chemicals involved. Therefore, while the general types of equipment that are needed to transfer and store chemicals are ubiquitous throughout the chemical industry, equipment subject to export controls has special features related to the hazards posed by CW precursors and agents – namely toxicity and corrosiveness. These design features include corrosion-resistant wetted parts and provisions for remote operation or leak containment/prevention. Equipment such as pumps, valves, storage tanks, and multi-walled piping are used throughout CW development and production to facilitate the movement and storage of chemicals. Furthermore, remotely-operated filling equipment could be used to fill delivery

[11] Manuel Laso and Urs von Stockar, “Absorption” in *Kirk-Othmer Encyclopedia of Chemical Technology*, Volume 1 (John Wiley & Sons, Inc., 2003).

systems with CW agents as well as safely fill other types of containers. All of these types of equipment appear on the AG chemical equipment control list. Like the other items on the list, this equipment also has legitimate uses in the commercial chemical industry for handling and storing corrosive, toxic, or otherwise highly hazardous chemicals.

Waste Destruction

With respect to CW, waste destruction can refer to the destruction of chemicals as well as munitions. The destruction of CW agents, precursors, and munitions represents a challenging and incredibly important operation. Fact sheets on CW destruction (also known as demilitarisation) can be found through the U.S. Army's Chemical Materials Activity website.[12]

The most widely-used method of waste destruction is high-temperature incineration. Incinerators destroy CW agents and decontaminate munitions using very high temperature incineration with stringent safety requirements, controls, and monitoring of emissions. The AG chemical equipment control list includes high temperature incinerators designed for destroying CW agents, precursors, and munitions.

Other methods of CW destruction have also been explored. After incineration, the next most widely-used method is chemical neutralisation. Neutralisation involves mixing agents with hot water or hot water and sodium hydroxide to convert agents into less harmful chemicals.[13] Several other alternative destruction methods have been developed to varying degrees and are described in a lengthy report by an IUPAC working party on CW destruction.[14]

Safety Considerations

Protection from and mitigation of chemical releases are critical facets of any chemical operation, but they are of even greater importance in the case of CW agent production, storage, and destruction given the extreme toxicity of agents. Due to the multiple hazards posed by chemicals involved in CW development (as well as destruction), safety measures could be incorporated into facilities to protect workers from exposure and alert them to even small chemical releases. Chemical safety practices generally involve a combination of active, passive, and administrative controls, the last involving sound practices for safely handling chemicals. Active controls include the use of personal protective equipment, while passive controls include the use of air monitoring devices. Toxic gas monitoring systems and their dedicated detecting components are included in the AG chemical equipment control list due to their utility in sensitively monitoring for the release of hazardous chemicals in a CW facility.

Summary

The production of CW agents bears similarities to commercial chemical production. Certain chemicals and chemical equipment traded for use in legitimate applications therefore can pose CW proliferation concerns. The discussions of AG-listed CW precursors and chemical equipment in the following sections are intended to familiarise officials with these controlled items to facilitate their identification in the field and aid assessments of their proliferation risk.

[12] Chemical Materials Activity; http://www.cma.army.mil. Some useful fact sheets are "Incineration: A Safe, Proven Disposal Process" (http://www.cma.army.mil/docviewerframe.aspx?docid=003673399); and "Neutralization of Chemical Agents" (http://www.cma.army.mil/docviewerframe.aspx?docid=003673563).

[13] CMA, "Neutralization of Chemical Agents;" http://www.cma.army.mil/docviewerframe.aspx?docid=003673563

[14] Graham S. Pearson and Richard S. Magee, "Critical Evaluation of Proven Chemical Weapon Destruction Technologies (IUPAC Technical Report)," *Pure Appl. Chem.* 74(2), 187-316 (2002); http://www.iupac.org/publications/pac/2002/7402/7402x0187.html. IUPAC is an abbreviation for the International Union of Pure and Applied Chemistry.

Chemical Packaging and Transportation

Introduction

The safe storage and transport of chemicals relies on using proper containers and effective warning labels for any hazards posed by their release. The container must be compatible with the chemical and physical properties of the substance. At the most basic level, the physical state of the chemical determines the type of container that is appropriate: gases are shipped in thick-walled tanks or cylinders while liquids or solids are shipped in bottles, drums, bins, tanks, or other containers such as ISO containers. Furthermore, containers should be constructed from materials that do not react adversely with the chemicals being stored. For example, the highly corrosive fluoride salts should not be stored in glass because they will etch the container. Certain plastics or corrosion-resistant metals are better choices of packaging materials for these substances. Individual CW precursor entries in this Handbook discuss what types of containers are typically used for each chemical.

The risk of a chemical release from even the most suitable containers requires measures to warn people of the hazards posed by chemicals in transit. International standards for the transport of hazardous materials dictate that containers bear specific markings and codes that identify the dangers associated with the shipped chemicals. These markings assist hazardous materials personnel in properly responding to a chemical release. In addition, international guidelines on labeling dangerous chemicals provide another set of measures for alerting personnel to the risks of chemical exposure.

This section provides an overview of international guidelines on transporting and labeling hazardous chemicals. The information in this chapter is not only relevant to assessing the hazards of the chemicals on the AG Chemical Weapons Precursors Control List; recognising chemical containers and the markings on them can help identify dual-use chemicals in transport and potentially aid in their interdiction.

United Nations Guidelines on the Transport of Dangerous Goods (UN Model Regulations)

The UN Recommendations on the Transport of Dangerous Goods, commonly known as the UN Model Regulations, were first published in 1956 to provide guidance on the safe transport of dangerous items. The UN Model Regulations are currently in their eighteenth revised edition (2013).[1] This document provides guidance on classifying materials into different hazard categories and provides details on approved containers for them. However, the section of greatest interest for chemical identification is the Dangerous Goods List (DGL), which is given in Part 3 of the UN Model Regulations. The DGL lists specific chemicals, items, and categories of chemicals that are considered dangerous for transport. Each chemical, item, or category is assigned an internationally-recognised four-digit number called a UN number. This number is the most specific identification code provided by the UN Model Regulations and is found on the outermost packaging of chemicals, such as on a box or a tank truck. A "Proper Shipping Name" is associated with each UN number and must accompany it on any labeling. In some cases, the Proper Shipping Name corresponds to a particular chemical (e.g., phosphorus pentasulphide). If the UN number corresponds to a generic or "n.o.s" (not otherwise specified) category of hazard, a technical name—*not* a trade name—for the chemical should also be provided after the Proper Shipping Name. This information can be used by emergency responders to identify hazardous materials during transportation emergencies, but can also aid chemical identification for export control purposes.

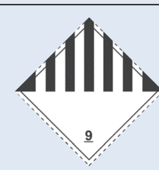
Each entry in the DGL is also assigned a Hazard Class. The Hazard Class assigns the chemical to a broader category of chemical or physical hazards (e.g., such as flammable liquids), with some classes divided further into Divisions. Table 1 gives a list of Hazard Classes and their Divisions. Any dangerous good in transport should bear a diamond-shaped label or placard, the appearance of which is dictated by the Hazard Class/ Division of the substance. Each diamond bears a pictogram representing the hazard and a one or two digit

[1] UN Model Regulations, 18th edition (2013); http://www.unece.org/trans/danger/publi/unrec/rev18/18files_e.html

number in the bottom corner. UN numbers, Proper Shipping Names, and Hazard Classes/Divisions are discussed in Part 2 (Classification) of the UN Model Regulations. It should be noted that Hazard Divisions 6.1 and 6.2 are applicable to AG-controlled toxins and pathogens; they are discussed in more detail in the Introduction to Pathogens and Toxins in Volume II.

Table 1. *UN Hazard Classes, Divisions, and Pictograms*

Class/Division	Name	UN Pictogram
Class 1	**Explosives**	**See UN Model Regulations Part 5***
Class 2	**Gases**	
Division 2.1	Flammable gases	 or 
Division 2.2	Non-flammable, non-toxic gases	 or 
Division 2.3	Toxic gases	
Class 3	**Flammable Liquids**	 or 
Class 4	**Flammable Solids**	
Division 4.1	Flammable solids, self-reactive substances, and solid desensitized explosives	
Division 4.2	Substances liable to spontaneous combustion	
Division 4.3	Substances which in contact with water emit flammable gases	 or 

Class/Division	Name	UN Pictogram
Class 5	**Oxidizing Substances and Organic Peroxides**	
Division 5.1	Oxidizing substances	
Division 5.2	Organic peroxides	 or 
Class 6	**Toxic and infectious substances**	
Division 6.1	Toxic substances	
Division 6.2	Infectious substances	
Class 7	**Radioactive material**	See the UN Model Regulations Part 5*
Class 8	**Corrosive substances**	
Class 9	**Miscellaneous dangerous substances and articles, including environmentally hazardous substances**	

*As these Hazard Classes and their Divisions are less relevant to CW precursors, their placards have been omitted. See Part 5 of the UN Model Regulations for pictures of the respective hazard diamonds.[2]

UN numbers and hazard diamonds are posted in close proximity to each other on tank trucks, ISO containers, or other types of bulk or outer packaging. Figure 1 displays the two options for this posting; the UN number should either be inside the diamond or next to it.

[2] UN Model Regulations, 18th edition (2013); http://www.unece.org/trans/danger/publi/unrec/rev18/18files_e.html

Figure 1. *Posting options for the UN number and hazard diamond on a chemical shipping container.*

Figure 2 shows the labeling of an aluminium tote bin containing the controlled CW precursor phosphorus pentasulphide, as an example of how hazard diamonds and the Proper Shipping Name would be posted on a bulk container.[3]

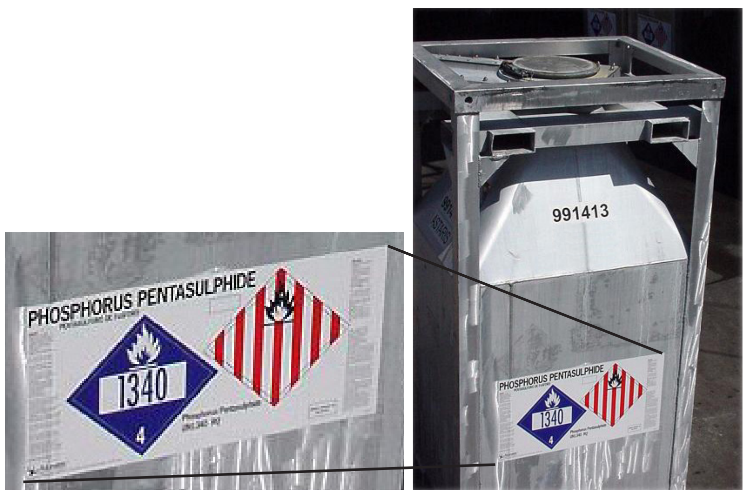


Figure 2. *Photograph of a tote bin containing phosphorus pentasulfide with expanded view of the UN label.*

UN numbers, Proper Shipping Names, and Hazard Classes/Divisions are required on hazardous goods shipping documents. Figure 3 shows the area of a shipper's declaration (for air transit, in this example) that would display this information.

NATURE AND QUANTITY OF DANGEROUS GOODS						
Dangerous Goods Identification				Quantity and type of packaging	Packing Inst.	Authorization
UN or ID No.	Proper Shipping Name	Class or Division (Subsidiary Risk)	Pack-ing Group			

Figure 3. *Section of a shipper's declaration for dangerous goods showing fields for the UN number, Proper Shipping Name, and Hazard Class or Division.*

[3] This tote bin can hold up to 3409 kilograms of the chemical and measures a few metres to a side.

Globally Harmonized System of Classification and Labelling of Chemicals (GHS)

The Globally Harmonized System of Classification and Labelling of Chemicals, known as the GHS, is a international system intended to ensure safe use, transportation, and disposal of chemicals by harmonising approaches to classifying and labeling chemicals according to the hazards they pose.[4] Use of the GHS helps to protect human health and the environment in a global trade environment through a system of easily recognisable pictograms. It additionally serves as a basis for harmonising rules and regulations on chemicals at multiple levels: nationally, regionally, and internationally. The first edition of the GHS was published in 2005, with the fifth revised edition issued in 2013.

The GHS uses a series of pictograms to represent health and environmental hazards on chemical labels. Table 2 reproduces these pictograms and the GHS Hazard Classes associated with each. It should be noted that GHS Hazard Classes can be different than the Hazard Classes and Divisions established by the UN Model Regulations. For example, there are no GHS Hazard Classes covering infectious or radioactive substances.

These pictograms would appear on GHS-compliant chemical labels on individual chemical containers as described in Annex 7 (Examples of Arrangements of the GHS Label Elements) of the GHS.[5] They may also appear in Safety Data Sheets. *The GHS pictograms do not definitively determine the identity of a chemical, but are included in this Handbook to alert those handling chemicals to hazards that may be present.*

Table 2. *GHS pictograms*

GHS Pictogram Name	GHS Pictogram	GHS Hazard Classes
Exploding Bomb		Explosives; organic peroxides*
Flame		Flammable gases; flammable liquids; flammable solids; aerosols; pyrophoric liquids; pyrophoric solids; self-heating substances and mixtures; substances and mixtures, which in contact with water emit flammable gases; organic peroxides*
Flame over Circle		Oxidizing gases; oxidizing liquids; oxidizing solids
Gas Cylinder		Gases under pressure

[4] For more details, see the United Nationals Economic Commission for Europe, “About the GHS”; http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html

[5] GHS official text and corrigenda, Rev. 5 (2013); http://www.unece.org/trans/danger/publi/ghs/ghs_rev05/05files_e.html

GHS Pictogram Name	GHS Pictogram	GHS Hazard Classes
Corrosive		Corrosive to metals; skin corrosion; serious eye damage
Skull		Acute toxicity*
Chronic Health Hazard		Respiratory sensitization; germ cell mutagenicity; carcinogenicity; reproductive toxicity; specific organ toxicity – single exposure*; specific organ toxicity – repeated exposure; aspiration hazard
Exclamation Mark		Skin sensitization; skin irritation; eye irritation; acute toxicity*; specific organ toxicity – single exposure*; hazardous to the ozone layer
Environmental Hazard		Hazardous to the aquatic environment, short term (acute); hazardous to the aquatic environment, long term (chronic);

*May bear this or another pictogram, depending on the specific hazard and its extent

Conclusions

Internationally-accepted markings can aid in determining the identity of a chemical, as well as alert inspectors to potential hazards. UN numbers and associated Proper Shipping Names are one tool for chemical identification, while UN hazard diamonds and GHS pictograms reflect various hazards that would be encountered in the case of a chemical release. For these reasons, UN numbers with their Proper Shipping Names, UN hazard diamonds, and GHS pictograms are provided for each chemical in the Export Control List: Chemical Weapons Precursors section.

Export Control List: Chemical Weapons Precursors

The following sections provide basic descriptions of and information on the notable features, packaging, and typical applications of items on the Australia Group Export Control List: Chemical Weapons Precursors.[1] Each section also includes an illustrative "Global Production" listing, which lists countries that are home to production facilities; when plant locations for multinational companies could not be determined, the headquarter country is listed by default. These listings should be considered illustrative and not exhaustive. The blue boxes at the beginning of each entry provide the chemical structure of the precursor, according to a shorthand described in Appendix C.

The complete AG control language as of its September 2009 revision is found in Appendix A. Entries in this chapter are numbered to match their order in the control list. See the Glossary for technical terms used in this Handbook.

[1] The current AG control language may be found at: http://www.australiagroup.net/en/precursors.html

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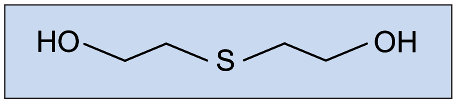
1. Thiodiglycol



1.1. Basic Description

Thiodiglycol is a vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	111-48-8
Formula	$C_4H_{10}O_2S$
Molecular Weight	122.19
CA Index Name	Ethanol, 2,2'-thiobis-
CWC Schedule	2B13
EC#	203-874-3
HS#	2930.90 [Organo-sulfur compounds, other]
UN#	May be assigned UN 3334 (AVIATION REGULATED LIQUID, N.O.S.)
UN Hazard Placard	
Other Names	Bis(2-hydroxyethyl)sulfide; bis(2-hydroxyethyl) thioether; di(2-hydroxyethyl sulfide); diethanol sulfide; 2,2'-dithiobis-(ethanol); 3-thiapentane-1,5-diol; 2,2'-thiobisethanol; 2,2'-thiodiethanol; thiodiethylene glycol; 2,2'-thiodiglycol; 2,2'-dihydroxydiethyl sulfide; sulfide, bis(2-hydroxyethyl); bis(2-hydroxyethyl) sulphide; dihydroxylethyl mercaptan Note: 2 might be replaced with β or "beta" in some synonyms
EU CL#	1C350.1
GHS Pictogram	

1.2. Notable Features

Thiodiglycol is a colourless or pale yellow liquid. Some report it has an odour similar to rotten eggs, while others claim it is odourless.

1.3. Packaging

Thiodiglycol often is supplied in plastic or plastic-lined containers, including polyethylene-lined steel drums. Glass bottles are used for small quantities.

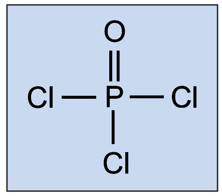
Global Production

- Armenia
- China
- Germany
- United Kingdom
- United States

1.4 Typical Applications

The most frequently-mentioned commercial uses of thiodiglycol are in the production of water-based inks, textile dyes, plastics, and coatings. For example, it can be used as a solvent in ball-point pen ink. The OPCW notes use in the textile industry for textile printing and fabric softeners. Thiodiglycol also can be used to prepare additives for plastics, rubber, resins, or lubricants.

2. Phosphorus Oxychloride



2.1. Basic Description

Phosphorus oxychloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	10025-87-3
Formula	$POCl_3$; Cl_3OP
Molecular Weight	153.33
CA Index Name	Phosphoryl chloride
CWC Schedule	3B05
EC#	233-046-7
HS#	2812.10 [Halide and halide oxides of nonmetals, chlorides and chloride oxides]
UN#	UN 1810 [PHOSPHORUS OXYCHLORIDE]
UN Hazard Placard	
Other Names	$OPCl_3$; phosphonyl trichloride; phosphoric chloride; phosphoric trichloride; phosphoroxychloride; phosphoroxytrichloride; phosphorus chloride oxide; phosphorus(V) trichloride oxide; phosphorus monoxide trichloride; phosphorus oxide trichloride; phosphorus oxytrichloride; phosphorus trichloride oxide; $POCl_3$; phosphoryl trichloride; trichlorophosphine oxide; trichlorophosphorus oxide; fosforoxychlorid; tlenochlorek fosforu; oxychlorid fosforecny
EU CL#	1C350.2
GHS Pictogram	

2.2. Notable Features

Phosphorus oxychloride is a colourless or slightly yellow liquid. It may have a pungent odour like musty hay.

2.3. Packaging

Small volumes of phosphorus oxychloride are supplied in glass containers. Bulk quantities of phosphorus oxychloride are shipped in nickel-clad or stainless steel tank cars or trucks. Many companies supply phosphorus oxychloride in plastic or plastic-lined containers, including plastic-lined metal drums.

2.4. Typical Applications

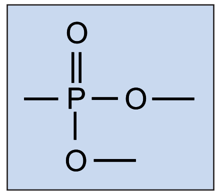
Phosphorus oxychloride is a basic building block for numerous organophosphorus compounds. It is a primary starting material for the synthesis of phosphate esters (also known as phosphate triesters), which in turn are used in the manufacture of hydraulic fluids, agrochemicals (pesticides/insecticides), flame retardants, oil stabilisers, medicinal intermediates, and plastic and elastomer additives (plasticisers). The OPCW's list of the most traded Scheduled chemicals additionally lists metal extraction solvents among the phosphate ester products derived from phosphorus oxychloride. Some phosphate esters are good solvents for certain chemicals involved in uranium processing.

Phosphorus oxychloride can play several roles in organic synthesis, such as introducing chlorine atoms or phosphorus-oxygen groups into other molecules. According to some sources, it can also be used to prepare dyes and fragrances. Extremely high purity phosphorus oxychloride can be used as a dopant for semiconductor manufacure.

Global Production

- China
- Egypt
- Germany
- India
- Japan
- Poland
- Russia
- Spain
- United Kingdom
- United States

3. Dimethyl Methylphosphonate



3.1. Basic Description

Dimethyl methylphosphonate (DMMP) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	756-79-6
Formula	$C_3H_9O_3P$
Molecular Weight	124.08
CA Index Name	Phosphonic acid, methyl-, dimethyl ester
CWC Schedule	2B04
EC#	212-052-3
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Most companies consider non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	DMMP; dimethoxymethyl phosphine oxide; dimethyl methanephosphonate; methanephosphonic acid dimethyl ester; methylphosphonic acid dimethyl ester; dimethyl ester of methylphosphonic acid
EU CL#	1C350.3
GHS Pictogram	

3.2. Notable Features

DMMP is a colourless liquid which may have a pleasant odour.

3.3. Packaging

DMMP is sold in high density polyethylene- (HDPE-)lined drums, iron drums, and ISO containers, according to the suppliers identified for this Handbook. Small quantities are sold in glass bottles, like the one shown on the left in Figure 3.A.

Figure 3.A. *Glass bottles of phosphonates. The bottle on the left is dimethyl methylphosphonate.*

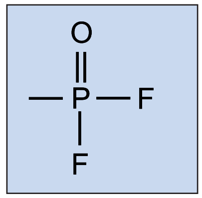
3.4. Typical Applications

The major use of DMMP is as a flame retardant for rigid materials like resins and polyurethane foams; the OPCW lists applications for such flame retardants in building materials, furnishings, upholstery, transportation equipment and fittings, and in the electrical industry for cables and housings. It also can be used to manufacture other flame retardants. In addition, DMMP is used as a hydraulic fluid additive, pre-ignition gasoline additive, antifoaming agent, plasticiser, stabiliser, and as a conditioner/softener and antistatic agent for textiles. Additional uses are in heavy metal extraction, solvent separation, and organic synthesis.

Global Production

- China
- France
- Germany
- India
- United Kingdom
- United States

4. Methylphosphonyl Difluoride (DF)



4.1. Basic Description

Methylphosphonyl difluoride (DF) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	676-99-3
Formula	CH_3F_2OP
Molecular Weight	100.0
CA Index Name	Phosphonic difluoride, methyl-
CWC Schedule	1B09
EC#	None
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	Difluoromethylphosphine oxide; methyl difluorophosphite; methylphosphonic difluoride; methyl phosphonyl difluoride; phosphonic difluoride, methyl-; phosphonodifluoridic acid, methyl-
EU CL#	1C350.4 (ML)
GHS Pictogram	Unknown

4.2. Notable Features

DF is a liquid with a pungent, acid-like odour.

Global Production

- None identified

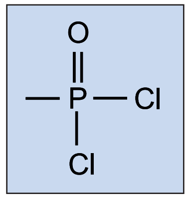
4.3. Packaging

Not applicable due to lack of commercial availability.

4.4. Typical uses

There are no reported commercial uses for DF. Its toxicity, lack of availability, and strict regulation per CWC mandates make civil use of this chemical highly unlikely.

5. Methylphosphonyl Dichloride (DC)



5.1. Basic Description

Methylphosphonyl dichloride (DC) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	676-97-1
Formula	CH_3Cl_2OP
Molecular Weight	132.91
CA Index Name	Phosphonic dichloride, methyl-
CWC Schedule	2B04
EC#	211-634-4
HS#	2931.90 [Other organo-inorganic compounds]
UN#	May be assigned UN 3390 (TOXIC BY INHALATION LIQUID, CORROSIVE, N.O.S) or UN 2928 (TOXIC SOLID, CORROSIVE, ORGANIC, N.O.S.)
UN Hazard Placard	
Other Names	Methanephosphonic dichloride; methanephosphonic acid dichloride; phosphonodichloridic acid, methyl-; methyl phosphonic dichloride; methylphosphonic dichloride; methyl phosphonyl dichloride
EU CL#	1C350.5
GHS Pictogram	

5.2. Notable Features

DC is colourless liquid or a white crystalline solid with a pungent or acrid odour.

5.3. Packaging

Small quantities of DC are sold in glass bottles.

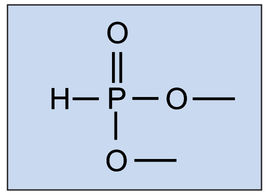
Global Production

- Germany
- United Kingdom
- United States

5.4. Typical Applications

DC can be used in organic synthesis. While in theory it could be used for applications similar to those of other organophosphorus compounds (e.g., crop protection chemicals), its limited availability may preclude commercial use of DC for such purposes.

6. Dimethyl Phosphite (DMP)



Note: The structure of DMP shown above exists in equilibrium with a structure containing a P–OH group instead of a H–P=O group; the other structure is found in some descriptions of DMP.

6.1. Basic Description

Dimethyl phosphite (DMP) is a nerve agent precursor with the following identifiers and properties:

Identifier	Value
CAS#	868-85-9
Formula	$C_2H_7O_3P$
Molecular Weight	110.05
CA Index Name	Phosphonic acid, dimethyl ester
CWC Schedule	3B10
EC#	212-783-8
HS#	2920.90 [Esters of inorganic acids of nonmetals and their salts…other]
UN#	May be assigned UN 3278 (ORGANOPHOSPHORUS COMPOUND, TOXIC, LIQUID, N.O.S.)
UN Hazard Placard	
Other Names	DMHP; dimethoxyphosphine oxide; dimethyl acid phosphite; dimethyl ester of phosphonic acid; dimethyl hydrogen phosphite; dimethyl phosphonate; hydrogen dimethyl phosphite; methyl phosphate; methyl phosphonate ((MeO)2HPO); O,O-dimethyl phosphonate; (CH3O)2PHO; dimethylester kyseliny fosforite; dimethylfosfit; dimethylfosfonat
EU CL#	1C350.6
GHS Pictogram	

6.2. Notable Features

DMP is a colourless liquid.

6.3. Packaging

DMP can be packaged in road tankers, ISO containers, or plastic (e.g., polyethylene) drums. Small quantities are sold in glass bottles.

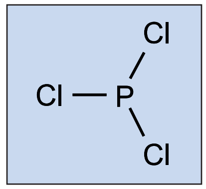
6.4. Typical Applications

Major uses of DMP are in the preparation of crop protection chemicals like the herbicide Glyphosate, flame retardants for textiles, and phosphonates. DMP can be used to synthesise lubricant additives, pharmaceuticals, and flavors.

Global Production

- Armenia
- China
- Germany
- Japan
- Russia

7. Phosphorus Trichloride



7.1. Basic Description

Phosphorus trichloride (PCl_3) is a nerve agent and vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	7719-12-2
Formula	Cl_3P
Molecular Weight	137.33
CA Index Name	Phosphorous trichloride
CWC Schedule	3B06
EC#	231-749-3
HS#	2812.10 [Halide and halide oxides of nonmetals, chlorides and chloride oxides]
UN#	UN 1809 (PHOSPHORUS TRICHLORIDE)
UN Hazard Placard	
Other Names	PCl3; phosphine, trichloro-; phosphorus chloride; phosphorus chloride (cl6p2); phosphorus (III) chloride; phosphorous trichloride; trichlorophosphine; fosforo(tricloruro di); fosfortrichloride; phosphore(trichlorure de); phosphortrichlorid; trojchlorek fosforu
EU CL#	1C350.7
GHS Pictogram	

7.2. Notable Features

PCl_3 is a colourless or slightly yellow liquid with a pungent odour.

7.3. Packaging

Small quantities of PCl_3 are shipped in glass containers. Plastic, iron, or mild or stainless steel drums; railcars; tank trucks; and ISO containers are used for larger shipments.

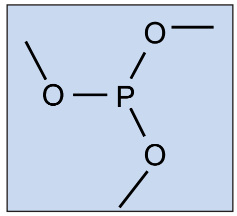
7.4. Typical Applications

PCl_3 is an important industrial chemical, serving as a starting material for numerous organic and inorganic phosphorus compounds. A major use of PCl_3 is in the production of the herbicide Glyphosate. PCl_3 can serve as a chlorinating agent or a catalyst in chemical reactions. The OPCW notes use of PCl_3 as a starting material for intermediates in the production of pharmaceutical products, synthetic colourants, and organophosphate flame retardants, insecticides, plasticisers, and metal extraction solvents. Note that PCl_3 could claim application for other downstream products such as lubricant additives, stabilisers, surfactants, antioxidants, textile processing chemicals, and water-treatment chemicals.

Global Production

- Chile
- China
- Denmark
- Egypt
- Germany
- India
- Japan
- Poland
- Russia
- United Kingdom
- United States

8. Trimethyl Phosphite (TMP)



8.1. Basic Description

Trimethyl phosphite (TMP) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	121-45-9
Formula	$C_3H_9O_3P$
Molecular Weight	124.08
CA Index Name	Phosphorous acid, trimethyl ester
CWC Schedule	3B08
EC#	204-471-5
HS#	2920.90 [Esters of inorganic acids of nonmetals and their salts…other]
UN#	UN 2329 (TRIMETHYL PHOSPHITE)
UN Hazard Placard	
Other Names	Methyl phosphite ((MeO)3P); P(OCH3)3; phosphorus acid trimethyl ester; trimethoxyphosphine; trimethoxyfosfin; trimethylfosfit; trimethyl ester of phosphorous acid; trimethylphosphite; fosforyn trojmetylowy
EU CL#	1C350.8
GHS Pictogram	

8.2. Notable Features

TMP is a colourless liquid with a pungent, irritating odour.

8.3. Packaging

High-density polyethylene-lined mild steel drums and ISO containers are used by some sources of TMP. Small quantities are sold in glass bottles.

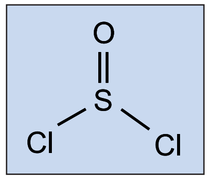
Global Production

- Armenia
- China
- Denmark
- Germany
- India
- Japan
- United States

8.4. Typical Applications

TMP is used primarily in the production of insecticides/pesticides and is an intermediate in the production of flame retardants. TMP can be used to synthesise phosphonate esters such as DMMP. The OPCW cites use of TMP as a stabiliser for PVC neoprene, a plasticiser in nylon, and a catalyst in polymerisation reactions, as well as in dyestuffs, plasticisers, optical brighteners, and lubricants.

9. Thionyl Chloride



9.1. Basic Description

Thionyl chloride is a nerve agent and vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	7719-09-7
Formula	Cl_2OS
Molecular Weight	118.97
CA Index Name	Thionyl chloride
CWC Schedule	3B14
EC#	231-748-8
HS#	2812.10 [Halide and halide oxides of nonmetals, chlorides and chloride oxides]
UN#	UN 1836 (THIONYL CHLORIDE)
UN Hazard Placard	
Other Names	SOCl2; Sulfinyl chloride; sulfinyl dichloride; sulfur chloride oxide; sulfur oxychloride; sulfurous acid dichloride; sulfurous dichloride; sulfurous oxychloride; thionyl dichloride
EU CL#	1C350.9
GHS Pictogram	

9.2. Notable Features

Thionyl chloride is a colourless, pale yellow, or red liquid with a pungent or suffocating odour.

9.3. Packaging

Thionyl chloride could be shipped in glass-lined steel tanks, galvanised steel drums, or special plastic drums. It could also be supplied in ISO containers or tank cars. Small quantities are often sold in glass or plastic-coated bottles.

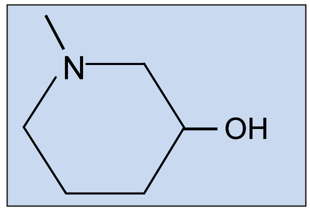
Global Production

- China
- Germany
- India
- Japan
- Spain
- Switzerland
- United States

9.4. Typical Applications

Thionyl chloride is a versatile reagent for organic synthesis. Its primary synthetic role is as a chlorinating agent, from which it finds many of its commercial applications. One major commercial use of thionyl chloride is in synthesising acid chlorides, which in turn are used in the production of herbicides and insecticides, as well as surfactants, pharmaceuticals (drugs and vitamins), dyestuffs, and paper and textile auxiliaries. Another application is in the preparation of engineering thermoplastics. It also is used in production of the synthetic sweetener sucralose. Some high performance, high energy density lithium batteries are made from lithium and thionyl chloride; thionyl chloride is a liquid cathode in such systems.

10. 3-Hydroxy-1-Methylpiperidine



10.1. Basic Description

According to *U.S. Army Field Manual FM 3-11.9*, 3-hydroxy-1-methylpiperidine "could be used in the synthesis of psychoactive compounds such as BZ." It has the following identifiers and properties:

Identifier/Property	Value
CAS#	3554-74-3
Formula	$C_6H_{13}NO$
Molecular Weight	115.18
CA Index Name	3-Piperidinol, 1-methyl-
CWC Schedule	Not Listed
EC#	222-609-2
HS#	2933.39 [Heterocyclic compounds with nitrogen hetero-atom(s) only; compounds containing an unfused pyridine ring (whether or not hydrogenated) in the structure]
UN#	Not considered hazardous for transport by many suppliers
UN Hazard Placard	Not applicable
Other Names	3-Hydroxy-N-methylpiperidine; 1-methyl-3-hydroxypiperidine; N-methyl-3-hydroxypiperidine; 1-methyl-3-piperidinol; 1-methylpiperidin-3-ol; N-methyl-3-piperidinol
EU CL#	1C350.10
GHS Pictogram	

10.2. Notable Features

3-Hydroxy-1-methylpiperidine is a colourless to light yellow liquid.

10.3. Packaging

Small quantities of 3-hydroxy-1-methylpiperidine are packaged in glass bottles.

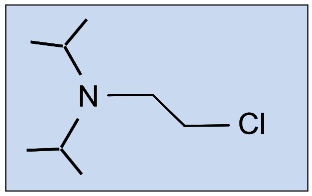
10.4. Typical Applications

3-Hydroxy-1-methylpiperidine can be used in organic synthesis. According to one supplier, it has synthetic roles in the preparation of compounds of relevance to pharmaceuticals.

Global Production

- China
- Germany
- Japan
- United Kingdom
- United States

11. N,N-Diisopropyl-(beta)-Aminoethyl Chloride



11.1. Basic Description

N,N-Diisopropyl-(beta)-aminoethyl chloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	96-79-7
Formula	$C_8H_{18}ClN$
Molecular Weight	163.69
CA Index Name	2-Propanamine, N-(2-chloroethyl)-N-(1-methylethyl)-
CWC Schedule	2B10
EC#	202-535-7
HS#	2921.19 [Amine-function compounds, acyclic monoamines…, other]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	β-(Diisopropylamino)ethyl chloride; 2-chloro-N,N-diisopropylethanamine; 2-chloro-N,N-diisopropylethylamine; N-(2-chloroethyl)-N-(1-methylethyl)-2-propanamine; N-(2-chloroethyl) diisopropylamine; diisopropylamine, N-(2-chloroethyl)-; N,N-diisopropyl-2-chloroethylamine; 1-(diisopropylamino)-2-cholorethane; 2-(diisopropylamino)ethyl chloride; diisopropylaminoethyl chloride
EU CL#	1C350.b.9
GHS Pictogram	Unknown

11.2. Notable Features

No additional information on the properties of N,N-diisopropyl-(beta)-aminoethyl chloride was found.

Global Production

- China
- United States

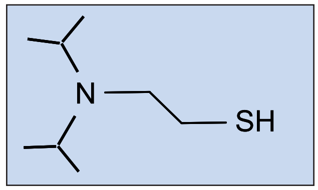
11.3. Packaging

No information on the packaging of this substance was found.

11.4. Typical Applications

N,N-Diisopropyl-(beta)-aminoethyl chloride could be used in organic synthesis. One source claims application as a pharmaceutical intermediate, citing patents that describe its use in drug formulations, but the extent of such use is unclear.

12. N,N-Diisopropyl-(beta)-Aminoethane Thiol



12.1. Basic Description

N,N-Diisopropyl-(beta)-aminoethane thiol is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	5842-07-9
Formula	$C_8H_{19}NS$
Molecular Weight	161.31
CA Index Name	Ethanethiol, 2-[bis(1-methylethyl)amino]-
CWC Schedule	2B12
EC#	None
HS#	2930.90 [Organo-sulfur compounds, other]
UN#	Likely considered non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	2-(Diisopropylamino) ethanethiol; 2-diisopropylaminoethanethiol; diisopropylaminoethanethiol; β-diisopropylaminoethanethiol; beta-diisopropylaminoethanethiol; 2-(bis(1-methylethyl)amino) ethanethiol
EU CL#	1C350.12
GHS Pictogram	

12.2. Notable Features

N,N-Diisopropyl-(beta)-aminoethane thiol is a colourless liquid with a strong odour.

12.3. Packaging

No information on the packaging of this substance was found.

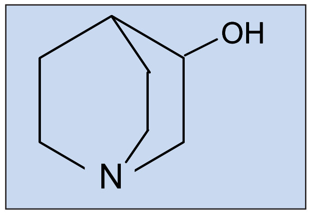
12.4. Typical Applications

N,N-Diisopropyl-(beta)-aminoethane thiol could be used in organic synthesis.

Global Production

- China
- India
- United Kingdom
- United States

13. 3-Quinuclidinol



13.1. Basic Description

3-Quinuclidinol is a precursor for the incapacitant BZ with the following identifiers and properties:

Identifier/Property	Value
CAS#	1619-34-7
Formula	$C_7H_{13}NO$
Molecular Weight	127.19
CA Index Name	1-Azabicyclo[2.2.2]octan-3-ol
CWC Schedule	2B09
EC#	216-578-4
HS#	2933.39 [Heterocyclic compounds with nitrogen hetero-atom(s) only; compounds containing an unfused pyridine ring (whether or not hydrogenated) in the structure
UN#	May be assigned UN 3263 (CORROSIVE SOLID, BASIC, ORGANIC N.O.S.)
UN Hazard Placard	
Other Names	Quinuclidine-3-ol; quinuclidinol; 3-hydroxyquinuclidine; quinuclidinol-3; 3-hydroxy-1-azabicyclo[2.2.2]octane; quinuclidin-3-ol
EU CL#	1C350.13
GHS Pictogram	

13.2. Notable Features

3-Quinuclidinol is a white to light yellow crystalline solid.

13.3. Packaging

Small quantities of 3-quinuclidinol are sold in glass bottles.

13.4. Typical Applications

According to commercial suppliers, 3-quinuclidinol can be used in the pharmaceutical industry for the preparation of certain drugs.

14. Potassium Fluoride

KF

14.1. Basic Description

Potassium fluoride (KF) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	7789-23-3
Formula	FK
Molecular Weight	58.1
CA Index Name	Potassium fluoride
CWC Schedule	Not Listed
EC#	232-151-5
HS#	2826.19 [Fluorides, other]
UN#	UN 1812 (POTASSIUM FLUORIDE, SOLID) UN 3422 (POTASSIUM FLUORIDE SOLUTION)
UN Hazard Placard	
Other Names	KF; potassium monofluoride; fluorure de potassium
EU CL#	1C350.14
GHS Pictogram	

14.2. Notable Features

KF is an odourless white solid. Aqueous solutions of KF are colourless.

14.3. Packaging

KF is often packaged in plastic (e.g., polyethylene, polypropylene, or "poly") containers such as bottles, pails, drums, or bags. Other packaging options include plastic-lined fibre drums, metal barrels, or woven sacks lined with plastic bags.

14.4. Typical Applications

KF is used extensively as a fluorinating agent for numerous applications. It also can play the role of a catalyst in some organic reactions. KF is used in pesticide/insecticide formulations and in metallurgical applications such as the production of fluxes for soldering. As with other inorganic fluorides, KF can be used as a cleaning agent and for etching glass. Eurofluor[2] notes that KF can be used as a fluorine source in some herbicides and insecticides, as well as some pharmaceutical preparations; it also claims that KF is added to edible table salt in parts of Central America, South America, and some places in Europe as an alternative to water fluorination for the prevention of tooth decay.

Global Production

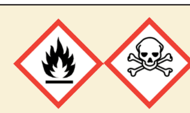
- Brazil
- China
- Germany
- India
- Italy
- Japan
- Mexico
- Spain
- United Kingdom
- United States

[2] Comité Technique Europeen du Fluor, "Eurofluor HF: A snapshot of the Fluorine Industry" (May 2013); http://www.eurofluor.org

15. 2-Chloroethanol

15.1. Basic Description

2-Chloroethanol is a vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	107-07-3
Formula	C_2H_5ClO
Molecular Weight	80.51
CA Index Name	Ethanol, 2-chloro-
CWC Schedule	Not Listed
EC#	203-459-7
HS#	2905.59 [Halogenated, sulfonated, nitrated or nitrosated derivatives of acyclic alcohols, other]
UN#	UN 1135 (ETHYLENE CHLOROHYDRIN)
UN Hazard Placard	
Other Names	CH2ClCH2OH; 2-Chloro-1-ethanol; 2-chloroethyl alcohol; 2-hydroxyethyl chloride; 2-monochloroethanol; chloroethanol; ethylene chlorohydrin; ethene chlorohydrin; ethylchlorohydrin; ethylene chlorhydrin; glycol chlorohydrin; glycol monochlorohydrin; 2-chlorethanol; aethylenechlorhydrin; ethyleen-chloorhydrine; glicol monocloridrina; glycolmonochloorhydrine; glycomonochlorhydrin; 2-chloorethanol; 2-chloraethanol; 2-chloro-1-hydroxyethane; 2-cloroetanolo; monochlorhydrine du glycol; 2-chloroetanolo; chloroethylowy alcohol; delta-chloroethanol; glycolmonochloorhydrine; glycomonochlorhydrin; Note: some synonyms replace 2 with β or add an "e" to the end of hydrin
EU CL#	1C350.15
GHS Pictogram	

15.2. Notable Features

2-Chloroethanol is a colourless liquid with an ether- or alcohol-like odour.

15.3. Packaging

2-Chloroethanol is frequently packaged in plastic or plastic-lined containers. Other packaging options include galvanised drums, steel-lined drums, rail tanks, and ISO containers. Small quantities are sold in glass bottles.

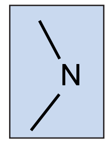
15.4. Typical Applications

Frequently-cited uses of 2-chloroethanol, commonly known as ethylene chlorohydrin, are in the manufacture of insecticides, plasticisers, pharmaceuticals, dye intermediates, and plant protection agents. It can be used to produce ethylene glycol and ethylene oxide. It also can serve as a solvent, particularly for ethylcellulose, cellulose esters, resins, and waxes. It is used in treating sweet potatoes before planting. In addition, 2-chloroethanol can be used as a cleaning solvent, as suggested by its ability to dissolve waxy substances.

Global Production

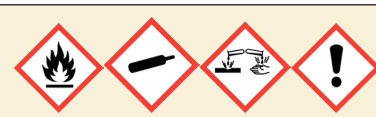
- China
- Germany
- India
- Japan
- Russia
- Slovak Republic
- United States

16. Dimethylamine



16.1. Basic Description

Dimethylamine (DMA) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	124-40-3
Formula	C_2H_7N
Molecular Weight	45.09
CA Index Name	Methanamine, N-methyl-
CWC Schedule	Not Listed
EC#	204-697-4 (aqueous solution)
HS#	2921.11 [Methylamine, di- or trimethylamine and their salts]
UN#	UN 1032 (DIMETHYLAMINE, ANHYDROUS) UN 1160 (DIMETHYLAMINE AQUEOUS SOLUTION)
UN Hazard Placard	UN 1032:  UN 1160: 
Other Names	(CH3)2NH; DMA; N,N-dimethylamine; N-methyl methanamine
EU CL#	1C350.16
GHS Pictogram*	

*Solutions of DMA would not bear the gas cylinder pictogram

16.2. Notable Features

In its anhydrous form, DMA is a clear, colourless gas. DMA is sold in both its anhydrous form and in aqueous solutions; the latter are colourless liquids. Either form would have a strong fishy or ammonia-like odour.

16.3. Packaging

DMA is commonly sold as a liquefied gas under pressure in cylinders or tanks. DMA is also sold as a liquid solution, which can be supplied in iron drums, mild steel drums, polyvinylchloride containers, or ISO containers; small quantities of the solutions are supplied in glass bottles.

16.4. Typical Applications

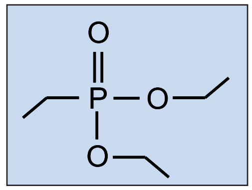
DMA has a wealth of commercial uses. Sectors using DMA include the water treatment, crop protection, pharmaceutical, rubber, and polymer/fibre industries. DMA is used in the manufacture of solvents (particularly dimethylformamide and dimethylacetamide); water treatment chemicals; surfactants, detergents, and ion exchange resins; agrochemicals; pharmaceuticals; dyes; rayon; and rubber chemicals such as accelerators. There are numerous other applications for DMA.[3]

Global Production

- Australia
- Belgium
- Brazil
- China
- Germany
- India
- Italy
- Japan
- Mexico
- The Netherlands
- Republic of Korea
- Republic of Turkey
- Romania
- Russia
- Saudi Arabia
- South Africa
- Spain
- United States

[3] Listings of end uses can be found at DuPont Methylamines; http://www2.dupont.com/Methylamines/en_US/ and Alkyl Amines DMA Application Areas; http://www.alkylamines.com/products/aa/dma_aa.htm

17. Diethyl Ethylphosphonate



17.1. Basic Description

Diethyl ethylphosphonate (DEEP) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	78-38-6
Formula	$C_6H_{15}O_3P$
Molecular Weight	166.16
CA Index Name	Phosphonic acid, ethyl-, diethyl ester
CWC Schedule	2B04
EC#	201-111-9
HS#	2931.90 [Other organo-inorganic compounds]
UN#	UN 3082 (ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S.)
UN Hazard Placard	
Other Names	Diethyl ethanephosphonate; diethylethylphosphonate; diethoxyethylphosphine oxide; ethanephosphonic acid, diethyl ester; ethylphosphonic acid diethyl ester
EU CL#	1C350.17
GHS Pictogram	

17.2. Notable Features

DEEP is a colourless liquid with a mild odour.

17.3. Packaging

Small quantities of DEEP are supplied in glass bottles. No other information was found, but commercial packaging likely is similar to that of DMMP.

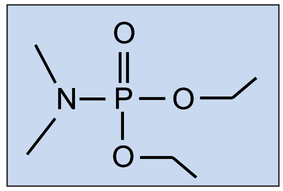
17.4. Typical Applications

DEEP has similar applications as DMMP, particularly as a gasoline additive, anti-foaming agent, plastics additive (stabiliser, antioxidant), textile conditioner, flame retardant, and anti-static agent. The OPCW lists an additional application as a raw material for insecticides.

Global Production

- Armenia
- Canada
- Germany
- United Kingdom
- United States

18. Diethyl N,N-Dimethylphosphoramidate



18.1. Basic Description

Diethyl N,N-dimethylphosphoramidate is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	2404-03-7
Formula	$C_6H_{16}NO_3P$
Molecular Weight	181.2
CA Index Name	Phosphoramidic acid, dimethyl-, diethyl ester
CWC Schedule	2B06
EC#	None
HS#	2929.90 [Compounds with other nitrogen function, other]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	N,N-Dimethyl-O,O'-diethyl phosphoramidate; diethyl dimethylphosphoramidate; dimethylphosphoramidic acid diethyl ester
EU CL#	1C350.18
GHS Pictogram	Unknown

18.2. Notable Features

Diethyl N,N-dimethylphosphoramidate is a liquid.

Global Production

- China

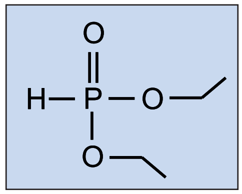
18.3. Packaging

No information on the packaging of this substance was found.

18.4. Typical Applications

Diethyl *N,N*-dimethylphosphoramidate could be used in organic synthesis. Its lack of availability suggests it has little or no commercial use.

19. Diethyl Phosphite



Note: The structure of diethyl phosphite shown above exists in equilibrium with a structure containing a P-OH group instead of a H–P=O group; the other structure is found in some descriptions of diethyl phosphite.

19.1. Basic Description

Diethyl phosphite (DEP) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	762-04-9
Formula	$C_4H_{11}O_3P$
Molecular Weight	138.1
CA Index Name	Phosphonic acid, diethyl ester
CWC Schedule	3B11
EC#	212-091-6
HS#	2920.90 [Esters of inorganic acids of nonmetals and their salts…other]
UN#	May be assigned UN 3334 (AVIATION REGULATED LIQUID, N.O.S.), but some companies consider it to be non-hazardous for transport
UN Hazard Placard	
Other Names	Diethyl acid phosphite; diethyl hydrogen phosphite; diethyl phosphonate; hydrogen diethyl phosphite; OPH(OC2H5)2; diethoxyphosphine oxide; DEPI; diethylfosfit
EU CL#	1C350.19
GHS Pictogram	

19.2. Notable Features

DEP is a colourless liquid with a distinct odour.

19.3. Packaging

DEP can be shipped in ISO containers and polyethylene drums. Other sources provide DEP in plastic or plastic-lined (e.g., high density polyethylene/HDPE) drums, with small quantities available in glass bottles.

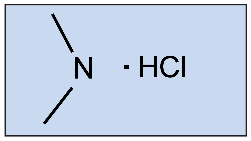
19.4. Typical Applications

DEP has a number of industrial applications. It is employed to synthesise intermediates for flame retardants, pharmaceuticals, agrochemicals, textile auxiliaries, and plastics additives. According to the OPCW, it can also be used as a paint solvent and an additive for lubricants.

Global Production

- China
- Germany
- Japan
- United Kingdom
- United States

20. Dimethylamine Hydrochloride



20.1. Basic Description

Dimethylamine hydrochloride (DMA HCl) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	506-59-2
Formula	C_2H_8ClN
Molecular Weight	81.55
CA Index Name	Methanamine, N-methyl-, hydrochloride
CWC Schedule	Not Listed
EC#	208-046-5
HS#	2921.11 [Methylamine, di- or trimethylamine and their salts]
UN#	Considered non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	Dimethylammonium chloride; hydrochloric acid dimethylamine; N-methyl methanamine hydrochloride
EU CL#	1C350.20
GHS Pictogram	

20.2. Notable Features

DMA HCl is a white to off-white odourless solid.

20.3. Packaging

Small quantities of DMA HCl are often packaged in glass or plastic bottles. Plastic or plastic-lined containers such as woven plastic bags, bags inside drums, or plastic-lined drums are used for larger quantities. Aqueous solutions are also sold; such products are provided in coated or polyethylene containers to avoid corrosion.

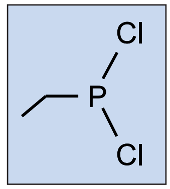
20.4. Typical Applications

The primary use of DMA HCl is in pharmaceutical preparations. Assorted applications in other fields have been cited by some sources; examples include the preparation of solder fluxes and crop protection chemicals.

Global Production

- Belgium
- Canada
- China
- Germany
- India
- Mexico
- Russia
- Spain
- United Kingdom
- United States

21. Ethylphosphinyl Dichloride



21.1. Basic Description

Ethylphosphinyl dichloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	1498-40-4
Formula	$C_2H_5Cl_2P$
Molecular Weight	130.94
CA Index Name	Phosphonous dichloride, ethyl-
CWC Schedule	2B04
EC#	216-096-4
HS#	2931.90 [Other organo-inorganic compounds]
UN#	UN 2845 (PYROPHORIC LIQUID, ORGANIC, N.O.S.)
UN Hazard Placard	
Other Names	Dichloroethylphosphine; ethyldichlorophosphine; dichlor-ethylfosfin; ethyl phosphonous dichloride; phosphine, dichloroethyl-
EU CL#	1C350.21
GHS Pictogram	

21.2. Notable Features

Ethylphosphinyl dichloride is colourless liquid with a pungent, foul odour.

Global Production

- China
- Germany
- United States

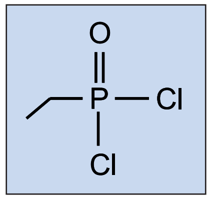
21.3. Packaging

Small quantities of ethylphosphinyl dichloride are sold in ampoules or glass bottles.

21.4. Typical Applications

Ethylphosphinyl dichloride is a specialty chemical that could be used in organic synthesis. In theory, it may have other applications, but its limited availability makes its use on an industrial scale unlikely.

22. Ethylphosphonyl Dichloride



22.1. Basic Description

Ethylphosphonyl dichloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	1066-50-8
Formula	$C_2H_5Cl_2OP$
Molecular Weight	146.94
CA Index Name	Phosphonic dichloride, ethyl-
CWC Schedule	2B04
EC#	None
HS#	2931.90 [Other organo-inorganic compounds]
UN#	May be assigned UN 2922 (CORROSIVE LIQUID, TOXIC, N.O.S.)
UN Hazard Placard	
Other Names	Dichloroethylphosphine oxide; ethanephosphonyl chloride; ethanephosphonic dichloride; ethylphosphonic acid dichloride; ethylphosphonic dichloride; ethylphosphoryl dichloride
EU CL#	1C350.22
GHS Pictogram	

22.2. Notable Features

Ethylphosphinyl dichloride is a colourless to light yellow liquid.

22.3. Packaging

Ethylphosphinyl dichloride is sold in glass bottles.

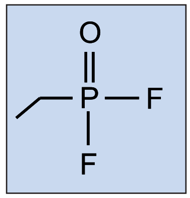
22.4. Typical Applications

Ethylphosphonyl dichloride can be used in organic synthesis as a phosphorylating agent. Like its methyl analogue DC, it has limited availability, making industrial scale uses unlikely.

Global Production

- Canada
- China
- Germany
- Japan
- United Kingdom
- United States

23. Ethylphosphonyl Difluoride



23.1. Basic Description

Ethylphosphonyl difluoride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	753-98-0
Formula	$C_2H_5F_2OP$
Molecular Weight	98.0
CA Index Name	Phosphonic difluoride, ethyl-
CWC Schedule	1B09
EC#	None
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	Ethyl phosphonyl difluoride; Ethanephosphonic difluoride
EU CL#	1C350.23 (ML)
GHS Pictogram	Unknown

23.2. Notable Features

No additional information on the properties of ethylphosphonyl difluoride was found.

Global Production

- None found

23.3. Packaging

Not applicable due to lack of commercial availability.

23.4. Typical Applications

Ethylphosphonyl difluoride could be used in organic synthesis, but no commercial uses were found for this CWC Schedule 1B chemical.

24. Hydrogen Fluoride

HF

24.1. Basic Description

Hydrogen fluoride (HF) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	7664-39-3
Formula	FH
Molecular Weight	20.01
CA Index Name	Hydrofluoric acid
CWC Schedule	Not Listed
EC#	231-634-8
HS#	2811.11 [Hydrogen fluoride (hydrofluoric acid)]
UN#	UN 1052 (HYDROGEN FLUORIDE, ANHYDROUS) UN 1790 (HYDROFLUORIC ACID, with [not] more than 60% hydrogen fluoride)
UN Hazard Placard	
Other Names	AHF; anhydrous hydrofluoric acid; fluorhydric acid; fluorine monohydride; fluorwasserstoff; HF; hydrofluoric acid gas
EU CL#	1C350.24
GHS Pictogram	

24.2. Notable Features

HF is a liquefied gas or colourless fuming liquid with a sharp, pungent odour. It is commonly sold as an aqueous solution with approximately 49% or 70% HF; solutions are colourless liquids that may fume in air, depending on their concentration.

24.3. Packaging

HF may be shipped in tank cars, tank trucks, or ISO containers; carbon steel tanks are often used for anhydrous HF, while tanks for aqueous solutions are likely to be lined. Anhydrous HF is also shipped in cylinders, while aqueous solutions in smaller quantities are available in plastic (e.g., PTFE or polyethylene) bottles, carboys, and IBCs, as well as plastic-lined drums.

24.4. Typical Applications

HF and its aqueous solutions have several industrial applications. HF finds extensive commercial use as a fluorinating agent – i.e., it is used to introduce fluorine atoms into other materials. The primary use of anhydrous HF is in the manufacture of fluorocarbons, which in turn are used in several applications such as refrigeration and the foam blowing of plastics. According to Eurofluor,[4] 60% of HF manufactured worldwide is used for the production of fluorocarbons. HF is also an intermediate in the preparation of fluoropolymers, which are used in numerous corrosion-resistant and “non-stick” applications, as well as crop protection products and other chemical derivatives. HF serves as an alkylation catalyst in the petroleum industry for producing high octane fuels and is used in a similar capacity for producing detergents. It is used in the nuclear industry to produce uranium conversion.

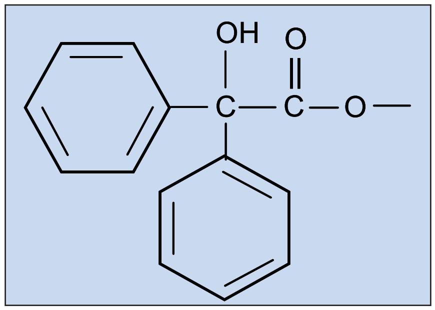
Applications of aqueous HF, also known as hydrofluoric acid, can differ somewhat from those of anhydrous HF. Hydrofluoric acid is used for cleaning and etching silicon in the semiconductor industry; glass etching and frosting; metallurgical applications like stainless steel and titanium pickling, aluminium anodization, and etching and cleaning non-ferrous metals; quartz purification; rare metal processing; and cleaning of industrial plants and buildings. It can also serve as a feedstock for other chemical derivatives.

Global Production

- Australia
- Brazil
- Canada
- China
- Germany
- India
- Italy
- Japan
- Kazakhstan
- Mexico
- Republic of Korea
- Republic of Turkey
- Russia
- South Africa
- Spain
- Taiwan
- United Kingdom
- United States

[4] Comité Technique Europeen du Fluor, “Eurofluor HF: A snapshot of the Fluorine Industry” (May 2013); http://www.eurofluor.org

25. Methyl Benzilate



25.1. Basic Description

Methyl benzilate is a precursor for the incapacitant BZ with the following identifiers and properties:

Identifier/Property	Value
CAS#	76-89-1
Formula	C15H14O3
Molecular Weight	242.3
CA Index Name	Benzeneacetic acid, α-hydroxy-α-phenyl-, methyl ester
CWC Schedule	Not Listed
EC#	200-991-1
HS#	2918.19 [Carboxylic acids with additional oxygen function…other]
UN#	Considered non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	Benzilic acid, methyl ester; α-hydroxy-α-phenylbenzeneacetic acid methyl ester; methyl diphenylglycolate; methyl α-phenylmandelate; hydroxy-diphenyl-acetic acid methyl ester; methyl hydroxy(diphenyl)acetate
EU CL#	1C350.25
GHS Pictogram	

25.2. Notable Features

Methyl benzilate is a white crystalline solid.

25.3. Packaging

No specific packaging information was found for methyl benzilate. Due to its lack of hazardous properties, it might be sold in standard glass, plastic, or metal containers.

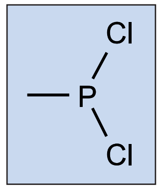
Global Production

- China
- Germany
- The Netherlands
- United States

25.4. Typical Applications

Methyl benzilate is used in organic synthesis and pharmaceutical manufacture.

26. Methylphosphinyl Dichloride



26.1. Basic Description

Methylphosphinyl dichloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	676-83-5
Formula	CH_3Cl_2P
Molecular Weight	116.92
CA Index Name	Phosphonous dichloride, methyl-
CWC Schedule	2B04
EC#	211-631-8
HS#	2931.90 [Other organo-inorganic compounds]
UN#	May be assigned UN 2845 (PYROPHORIC LIQUID, ORGANIC, N.O.S.) or UN 2924 (FLAMMABLE LIQUID, CORROSIVE, N.O.S.)
UN Hazard Placard	UN 2845:  UN 2924: 
Other Names	Methyldichlorophosphine; CH3PCl2; phosphonous dichloride, methyl-; methylphosphinic dichloride; methyl phosphinyl dichloride; methylphosphonous dichloridephosphine, dichloromethyl-; dichloromethylphosphine
EU CL#	1C350.26
GHS Pictogram	

26.2. Notable Features

Methylphosphinyl dichloride is a colourless to pale yellow liquid with a pungent, acidic odour.

26.3. Packaging

Small volumes are supplied in ampoules.

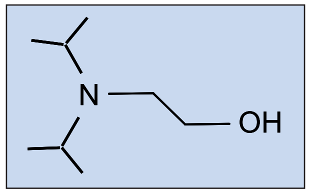
Global Production

- China
- Germany
- Slovak Republic
- United States

26.4. Typical Applications

Methylphosphinyl dichloride can be used in organic synthesis. According to the OPCW, it is used to make methylphosphinic acid.

27. N,N-Diisopropyl-(beta)-Amino-Ethanol



27.1. Basic Description

N,N-Diisopropyl-(beta)-amino-ethanol is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	96-80-0
Formula	$C_8H_{19}NO$
Molecular Weight	145.2
CA Index Name	Ethanol, 2-[bis(1-methylethyl)amino]-
CWC Schedule	2B11
EC#	202-536-2
HS#	2922.19 [Oxygen-function amino-compounds, amino-alcohols…other]
UN#	UN 2922 (CORROSIVE LIQUID, TOXIC, N.O.S.)
UN Hazard Placard	
Other Names	2-(Diisopropylamino) ethanol; 2-diisopropylaminoethanol; 2-(diisopropylamino) ethyl alcohol; (N,N-diisopropylamino)ethanol; N,N-diisopropyl-2-aminoethanol; N,N-diisopropyl-β-amino ethanol; ethanol, 2-(diisopropylamino)-; N,N-diisopropylaminoethanol; N,N-diisopropylethanolamine; N,N-diisopropylethanolamine; ethanol, diisopropylamino-; DIPAE
EU CL#	1C350.27
GHS Pictogram	

27.2. Notable Features

N,N-Diisopropyl-(beta)-amino-ethanol is a colourless to light yellow liquid with an ammonia-like odour.

27.3. Packaging

Small quantities of this chemical are sold in glass bottles. Larger amounts might be sold in drums.

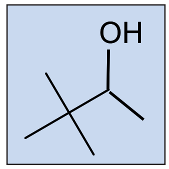
Global Production

- Belgium
- China
- India
- Japan
- United States

27.4. Typical Applications

N,N-Diisopropyl-(beta)-amino-ethanol is a specialty alkyl alkanolamine with potential applications in pharmaceuticals; corrosion control; inks, paints, and coatings; and functional fluids.

28. Pinacolyl Alcohol



28.1. Basic Description

Pinacolyl alcohol is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	464-07-3
Formula	$C_6H_{14}O$
Molecular Weight	102.2
CA Index Name	2-Butanol, 3,3-dimethyl-
CWC Schedule	2B14
EC#	207-347-9
HS#	2905.19 [Acyclic alcohols…other]
UN#	UN 1987 (ALCOHOLS, N.O.S.)
UN Hazard Placard	
Other Names	3,3-Dimethylbutane-2-ol; tert-butyl methyl carbinol; 2,2-dimethyl-3-butanol; 3,3-dimethyl-2-butanol; (CH3)3CCH(CH3)OH; 1-methyl-2,2-dimethylpropanol
EU CL#	1C350.28
GHS Pictogram	

28.2. Notable Features

Pinacolyl alcohol is a clear, colourless or very faint yellow liquid with an alcohol-like odour.

28.3. Packaging

Small quantities are sold in glass containers.

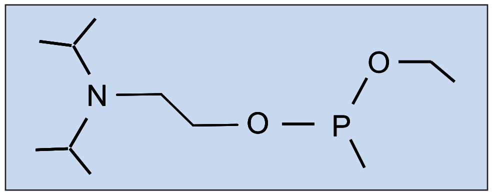
Global Production

- China
- Germany
- Japan
- United States

28.4. Typical Applications

Pinacolyl alcohol is a specialty chemical that could be used in organic synthesis.

29. O-Ethyl 2-Diisopropylaminoethyl Methylphosphonite (QL)



29.1. Basic Description

O-Ethyl 2-diisopropylaminoethyl methylphosphonite (QL) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	57856-11-8
Formula	$C_{11}H_{26}NO_2P$
Molecular Weight	235.3
CA Index Name	Phosphonous acid, methyl-, 2-[bis(1-methylethyl)amino]ethyl ethyl ester
CWC Schedule	1B10
EC#	None
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	O-ethyl-O'-(2-diisopropylaminoethyl) methylphosphonite
EU CL#	1C350.29 (ML)
GHS Pictogram	Unknown

29.2. Notable Features

QL is a colourless liquid with a strong, fishy odour.

Global Production

- None found

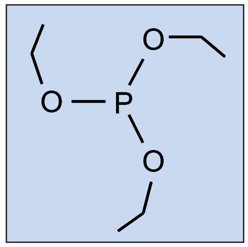
29.3. Packaging

Not applicable due to lack of commercial availability.

29.4. Typical Applications

There are no commercial uses for QL.

30. Triethyl Phosphite



30.1. Basic Description

Triethyl phosphite (TEP) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	122-52-1
Formula	$C_6H_{15}O_3P$
Molecular Weight	166.2
CA Index Name	Phosphorous acid, triethyl ester
CWC Schedule	3B09
EC#	204-552-5
HS#	2920.90 [Esters of inorganic acids of nonmetals and their salts…other]
UN#	UN 2323 (TRIETHYL PHOSPHITE)
UN Hazard Placard	
Other Names	(C2H5O)3P; triethoxyphosphine; fosforyn trojetylowy; tris(ethoxy)phosphine; TEPI; trietil fosfito
EU CL#	1C350.30
GHS Pictogram	 

30.2. Notable Features

TEP is a clear, colourless to light yellow liquid with an unpleasant odour.

30.3. Packaging

Small quantities of TEP are sold in glass bottles. Larger amounts may be packaged in bulk tankers; IBCs; ISO containers; and metal or plastic-lined drums.

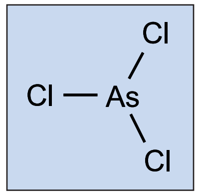
30.4. Typical Applications

TEP can be used to synthesise phosphonate esters. According to several sources, it is used in the manufacture of insecticides, flame retardants, pharmaceutical active ingredients, additives for lubricants and plastics, and whitening agents.

Global Production

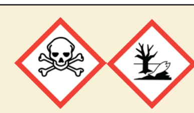
- China
- Germany
- India
- Japan
- United Kingdom
- United States

31. Arsenic Trichloride



31.1. Basic Description

Arsenic trichloride is a vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	7784-34-1
Formula	$AsCl_3$
Molecular Weight	181.3
CA Index Name	Arsenous trichloride
CWC Schedule	2B07
EC#	232-059-5
HS#	2812.10 [Halides and halide oxides of nonmetals, chlorides and chloride oxides]
UN#	UN 1560 (ARSENIC TRICHLORIDE)
UN Hazard Placard	
Other Names	Arsenic (III) chloride; arsenic(3+) chloride; AsCl3; arsenous chloride; arsenic butter; butter of arsenic; chlorure arsenieux; chlorure d'arsenic; fuming liquid arsenic; trichloroarsine; trichlorure d'arsenic
EU CL#	1C350.31
GHS Pictogram	

31.2. Notable Features

Arsenic trichloride is a colourless to pale yellow oily liquid with an unpleasant odour.

Global Production

- Canada
- Germany
- United States

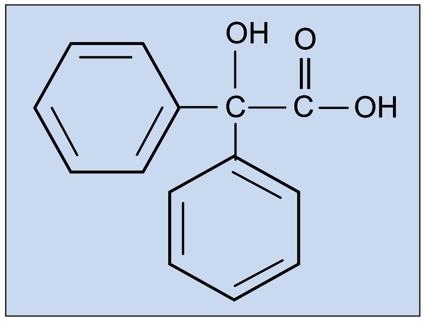
31.3. Packaging

Arsenic trichloride is sold in glass bottles or ampoules.

31.4. Typical Applications

Arsenic trichloride is used in the ceramics industry. It is also employed in the synthesis of organic arsenicals, including chlorine-containing arsenicals. Some resources mention use in the semiconductor industry, but it is not clear if this is current practice.

32. Benzilic Acid



32.1. Basic Description

Benzilic acid is a precursor for the incapacitant BZ with the following identifiers and properties:

Identifier/Property	Value
CAS#	76-93-7
Formula	$C_{14}H_{12}O_3$
Molecular Weight	228.25
CA Index Name	Benzeneacetic acid, αhydroxy-αphenyl-
CWC Schedule	2B08
EC#	200-993-2
HS#	2918.19 [Carboxylic acids with additional oxygen function]
UN#	Considered non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	α-Hydroxy-α-phenyl-benzeneacetic acid; 2,2-diphenyl-2-hydroxyacetic acid; α-hydroxy-2,2-diphenylacetic acid; α,α-diphenyl-α-hydroxyacetic acid; α,α-diphenylglycolic acid; diphenylglycolic acid; diphenylhydroxyacetic acid; α,α-diphenylglycolic acid; hydroxyl(diphenyl)acetic acid; 2-hydroxy-2,2-diphenylacetic acid; α-hydroxy-α-phenylbenzeneacetic acid Note: α may be replaced by “alpha” or “a” in some synonyms
EU CL#	1C350.32
GHS Pictogram	

32.2. Notable Features

Benzilic acid is a white or yellowish solid.

32.3. Packaging

Benzilic acid may be packaged in plastic bottles or plastic bags inside cardboard drums.

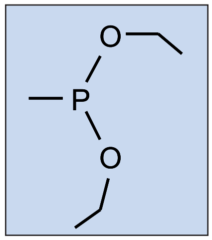
32.4. Typical Applications

Benzilic acid is used primarily as pharmaceutical intermediate. The OPCW also claims use in the dyestuff industry and acaricides and notes that aluminium benzilic acid is a toner ingredient.

Global Production

- Canada
- China
- Germany
- India
- The Netherlands
- Spain

33. Diethyl Methylphosphonite



33.1. Basic Description

Diethyl methylphosphonite is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	15715-41-0
Formula	$C_5H_{13}O_2P$
Molecular Weigh	136.1
CA Index Name	Phosphonous acid, methyl-, diethyl ester
CWC Schedule	2B04
EC#	239-805-9
HS#	2931.90 [Other organo-inorganic compounds]
UN#	May be assigned UN 3279 (ORGANOPHOSPHORUS COMPOUND, TOXIC, FLAMMABLE, N.O.S.) or UN 1993 (FLAMMABLE LIQUID, N.O.S.)
UN Hazard Placard	UN 3279:  UN 1993: 
Other Names	Diethyl methanephosphonite; O,O-diethyl methylphosphonite; diethoxymethylphosphine; methyldiethoxyphosphine; methylphosphonous acid diethyl ester
EU CL#	1C350.33
GHS Pictogram	

33.2. Notable Features

Diethyl methylphosphonite is a colourless liquid with an unpleasant, pungent odour.

33.3. Packaging

Diethyl methylphosphonite is sold in glass bottles or ampoules.

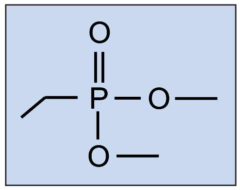
33.4. Typical Applications

Diethyl methylphosphonite could be used in organic synthesis.

Global Production

- Germany
- United States

34. Dimethyl Ethylphosphonate



34.1. Basic Description

Dimethyl ethylphosphonate (DMEP) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	6163-75-3
Formula	$C_4H_{11}O_3P$
Molecular Weight	138.1
CA Index Name	Phosphonic acid, ethyl-, dimethyl ester
CWC Schedule	2B04
EC#	None
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	Dimethyl ethanephosphonate; ethylphosphonic acid, dimethyl ester
EU CL#	1C350.34
GHS Pictogram	

34.2. Notable Features

DMEP is a colourless liquid.

Global Production

- China
- United States

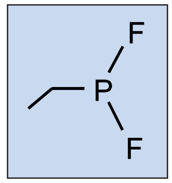
34.3. Packaging

No specific information on the packaging of this substance was found. Its packaging might be similar to that of DMMP.

34.4. Typical Applications

DMEP can used in organic synthesis. The *Handbook of Chemical and Biological Warfare Agents* lists the following commercial uses: antifoam agent, gasoline additive, and chelating agent. One source lists additional uses as a flame retardant and in the preparation of antioxidants for lubricants. Given that DMEP has a similar structure to DMMP, these applications are plausible. However, its actual use in industry probably is limited given the lack of commercial sources.

35. Ethylphosphinyl Difluoride



35.1. Basic Description

Ethylphosphionyl difluoride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	430-78-4
Formula	$C_2H_5F_2P$
Molecular Weight	98.0
CA Index Name	Phosphonous difluoride, ethyl-
CWC Schedule	2B04
EC#	None
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	Ethyldifluorophosphine; difluoroethylphosphine
EU CL#	1C350.35
GHS Pictogram	Unknown

35.2. Notable Features

Ethylphosphinyl difluoride is a gas at room temperature.

Global Production

- None found

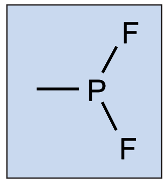
35.3. Packaging

No specific information on the packaging of this substance was found.

35.4. Typical Applications

Ethylphosphinyl difluoride could be used in organic synthesis; no industrial applications of this compound were identified.

36. Methylphosphinyl Difluoride



36.1. Basic Description

Methylphosphinyl difluoride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	753-59-3
Formula	CH_3F_2P
Molecular Weight	84.0
CA Index Name	Phosphonous difluoride, methyl-
CWC Schedule	2B04
EC#	None
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	(Difluoro)methyl-phosphine, CH3PF2; methyl phosphinyl difluoride; methyldifluorophosphine; difluoromethylphosphine
EU CL#	1C350.36
GHS Pictogram	Unknown

36.2. Notable Features

Properties of this substance are expected to be somewhat similar to those of ethylphosphinyl difluoride.

Global Production

- None found

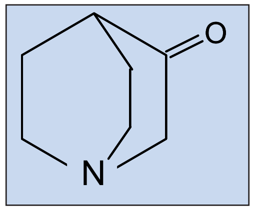
36.3. Packaging

No specific information on the packaging of this compound was found.

36.4. Typical Applications

Methylphosphinyl difluoride could be used in organic synthesis; no industrial applications were found for this substance.

37. 3-Quinuclidone



37.1. Basic Description

3-Quinuclidone is a precursor for the incapacitant BZ with the following identifiers and properties:

Identifier/Property	Value
CAS#	3731-38-2
Formula	$C_7H_{11}NO$
Molecular Weight	125.17
CA Index Name	1-Azabicyclo[2.2.2]octan-3-one
CWC Schedule	Not Listed
EC#	223-087-9
HS#	2933.39 [Heterocyclic compounds with nitrogen hetero-atom(s) only; compounds containing an unfused pyridine ring (whether or not hydrogenated) in the structure]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	Quinuclidone; 3-oxoquinuclidine; 3-oxyquinuclidine; quinuclidin-3-one
EU CL#	1C350.37
GHS Pictogram	

37.2. Notable Features

3-Quinuclidone is a white solid.

Global Production
- China
- United States

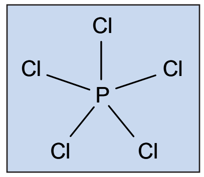
37.3. Packaging

No specific information on packaging was found for this chemical.

37.4. Typical Applications

3-Quinuclidone can be used in the organic synthesis, potentially as a pharmaceutical intermediate.

38. Phosphorus Pentachloride



38.1. Basic Description

Phosphorus pentachloride (PCl_5) is a nerve agent and vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	10026-13-8
Formula	Cl_5P
Molecular Weight	208.2
CA Index Name	Phosphorane, pentachloro-
CWC Schedule	3B07
EC#	233-060-3
HS#	2812.10 [Halides and halide oxides of metals, chlorides and chloride oxides]
UN#	UN 1806 (PHOSPHORUS PENTACHLORIDE)
UN Hazard Placard	
Other Names	PCl5; pentachlorophosphorane; pentachlorophosphorus; phosphoric chloride; phosphorus(V) chloride; fosforo(pentacloruro di); fosforpentachloride; pieciochlorek fosforu; phosphore(pentachlorure de); phosphorpentachlorid; phosphorus perchloride; phosphorus chloride
EU CL#	1C350.38
GHS Pictogram	

38.2. Notable Features

PCl_5 is a white to yellow solid with a pungent, unpleasant odour.

38.3. Packaging

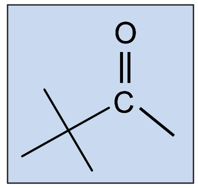
PCl_5 is packaged in plastic containers of various sizes, including bulk. Small quantities can be packaged in glass bottles.

Global Production
- China
- Germany
- India
- Japan
- United States

38.4. Typical Applications

One of the main synthetic roles of PCl_5 is as a chlorinating agent. It is used in the manufacture of pharmaceuticals, flame retardants, crop protection chemicals, dyes, and plastics additives. Additional reported uses are in the manufacture of electrolytes for batteries and in metallurgy.

39. Pinacolone



39.1. Basic Description

Pinacolone is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	75-97-8
Formula	$C_6H_{12}O$
Molecular Weight	100.2
CA Index Name	2-Butanone, 3,3-dimethyl
CWC Schedule	Not Listed
EC#	200-920-4
HS#	2914.19 [Ketones and quinones…, acyclic ketones without other oxygen function, other]
UN#	UN 1224 (KETONES, LIQUID, N.O.S.); UN 1993 (FLAMMABLE LIQUID, N.O.S.)
UN Hazard Placard	
Other Names	1,1,1-Trimethylacetone; 1,1-dimethylethyl methyl ketone; 2,2-dimethyl-3-butanone; 2,2-dimethylbutanone; 3,3-dimethyl-2-butanone; 3,3-dimethylbutanone; tert-butyl methyl ketone; methyl tert-butyl ketone; pinacolin; pinacoline; pinakolin; ketone, tert-butyl methyl; α,α,α-trimethylacetone; t-butyl methyl ketone; ketone, t-butyl methyl; methyl t-butyl ketone; 3,3-dimethyl-butan-2-one
EU CL#	1C350.39
GHS Pictogram	

39.2. Notable Features

Pinacolone is a colourless to light yellow liquid with a mint-like odour.

Global Production
- China
- United States

39.3. Packaging

Pinacolone is commonly packed in iron drums, potentially lined with plastic. Small quantities are packaged in glass bottles.

39.4. Typical Applications

Pinacolone is used primarily as an intermediate in the production of crop protection chemicals.

40. Potassium Cyanide

K–C≡N

40.1. Basic Description

Potassium cyanide (KCN) is a nerve and blood agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	151-50-8
Formula	CKN
Molecular Weight	65.1
CA Index Name	Potassium cyanide
CWC Schedule	Not Listed
EC#	205-792-3
HS#	2837.19 [Cyanides and cyanide oxides, other]
UN#	UN 1680 (POTASSIUM CYANIDE, SOLID) UN 1935 (CYANIDE SOLUTION, N.O.S.) UN 3413 (POTASSIUM CYANIDE SOLUTION)
UN Hazard Placard	
Other Names	KCN; cyanide of potassium; cyanure de potassium; hydrocyanic acid, potassium salt; kalium-cyanid
EU CL#	1C350.40
GHS Pictogram	

40.2. Notable Features

KCN is a white granular hygroscopic powder or crystalline solid which some companies may press into brick- or pillow-shaped blocks (see sodium cyanide). It has a bitter, almond-like odour.

40.3. Packaging

Small quantities of KCN are packaged in glass, plastic, or plastic-coated bottles. Larger quantities may be supplied in steel or plastic drums, bags inside wooden boxes, or steel bins. See the Packaging section for sodium cyanide for pictures of the types of packages expected to be used for KCN.

40.4. Typical Applications

KCN is used primarily for electroplating (e.g., silver and gold plating), but is also used in the extraction of gold and silver from ores; electrolytic separation of gold, silver, and copper from platinum; dye production; steel nitriding; and metal cleaning. KCN is also used in pesticides/fumigants. It has similar uses to sodium cyanide, but tends to be more expensive; it has been replaced by sodium cyanide in many applications for this reason. KCN also might be found in chemicals used in photographic processing,[5] but its current prevalence is unclear because of the availability of safer alternatives. KCN can be used in organic synthesis, with some claiming use in the pharmaceutical industry.

Global Production

- Australia
- Brazil
- China
- Czech Republic
- Germany
- India
- Japan
- Mexico
- Poland
- Russia
- South Africa
- Spain
- United States

[5] University of Florida, "Photographic Materials: Safety Issues and Disposal Procedures"; http://www.ehs.ufl.edu/programs/chemrad_waste/photo/

41. Potassium Bifluoride

KHF_2

41.1. Basic Description

Potassium bifluoride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	7789-29-9
Formula	F_2HK
Molecular Weight	78.1
CA Index Name	Potassium fluoride
CWC Schedule	Not Listed
EC#	232-156-2
HS#	2826.19 [Fluorides, other]
UN#	UN 1811 (POTASSIUM HYDROGEN DIFLUORIDE SOLID) UN 3421 (POTASSIUM HYDROGEN DIFLUORIDE SOLUTION)
UN Hazard Placard	
Other Names	Hydrogen potassium difluoride; hydrogen potassium fluoride; potassium acid fluoride; potassium hydrogen fluoride; potassium hydrogen difluoride; potassium fluoride; potassium fluoride compound with hydrogen fluoride (1:1); K(HF2); bifluorure de potassium; potassium monohydrogen difluoride
EU CL#	1C350.41
GHS Pictogram	

41.2. Notable Features

Potassium bifluoride is a white crystalline solid. It may have a pungent odour.

41.3. Packaging

Appropriate packaging for potassium bifluoride includes plastic bottles, woven plastic bags, paper bags with internal plastic bags, plastic drums, and fibre drums with plastic liners.

41.4. Typical Applications

Potassium bifluoride can be used in the production of elemental fluorine, fluxes, wood preservatives, and glass. Potassium bifluoride can be used for surface treatment of metals and as a catalyst for alkylation reactions. It also serves as a fluorinating agent in the preparation of other fluorine compounds.

Global Production

- Brazil
- China
- Germany
- India
- Japan
- Poland
- Republic of Korea
- Spain
- United States

42. Ammonium Bifluoride

NH_4HF_2

42.1. Basic Description

Ammonium bifluoride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	1341-49-7
Formula	F_2H_5N
Molecular Weight	57.0
CA Index Name	Ammonium fluoride
CWC Schedule	Not Listed
EC#	215-676-4
HS#	2826.11 [Fluorides, of ammonium or of sodium]
UN#	UN 1727 (AMMONIUM HYDROGENDIFLUORIDE, SOLID) UN 2817 (AMMONIUM HYDROGENDIFLUORIDE SOLUTION)
UN Hazard Placard	UN 1727:  UN2817: 
Other Names	Acid ammonium fluoride; ammonium acid fluoride; ammonium difluoride; ammonium hydrogen bifluoride; ammonium hydrogen difluoride; ammonium monohydrogen difluoride; ammonium fluoride compound with hydrogen fluoride (1:1); ammonium hydrofluoride
EU CL#	1C350.42
GHS Pictogram	

42.2. Notable Features

Ammonium bifluoride is a white crystalline solid. It can be odourless or have an acidic and pungent odour when excess hydrogen fluoride is present. Solutions of ammonium bifluoride are colourless liquids with a slightly sharp, pungent odour.

42.3. Packaging

Multi-kilogram quantities of ammonium bifluoride are frequently packed in bags of various types (e.g., plastic, woven plastic, plastic-lined, paper with inner plastic bag). Fibre cartons might also be used. Small quantities are supplied in plastic bottles.

42.4. Typical Applications

Ammonium bifluoride can be used in acidifying oil wells, industrial cleaning applications (e.g., buildings, brick, and possibly boiler tubes), and glass frosting and polishing. Additional applications for this substance are in metallurgy, where it is used in metal pickling and other surface treatments. Ammonium bifluoride can also be used in industrial laundry and textile cleaning applications for pH adjustment. Manufacture of wood preservatives also is mentioned by some sources as a use for this chemical.

Global Production

- Australia
- Brazil
- China
- Germany
- India
- Japan
- Mexico
- Republic of Korea
- South Africa
- Spain
- Taiwan
- United States

43. Sodium Bifluoride

$NaHF_2$

43.1. Basic Description

Sodium bifluoride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	1333-83-1
Formula	F_2HNa
Molecular Weight	62.0
CA Index Name	Sodium fluoride
CWC Schedule	Not Listed
EC#	215-608-3
HS#	2826.11 [Fluorides, of ammonium or of sodium]
UN#	UN 2439 (SODIUM HYDROGENDIFLUORIDE)
UN Hazard Placard	
Other Names	Sodium hydrogen fluoride; sodium hydrogen difluoride; sodium acid fluoride
EU CL#	1C350.44
GHS Pictogram	 

43.2. Notable Features

Sodium bifluoride is a white crystalline solid. It may have a pungent odour.

43.3. Packaging

Common packaging for sodium bifluoride includes plastic woven bags with or without additional plastic liners. Multi-layered paper bags with inner plastic bags are also used. Other options include plastic-lined drums and fibre drums with inner plastic bags, as well as plastic bottles.

43.4. Typical Applications

Sodium bifluoride shares many applications with ammonium bifluoride. It is used in industrial laundry and textile cleaning applications, e.g. for pH adjustment and stain removal. It is also used in cleaning products for brick, stone, and masonry. Sodium bifluoride has metallurgical applications as well – it is used in metal plating and metal surface treatments. Sodium bifluoride finds additional applications in in glass etching and acts as a fluorinating agent in organic synthesis and inorganic preparations. It is also mentioned in connection with leather treatments, pest control, and the cement industry, but such uses do not appear to be common.

Global Production

- Australia
- Brazil
- China
- Germany
- India
- Japan
- South Africa
- Spain
- Taiwan
- United States

44. Sodium Fluoride

NaF

44.1. Basic Description

Sodium fluoride (NaF) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	7681-49-4
Formula	FNa
Molecular Weight	42.0
CA Index Name	Sodium fluoride
CWC Schedule	Not Listed
EC#	231-667-8
HS#	2826.11 [Fluorides, of ammonium or of sodium]
UN#	UN 1690 (SODIUM FLUORIDE, SOLID) UN 3415 (SODIUM FLUORIDE SOLUTION)
UN Hazard Placard	
Other Names	NaF; disodium difluoride; fluorid sodny; fluoride, sodium; fluorure de sodium; natrium fluoride; sodium fluorure; sodium monofluoride; trisodium trifluoride; hydrofluoric acid sodium salt; numerous common names such as Chemifluoro, Dentafluoro, and Villiaumite
EU CL#	1C350.43
GHS Pictogram	

44.2. Notable Features

NaF is a white to off-white crystalline solid.

44.3. Packaging

Like other inorganic fluoride salts, plastic containers are commonly used to package NaF. Plastic-lined bags, woven plastic bags (which may have an inner plastic lining), plastic pails, and plastic bottles are all suitable containers. Lined fibre or polyethylene drums for larger quantities are also used.

44.4. Typical Applications

The major, and most familiar, use of NaF is for the prevention of tooth decay; it is added to drinking water, toothpaste, and other dental products for this purpose. NaF can be used as a pesticide—it is often tinted blue or green for this application. There are numerous other applications for NaF, including use in glass and enamel production (e.g., frosting glass), fluxing/welding/soldering agents, aluminium production, metal surface treaments, and for pH adjustment in industrial laundries and textile processing. It also can have use as a wood preservative.

Global Production

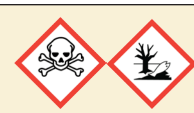
- Australia
- Belgium
- Brazil
- China
- Czech Republic
- Germany
- India
- Japan
- Mexico
- Poland
- Russia
- South Africa
- Spain
- Taiwan
- United Kingdom
- United States

45. Sodium Cyanide

Na–C≡N

45.1. Basic Description

Sodium cyanide (NaCN) is a nerve and blood agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	143-33-9
Formula	CNNa
Molecular Weight	49.0
CA Index Name	Sodium cyanide
CWC Schedule	Not Listed
EC#	205-599-4
HS#	2837.11 [Cyanides and cyanide oxides, of sodium]
UN#	UN 1689 (SODIUM CYANIDE, SOLID) UN 1935 (CYANIDE SOLUTION, N.O.S.) UN 3414 (SODIUM CYANIDE SOLUTION)
UN Hazard Placard	
Other Names	NaCN; cyanide of sodium; cianuro di sodio; cyanure de sodium; Cymag; hydrocyanic acid, sodium salt; kyanid sodny; natrium cyanide; Cyanobrik; Cyanogran; Prussiate of soda
EU CL#	1C350.45
GHS Pictogram	

45.2. Notable Features

NaCN is a white granular or powdered solid which some companies may press into brick- or pillow-shaped blocks (Figure 45.A) for dust reduction. It has a slight bitter-almond odour when moist, but is odourless when perfectly dry. It is also available commercially as 30% aqueous solutions.

45.3. Packaging

Small quantities of NaCN are packaged in glass, plastic, or plastic-coated bottles. Larger quantities may be supplied in steel or plastic drums, bags inside wooden boxes, or steel bins. Figure 45.B shows barrels and a box (with inner bag) of NaCN. Bulk quantities of NaCN are used by the mining industry, typically in 30% solutions of the compound in water. This “liquid sodium cyanide” often is shipped in stainless steel double-shelled trailers, railcars, or ISO containers. Solid NaCN in shipping containers that can be filled with

Figure 45.A. *Sodium cyanide “bricks”.*

water to prepare the solution at the mining site also are available from some companies. Figure 45.C shows returnable steel bins and an ISO container for NaCN.

Figure 45.B. *Bulk containers for NaCN. Left: Wooden box with inner bag; Right: Palleted steel drums.*

Figure 45.C. *Larger bulk containers for NaCN. Left: ISO container; Right: Returnable steel bin.*

45.4. Typical Applications

The primary use of NaCN is in the mining industry, with about 78% of the world's supply being consumed for gold and silver processing.[6] NaCN also has other roles in mining or metallurgy (e.g., electroplating, ore floatation, metal cleaning, and surface hardening),[7] as well as in the production of dyes and pigments, fumigants, pharmaceutical intermediates, and specialty chemicals.

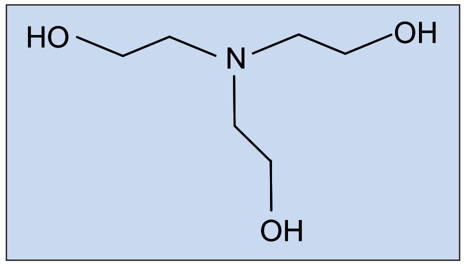
Global Production

- Australia
- Brazil
- China
- Czech Republic
- Georgia
- Germany
- India
- Japan
- Mexico
- The Netherlands
- Poland
- Republic of Korea
- Russia
- South Africa
- Spain
- Taiwan
- United Kingdom
- United States

[6] B. Suresh and T. Kumamoto, Abstract for "Sodium Cyanide," IHS (December 2012); http://chemical.ihs.com/CEH/Public/Reports/770.9000

[7] For example, see NICNAS, "Sodium Cyanide," Priority Existing Chemical Assessment Report No. 31 (February 2010); http://www.nicnas.gov.au/__data/assets/pdf_file/0018/4392/PEC_31_Sodium-Cyanide_Full_Report_PDF.pdf

46. Triethanolamine



46.1. Basic Description

Triethanolamine (TEA) is a nitrogen vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	102-71-6
Formula	$C_6H_{15}NO_3$
Molecular Weight	149.2
CA Index Name	Ethanol, 2,2',2"-nitrilotris
CWC Schedule	3B17
EC#	203-049-8
HS#	2922.13 [Triethanolamine and its salts]
UN#	Considered non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	2,2',2"-nitrilotriethanol; 2,2',2"-nitrilotris(ethanol); N(CH2CH2OH)3; nitrilotriethanol; TEA; TEA(amino alcohol); triethanolamin; tri(hydroxyethyl)amine; tris(2-hydroxyethyl) amine; tris(β-hydroxyethyl)amine; trolamine; numerous trade names
EU CL#	1C350.46
GHS Pictogram	Not applicable

46.2. Notable Features

TEA is a viscous colourless to pale amber liquid with a weak ammonia-like odour. It is typically sold in 85% or 99% solutions.

46.3. Packaging

TEA is packaged glass containers, steel or iron drums, or steel tanks. Plastic containers are also used.

46.4. Typical Applications

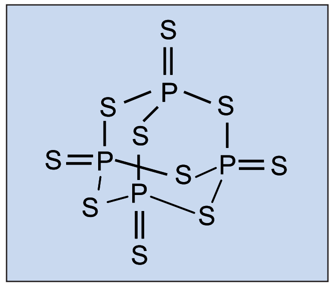
TEA is a widely-traded, high-volume industrial chemical with a wealth of commercial uses,[8] many stemming from its alkaline character, detergent properties, and ability to complex metals. TEA is used for surfactant production and finds extensive use in personal care products, including soaps, shampoos, hair styling products and dyes, skin cleansers, and cosmetics. It also is used in the textile industry in several capacities (e.g., finishing). The alkaline properties of TEA make it useful as an acid scavenger in natural gas processing and as a buffer or neutraliser in other applications. For metalworking applications, it is found in cutting fluids and lubricating oils. It also appears in anti-corrosion formulations. TEA is also used in down-hole oil wells to prevent corrosion of drilling eqipment. TEA has use in cement grinding aids and concrete additives; in the preparation of rubber, adhesive, agricultural, and photographic chemicals; and as a catalyst for the production of urethane foams.

Global Production

- Belgium
- Brazil
- Canada
- China
- France
- Germany
- India
- Iran
- Italy
- Japan
- Mexico
- Poland
- Republic of Korea
- Russia
- South Africa
- Spain
- Taiwan
- Thailand
- United Kingdom
- United States

[8] For example, see brochures posted at http://www.dow.com/amines/prod/ethano-tea.htm

47. Phosphorus Pentasulphide



47.1. Basic Description

Phosphorus pentasulphide is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	1314-80-3
Formula	P2S5 (exists as P4S10)
Molecular Weight	222.3 (444.6 for the dimer pictured above)
CA Index Name	Phosphorus sulfide
CWC Schedule	Not Listed
EC#	215-242-4
HS#	2813.90 [Sulfides of nonmetals, other]
UN#	UN 1340 (PHOSPHORUS PENTASULPHIDE, free from yellow and white phosphorus)
UN Hazard Placard	
Other Names	Diphosphorus pentasulfide; phosphoric sulfide; phosphorus pentasulfide; phosphorus sulfide (P4S10); phosphorus persulfide; tetraphosphorus decasulfide; pentasulfure de phosphore; sirnik fosforecny
EU CL#	1C350.47
GHS Pictogram	

47.2. Notable Features

Phosphorus pentasulphide is a yellow to green crystalline solid and has an odour of rotten eggs. It may be sold as a powder or flakes (Figure 47.A) or in tablets.

Figure 47.A. *Phosphorus pentasulphide powder and flakes*

47.3. Packaging

Small quantities of phosphorus pentasulphide are sold in glass bottles. Common bulk packaging consists of plastic-lined containers (e.g., lined steel drums), as well as simple metal drums or plastic bags in drums. Some major producers use aluminium tote bins for shipments; these bins often hold 2-3 metric tons of the material. These bins are often shipped in multiples, either strapped to truck trailers or encased in cages. Pictures of tote bins are shown in Figure 47.B.

Figure 47.B. *Aluminium tote bins used for shipping bulk quantities of phosphorus pentasulphide. The single bin on the left measures 218 cm × 112 cm × 132 cm and holds up to 2636 kilograms of the solid. The top right photograph shows a low-boy trailer hauling six tote bins, and the bottom right photograph shows a cage container for tote bins.*

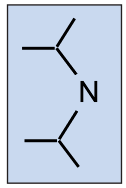
47.4. Typical Applications

Phosphorus pentasulphide is used in the production of lubricant additives, primarily zinc dialkyldithiophosphates. Other major applications are in the production of pesticides/insecticides and ore floatation agents. It also can be used to prepare specialty chemicals.

Global Production

- Chile
- China
- Germany
- India
- Italy
- United States

48. Diisopropylamine



48.1. Basic Description

Diisopropylamine (DIPA) is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	108-18-9
Formula	$C_6H_{15}N$
Molecular Weight	101.2
CA Index Name	2-propanamine, N-(1-methylethyl)-
CWC Schedule	Not Listed
EC#	203-558-5
HS#	2921.19 [Amine-function compounds, acyclic monoamines…, other]
UN#	UN 1158 (DIISOPROPYLAMINE)
UN Hazard Placard	
Other Names	N,N-Diisopropylamine; N-(1-methylethyl)-2-propanamine; DIPA; (iso-C3H7)2NH; N-isopropyl-1-amino-2-methylethane; N-isopropyl-isopropylamine
EU CL#	1C350.48
GHS Pictogram	

48.2. Notable Features

DIPA is a clear, colourless liquid with a fishy or ammonia-like odour.

48.3. Packaging

There are a number of packaging options for DIPA. Containers in use include glass bottles, polyethylene-coated bottles, and metal steel drums. Larger quantities can be shipped in railway tanks, tanker trucks, and ISO containers.

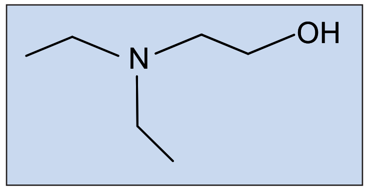
48.4. Typical Applications

DIPA is used in the manufacture of crop protection chemicals, pharmaceutical intermediates, polyester fibres, and rubber accelerators. It also is used as an extraction solvent and in the preparation of certain corrosion inhibitors, proton scavengers, and catalysts.

Global Production

- Belgium
- China
- France
- Germany
- India
- Israel
- Spain
- United States

49. Diethylaminoethanol



49.1. Basic Description

Diethylaminoethanol is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	100-37-8
Formula	$C_6H_{15}NO$
Molecular Weight	117.19
CA Index Name	Ethanol, 2-(diethylamino)-
CWC Schedule	Not Listed (Exempted under 2B11)
EC#	202-845-2
HS#	2922.19 [Oxygen-function amino-compounds, amino-alcohols…other]
UN#	UN 2686 (2-DIETHYLAMINOETHANOL)
UN Hazard Placard	
Other Names	DEAE; DEEA; 2-(diethylamino)ethanol; N,N-diethylaminoethanol; N,N-diethyl-2-aminoethanol; N-diethylaminoethanol; N-(diethylamino)ethanol; diethyl(2-hydroxyethyl)amine; N,N-diethyl-2-hydroxyethylamine; N,N-diethylethanolamine; N,N-diethylmonoethanolamine; 2-(diethylamino)ethanol; 2-(diethylamino)ethyl alcohol; 2-(N,N-diethylamino)ethanol; 2-hydroxytriethylamine; (2-hydroxyethyl) diethylamine; diaethylaminoaethanol; diethylethanolamine; 2-hydroxytriethylamine; N-(2-hydroxyethyl)diethylamine Note: 2 may be replaced with β in some names
EU CL#	1C350.49
GHS Pictogram	

49.2. Notable Features

Diethylaminoethanol is a colourless to faint yellow liquid with an ammonia-like odour.

49.3. Packaging

There are a number of packaging materials suitable for diethylaminoethanol, including glass bottles and steel drums.

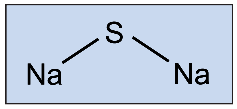
49.4. Typical Applications

The primary use of diethylaminoethanol is in corrosion inhibitors for boilers. It also is used in various coating formulations and to prepare soaps used in water-resistant waxes and polishes. Some sources claim it is an intermediate for making textile-related chemicals, pharmaceuticals, crop protection chemicals, explosives, dyes, and cosmetics, as well as in lubricants and resins.

Global Production

- Belgium
- China
- Germany
- India
- Japan
- United States

50. Sodium Sulphide



50.1. Basic Description

Sodium sulphide is a vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	1313-82-2
Formula	Na_2S
Molecular Weight	78.0
CA Index Name	Sodium sulfide
CWC Schedule	Not Listed
EC#	215-211-5
HS#	2830.10 [Sulfides…, sodium sulfides]
UN#	UN 1385 (SODIUM SULPHIDE, ANHYDROUS or SODIUM SULPHIDE with less than 30% water of crystallization) UN 1849 (SODIUM SULPHIDE, HYDRATED with not less than 30 per cent water)
UN Hazard Placard	UN 1385:  UN 1849: 
Other Names	Disodium monosulfide; disodium sulfide; sodium monosulfide; sodium sulfide
EU CL#	1C350.50
GHS Pictogram	

50.2. Notable Features

Sodium sulphide is a white to yellow, orange, or red solid with a rotten egg-like odour. It is often sold in flake form (Figure 50.A).

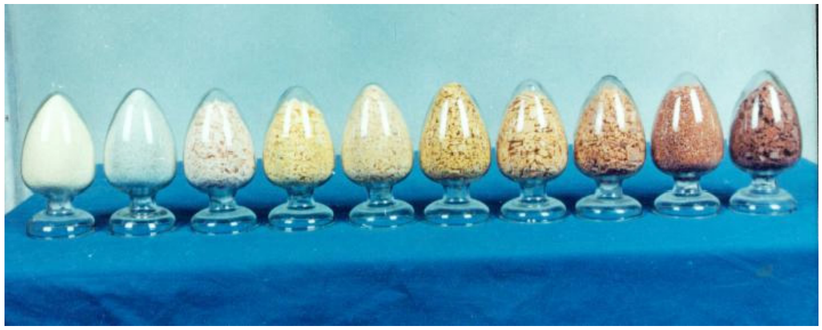


Figure 50.A. *Glass bulbs containing various grades of sodium sulphide.*

50.3. Packaging

Small quantities of sodium sulphide are typically packaged in glass or plastic bottles. Steel drums, paper bags, and plastic or plastic-lined bags are used for larger quantities.

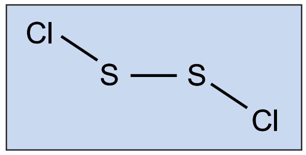
50.4. Typical Applications

Sodium sulphide finds its major application in the leather industry, where it is used to dehair hides before tanning. It also is used in the mining industry for ore floatation. In addition, sodium sulphide is used in the preparation of sulphur dyes, rubber, and plastics, as well as in the pulp & paper industry, among other applications. Some sources mention use in the treatment of waste water and remediation of soils.

Global Production

- Belgium
- Brazil
- China
- Colombia
- Germany
- India
- Iran
- Italy
- Japan
- Kazakhstan
- Mexico
- Republic of Korea
- Russia
- Spain
- Taiwan
- Ukraine
- United Kingdom
- United States

51. Sulphur Monochloride



51.1. Basic Description

Sulphur monochloride is a vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	10025-67-9
Formula	Cl_2S_2
Molecular Weight	135.0
CA Index Name	Sulfur chloride
CWC Schedule	3B12
EC#	233-036-2
HS#	2812.10 [Halides and halide oxides of nonmetals, chlorides and chloride oxides]
UN#	UN 1828 (SULPHUR CHLORIDES)
UN Hazard Placard	
Other Names	Sulfur monochloride; disulfur dichloride; sulfur chloride (S2Cl2); chlorosulfane; chlorschwefel; sulfur subchloride; thiosulfurous dichloride; S2Cl2; sulfur(I) chloride; chloride of sulfur; siarki chlorek; sulfur chloride(di); ClSSCl; sulfur mono
EU CL#	1C350.51
GHS Pictogram	

51.2. Notable Features

Sulphur monochloride is a yellow-orange to red oily liquid with a pungent, nauseating odour.

51.3. Packaging

Sulphur monochloride is shipped in tank cars, tank trucks, ISO containers, and metal drums. Small quantities are sold in glass bottles.

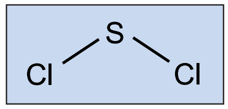
Global Production

- China
- Germany
- India
- Japan
- United States

51.4. Typical Applications

The primary commercial uses of sulphur monochloride are in the production of lubricant additives and vulcanising agents for rubber. Other end uses are in the production of gum erasers, and as an intermediate in the production of some dyes, pharmaceuticals, and agrochemicals. The OPCW notes additional uses in the manufacture of paper and textile auxiliaries, rubber additives and substitutes, and plastics.

52. Sulphur Dichloride



52.1. Basic Description

Sulphur dichloride is a vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	10545-99-0
Formula	Cl_2S
Molecular Weight	103.0
CA Index Name	Sulfur chloride
CWC Schedule	3B13
EC#	234-129-0
HS#	2812.10 [Halides and halide oxides of nonmetals, chlorides and chloride oxides]
UN#	UN 1828 (SULFUR CHLORIDES)
UN Hazard Placard	
Other Names	Sulfur dichloride; sulfur chloride (SCl2); chlorine sulfide (Cl2S); dichlorosulfane; monosulfur dichloride; SCl2; sulfur(II) chloride; chloride of sulfur; chlorine sulfide; sulfur chloride(mono); sulfur dichloride (scl2); dichloro sulfide
EU CL#	1C350.52
GHS Pictogram	

52.2. Notable Features

Sulphur dichloride is a dark red or brownish-red fuming liquid with a pungent odour.

52.3. Packaging

Sulphur dichloride could be shipped in in plastic barrels, tanks, ISO containers, or rail cars.

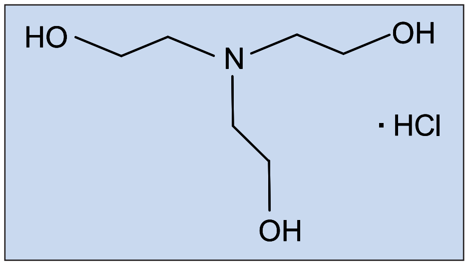
Global Production

- China
- Germany
- India
- United States

52.4. Typical Applications

Sulphur dichloride has applications similar to those of sulphur monochloride, most of which are related to lubricant additives, rubber and polymers, and crop protection chemicals. Major uses of sulphur dichloride are in the production of intermediates for insecticides and lubricant additives. The OPCW claims use in the production of captafol (Difolatan), a fungicide, as well as in rubber vulcanisation, modification of drying oils for varnishes and inks, and purification of sugar juices.

53. Triethanolamine Hydrochloride



53.1. Basic Description

Triethanolamine hydrochloride (TEA HCl) is a nitrogen vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	637-39-8
Formula	$C_6H_{15}NO_3$•ClH
Molecular Weight	185.65
CA Index Name	Ethanol, 2,2',2"-nitrilotris-, hydrochloride
CWC Schedule	Not Listed
EC#	211-284-2
HS#	2922.13 [Triethanolamine and its salts]
UN#	Considered non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	Triethanolammonium chloride; 2,2',2"-nitrilotriethanol hydrochloride; ethanol, 2,2',2"-nitrilotris-, hydrochloride; 2,2',2"-nitrilotris(ethanol) hydrochloride; ethanol, 2,2',2"-nitrilotri-, hydrochloride; 2,2',2-nitrilotris(ethanol) hydrochloride; TEA-HCl; 2-[bis(hydroxyethyl)amino]ethanol hydrochloride; tris(2-hydroxyethyl)amine hydrochloride; triethanolamine hydrochloric acid salt
EU CL#	1C350.53
GHS Pictogram	Not applicable

53.2. Notable Features

TEA HCl is a white crystalline powder.

53.3. Packaging

TEA HCl is packaged in glass or plastic containers.

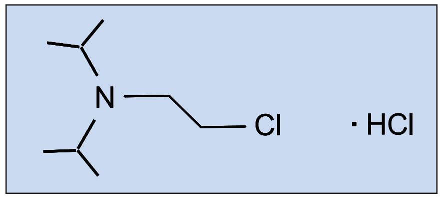
53.4. Typical Applications

TEA HCl may have use as a reagent for biological applications (e.g., buffers, protein purification) and as an additive in fluxes. Its limited availability suggests uses are small-scale.

Global Production

- Germany
- India
- Japan
- Poland
- United States

54. N,N-Diisopropyl-2-Aminoethyl Chloride Hydrochloride



54.1. Basic Description

N,N-Diisopropyl-2-aminoethyl chloride hydrochloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	4261-68-1
Formula	$C_8H_{18}ClN{\bullet}ClH$
Molecular Weight	200.15
CA Index Name	2-Propanamine, N-(2-chloroethyl)-N-(1-methylethyl)-, hydrochloride
CWC Schedule	2B10
EC#	224-238-1
HS#	2921.19 [Amine-function compounds, acyclic monoamines…, other]
UN#	UN 2811 (TOXIC SOLID, ORGANIC, N.O.S)
UN Hazard Placard	
Other Names	2-chloroethyldiisopropylammonium chloride; 2-diisopropylaminoethyl chloride hydrochloride; 2-(diisopropylamino)ethyl chloride hydrochloride; β-diisopropylaminoethyl chloride HCl; N-(2-chloroethyl)diisopropylamine hydrochloride; (diisopropylamino)ethylchloride hydrochloride
EU CL#	1C350.54
GHS Pictogram	

54.2. Notable Features

N,N-Diisopropyl-2-aminoethyl chloride hydrochloride is a white to light beige or tan crystalline powder. Some companies supply it in aqueous solution.

54.3. Packaging

Specific packaging information for this chemical was not found.

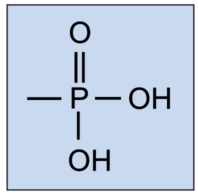
54.4. Typical Applications

N,N-Diisopropyl-2-aminoethyl chloride hydrochloride can be used in the synthesis of pharmaceuticals.

Global Production

- Armenia
- China
- France
- Germany
- India
- Japan
- United Kingdom
- United States

55. Methylphosphonic Acid



55.1. Basic Description

By analogy with other CWC Schedule 2B phosphorus compounds, methylphosphonic acid could be used to prepare nerve agents. It has the following identifiers and properties:

Identifier/Property	Value
CAS#	993-13-5
Formula	CH_5O_3P
Molecular Weight	96.0
CA Index Name	Phosphonic acid, methyl-
CWC Schedule	2B04
EC#	213-607-2
HS#	2931.90 [Other organo-inorganic compounds]
UN#	May be assigned UN 3261 (CORROSIVE SOLID, ACIDIC, ORGANIC, N.O.S.)
UN Hazard Placard	
Other Names	Methanephosphonic acid; phosphonic acid, methyl-; phosphonic acid, methyl-dihydrogen methylphosphonate, methylphsophonsäure; ácido metilfosfónico; acide méthylphosphonique
EU CL#	1C350.55
GHS Pictogram	

55.2. Notable Features

Methylphosphonic acid is a white solid.

Global Production

- France
- Germany
- United Kingdom
- United States

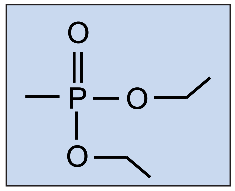
55.3. Packaging

Small quantities of methylphosphonic acid are sold in glass bottles.

55.4. Typical Applications

Little information was found on uses for methylphosphonic acid. The OPCW notes that a compound of methylphosphonic acid with (aminoiminomethyl)urea is used as a flame retardant and has applications in cleaning agents, emulsifiers, textile improvers, anticorrosion agents, and fabrics.

56. Diethyl Methylphosphonate



56.1. Basic Description

By analogy with other controlled phosphonates, diethyl methylphosphonate could be used to prepare nerve agents. It has the following identifiers and properties:

Identifier/Property	Value
CAS#	683-08-9
Formula	$C_5H_{13}O_3P$
Molecular Weight	152.1
CA Index Name	Phosphonic acid, methyl-, diethyl ester
CWC Schedule	2B04
EC#	211-667-4
HS#	2931.90 [Other organo-inorganic compounds]
UN#	Considered non-hazardous for transport
UN Hazard Placard	Not applicable
Other Names	DEMP; diethyl methanephosphonate; diethoxymethylphosphine oxide; O,O-diethyl methylphosphonate; methylphosphonic acid, diethyl ester; diethyl methylphosphonic acid; methanephosphonic acid diethyl ester; diethylmethylphosphonat; metilfosfonato de dietilo; méthylphosphonate de diéthyle
EU CL#	1C350.56
GHS Pictogram	

56.2. Notable Features

Diethyl methylphosphonate is a colourless liquid.

56.3. Packaging

Small quantities of diethyl methylphosphonate are sold in glass bottles.

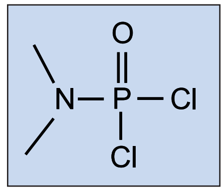
56.4. Typical Applications

Diethyl methylphosphonate can be used in the synthesis of other phosphonates.

Global Production

- Armenia
- China
- France
- Germany
- United Kingdom
- United States

57. N,N-Dimethylaminophosphoryl Dichloride



57.1. Basic Description

N,N-Dimethylaminophosphoryl dichloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	677-43-0
Formula	$C_2H_6Cl_2NOP$
Molecular Weight	162.0
CA Index Name	Phosphoramidic dichloride, dimethyl-
CWC Schedule	2B05
EC#	211-641-2
HS#	2929.90 [compounds with other nitrogen function, other]
UN#	UN 3265 (CORROSIVE LIQUID, ACIDIC, ORGANIC, N.O.S.)
UN Hazard Placard	
Other Names	Dimethylphosphorodichloride amide; dimethylphosphoramidic dichloride; (dimethylamido)phosphoric dichloride; dimethylamidophosphoric acid dichloride; dichlorophosphoric dimethylamide; dichloro(dimethylamino)phosphine oxide; phosphoramidic dichloride, dimethyl-; dichlorophosphoric dimethylamide; dimethylamidophosphoric acid dichloride; (dimethylamido)phosphoric dichloride; (dimethylamino)phosphonic dichloride; N,N-dimethylphosphoramidic dichloride; N,N-dimethylphosphoramidodichloridate; phosphoramidic dichloride, dimethyl-; dichloro-(dimethylamine)-phosphine oxide; dichlorophosphoric dimethylamide; N,N-dimethylamidophosphoric dichloride; (dimethylamine)-phosphoric dichloride; N,N-dimethylphosphoramidic dichloride; dimethylphosphorodichloridic amide; dimethylphosphoramiddichlorid; dichloruro dimetilfosforamídico; dichlorure diméthylphosphoramidque
EU CL#	1C350.57
GHS Pictogram	

57.2. Notable Features

N,N-Dimethylaminophosphoryl dichloride is a colourless to faint yellow liquid.

Global Production

- Armenia
- Germany
- United States

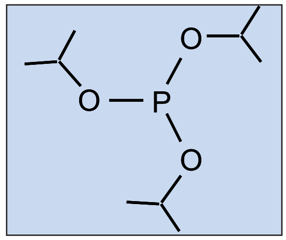
57.3. Packaging

Small quantities are sold in glass bottles.

57.4. Typical Applications

N,N-Dimethylaminophosphoryl dichloride could be used as a reagent in organic synthesis.

58. Triisopropyl Phosphite



58.1. Basic Description

By analogy with other controlled phosphites, triisopropyl phosphite (TIPP) could be used to prepare nerve agents. It has the following identifiers and properties:

Identifier/Property	Value
CAS#	116-17-6
Formula	$C_9H_{21}O_3P$
Molecular Weight	208.2
CA Index Name	Phosphorous acid, tris(1-methylethyl) ester
CWC Schedule	Not Listed
EC#	204-130-0
HS#	2920.90 [Esters of inorganic acids of nonmetals and their salts…other]
UN#	May be assigned UN 3278 (ORGANOPHOSPHORUS COMPOUND, TOXIC, LIQUID, N.O.S.) or UN 2810 (TOXIC LIQUID, ORGANIC, N.O.S.)
UN Hazard Placard	
Other Names	Isopropyl phosphite, tri-; phosphorous acid, triisopropyl ester; phosphorous acid, tris(1-methylethyl) ester; tri-2-propyl phosphite; tri-isopropyl phosphite; isopropyl phosphite ((C3H7O)3P)); tri-2-propylphosphite; tri-iso-propylphosphite; triisopropoxyphosphine; triisopropylphosphit; fosfito de triisopropilo; phosphite de triisopropyle; TIPP
EU CL#	1C350.58
GHS Pictogram	

58.2. Notable Features

TIPP is a colourless to pale yellow liquid with a pungent odour.

58.3. Packaging

TIPP could be sold in glass bottles or plastic drums.

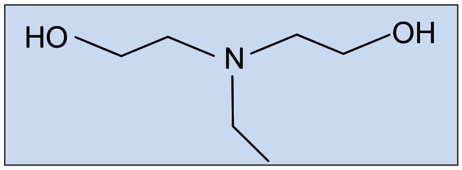
Global Production

- China
- Germany
- United Kingdom

58.4. Typical Applications

TIPP could be used in organic synthesis to prepare other phosphorus compounds.

59. Ethyldiethanolamine



59.1. Basic Description

Ethyldiethanolamine (EDEA) is a nitrogen vesicant precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	139-87-7
Formula	C6H15NO2
Molecular Weight	133.2
CA Index Name	Ethanol, 2,2'-(ethylimino)bis-
CWC Schedule	3B15
EC#	205-379-8
HS#	2922.19 [Amino-alcohols...other]
UN#	Considered nonhazardous for transport by most suppliers; some assign 2735 (AMINES, LIQUID, CORROSIVE, N.O.S.)
UN Hazard Placard	
Other Names	N-bis(2-Hydroxyethyl)-N-ethylamine; diethanolethylamine; ethanol, 2,2'-(ethylimino) bis-; ethanol, 2,2'-(ethylimino)di-; ethylamine, bis(2-hydroxyethyl)-; ethylbis(2-hydroxyethyl)amine; N-ethyldiethanolamine; N-ethyl-2,2'-iminodiethanol; 2,2'-(ethylimino)diethanol; 2-(N-ethyl-N-2-hydroxyethylamino)ethanol; N,N-bis(2-hydroxyethyl)ethylamine; 2-[ethyl-(2-hydroxy-ethyl)-amino]-ethanol; N-ethyldiethanolamine; ethyl diethanolamine; diethanolethylamine; ethylbis(2-hydroxyethyl)amine; N-ethyldiethanolamine; 2-(N-ethyl-N-2-hydroxyethylamino) ethanol; 2,2'-(ethylimino)bisethanol; N-ethyl-2,2'-iminodiethanol; 2,2'-(ethylimino) diethanol; N-ethyldiethanolamin; N-etildietanolamina; N-éthyldiéthanolamine; EDEA
EU CL#	1C350.59
GHS Pictogram	

59.2. Notable Features

EDEA is a colourless to light yellow liquid.

59.3. Packaging

Small amounts of EDEA are sold in glass bottles. Use of iron or mild steel/high molecular weight and high density polyethylene (HM HDPE) drums is possible. EDEA might be packaged in a way similar to that of other alkyl alkanolamines; see the entry on diethylaminoethanol for information on alkyl alkanolamine packaging.

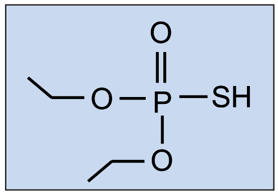
59.4. Typical Applications

The OPCW lists several uses of EDEA, including applications in the agricultural, cosmetic, detergent, metallurgical, plastics, and pharmaceutical industries. It is used as an intermediate in the production of pharmaceuticals, crop protection agents, and flocculants, as well as in the production of compounds for the paper and leather industries. EDEA also is used for removing acidic gases in gas purification methods. One supplier mentions use in coating applications. However, few of these uses were found in multiple sources.

Global Production

- Germany
- India
- Japan

60. O,O-Diethyl Phosphorothioate



60.1. Basic Description

Based on its chemical composition, O,O-diethyl phosphorothioate could be used to prepare nerve agents. It has the following identifiers and properties:

Identifier/Property	Value
CAS#	2465-65-8
Formula	$C_4H_{11}O_3PS$
Molecular Weight	170.2
CA Index Name	Phosphorothioic acid, O,O-diethyl ester
CWC Schedule	Not Listed
EC#	None
HS#	2920.10 [Thiophosphoric esters (phosphorothioates) and their salts…]
UN#	Unknown
UN Hazard Placard	Unknown
Other Names	O,O-Diethyl phosphorothionate; DETP; DETP (ester); DEPTh; diethyl hydrogen phosphorothionate; diethyl phosphorothionate; diethyl phosphothionate; ethyl phosphorothioate ((EtO)2(HS)PO); O,O-diethyl hydrogen phosphorothioate; O,O-diethyl phosphorothiolate; O,O-diethyl thiophosphate
EU CL#	1C350.60
GHS Pictogram	Unknown

60.2. Notable Features

No additional information on the properties of this material was found.

Global Production

- None found

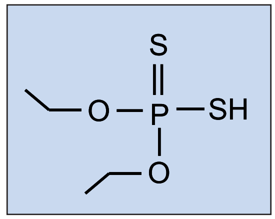
60.3. Packaging

No packaging information on this substance was found.

60.4. Typical Applications

O,O-Diethyl phosphorothioate could be used in organic synthesis.

61. O,O-Diethyl Phosphorodithioate



61.1. Basic Description

Based on its chemical composition, O,O-diethyl phosphorodithioate could be used to prepare nerve agents. It has the following identifiers and properties:

Identifier/Property	Value
CAS#	298-06-6
Formula	$C_4H_{11}O_2PS_2$
Molecular Weight	186.2
CA Index Name	Phosphorodithioic acid, O,O-diethyl ester
CWC Schedule	Not Listed
EC#	206-055-9
HS#	2920.10 [Thiophosphoric esters (phosphorothioates) and their salts…]
UN#	UN 3265 (CORROSIVE LIQUID, ACIDIC, ORGANIC, N.O.S.)
UN Hazard Placard	
Other Names	Diethyl dithiophosphate; diethyl phosphorodithioate; diethyl phosphorodithioic acid; phosphorodithioic acid, o,o'-diethyl ester; dithiophosphoric acid, O,O-diethyl ester; O,O-diethyl dithiophosphate; O,O-diethyl dithiophosphoric acid; O,O-diethyl hydrogen phosphorodithioate; O,O-diethyl phosphorodithioic acid; O,O-diethyl-S-hydrogen phosphorodithioate; O,O'-diethyl dithiophosphate; O,O'-diethyl hydrogen dithiophosphate; phosphonodithioic acid, O,O-diethyl ester; o,o-diethylphosphorodithioate; Kyselina O,O-diethyldithiofosforecna; phosphorothiothionic acid, o,o-diethyl ester; o,o-diethyl hydrogen dithiophosphate; phosphorodithioic acid O,O-diethyl ester; di-O-ethyl dithiophosphate; O,O-diethyl thiolothionophosphate; O,O-diethylhydrogendithiophosphate; O,O-diethylhydrogendithiophosphat; hidrogenditiofosfato de O,O-dietilo; hydrogénodithiophosphate de O,O-diéthyle
EU CL#	1C350.61
Hazards	TOXIC
GHS Pictogram	

61.2. Notable Features
O,O-Diethyl phosphorodithioate is a colourless to nearly colourless liquid with an unpleasant odour like rotten eggs.

Global Production
- China
- Germany
- India

61.3. Packaging
Small quantities of O,O-diethyl phosphorodithioate are sold in glass bottles. Larger amounts might be shipped in high molecular weight, high density polyethylene (HMHDPE) drums, stainless steel tankers, or ISO containers.

61.4. Typical Applications
O,O-Diethyl phosphorodithioate could be used in the manufacturing of pesticides.

62. Sodium Hexafluorosilicate

Na_2SiF_6

62.1. Basic Description

By analogy with other controlled fluorides, sodium hexafluorosilicate could be used to prepare nerve agents. It has the following identifiers and properties:

Identifier/Property	Value
CAS#	16893-85-9
Formula	F_6Na_2Si
Molecular Weight	188.1
CA Index Name	Silicate(2-), hexafluoro-, disodium
CWC Schedule	Not Listed
EC#	240-934-8
HS#	2826.20 [Fluorosilicates of sodium or of potassium]
UN#	UN 2674 (SODIUM FLUOROSILICATE)
UN Hazard Placard	
Other Names	Sodium fluosilicate; sodium silicofluoride; sodium fluorosilicate; disodium hexafluorosilicate; disodium silicofluoride; fluosilicate de sodium; natriumsilicofluorid; silicon sodium fluoride; sodium hexafluosilicate; sodium silicon fluoride; dinatriumhexafluorosilicat; hexafluorosilicato de disodio; hexafluorosilicate de disodium Note: products with earwig or weevil bait in the name may contain sodium hexafluorosilicate
EU CL#	1C350.62
GHS Pictogram	

62.2. Notable Features

Sodium hexafluorosilicate is a white crystalline or granular solid. It may be odourless or have a slight pungent odour.

62.3. Packaging

Sodium hexafluorosilicate is typically packaged in bags made of or lined with plastic. Small quantities are sold in plastic bottles.

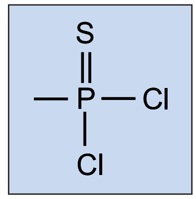
62.4. Typical Applications

Sodium hexafluorosilicate has numerous industrial uses. Like sodium fluoride, it has a major use in drinking water fluoridation. According to suppliers, sodium hexafluorosilicate also has applications in the following areas: enamel and glass (e.g., opalizing, etching); metallurgy; wood and leather preservation; and latex and foam manufacturing. Other uses common to fluoride salts may be possible, such as laundry souring.

Global Production

- Australia
- Belgium
- Brazil
- China
- Egypt
- India
- Japan
- South Africa
- Spain
- United States
- Vietnam

63. Methylphosphonothioic Dichloride



63.1. Basic Description

By analogy with other CWC Schedule 2B phosphorus compounds, methylphosphonothioic dichloride is a nerve agent precursor with the following identifiers and properties:

Identifier/Property	Value
CAS#	676-98-2
Formula	CH_3Cl_2PS
Molecular Weight	149.0
CA Index Name	Phosphonothioic dichloride, methyl-
CWC Schedule	2B04
EC#	211-636-5
HS#	2930.90 [Organo-sulfur compounds...other]
UN#	May be assigned UN 2927 (TOXIC LIQUID, CORROSIVE, ORGANIC, N.O.S.) or UN 3265 (CORROSIVE LIQUID, ACIDIC, ORGANIC, N.O.S.)
UN Hazard Placard	UN 2927:  UN 3265: 
Other Names	Dichloromethylphosphine sulfide; methanephosphonothioic dichloride; methyldichlorophosphine sulfide; methylphosphonothioyl dichloride; methylthionophosphonic dichloride; methylthiophosphonic acid dichloride; methylphosphonothiodichloride; methyl phosphonothioic dichloride; methylthiophosphonic dichloride; phosphine, dichloro-methyl-thioxo-; phosphonothioic dichloride, methyl-; methylthiophosphonsaeuredichlorid; dicloruro metilfosfonotioico; dichlorure méthylphosphonothioïque
EU CL#	1C350.63
GHS Pictogram	

63.2. Notable Features

Methylphosphonothioic dichloride is colourless to pale yellow liquid.

63.3. Packaging

No specific packaging information was found for this substance.

Global Production

- United States

63.4. Typical Applications

Methylphosphonothioic dichloride could be used in organic synthesis.

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Overview of Materials of Construction for Australia Group Chemical Manufacturing Equipment

Introduction

As discussed in the Introduction to Chemical Weapons and Dual-Use Chemical Technology, many CW agents and their precursors are highly corrosive compounds. Therefore, corrosion-resistant chemical processing equipment is suitable for CW production, and corrosion-resistance is a key characteristic of export-controlled chemical manufacturing equipment. Several corrosion-resistant materials of construction appear in the control specifications of items on the AG Control List of Dual-Use Chemical Manufacturing Facilities and Equipment. With a few exceptions, materials are repeated for numerous entries – for example, certain high nickel and nickel-chromium alloys appear in the specifications for every item on Part I of the list. This chapter examines some of the more commercially common AG-listed materials of construction which must comprise the wetted surfaces of chemical equipment for those items to be controlled. *This section is meant to give an illustrative overview of these materials and does not include every possible material that may meet control specifications*.

The Unified Numbering System for Metals and Alloys (UNS) is used in this Handbook as a point of reference for alloys. In general, there are multiple identifiers for alloys, and the UNS seeks to serve as a harmonised means of "correlating many internationally used metal and alloy numbering systems currently administered by technical societies, trade associations, and those individual users and producers of metals and alloys."[1] It should be noted that a UNS designation is not a specification. Rather, it is correlated with metal and alloy composition limits. A UNS designation takes the form of a letter followed by five digits: the letter denotes a family of metals/alloys, while the number ranges are associated with the base metal of the alloy. These designations are used throughout this section for metals and alloys appearing in AG control specifications.

High Nickel and Nickel-Chromium Alloys

Two types of nickel alloys appear in the list of materials of construction for every item on Part I of the Dual-Use Chemical Manufacturing Facilities and Equipment list: (1) Nickel or alloys with more than 40% nickel by weight; and (2) alloys with more than 25% nickel and 20% chromium by weight. There are numerous alloys that meet these criteria. Trade names for such "high nickel" alloys include Hastelloy®, Inconel®, Incoloy®, Monel®, and Nickelvac®, among others. However, it should be noted that there are many different alloys associated with each of these trade names, and not all of them necessarily meet the composition guidelines of the AG control specifications. Specific composition information from a manufacturer generally will be necessary to determine whether the material meets AG specifications. UNS numbers starting with N indicate nickel-base alloys.

Nickel alloys are useful in numerous corrosive applications. While chemical resistance varies from one alloy to another, resistance to acids, chlorine-containing chemicals, and sea water is exhibited by many nickel alloys meeting AG specifications.

Table 1 gives an illustrative (not exhaustive) list of high nickel and nickel-chromium alloys and their compositions, focused on those typically used in the chemical process industries. These materials were selected from material supplier websites that list nickel alloys used in chemical processing equipment.[2,3]

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1 *Metals & Alloys in the Unified Numbering System*, 10th Edition, Society of Automotive Engineers and American Society for Testing and Materials (Warrendale, PA: 2004)

2 Special Metals, "Chemical Processing;" http://www.specialmetals.com/chemical.php; see also the "Product Handbook of High-Performance Alloys" at http://www.specialmetals.com/general.php

3 Haynes International, "Corrosion Resistant Alloys;" http://www.haynesintl.com/CRAlloys.htm

***Table 1.** Examples of high nickel and nickel-chromium alloys, with weight percentages from Metals & Alloys in the Unified Numbering System, 10th Edition.*

UNS	%Ni	%Cr	Trade Name(s)	Notes
N02200	99.0 min	–	Nickel 200; AL 200	
N02201	99.0 min	–	Nickel 201; AL 201	Differs from N02200 in carbon content
N04400	63.0-70.0	–	Monel Alloy 400; Nickelvac 400; AL 400	
N04405	63.0-70.0	–	Monel Alloy R-405	
N05500	63.0-70.0	–	Monel Alloy K-500; Nickelvac K-500	
N06022	50.0 min	20.0-22.5	Hastelloy Alloy C-22; Inconel Alloy 22; AL 22	*
N06030	30.2 min	28.0-31.5	Hastelloy G-30	*
N06200	51.0 min	22.0-24.0	Hastelloy C-2000	*
N06455	58.8 min	14.0-18.0	Hastelloy C-4	*
N06600	72.0 min	14.0-17.0	Inconel Alloy 600; Nickelvac 600; AL 600	
N06601	58.0-63.0	21.0-25.0	Inconel Alloy 601; Nickelvac 601, AL 601; Carlson Alloy C 601	
N06625	55.9 min	20.0-23.0	Inconel Alloy 625; Nickelvac 625; Haynes 625; AL Altemp 625; AL 625 HP	*
N06686	49.5 min	19.0-23.0	Inconel Alloy 686	*
N06690	58.0 min	27.0-31.0	Inconel Alloy 690; Nickelvac 690	
N06950	50.0 min	19.0-21.0	Inconel Alloy 50; Hastelloy G-50	
N07718	50.0-55.0	17.0-21.0	Inconel 718; Allvac 718, Haynes 718 alloy; Altemp 718; Alloy 718	
N07725	55.0-59.0	19.0-22.5	Inconel Alloy 725	
N07750	70.0 min	14.0-17.0	Inconel Alloy X-750; Nickelvac X-750; Altemp X-750	
N08020	32.0-38.0	19.00-21.00	Incoloy alloy 020; AL 20; Nickelvac 23; Carpenter 20Cb-3 Stainless Steel	
N08800	30.0-35.0	19.0-23.0	Incoloy alloy 800; Nickelvac 800; Industeel Sirius 800; Stainless Steel Type 332; AL 800	
N08825	38.0-46.0	19.5-23.5	Incoloy alloy 825; Nickelvac 825; AL 825; Alloy 825	
N08926	24.0-26.0	19.0-21.0	Incoloy alloy 25-6Mo; Industeel Uranus B26 6 Mo	
N09925	38.0-46.0	19.5-23.5	Incoloy alloy 925; Nickelvac 925	
N10003	64.8 min	6.0-8.0	Hastelloy N; Nickelvac H-N	*
N10276	51.0 min	14.5-16.5	Hastelloy C-276; Inconel alloy C-276; Nickelvac 276; AL 276	*
N10665	64.8 min	1.0 max	Hastelloy B-2; Nickelvac HB-2; Alloy B-2	*
N10675	65.0 min	1.0-3.0	Hastelloy B-3	

* = %Ni calculated from maximum percentage of all other constituents, rounded to one decimal place. Trade names were identified with the assistance of the UNS search engine at http://www.matweb.com/search/SearchUNS.aspx.

Reactive Metals: Tantalum, Titanium, Zirconium, Niobium, and their Alloys

Tantalum, titanium, zirconium, and niobium are known as "reactive metals" – metals that react with oxygen to form protective, corrosion-resistant oxide layers on their surfaces. The term exotic metal is also used for these materials, although this descriptor can refer to high nickel alloys as well. These metals and their alloys appear in the UNS by base element under section Rxxxxx, in the ranges noted in their respective paragraphs below. The AG does not specify composition limits for these alloys as it does for nickel and nickel-chromium alloys. Rather, all tantalum, titanium, zirconium, and niobium *base* alloys are of relevance for control, per the AG chemical equipment control list's Technical Note:

For the listed materials in the above entries, the term 'alloy' when not accompanied by a specific elemental concentration is understood as identifying those alloys where the identified metal is present in a higher percentage by weight than any other element.

All four reactive metals and their alloys are listed as a material of construction in the control specifications for reaction vessels; agitators; storage tanks, containers, or receivers; heat exchangers or condensers; distillation or absorption columns; valves; multi-walled piping; and pumps.

Titanium

Titanium alloys are often indicated by the chemical symbol for titanium, Ti, in alloy names listing elemental composition. There are several grades of "commercially pure" titanium – often designated by Grade numbers (i.e., Ti Grade # or simply Grade #) – as well as titanium alloys. Grade 2 is the most widely used form of titanium. Titanium equipment is used in power plants, chemical plants, oil refineries, desalination plants, liquid natural gas (LNG) plants, and offshore platforms due to its resistance to aggressive chemicals such as hydrochloric, phosphoric, nitric, sulphuric, and organic acids; bleach; wet and anhydrous chlorine; alkaline solutions; chlorine dioxide; salt brines; hydrogen sulphide; inorganic salts; and fresh and sea water. Titanium base alloys have UNS designators in the range R50001-R59999.

Tantalum

The corrosion resistance of tantalum is often described as being comparable to glass. Like other reactive metals, it shows high resistance to acid corrosion. Tantalum is used in applications involving hydrochloric, sulphuric, nitric, phosphoric, and strong organic acids, as well as bromine and pharmaceuticals. It can be used to make heat exchangers, condensers, reaction vessels, columns, and valve linings, among other equipment.

Tantalum base alloys have UNS designators in the range R05001-R05999. The chemical symbol for tantalum is Ta, which may appear in names for tantalum alloys. Examples of tantalum base alloys are Tantalum 2.5% Tungsten (97.5Ta-2.5W; Ta2.5W; Tantalum-Tungsten 2.5%; KBI-6®); Tantalum 10% Tungsten (90Ta-10W; Ta10W; KBI-10®); and Tantalum 40% Niobium (60Ta-40Nb; Ta40Nb; KBI-40®). All three can be used as materials of construction for chemical processing equipment of various types.

Zirconium

Zirconium alloys find substantial use in the chemical process industries due to their resistance to corrosion by most acids (organic and inorganic), alkaline environments, urea, chloride salt solultions (including sea water), and hydrogen peroxide. Zirconium is considered to be one of the materials most resistant to corrosion by acetic acid, and it shows good resistance to nitric, sulphuric, hydrochloric, and formic acids as well. Zirconium base alloys have UNS designators in the range R60001-R69999. Four zirconium alloys often used for chemical processing are ASTM grades Zr702, Zr704, Zr705, and Zr706 – as with other reactive metals, the chemical symbol for zirconium, Zr, is incorporated into the alloy name and is an indicator of the element's presence as an alloy base.[4] Zircadyne® is a trade name for some zirconium alloys used in chemical processing equipment.

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[4] Richard Sutherlin, "Zirconium, Anyone;" http://www.chemicalprocessing.com/articles/2003/261.html

Niobium (Columbium)

A number of niobium alloys are available, but many of their predominant uses are in aerospace, nuclear, and superconductivity applications rather than in the chemical process industries. However, niobium can be used to make condensers, heat exchangers, and valve linings and finds use in the production of nitric acid and nitric acid-derived chemicals.[5] Niobium also resists corrosion by several other mineral and organic acids, certain organic solvents, and chlorine. Niobium base alloys have UNS designators in the range R04001-R04999. The chemical symbol for niobium is Nb, which appears in several alloy names. However, some names may reflect an archaic name sometimes used in the United States, columbium (Cb). Niobium alloys include niobium 1% zirconium (also known as one niobium alloy, Nb-1Zr, Nb-Zirc, Niobium-Zirc, Niobium Zirconium, Niobium - 1 Zirconium, NB-1%Zr, or Niobium 1% Zirc, or Nb1Zr), C-103, C-129Y, Cb-752, C-3009, Niobium 7.5% Tantalum (Nb7.5 Ta®), and Niobium 47% Titanium (Nb47Ti®).

Ferrosilicon (High Silicon Iron Alloys)

Ferrosilicon is a name for alloys of iron containing higher silicon levels than simple cast iron. It is also known as silicon iron, high-silicon iron, or by trade names such as Duriron™, Durichlor™, Superchlor™, and Siguss®. It is highly resistant to sulphuric acid, leading to its primary use in sulphuric acid-related applications. It also shows resistance to nitric acid, hydrochloric acid, and many other aggressive media. A brochure on high-silicon iron alloys notes use of these materials in the following applications: petroleum refining; sewage disposal; metal processing, including cleaning and pickling; electroplating; sulphuric and nitric acid production; manufacturing of explosives (acid-handling), textiles, paper, beverages, paint, pigments, dyes, and fertilisers; and in water treatment and fertiliser plants.[6] Ferrosilicon is only found in the control specifications for pumps in the AG chemical equipment control list.

Fluoropolymers

Fluoropolymers are highly corrosion-resistant, fluorine-containing polymeric or elastomeric materials. Fluoroplastics are relatively high molecular weight, moldable polymers which have some or all hydrogen atoms replaced with fluorine atoms. They look much like other plastics and can come in a variety of colours. Fluoroelastomers are fluorinated synthetic rubbers which often find use in sealing applications. Fluoropolymers are popular for applications requiring high purity as well as corrosion-resistance, such as those in the semiconductor, pharmaceutical, and food industries. Other uses of fluoropolymer equipment include metallurgy (plating, pickling, and other finishing operations) and deionised water handling and processing. Fluoropolymers are often referred to by trade names and/or acronyms as a substitute for their long scientific names.

Fluoropolymers are listed as a material of construction in the control specifications for reaction vessels; agitators; storage tanks, containers, or receivers; heat exchangers or condensers; distillation or absorption columns; valves; multi-walled piping; and pumps. AG control language covers polymeric and elastomeric materials with more than 35% fluorine by weight. Some of the more common fluoropolymers meeting this specification are listed in Table 2 by their acronyms, with their associated scientific and trade names. The fluoropolymers in the table were selected based on their use in chemical applications. The examples given are fluoroplastics – while fluoroelastomers such as those of the Viton® family can meet control specifications, they appear to be used in sealing applications more than as wetted parts for equipment. Interchangeable seals for controlled chemical equipment do not influence an item's control status, per Note 3 of the AG chemical equipment control list.[7]

5 Grandview Materials, "Applications of Niobium in Different Industries"; http://www.grandviewmaterials.com/product/niobium-industry

6 Flowserve Corporation, "Duriron and Durichlor 51M"; http://www.flowserve.com/files/Files/Literature/Foundry/materials%20literature/bulletin_A2.pdf

7 Note 3 states: "The materials used for gaskets, packing, seals, screws, washers or other materials performing a sealing function do not determine the status of control of the items listed below, provided that such components are designed to be interchangeable."

Table 2. *Examples of fluoroplastics used in chemical applications*

Acronym	Technical Name	Associated Trade Name(s)	%wt F†
ECTFE	Ethylene chlorotrifluoroethylene	Halar®	39
ETFE	Ethylene tetrafluoroethylene	Tefzel®, Neoflon®, Dyneon™, Fluon®	59
FEP	Fluorinated ethylene propylene	Teflon®, Dyneon™, Neoflon®	76
PFA	Perfluoroalkoxy (vinyl ether)	Teflon®, Hyflon®, Dyneon™, Neoflon®, Fluon®	76
PCTFE	Polychlorotrifluoroethylene	Neoflon®	49
PTFE	Polytetrafluoroethylene	Teflon®, Algoflon®, Fluon®, Dyneon™ TFM™	76
PVDF	Polyvinylidine fluoride	Kynar®, Dyneon™, Solef®, Hylar®	59

†Fluorine weight percentages were calculated from the molecular weights of the respective monomers. For copolymers, percentages were calculated based on 1:1 monomer ratios for ECTFE and FEP and a 100:1 tetrafluoroethylene:perfluoroalkoxy monomer ratio.

Glass (including Vitrified or Enamelled Coating)

Glass is a familiar material used in laboratory scale chemical equipment like beakers and reflux condensers, but it is impractical for larger-scale equipment due to its fragility. As a result, glass-lined steel equipment has found use in several industrial sectors because it combines the inertness, cleanability, and non-stick properties of glass with the structural integrity of steel. Glass coatings for steel equipment can come in a number of formulations for different applications, and are often blue or white (see Figure 1.1.E). Glass-lined steel equipment finds use in industries such as pharmaceuticals and fine chemicals. It can show excellent resistance to a variety of chemicals, including many acids. Glass is listed as a material of construction in the control specifications for reaction vessels; agitators; storage tanks, containers, or receivers; heat exchangers or condensers; distillation or absorption columns; valves; multi-walled piping; and pumps.

Graphite and Carbon-Graphite[8]

Graphite exhibits high corrosion-resistance and excellent thermal conductivity, giving it a wide variety of uses in temperature control applications involving corrosive substances (e.g., heat exchangers). A number of companies manufacture chemical equipment made of impregnated or impervious graphite; fluoropolymers and carbon are examples of impregnants used in this material. Sectors using graphite equipment include fine chemicals, pharmaceuticals, petrochemicals, pesticides, and those processing acids (hydrochloric, sulphuric, hydrofluoric, phosphoric, chlorinated organic, and waste acids). Carbon-graphite also finds use in mechanical seals for pumps. Graphite and carbon graphite are listed as materials of construction in the control specifications for heat exchangers or condensers; distillation or absorption columns; multi-walled piping; and pumps.

Ceramics

Ceramics of various types are listed as materials of construction in the control specifications of heat exchangers or condensers; valves; pumps; and incinerators. The pump and incinerator entries do not identify specific ceramics, but the other entries name silicon carbide (heat exchangers or condensers and valves), titanium carbide (heat exchangers or condensers), aluminium oxide (alumina; valves), and zirconium oxide (zirconia; valves) as controlled materials of construction. This section discusses characteristics of the carbide and oxide ceramics found in the control specficiations.

8 This material carries the following technical note in the AG specifications: “Carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.”

Carbides

Silicon carbide is a ceramic with high thermal conductivity, strength, hardness, and corrosion resistance, making it well suited for use in equipment such as heat exchanger tubes and blocks. These properties, its resistance to wear and shock, and the low friction it exhibits against other materials also make it a useful material for mechanical seal faces for pumps. It exhibits resistance to corrosion by nitric and hydrofluoric acids, mixed acids, bases, chlorinated organics, bromine, and oxidants. Silicon carbide is also known by its chemical formula SiC, and Hexoloy® is one trade name for this material. Titanium carbide (TiC) has similar characteristics as silicon carbide – e.g., hardness and resistance to corrosion, high temperature, and wear. However, its use in chemical processing applications appears to be less common than that of SiC. Both carbides can have a range of colours, although manufactured components are likely to be brown, grey, or black.

Oxides

Aluminium oxide (alumina; Al_2O_3) and zirconium oxide (zirconia; ZrO_2) are also durable, highly corrosion-resistant ceramics. Aluminium oxide shows broad chemical resistance, with the exception of wet fluorine, hydrofluoric acid, phosphoric acid, and strongly alkaline solutions. Aluminium oxide is usually white, but may also be brown or pink. Zirconium oxide is commonly stabilised with other oxides such as magnesia (MgO), yttria (Y_2O_3), or calcia (CaO) for structural integrity at a range of temperatures. It is chemically resistant to nearly all acids, bases, solvents, and other corrosive chemicals. Zirconium oxide is white to ivory in colour.

Control List of Dual-Use Chemical Manufacturing Facilities and Equipment and Related Technology and Software

The following sections provide basic descriptions of and information on the notable features, packaging, and typical applications of items on the Australia Group Control List of Dual-Use Chemical Manufacturing Facilities and Equipment and Related Technology and Software. Each section also includes an illustrative "Global Production" listing, which lists countries that are home to the headquarters of equipment producers. Those producers may have subsidiaries in other countries, but subsidiary locations are not included in these lists. The text in the blue boxes at the beginning of each equipment section provides the AG control language as of its February 2014 revision.[9] Brief discussions of related technology and software follow the sections on equipment.

The complete AG control language as of February 2014 is found in Appendix B. Sections in this chapter are numbered to match the respective AG control list entry numbers. See the Glossary for technical terms used in this Handbook.

[9] The current AG control language may be found online at: http://www.australiagroup.net/en/dual_chemicals.html

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I. Manufacturing Facilities and Equipment

1. Reaction Vessels, Reactors or Agitators

Reaction vessels or reactors, with or without agitators, with total internal (geometric) volume greater than 0.1 m^3 (100 l) and less than 20 m^3 (20000 l), where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;
(b) alloys with more than 25% nickel and 20% chromium by weight;
(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
(d) glass or glass-lined (including vitrified or enamelled coating);
(e) tantalum or tantalum alloys;
(f) titanium or titanium alloys;
(g) zirconium or zirconium alloys; or
(h) niobium (columbium) or niobium alloys.

Agitators designed for use in the above-mentioned reaction vessels or reactors; and impellers, blades or shafts designed for such agitators, where all surfaces of the agitator or component that come in direct contact with the chemical(s) being processed or contained are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;
(b) alloys with more than 25% nickel and 20% chromium by weight;
(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
(d) glass or glass-lined (including vitrified or enamelled coating);
(e) tantalum or tantalum alloys;
(f) titanium or titanium alloys;
(g) zirconium or zirconium alloys; or
(h) niobium (columbium) or niobium alloys.

1.1. Chemical Reaction Vessels or Reactors

1.1.1. Basic Description

Chemical reaction vessels, or reactors, are key pieces of industrial equipment used in chemical synthesis. Reaction vessels provide containment for chemicals undergoing reactions as well as provisions for fluid transfer, mixing, vessel maintenance, and monitoring and controlling reaction conditions. Chemical reaction vessels may be described using a variety of terms, depending on the details of their design and/or application. Examples include: jacketed reactors, Limpet coil reactors, half-pipe reactors, inner coil reactors, dimpled reactors, process reactors, batch reactors, pressure reactors, pressure vessels, and continuous flow or continuous stirred reactors.

Global Production

- Canada
- China
- France
- Germany
- India
- Italy
- Japan
- The Netherlands
- Switzerland
- United States

1.1.2. Notable Features

Reaction vessels are available in a wide variety of sizes and designs with varying levels of sophistication. However, all reaction vessels have some basic features in common. In general, reaction vessels are cylindrical in shape with slightly curved (convex) ends. The main body of the vessel usually is smooth or bears helical ridges. In the latter case, the helices are indicative of coils incorporated into the vessel for circulation of a temperature control fluid. Jacketed vessels without externally-visible coils are also common; these reactors incorporate a space between outer and inner vessel walls for temperature control fluids (Figure 1.1.A). Such vessels have smooth outer surfaces but typically have inlet and outlet ports (connections) on the side of the vessel for the temperature control fluid. Alternatively, the outer surface of the vessel may be dimpled. Figure 1.1.A displays a cutaway view of a typical batch reaction vessel with an agitator and a cooling jacket.

Figure 1.1.B shows two reaction vessels with different external surfaces. Both reactors have agitators mounted on them, as indicated by the green arrows. A chemical production facility is likely to use multiple reaction vessels. Vessels will not necessarily have the agitators mounted for sale or shipping (e.g., see Figure 1.1C). However, reaction vessels *with or without* agitators are controlled if they meet AG specifications on volume and material of construction.

Figure 1.1.A. *Cut-away view of a chemical reaction vessel with a cooling jacket, showing agitator shaft and blades. The connections on the sides of the vessel allow for cooling fluid to circulate between the inner and outer vessel walls.*

Figure 1.1.B. *Chemical reaction vessel designs with agitators. The green arrows are pointing to the agitator motors protruding from the tops of the vessels. Left: 500 litre glass-lined reactor with welded top head and smooth sides; Right: Reactors with visible temperature control coils and bolted top heads.*

The top of the vessel, called the top head, may be welded or clamped. In the latter case, a ring of bolts will be visible around its circumference; this feature can be seen clearly in two of the reactors in Figure 1.1.C. The top head will also have a series of ports or nozzles of various sizes. A typical vessel will have a large port called a manway or manhole, which provides access to the interior of the vessel for maintenance. The manway may be hinged or bolted and may also have a sightglass (or space for one) in its centre for viewing the vessel interior. Other smaller ports, often flanged, are found in a ring with the manway on the top head of the vessel. A port in or near the centre of the top head is typically present for mounting an agitator. Conversely, the vessel may have the agitator already mounted, in which case a motor assembly would be seen protruding from the top of the vessel, as seen in Figure 1.1.A. Figure 1.1.D displays multiple views of a 100 gallon (~ 378 litre) Hastelloy C-276 reactor – the agitator mount, manway, ports, and bolted top head are clearly visible in these photographs.

Figure 1.1.C. *Left: 6000 litre glass-lined vessel; Centre: Hastelloy C-276 half-pipe reactor; Right: 450 litre fluoropolymer-lined reactor.*

Other common features of reaction vessels are mounting plates around the side of the vessel and a drain valve or port on the bottom. The bottom of the vessel may also have legs attached (Figure 1.1.B) or provisions for mounting legs. The reactor may also have internal structures such as baffles that would not be visible unless one or more of the ports was open.

AG control specifications for reaction vessels specify an internal volume between 100 litres and 20000 litres. This range suggests that a controlled reactor could vary in size from half of a standard chemical drum to a few metres in diameter and/or length. The remaining control specifications give requirements for the material of construction of reactor surfaces coming into contact with chemicals. The material is likely not apparent upon visual inspection; however, if one or more ports is open, a non-metallic lining like glass or polymer might be visible. For example, the left and right images of Figure 1.1.C show white glass and fluoropolymer linings, respectively. Glass linings for steel vessels would have an enamel-like appearance and are often blue or white in colour (Figure 1.1.E). However, vessels should bear nameplates (e.g., the reactor in Figure 1.1.D) which can at least provide a manufacturer and model number for gaining additional information.

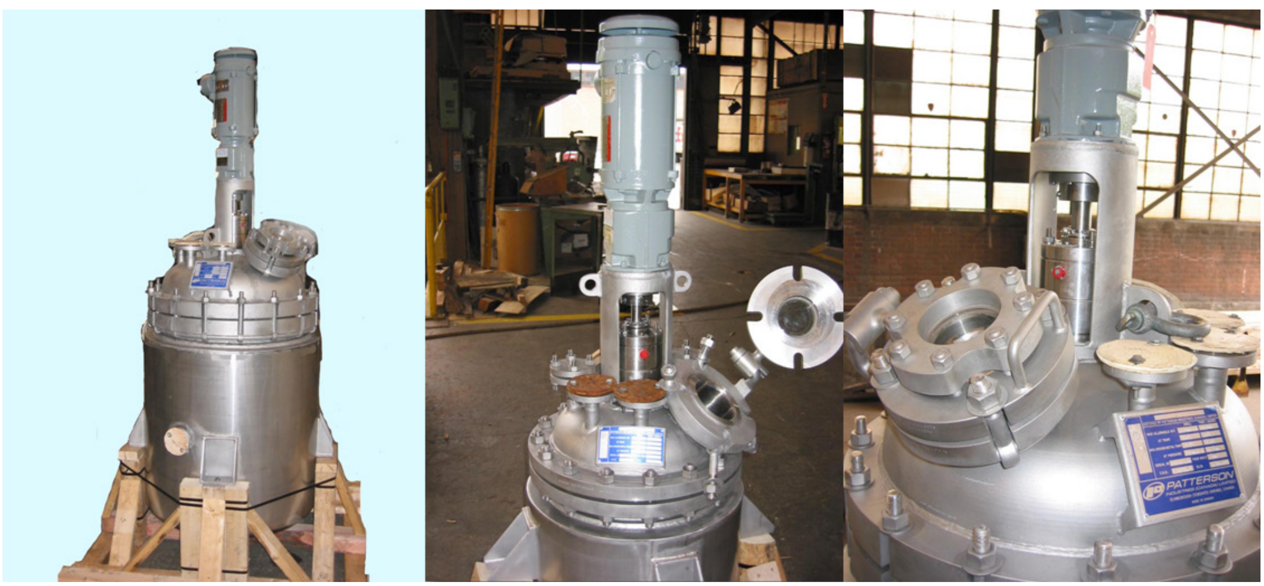

Figure 1.1.D. *100 gallon (~378 litre) Hastelloy C-276 reaction vessel.*

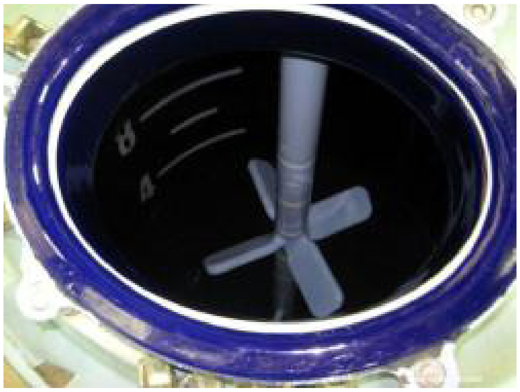

Figure 1.1.E. Glass-lined vessel and agitator.

Many reaction vessels bear a similarity to storage tanks and receivers, as well as fermenters (Volume II) used in the bioprocess industries. See the respective Handbook sections for more information on those items.

1.1.3. Packaging

The specific means of packaging depends on the size of the reactor. In any case, the reactor ports should be covered for shipping to avoid contamination of the vessel. Figure 1.1.F shows large vessels strapped to trailers for shipping; note the caps on the ports of all reactors and the wrapped agitator motor in the centre photograph. Smaller vessels may be secured in form-fitting pallets like the one in Figure 1.1.D (left) or possibly inside crates.

Figure 1.1.F. *Reaction vessels with sealed ports strapped to trailers for shipment. The image on the left is a Zirconium 702-clad reactor. Note: the volume and – by extension – the control status of these reaction vessels is unknown.*

1.1.4. Typical Applications

Many industries have use for reaction vessels meeting AG specifications. Such industries include pharmaceuticals, fine chemicals, chlor-alkali, and those handling acids. The proper choice of material of construction depends on the specific chemicals and process conditions, so not all AG materials of construction are suitable for all corrosive conditions. See the materials of construction section for examples of chemical compatibility with AG-listed materials.

1.2. Agitators

1.2.1. Basic Description

Agitators stir chemical mixtures to promote thorough, uniform mixing within reaction vessels. For this reason, they are also called mixers, although this term applies to a wider variety of equipment than just agitators. Many agitators resemble a hand-held blender, but on a scale appropriate for mixing large quantities of chemicals – namely, controlled agitators are designed for use in controlled reactors with internal volume between 100 and 20000 litres and have corrosion-resistant wetted surfaces.

Global Production

- China
- France
- Germany
- India
- Italy
- The Netherlands
- United States

1.2.2. Notable Features

As a complete unit, agitators are composed of a drive mechanism (motor with mount, and potentially a gearbox and variable speed drive); a shaft for extending down into the reaction mixture; and one or more impellers (blade sets) for stirring. Figure 1.2.A shows a series of complete agitators with different types of motors and mounting options. A C-clamp might be used on portable agitators (e.g., for attachment to a tank rim), like the left agitator in Figure 1.2.A. It is not clear, however, that such agitators would be suitable for use in a controlled reaction vessel, as opposed to a simple tank, since agitators must be designed for controlled reactors to be controlled. Flanged or plate mountings are more common for reaction vessels or tanks. There may be provisions for mounting the agitator at an angle for improved mixing in vessels without internal baffles; such a wedge-shaped mount is visible in the right agitator in Figure 1.2.A.

Figure 1.2.A. *Complete agitators with a variety of motor and mounting options. Left: Gear drive motor with C-clamp mount; Centre: Belt drive motor with flanged mount; Right: Gear drive motor with angle riser and plate mount.*

Agitators also may be sold without motors, i.e. as attached impeller-shaft sets like those shown later in this section (see Packaging). Impellers and shafts may be sold separately from each other as well. The AG specifications control impellers, blades, and shafts for controlled agitators separate from motors, in addition to complete agitator units. However, agitator motors alone do not meet AG control requirements.

Impellers come in several designs and are chosen for a given application based on the properties of the chemicals that need to be mixed (e.g., viscosity and phase). The AG does not specify any particular impeller design for control. It should be noted that impellers for agitators are generally different in appearance from impellers for pumps; pump impellers often have a solid disk on one side rather than blades open on both sides. However, agitators for controlled pumps also can be controlled.

Basic multi-blade impeller designs induce radial flow or some combination of radial and axial flow for relatively low viscosity fluids. The simplest design is the flat blade impeller, which may have from two to eight blades; a four-blade design is the most common. In this configuration, the blade surfaces are aligned parallel to the shaft and may be open type or disc type (Figure 1.2.B far left and centre left, respectively). The open type has the blades attached to the impeller hub, while the disc type has blades attached to a disc which is in turn fastened to the hub; one example of the latter is the Rushton turbine pictured in Figure 1.2.B. Both of these impeller designs also can be made with curved instead of flat blades. Another variation of the flat blade design is the pitched blade impeller, in which the blades are tilted at an angle to the agitator shaft (Figure 1.2.B centre right). A more sophisticated variation is the hydrofoil impeller, which is particularly efficient (i.e., induces more flow for less power). Figure 1.2.B shows examples of these basic designs.

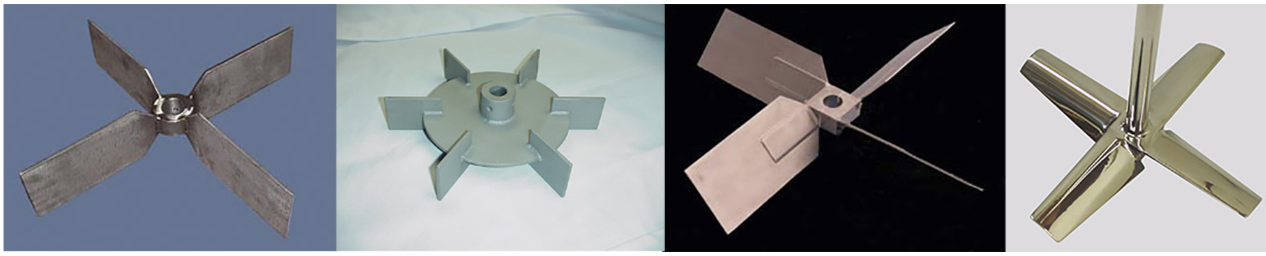

Figure 1.2.B. *Radial and axial flow impellers. From left to right: vertical flat-blade turbine; Rushton turbine; 45° pitched blade turbine; hydrofoil blades.*

More unusual, and often complicated, impeller designs are available, typically for use with viscous mixtures such as polymers. The simplest of these is the anchor impeller. Double helix ribbon-type impellers or screw (auger) impellers also are useful for high viscosity applications. Figure 1.2.C displays some impeller designs used in high viscosity applications.

Shafts bearing multiple impellers are necessary for effectively mixing chemicals in large, tall vessels. Figure 1.2.D shows a glass-lined double-impeller agitator.

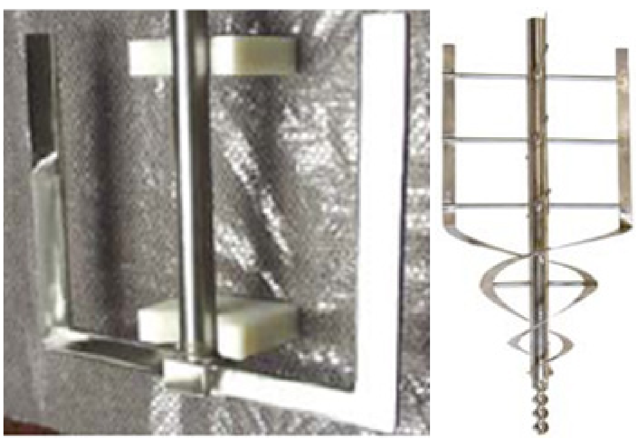

Figure 1.2.C. *Agitators for high-viscosity applications. Left: Anchor type; Right: Hybrid helix anchor design.*

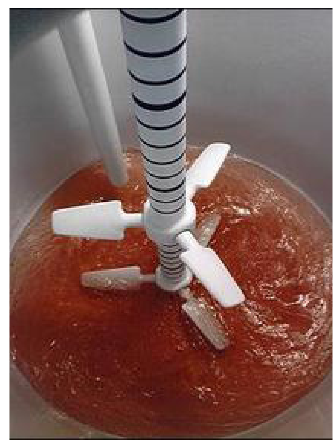

Figure 1.2.D. *Glass-lined agitator shaft with two sets of impellers. A baffle can be seen to the upper left of the agitator shaft.*

1.2.3. Packaging

There are a variety of packaging options for agitators, depending on their size, durability, and the combination of components shipped. Figure 1.2.E shows a pallet-mounting option for complete agitators, which can vary somewhat depending on the motor design and impeller size. Agitator shafts with attached impellers often are crated. For large agitator shaft-impeller combinations, a narrower crate might be used for the shaft with a larger attached crate to fit the impeller blades. Smaller units may be shipped in a one-sized crate. Pictures of such crates are shown in Figure 1.2.F. Separately-supplied components such as shafts or impellers likely would be shipped in boxes or crates, or on pallets with appropriate cushioning. Figure 1.2.G shows some examples of agitator shafts and impellers ready for shipping.

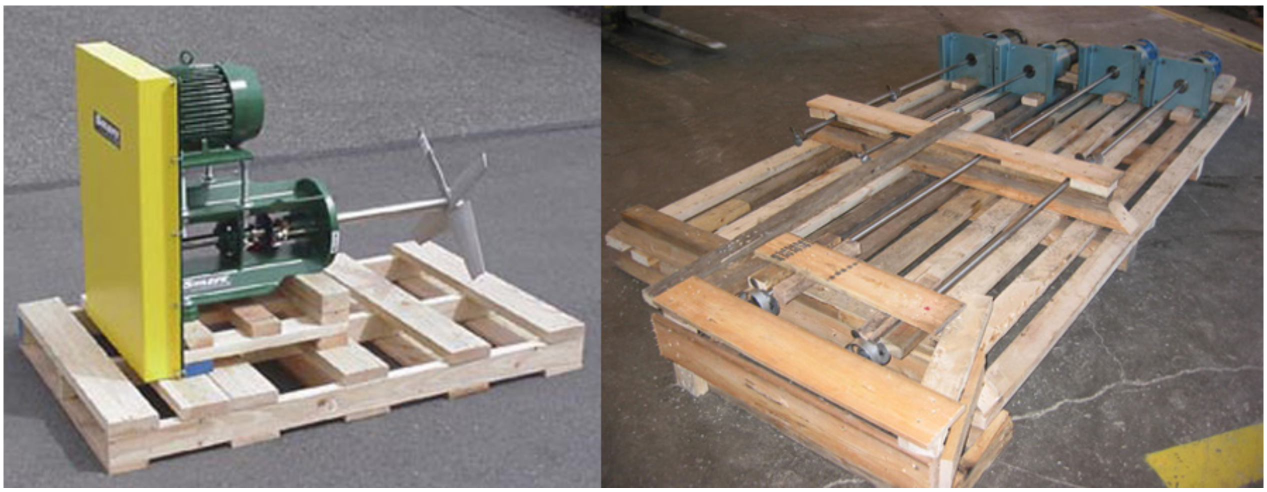

Figure 1.2.E. *Complete agitator units secured to pallets.*

Figure 1.2.F. *Crated agitator shaft-impeller units. Left: Crate with larger box to accommodate impeller. Centre: Protectively-wrapped glass-lined impeller; Right: View of wrapped and shaft in a one-size crate.*

1.2.4. Typical applications

Industries using agitators made of or lined with AG-listed corrosion-resistant materials are the same as those using the corresponding corrosion-resistant chemical reaction vessels. These industries include but are not limited to chlor-alkali, pulp and paper, pharmaceuticals, fine chemicals, and sectors producing or processing acids. The material used for the agitator wetted surfaces would likely be matched to that of the reactors, or at least have comparable chemical resistance.

Figure 1.2.G. *Agitator components ready for shipping. Top: Pitched-blade impeller; Bottom: Agitator shafts.*

2. Storage Tanks, Containers or Receivers

Storage tanks, containers or receivers with a total internal (geometric) volume greater than 0.1 m^3 (100 l) where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) tantalum or tantalum alloys;

(f) titanium or titanium alloys;

(g) zirconium or zirconium alloys; or

(h) niobium (columbium) or niobium alloys.

2.1. Basic Description

As their names imply, storage tanks and containers are holding vessels for chemicals. Depending on their design details, such vessels could also serve as mixing tanks or rudimentary reaction vessels, or play other roles in the chemical process industries. Receivers are also holding vessels, but this term usually applies to a container for collecting chemicals after a processing operation – for example, collecting a distilled chemical after condensation of the purified vapour.

Global Production

- Canada
- China
- France
- Germany
- India
- Italy
- Unitied States

2.2. Notable Features

Storage tanks are usually cylindrical vessels that may be used in a horizontal or vertical orientation; storage tanks may also be designed for above- or below-ground use. The ends of a storage tank may be curved (convex), flat, or conical. Figure 2.A shows photographs of some basic storage tank designs. While most tanks are cylindrical, rectangular designs are also found (Figure 2.A, top right).

Vertical tanks and receivers often resemble reaction vessels. Besides having cylindrical vessels, common features to tanks, receivers, and reactors are welded or bolted heads, manways, and drain ports. Tanks might also be jacketed and agitated (or have a mount for an agitator) to prevent settling of the contents. Receivers and tanks may also have legs attached to them. However, in their basic designs, tanks and receivers usually have fewer ports than reaction vessels, and these ports may have a different configuration than those typically seen on reactor heads. In addition, reaction vessels more commonly have dished (convex) heads, whereas the curvature of receiver heads can be less pronounced. Figure 2.B shows some examples of simple receivers. However, it should be noted that more elaborate tanks and receivers may closely resemble reactors.

The control list entry also refers to "containers," a rather vague descriptor that could encompass a wide variety of barrels/drums, tote bins, and other intermediate bulk containers (IBCs). They would be controlled as long as they have wetted surfaces comprised of the materials in the control specifications and sufficient capacity. One example of such a container is the fluoropolymer-lined IBC shown in Figure 2.A (bottom right). Like reaction vessels, a distinct nonmetallic lining might be visible for glass- or fluoropolymer-lined tanks, provided some access to the interior is possible in physical inspection.

Figure 2.A. *Simple storage tanks and containers. Top left: Glass-lined horizontal tank; Top right: Zirconium alloy storage tank; Bottom left: Glass-lined vertical tank; Bottom right: Fluoropolymer-lined IBC.*

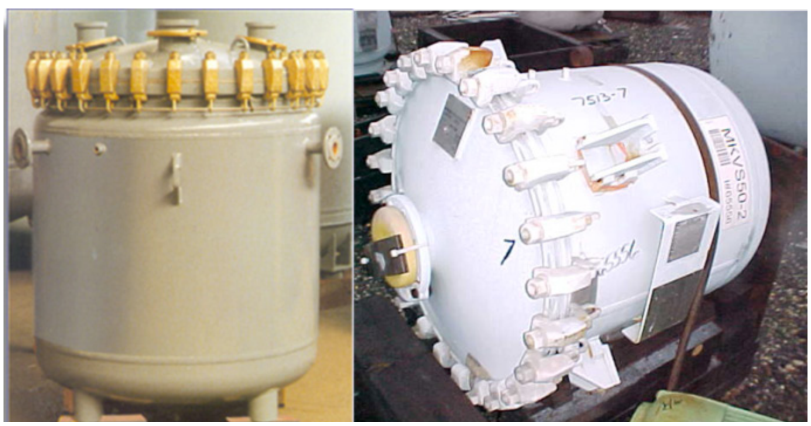

Figure 2.B. *Glass-lined receivers*

2.3. Packaging

Like reaction vessels, tanks and receivers can be shipped strapped to pallets or trailers, in each case with their ports covered to prevent contamination. A tank prepared for shipping is shown in Figure 2.C.

Figure 2.C. *Storage tank ready for shipping.*

2.4. Typical Applications

Numerous sectors of the chemical industry have uses for storage tanks, containers, and receivers made of materials in the AG control specifications. Among them are the pharmaceutical, fine chemical, petrochemical, and food processing industries, as well as sectors that handle strong acids and caustics. See the section on corrosion-resistant materials of construction for information on chemical compatibility with materials found in the control specifications.

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3. Heat Exchangers or Condensers

Heat exchangers or condensers with a heat transfer surface area of greater than 0.15 m^2, and less than 20 m^2; and tubes, plates, coils or blocks (cores) designed for such heat exchangers or condensers, where all surfaces that come in direct contact with the chemical(s) being processed are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) graphite or carbon-graphite;

(f) tantalum or tantalum alloys;

(g) titanium or titanium alloys;

(h) zirconium or zirconium alloys;

(i) silicon carbide;

(j) titanium carbide; or

(k) niobium (columbium) or niobium alloys.

Technical note: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

3.1. Basic Description

Heat exchangers and condensers are used to control or change the temperature of various process streams in chemical operations. Both of these devices exchange heat using temperature control fluids, but they perform different functions. Heat exchangers are used to control the temperature of reaction mixtures, chemical feeds, or products, while condensers can be used to collect chemicals from a process such as distillation by condensing them from the gas to the liquid phase. To prevent mixing of the two fluids involved in the temperature control process (and thereby prevent cross-contamination), the fluids are physically separated from one another by thermally-conductive tubes, plates, or blocks. In the case of controlled equipment, these structures will be made of or lined with the corrosion-resistant materials identified in the control language. While functionally different, heat exchangers and condensers often look very similar; they may also be called reboilers, evaporators, liquid-liquid exchangers, gas coolers, or vapour condensers depending on their specific use. This section will refer to these items collectively as heat exchangers, noting visually unique aspects of condensers as applicable.

Global Production

- Canada
- China
- France
- Germany
- India
- Italy
- Japan
- The Netherlands
- Sweden
- Switzerland
- United Kingdom
- United States

3.2. Notable Features

Heat exchangers and condensers come in a wide variety of designs, but all share some common physical features. First, they will have pairs of fluid connections for the chemical stream of interest ("process chemicals") and the temperature-controlling fluid. Second, they will be composed of a series of thermally-conductive barriers to keep the process chemicals and temperature-controlling fluid physically separated. Four common types of heat exchangers are coil, shell and tube, plate and frame, and block designs.[1] The following subsections address each type. It should be noted that the component coils, tubes, plates, and blocks are also subject to control when designed for use in a controlled heat exchanger or condenser.

Coil Designs

Figure 3.A shows a series of coil heat exchanger and condenser designs. Due to the heat transfer area requirements of the AG control specifications, small and/or simple coil designs are less likely to be controlled than larger units. There are several variations on this type of design: coil or "double-pipe" heat exchangers consist of concentric coils (Figure 3.A, left), while coil condensers are composed of a coil within a larger shell (Figure 3.A, centre and right). It should be noted that simple glass-in-glass reflux condensers used in university laboratories (Figure 3.A, centre) are typically too small to meet the heat transfer area specification given by the AG. However, larger reflux condensers over approximately 0.5 m in length with internal glass coils may meet this requirement. These coil designs should be distinguished from simple immersion coils (heaters), which would not be considered heat exchangers.

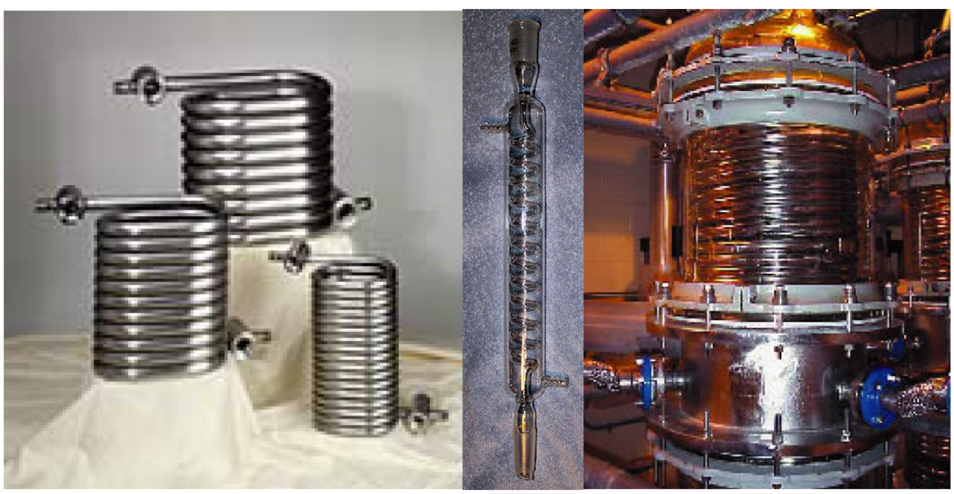

Figure 3.A. *Heat exchanger/condenser designs based on coils. Left: Coil-within-a-coil design; Centre: Glass reflux condenser; Right: Alloy coil condenser.*

Shell and Tube Designs

Shell and tube heat exchangers (also known as tube heat exchangers) are the most common design used in the chemical process industries. As its name implies, the shell and tube heat exchanger is comprised of a bundle of tubes encased in a cylindrical shell, which often contains baffles to encourage flow of the shell-side fluid around the tubes. The tubes are attached at one or both ends to a tube sheet, which stabilises them and seals them against the fluid flowing in the shell. The shell will have inlet-outlet pairs of fluid connections that may appear in a variety of configurations, either on the same or opposite sides of the shell. The heat exchanger may also come with end caps called "heads." The Tubular Exchanger Manufacturers Association (TEMA) maintains standards for shell and tube heat exchanger designs, including head configurations.[2] Shell and tube heat exchangers should also have nameplates, which typically bear

[1] Others, such as spiral heat exchangers, are also available.

[2] A figure depicting different head and shell configurations can be found at the TEMA website, http://standards.tema.org/images/HeatExchangerNomenclature.pdf.

the manufacturer's name, a model number, and operating temperature and pressure ranges. In the case of equipment manufactured to TEMA standards, there should also be a TEMA plate. Figure 3.B shows a variety of shell and tube heat exchangers with some detailed views of tube bundles. Tubes designed for controlled heat exchangers are also controlled according to the AG specifications.

Figure 3.B. *Shell and tube heat exchangers. Top left: U-shaped tube bundle made from high-nickel Alloy 625; Top centre: End view of a tantalum tube sheet; Top right: Heat exchanger with silicon carbide tube bundle and glass shell; Bottom left: Tantalum heat exchangers with a variety of sizes, tube arrays, and fluid connections; note the heads with fluid connections on the palletted heat exchangers. Bottom right: Heat exchanger with fluoropolymer tube bundle pulled out.*

Figure 3.C displays a schematic of fluid flow in a shell and tube heat exchanger. Often with corrosive chemicals, the chemical mixture of interest will be sent through the tube bundle because it can be less expensive to make a tube set out of corrosion-resistant materials than it is to construct both the shell and tubes of such materials. In any case, the tube material of construction will be important for control status. Dimensions of controlled shell and tube heat exchangers vary due to variations in the number and dimensions of tubes that can be placed inside shells, which impacts the heat transfer area.

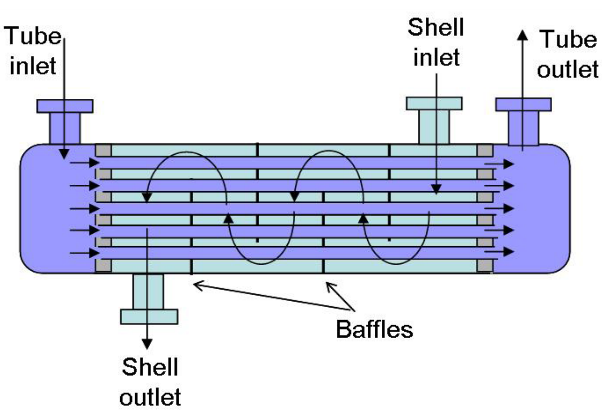

Figure 3.C. *Schematic of a shell and tube heat exchanger showing fluid flows.*

Plate and Frame Designs

Plate and frame heat exchangers are also known simply as plate heat exchangers. They are composed of a series of thin, corrugated plates pressed together in a frame, forming a series of liquid channels that are sealed by gaskets, welds, or a combination of both. Plate and frame heat exchangers come in four basic types: gasketed, welded, semi-welded, or brazed, which refer to the connections between the plates that provide seals so that the hot and cold fluids do not intermix. However, brazed heat exchangers are typically made of stainless steel plates with copper or nickel brazing and are therefore less likely to be controlled.

Like the other heat exchanger designs, plate and frame models have pairs of fluid inlets and outlets that may be on the same or opposite sides of the frame, depending on the specific requirements of the process. The ports typically will be located at the corners of the frame. Ports may be threaded, studded, flanged, or sanitary connections. These heat exchangers are likely to have a nameplate prominently mounted on the frame. Figure 3.D shows some examples of plate and frame heat exchangers. A plate and frame condenser may have a large vapour inlet port that would distinguish it from a plate and frame heat exchanger.

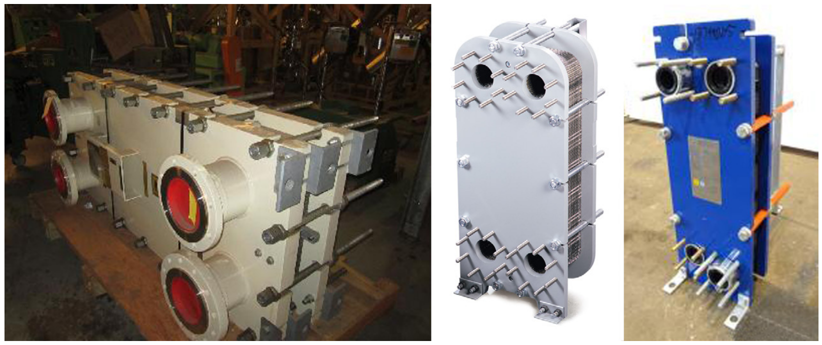

Figure 3.D. *Examples of plate and frame heat exchangers with flanged (left) and studded (centre and right) connections.*

Plates for these heat exchangers are typically very thin; graphite plates may be ~ 1 cm or less in thickness, while some suppliers claim that 0.5 mm thickness is a typical dimension for metal plates. Double-wall plates are also available, which may be thicker because they incorporate a thin airspace between a set of plates and therefore allow for extra protection against plate failures. Plates are corrugated, usually with a herringbone or chevron pattern, to induce turbulent flow over the plates for better heat transfer, increase the surface area of the plates, and increase the strength and rigidity of the unit.[3] Plates designed for controlled heat exchangers are also controlled according to AG specifications.

Plate and frame designs are also used for condensation and evaporation applications. Such units may be visually distinguishable from typical plate and frame heat exchangers by unusual fluid/steam connections. The presence of connections allowing gas/liquid as opposed to liquid/liquid operations is a clue to use in condensation or evaporation applications instead of simple temperature control.

Plate and frame heat exchangers are typically more compact than shell and tube heat exchangers. Therefore, plate and frame heat exchangers may meet the AG heat transfer area specification in a smaller unit than a shell and tube design.

Block Heat Exchangers

Block heat exchangers consist of a core of material that has fluid channels drilled through it, surrounded by a housing with fluid connections. Figure 3.E shows examples of block heat exchangers and a component block (core). Housings for block heat exchangers may be rectangular or cylindrical; cylindrical housings will therefore resemble shell and tube heat exchangers, but with a ring of bolts around one of the end plates as seen in Figure 3.E (left). Likewise, blocks can be cylindrical or have square or rectangular cross-sections, and blocks designed for controlled heat exchangers are also controlled as individual components. Of the materials of construction in the control list entry, graphite and silicon carbide are the most likely materials to be used in block heat exchangers.

[3] Images of heat exchanger plates can be found in product brochures. For example, see SGL Group, “Plate Heat Exchangers”; http://www.sglgroup.com/cms/_common/downloads/products/product-groups/pt/pt_downloads_new/SGL-PT-Brochure-Graphite_Plate_Heat_Exchangers.pdf

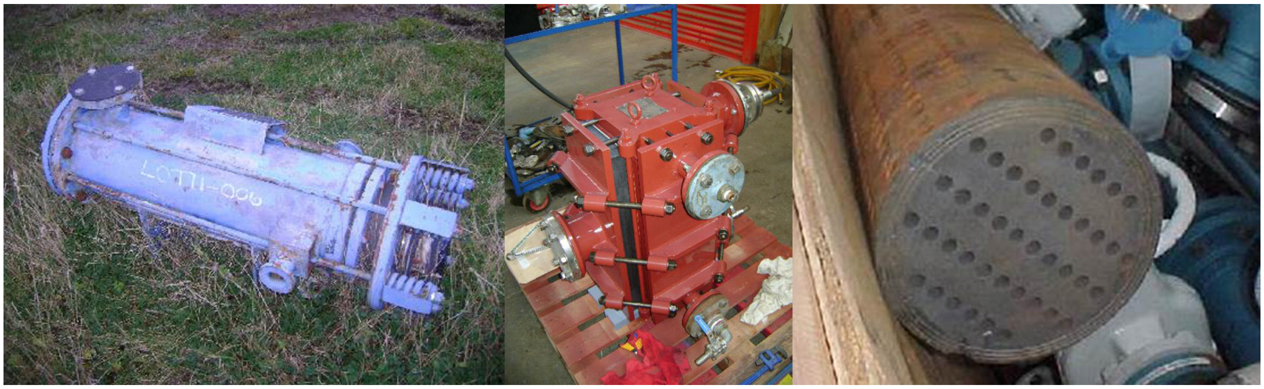

***Figure 3.E.** Graphite block heat exchangers. A cylindrical block (core) for a heat exchanger is pictured on the right.*

3.3. Packaging

Depending on their size and durability, heat exchangers may be strapped to pallets or secured in crates for shipping. Ports should be capped for shipping to prevent contaminants from entering the heat exchanger. Large heat exchangers might be strapped to flatbed trucks, with special cradles for holding the unit. Figure 3.F shows shell and tube heat exchangers and condensers in different types of packaging.

***Figure 3.F.** Packaging for shell and tube heat exchangers, condensers, and tube bundles. For final shipment, the heat exchanger on the left would probably have its ends sealed to prevent debris from entering the tube bundle. The units on the far right are condensers, the left and centre left units are heat exchangers, and the centre right image is of a tube bundle."*

3.4. Typical Applications

Heat exchangers are ubiquitous. They can be found practically anywhere heating or cooling of fluids is required. Because of the material requirement in the AG specifications, the range of applications of controlled heat exchangers is somewhat narrower than the full set of possible applications. However, there are still a wide variety of legitimate uses of controlled heat exchangers and condensers. See the materials of construction section for information on what sectors that might use controlled heat exchangers or condensers constructed from a given material.

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4. Distillation or Absorption Columns

Distillation or absorption columns of internal diameter greater than 0.1 m; and liquid distributors, vapour distributors or liquid collectors designed for such distillation or absorption columns, where all surfaces that come in direct contact with the chemical(s) being processed are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) graphite or carbon-graphite;

(f) tantalum or tantalum alloys;

(g) titanium or titanium alloys;

(h) zirconium or zirconium alloys; or

(i) niobium (columbium) or niobium alloys.

Technical note: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

4.1. Basic Description

Distillation and absorption columns are key pieces of equipment for chemical separations. These are devices in which liquids and gases are contacted to either enrich the vapour phase with a desired product (distillation) or selectively absorb gases into a solvent (absorption). A useful primer on distillation that discusses the anatomy of columns can be found at the Newcastle University Chemical and Process Engineering Web Server.[1]

Global Production

- Canada
- China
- France
- Germany
- India
- Italy
- The Netherlands
- Switzerland
- United States

4.2. Notable Features

Distillation and absorption columns are tall cylindrical vessels containing internal structures that enhance the interaction between the liquid and vapour inside the column. The outer appearance is that of a column with multiple ports. They have a somewhat similar appearance to shell and tube heat exchangers, but are typically much longer than their diameters[2] and can bear more ports than just the pair of inlets and outlets that would be needed for a standard shell and tube heat exchanger. When in operation, they are installed vertically and are sometimes called “stacks.” For columns, ports are not only used for material transfer; large columns will also include manways to provide access for installing column internals. Distillation columns also can come in multiple sections to be connected, for example, by bolts, clamps, or tie-rods. The column may also have fins around its circumference for mounting guide rails or platforms. The interior of the column will be filled or “packed” with various structures that facilitate the distillation process. Figure 4.A displays pictures of typical packed distillation columns with a simplified schematic showing some typical internal components. Absorption columns have the same general appearance as distillation columns.

[1] Distillation: An Introduction; http://lorien.ncl.ac.uk/ming/distil/distil0.htm

[2] However, this is not the case for vacuum distillation units.

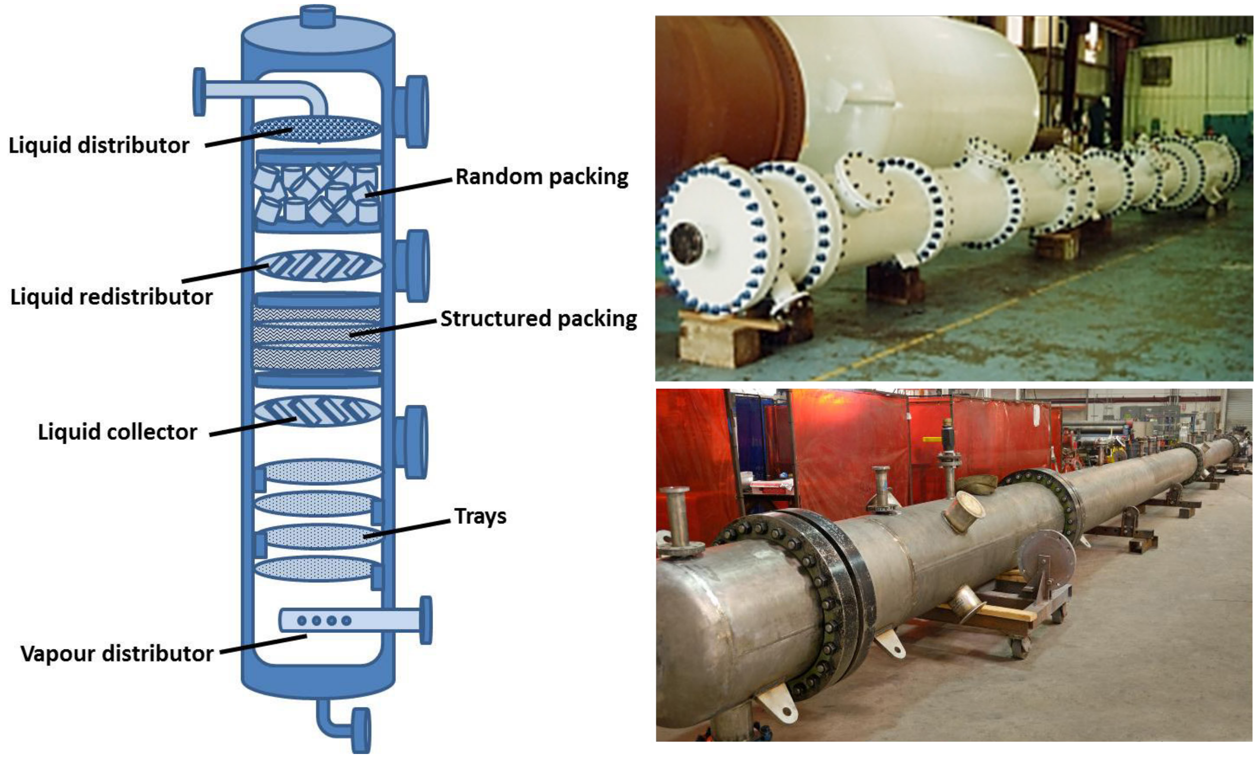

Figure 4.A. *Distillation columns. Left: Simplified schematic of a distillation column showing packings, trays, and selected column internals. Components are not to scale. Right: Complete distillation columns lying on their sides (with ports covered).*

Several internal column structures serve to promote the distillation or absorption process. Structures that enhance contact between liquid and vapour inside a column include trays (plates) and packings (Figure 4.A). While not controlled under AG specifications, it is worthwhile to describe the appearances of these structures as they are common components for these columns.

Examples of column trays or plates are shown in Figure 4.B. These structures, like their names imply, are discrete discs perforated for the passage of vapour; liquid either flows across the trays as gases bubble upwards (cross-flow design) or passes through the same orifices as the vapours (counter-flow design). Typical tray designs include sieve plates, valve plates, fixed-valve plates, and bubble cap trays. The sieve plate is the simplest tray, with holes measuring approximately 1-12 millimetres in diameter[3] distributed throughout the plate. In valve trays, the orifices are fitted with disks or slats (often of proprietary design) that raise or lower depending on vapour flow, providing adjustable holes. Fixed valve trays incorporate stationary (always open) valves into the tray. Bubble cap trays are the most elaborate, incorporating solid or slotted caps over risers on the plate. In addition to orifices, trays will typically have a conduit called a downcomer to facilitate the movement of liquid to lower trays in the column. Downcomers often take the form of pipes or of plates tilted from the plane of the tray.

[3] James R. Fair, “Distillation,” in *Kirk-Othmer Encyclopedia of Chemical Technology*; http://onlinelibrary.wiley.com/doi/10.1002/0471238961.0409192006010918.a01.pub2/abstract

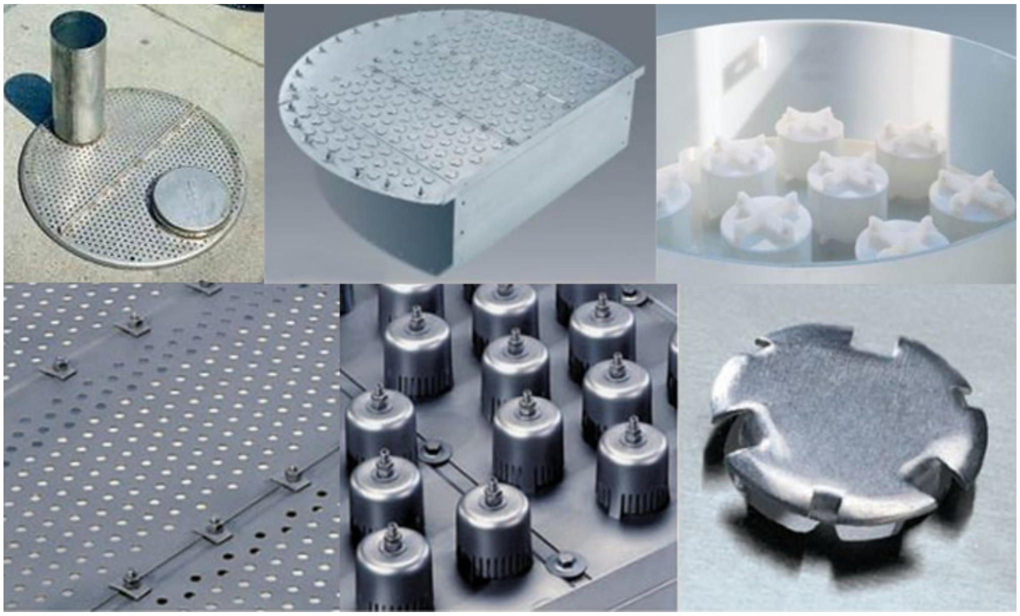

Figure 4.B. *Trays (plates) for columns. Top left: Sieve tray with pipe downcomer; Top centre: Valve tray with plate downcomer; Top right: Bubble cap tray in PVDF; Bottom left: Sieve tray detail; Bottom centre: Bubble cap tray detail; Bottom right: Valve detail.*

Packings may be random or structured. Structured packing is often in the form of corrugated sheets gathered into a cylindrical shape by outer bands; they can be made from metals/alloys, ceramics, plastics (including fluoropolymers), or even graphite. Structured packing made of metal or plastic mesh or gauze is also used (in woven or knitted form). In contrast, random packings are often in the form of rings or saddles with varying levels of sophistication and can also be constructed from metal, ceramic, or plastic. Some classic shapes include the Raschig ring, Pall ring, Intalox saddle, and Berl saddle; newer designs are variations on these themes. Figure 4.C shows examples of structured and random packings.

Figure 4.C. *Structured and random packings for columns. Top left: Corrugated metal structured packing; Top centre: Carbon Raschig rings; Top right: Ceramic Torus Saddles; Bottom left: Plastic rings; Bottom right: Plastic low profile rings.*

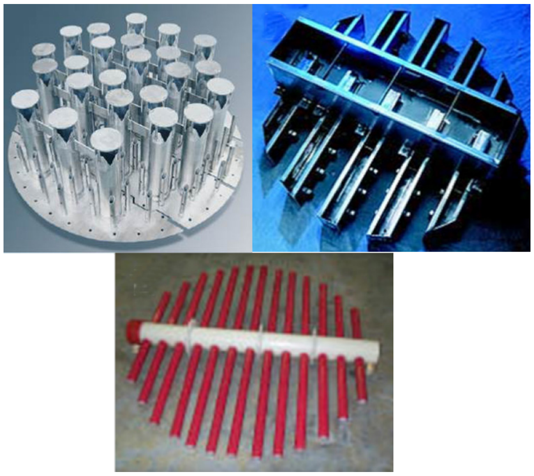

Figure 4.D. *Liquid distributors. Top left: Zirconium orifice riser plate distributor; Top right: Trough distributor; Bottom: Fluoropolymer lateral pipe distributor.*

The AG control language for distillation and absorption columns includes liquid distributors, vapour distributors, and liquid collectors, separate from the columns themselves.[4] In packed columns, liquid distributors serve to distribute liquid uniformly over the entire cross-section of the packing bed (see Figure 4.A). There are a number of standard designs for liquid distributors, such as the orifice/riser pan or plate, trough or channel, lateral pipe, and spray nozzle types. Risers in orifice/riser designs may be cylindrical or rectangular in shape. Additional variations on the orifice/riser and trough designs can incorporate weirs, V-shaped notches that serve as liquid downcomers. All provide a series of liquid distribution points covering most of the column cross section; holes in these components are typically less than 20 millimetres in diameter. For small columns, liquid distributors are supplied in one piece, while larger distributors can be provided in multiple sections for easier installation. Figure 4.D shows photographs of some liquid distributor designs.

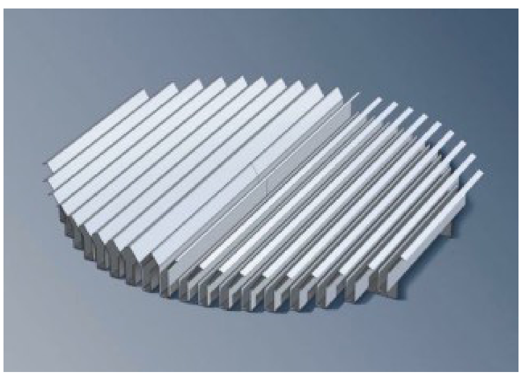

Figure 4.E. *Example of a liquid collector.*

Liquid collectors are also used in packed columns. A liquid collector, as its name implies, collects liquid from packed beds, either feeding a liquid distributor below it or collecting liquid for a separated fraction. In the former case, the functions of collection and distribution may be combined into a single-piece liquid "redistributor." Liquid collectors resemble liquid distributors, but with some design variations; for example, chimney tray collectors look similar to orifice riser liquid distributors, but without orifices. Other designs include vane and chevron collectors. Collectors may also have a pipe jutting out from their lower side for funneling liquids. Figure 4.E shows an example of a vane-type liquid collector.

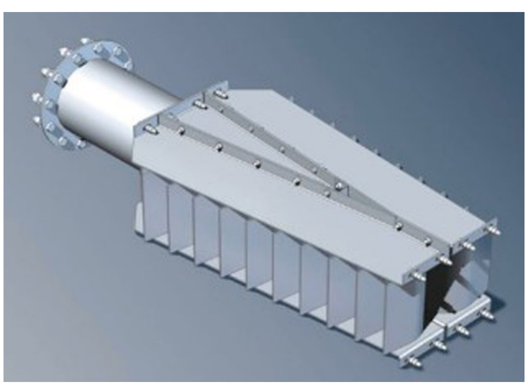

Figure 4.F. *Example of a vane-type vapour distributor.*

Like liquid distributors, vapour distributors (or gas distributors) are used to distribute vapour uniformly across the column cross-section in packed columns. They are installed in the lower portion of the column (Figure 4.A, left) and can take a number of forms, ranging from tubes with holes or slits to more sophisticated designs like the vane-type, comprised of a series of tilted plates. An example of the vane-type distributor is shown in Figure 4.F.

4 Images and additional discussion of these internals can be found in product brochures. For example, see RVT, "Column internals"; http://www.rvt-pe.com/wp-content/uploads/prospekte/RVT_Column_Internals_120601.pdf

4.3. Packaging

Industrial scale distillation or absorption columns are often large pieces of equipment, and therefore are frequently shipped strapped to flatbed trucks, supported by form-fitting cradles underneath them. Their ports should be sealed to prevent contamination. They may also be shipped as disassembled sections, like the palletted column components in Figure 4.G. Certain column internals are controlled as separate components and are likely to be shipped in boxes or crates. Figure 4.G shows pictures of columns ready for shipment.

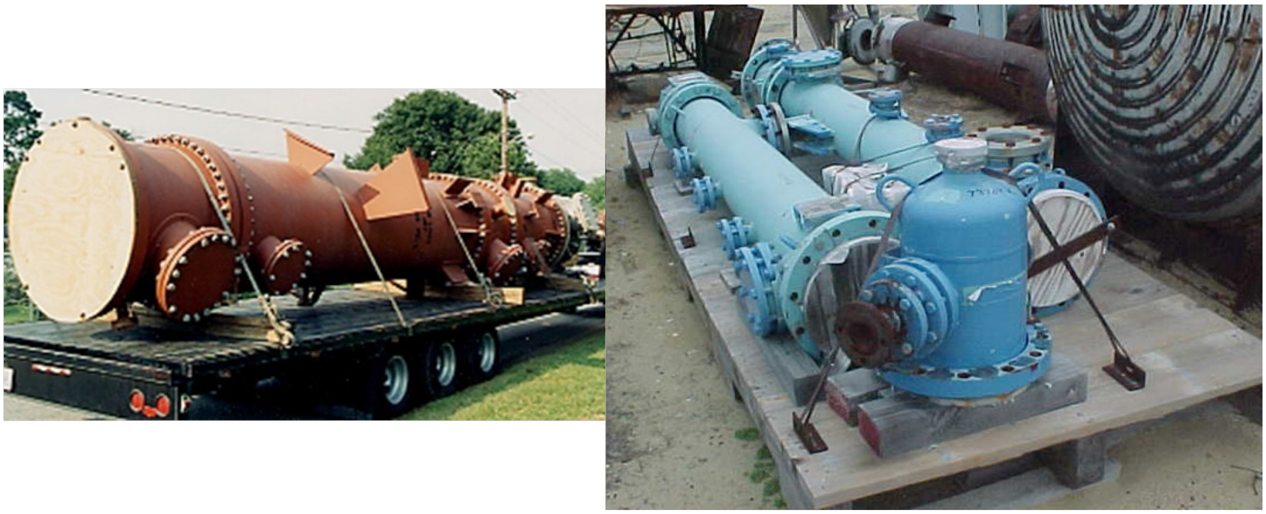

Figure 4.G. *Columns ready for shipment.*

4.4. Typical Applications

Distillation and absorption columns are used throughout the chemical, petrochemical, and oil and gas industries. Columns and internals made of or lined with materials listed in the AG specifications find their major use in corrosive service, especially processes involving strong acids. For example, graphite columns can be used for separation of acids by distillation, purification of highly aggressive flue gases, and absorption of hydrogen chloride. See the materials of construction section for information on sectors for which a given material of construction is appropriate.

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5. Filling Equipment

Remotely operated filling equipment in which all surfaces that come in direct contact with the chemical(s) being processed are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight; or

(b) alloys with more than 25% nickel and 20% chromium by weight.

5.1. Basic Description

Filling equipment is used to transfer materials into bulk containers such as drums or shipping tanks, or into individual containers for final use. In the case of chemical weapons, filling equipment could be used to fill delivery systems such as munitions or other devices.

5.2. Notable Features

Global Production

- United States

Filling machines come in a wide variety of designs named according to the mechanism by which they deliver materials into containers. Filling equipment generally can be divided into machines for filling gases, liquids or solids, and those that fill according to volume, weight, or product level, or by gravity delivery. Table 5 lists some examples of basic types of filling machines – however, it should be noted that the distinctions among the various basic designs are not always clear-cut. Automated versions of these filling machines can be either in-line or rotary indexing, where containers are delivered to and from the filling heads on a linear or rotating conveyor, respectively. Combinations of these basic types are also marketed. The only design features specified in AG control language are remote operation and high-nickel or nickel-chromium alloy wetted parts – therefore, any of these designs could be eligible for control if they meet both specifications and are remotely operated.

Table 5. *Basic types of filling machines*

Machine Type	Examples
Gravity	Time/gravity; also volumetric/gravity and pressure/gravity
Volumetric	Piston, positive displacement, rotating chamber, auger, flow metre, timed flow, aerosol
Net weight or mass	Combined with other methods (e.g., time/gravity or volumetric); also mass flow metre
Fill-to-level	Overflow (gravity or pressure), vacuum, level-sensing; also known as pressure fillers

While there are several varieties of filling machines, the major features of each are largely the same. Figure 5.A shows several types of filling machines for relatively small containers. It should be noted that *no photographs of machines that meet the AG control specifications were found*. These images therefore are meant to be simply illustrative of the general features of these machines.

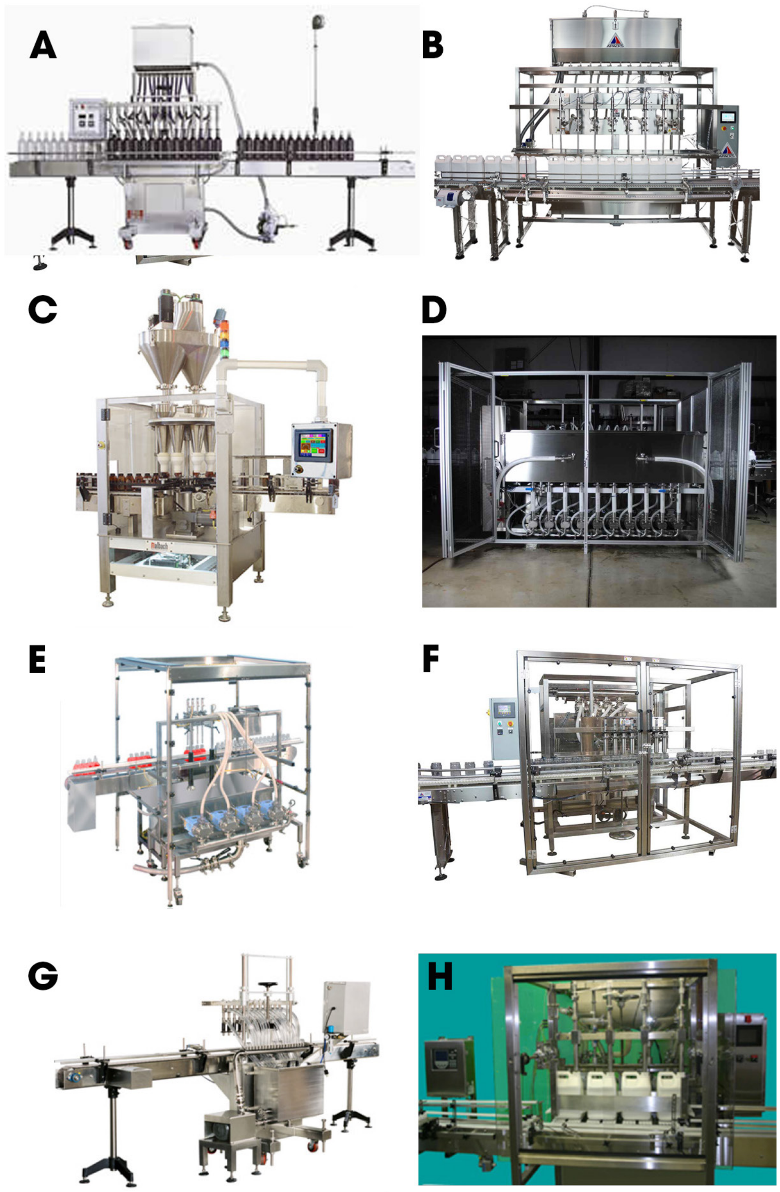

Figure 5.A. *Filling machine designs. A: Linear gravity overflow; B: Volumetric gravity; C: Rotary auger; D: Rear view of inline positive displacement filler; E: Rear view of rotary lobe pump filler; F: Piston; G: Rear view of pressure overflow filler; H: Net weight filler.* **None of these units meet Australia Group control specifications but rather display typical design features of filling equipment.**

As can be observed from Figure 5.A, automated filling machines have four basic features: (1) a set of nozzles (filling heads) for delivering chemicals to containers; (2) a linear (and/or rotary) conveyor for moving containers through the filling process; (3) a controller for operating the system; and (4) one or more tanks or fluid connections to a bulk source of material to be delivered to containers. Gravity-fill or auger fillers have tanks/hoppers above the fill heads; tanks also are needed to capture excess fluid in overflow designs but might be low on the unit (Figure 5.A, photograph G). Fill heads also may be enclosed in a cabinet for protection from exposure and/or environmental control. Filling machines operating by positive displacement or otherwise employing mechanical pressure may employ a number of types of pumps, such as the rotary lobe pump filler in Figure 5.A. Complete aerosol fillers have two filling stations – one for product fill and the other for propellant fill – but these stages may be supplied separately.

Remote operation is required for a filling machine to qualify for control. This feature may be offered as a separate option on filling machines, or possibly as a capability integrated into certain designs. Figure 5.B shows an example of a simple remote control unit that can be used with filling equipment.

5.3. Packaging

Filling machines typically consist of several parts that could be packaged separately from the main unit. Therefore, units may be shipped in one piece or in sections. Care will likely be taken to prevent damage to fragile and/or precision components. Components such as nozzles, pumps, and control panels might be boxed and shipped separately.

5.4. Typical Applications

Filling equipment is used widely in the food, beverage, pharmaceutical, cosmetics/personal care, household product, petroleum, and chemical industries. However, it appears that the majority of these applications involve filling machines with contact parts of stainless steel, plastics, fluoropolymers, or titanium, making filling equipment meeting controls more likely to be custom built than an off-the-shelf item.

Filling equipment with contact surfaces made of the high nickel or nickel-chromium alloys outlined in the AG specifications would be expected for corrosive service. One manufacturer of filling equipment notes use of remote control units for filling explosives, though use in handling toxics could also be an expected application. Remote controls might be used for filling applications in the pharmaceutical industry as well.

Figure 5.B. *Simple remote control unit for use with filling equipment.*

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6. Valves

a. Valves, having both of the following:
   1. A nominal size greater than 1.0 cm (3/8”), and
   2. All surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry;

b. Valves, not already identified in paragraph 6.a., having all of the following:
   1. A nominal size equal to or greater than 2.54 cm (1”) and equal to or less than 10.16 cm (4”)
   2. Casings (valve bodies) or preformed casing liners,
   3. A closure element designed to be interchangeable, and
   4. All surfaces of the casing (valve body) or preformed case liner that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry;

c. Components, as follows:
   1. Casings (valve bodies) designed for valves in paragraphs 6.a.or 6.b., in which all surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry;
   2. Preformed casing liners designed for valves in paragraphs 6.a.or 6.b., in which all surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry.

Technical Note 1. Materials of construction for valves are any of the following:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) tantalum or tantalum alloys;

(f) titanium or titanium alloys;

(g) zirconium or zirconium alloys;

(h) niobium (columbium) or niobium alloys; or

(i) ceramic materials as follows:
   1. silicon carbide with a purity of 80% or more by weight;
   2. aluminum oxide (alumina) with a purity of 99.9% or more by weight;
   3. zirconium oxide (zirconia).

Technical Note 2. The ‘nominal size’ is defined as the smaller of the inlet and outlet port diameters.

6.1. Basic Description

Valves are used to control the flow of fluids. They are available in a wide variety of configurations, which can vary not only by material of construction and basic valve type, but also by the number of fluid ports, types of end connectors, body style, and means of opening and closing (actuation). Accordingly, valves can be named using numerous descriptors related to their design and/

Global Production

- Worldwide, including:
- China
- France
- Germany
- India
- Italy
- United Kingdom
- United States

or function: check, ball, globe, butterfly, swing, gate, plug, needle, flush, relief, diaphragm, bellows seal, and diverter are all adjectives that describe valves. The AG control specifications do not dictate any particular valve type; rather, the nominal size, wetted surface material(s), and interchangeability of the closure element are relevant to a valve's control status, as well as the control status of certain components. Consequently, AG valves are a diverse group of commodities.

6.2. Notable Features

Valves are characterised by two or more fluid connections (ports) and some means of opening and closing the device. Fluid connections may have flanges, threads, a thread/nut combination, or other provisions for connecting pipes or tubing. Valves can be actuated (opened or closed) via operator intervention or automatically (self-actuated); electrical, pneumatic, hydraulic, or manual control may be employed to actuate a valve.[1]

Figures 6.A, 6.B, and 6.C show a variety of valves of different styles, materials, and methods of actuation. Figure 6.D shows some additional designs with prominent labels and/or stamps. Most valves should have markings indicating the manufacturer and a part or model number, either stamped into the valve or on a label or nameplate. This information can be used to find additional technical information on the valve. Valve casings and preformed casing liners for controlled valves are also controlled as separate items, per paragraph 6.c of the control; examples of casing liners are shown in Figure 6.E.

The AG also prescribes controls on valves with nominal sizes between 2.54 cm (1") and 10.16 cm (4") [inclusive] that have closure elements designed to be interchangeable, provided that the wetted surfaces of their casings or casing liners are composed of materials of construction from the list in Technical Note 1. Examples of such closure elements would be balls, plugs, diaphragms, and discs for valves. Therefore, a 5 cm ball valve with a fluoropolymer casing liner and a carbon steel ball designed to be interchangeable would be subject to control.

Figure 6.A. *Fluoropolymer valves in a variety of designs. Left: PFA-lined plug valves with different actuation mechanisms (manual, pneumatic, and electrical); Right: 6 inch (DN150) PFA-lined butterfly valve with pneumatic actuator, indicator, and limit switch enclosure.*

[1] Useful overviews of valve types and nomenclature can be found on the Plast-O-Matic Valves website, especially in their eBook on plastic valves: http://www.plastomatic.com/intro-to-plastic-valves-ebook.pdf

Figure 6.B. *Alloy valves. Left: Hastelloy® globe valve; Centre: Titanium gate valve; Top right: Alloy 20 check valve; Bottom right: Inconel® check valve.*

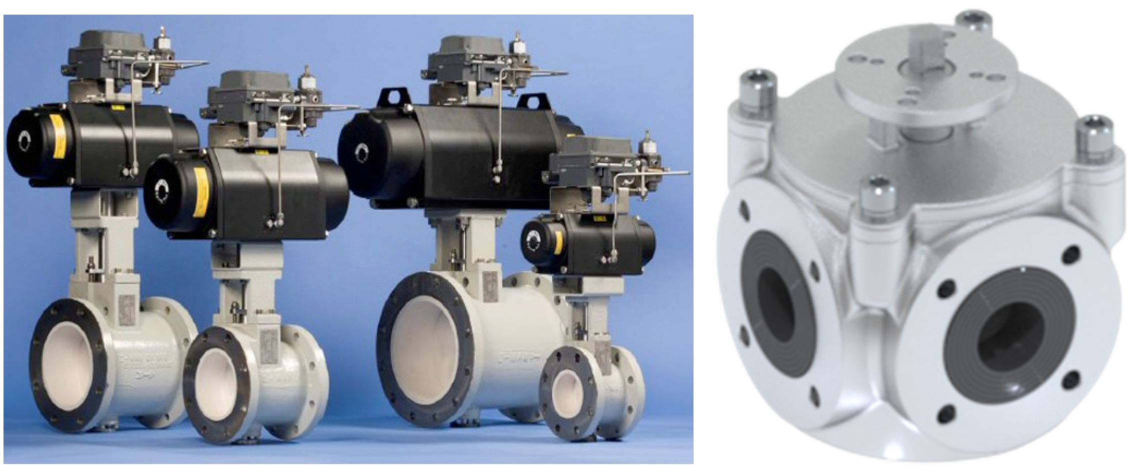

Figure 6.C. *Ceramic-lined valves. Left: Zirconia-lined butterfly valves; Right: Three-way ball valve with zirconia, alumina, and silicon carbide components.*

Figure 6.D. *Valves showing nameplates, labels, and stamps. Left: 2 inch (DN50) PFA-lined ball valve with pneumatic actuator; Centre: Teflon® solenoid valves; Right: Monel® bellows seal valve.*

Figure 6.E. *Valve components. Left: Components of a fluoropolymer-lined butterfly valve showing casing liner; Right: PTFE liners for butterfly valves.*

6.3. Packaging

Small valves are typically packaged in boxes (one valve per box) and are likely to be wrapped in plastic. Cushioning in the box may be provided. Large valves could be crated or strapped to pallets for shipping. In this case, the ports will probably be capped or otherwise sealed to prevent contaminants from entering the valves. Figure 6.F shows large valves ready for shipping. Figure 6.G shows the packaging associated with a small valve – note the box label. The box gives not only the manufacturer and part number but also notes that it is a restricted product, in this case because it is a Monel® valve with high enough nickel content and sufficient nominal size to meet control specifications.[2]

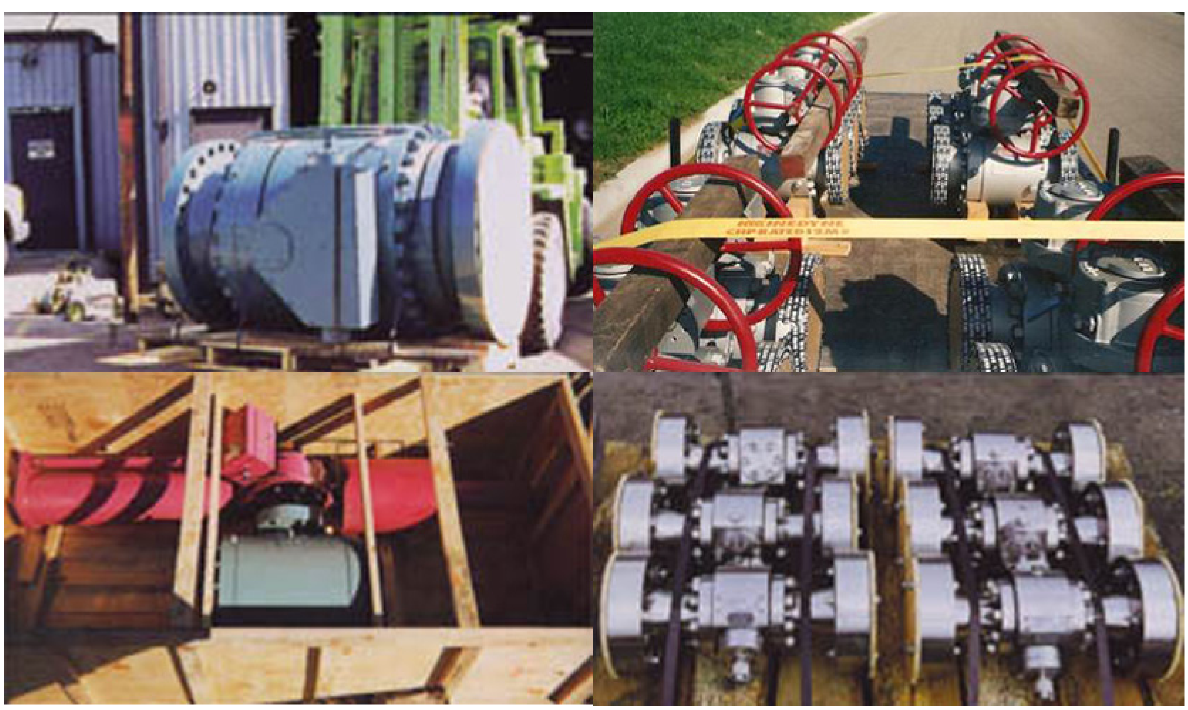

Figure 6.F. *Valves ready for shipment.*

[2] This valve has a 3/8" end connection, which is at the cut-off size for the AG control; however, it is a bellows seal valve, and with its material of construction and size it meets the control specifications of the Nuclear Suppliers Group Dual-Use List (see http://www.nuclearsuppliersgroup.org).

Figure 6.G. *Packaging for a small valve. Left: Box label indicating part number and restricted product designation; Centre: View of packaging upon opening the box; Right: Box contents, including valve sealed in a plastic bag.*

6.4. Typical Applications

As an integral part of any chemical plant, valves constructed of or lined with AG-listed materials of construction can be expected to have use in the same industries as controlled chemical processing equipment. Examples include chlor-alkali, petrochemicals, fertilisers, pulp & paper, pharmaceuticals, power & desalination, and fine chemicals. Acid service is another area; for example, zirconium valves find use in handling acetic or hydrochloric acids. Fluoropolymer valves are used in the semiconductor, pharmaceutical, biotech and chemical process industries as well as use for ultrapure/deionised water applications; they are particularly suitable for corrosive applications when high purity is important. See the materials of construction section for more information on sectors using equipment with wetted parts of a particular listed material.

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7. Multi-Walled Piping

Multi-walled piping incorporating a leak detection port, in which all surfaces that come in direct contact with the chemical(s) being processed or contained are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) graphite or carbon-graphite;

(f) tantalum or tantalum alloys;

(g) titanium or titanium alloys;

(h) zirconium or zirconium alloys; or

(i) niobium (columbium) or niobium alloys.

Technical note: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite-content is eight percent or more by weight.

7.1. Basic Description

Global Production

- Austria
- Canada
- United States

Multi-walled piping systems serve to transport chemicals while protecting against leaks and providing the ability to detect them. Commonly known as double-containment or dual-containment piping, they are most often composed of two pipes separated by an annular space. The inner pipe – also known as the carrier, primary, medium, or product pipe – carries the fluid to be transported. The outer – or containment or secondary pipe – provides containment for any leaked chemicals until the location of the leak is detected and repaired. The annular space can be monitored by several techniques to detect failure of the carrier pipe. The use of multi-walled piping therefore provides protection for both people and the environment from exposure to hazardous chemicals, whether they are incorporated into a chemical processing facility or buried underground for the transport of aggressive media.

7.2. Notable Features

Multi-walled piping is a pipe-within-a-pipe arrangement with an annular space between the (typically) two pipes for leak monitoring and containment. Figure 7.A shows pictures of multi-walled piping. The two concentric pipes are typically separated by internal structures such as support ribs or disks, giving slightly different end-on appearances of piping from different manufacturers. Some manufacturers produce multi-walled piping from two separate pipes, allowing them to construct the carrier and containment pipes from two different materials. As with single-walled pipe, manufacturers of multi-walled pipe provide a variety of fittings such as tees, elbows, lateral bends, caps, and reducers. The presence of a second pipe within the fittings will similarly be apparent on visual inspection of these components. In order to meet control specifications, however, the piping must incorporate a leak detection port in addition to having corrosion-resistant surfaces.

Figure 7.A. *Examples of multi-walled piping. Left: straight pipe and fittings made of plastic; Right: cutaway view of a multi-walled plastic tee.*

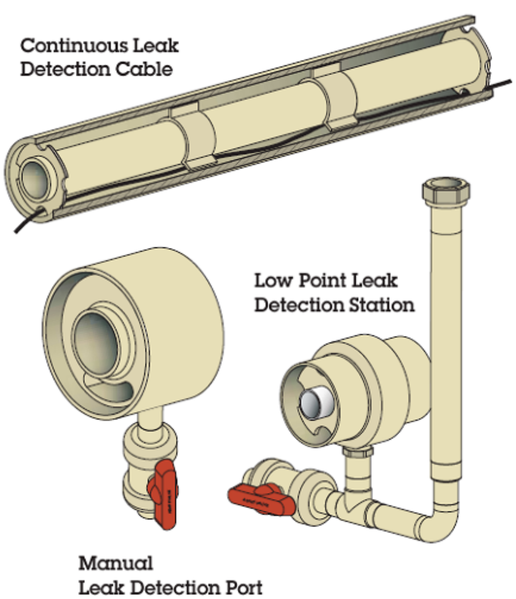

Figure 7.B. *Some options for leak detection in double-walled piping systems.*

Leak detection is an important and integral part of multi-walled piping systems, and there are several methods that can be used to monitor the annular space for failures of the carrier pipe. Leak detection equipment is not listed separately by the AG, but the available methods lead to certain features of the piping systems themselves in order to accommodate leak testing – this is an important consideration because the presence of a leak detection port is a key part of the AG control specifications. There are a few basic options for leak detection: continuous leak detection cables within the annular space, low point detection stations for either manual or probe/switch monitoring, and in-line detection from pipe fittings. Figure 7.B shows some arrangements for leak detection in double-containment systems.

Ports useful for leak detection provide access to the annular space while leaving the carrier pipe unbreached, such as those shown in the bottom portion of Figure 7.B. Several such fittings would be expected for a double-containment piping system in order to help locate the leak. Detector cables must have some way to escape the double-containment system, so annular space access ports also will be required for piping systems when cable detection methods are employed. The schematics in Figure 7.C show some additional arrangements for leak detection. Leak detection could be accomplished by visual inspection using a sightglass or other see-through area attached to the lower part of the containment pipe, but still requires a port for access to the space between the pipes.

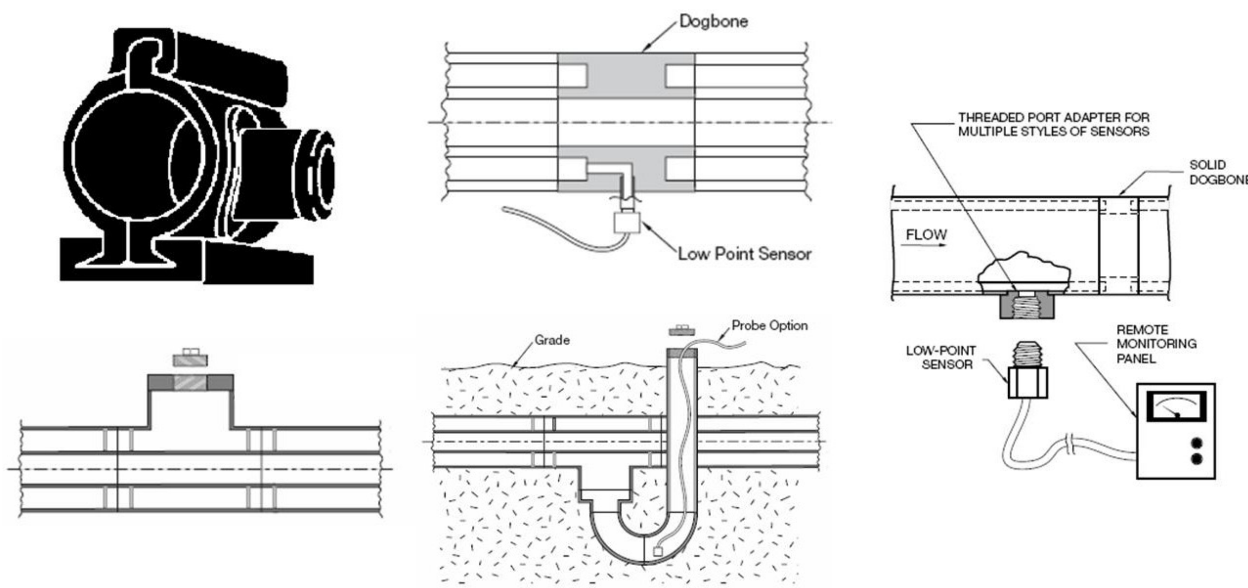

Figure 7.C. *Schematics of leak detection arrangements for multi-walled piping systems. Top left: cartoon of a pipe section with a leak detection port protruding from the right; Top centre: attachment for a low point sensor; Bottom left: access tee; Bottom centre: inspection well; Far right: threaded port for single-point detection incorporated into straight piping.*

7.3. Packaging

One producer of plastic double-containment piping, gives packaging and handling information in the technical information provided on its website. It states that shipment is typically via truck, noting that "the pipe is capped or polyethylene wrapped to protect the ends from damage. Unless sizes prohibit, fittings are boxed and palletized according to the order quantities. Prefabricated spools can often be shipped by flatbed for easier loading and unloading. On larger pipe orders, pipe may be palletized and polyethylene wrapped upon request."[1] Similar packaging considerations would be expected for multi-walled piping constructed from other materials.

7.4. Typical Applications

In general, multi-walled piping is used in several industries, including the nuclear, gas, petroleum, and chemical processing industries; semiconductor manufacturing; pulp and paper; waste handling; battery manufacturing; and pharmaceuticals. Multi-walled piping made of the materials in the AG specifications also has use in several sectors, especially those working with particularly corrosive, toxic, or otherwise aggressive fluids and some in which high product purity is required. One producer notes that PVDF provides the "broadest protection" for chemical processing, pulp mill bleaching, processing bromine pharmaceuticals, and manufacturing electronic products (metal etching operations and ultrapure deionised water lines). It also notes the resistance of another fluoropolymer, ECTFE, to strong acids and bases, solvents, and chlorine. Examples of applications for PVDF double-walled piping include use with hydrofluoric and nitric acids and sulphuric acids in pulp/paper mills and power plants.[2]

[1] Asahi/America, Inc. Catalog DC-98/A

[2] Asahi/America, Inc. Duo-Pro Catalog DC-98/A

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8. Pumps

Multiple-seal and seal-less pumps with manufacturer's specified maximum flow-rate greater than 0.6 m^3/h, or vacuum pumps with manufacturer's specified maximum flow-rate greater than 5 m^3/h (under standard temperature (273 K (0°C)) and pressure (101.3 kPa) conditions), and casings (pump bodies), preformed casing liners, impellers, rotors or jet pump nozzles designed for such pumps, in which all surfaces that come into direct contact with the chemical(s) being processed are made from any of the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) graphite or carbon-graphite;

(f) tantalum or tantalum alloys;

(g) titanium or titanium alloys;

(h) zirconium or zirconium alloys;

(i) ceramics;

(j) ferrosilicon (high silicon iron alloys); or

(k) niobium (columbium) or niobium alloys.

Technical note 1: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

Technical note 2: The seals referred to in this control come into direct contact with the chemical(s) being processed (or are designed to), and provide a sealing function where a rotary or reciprocating drive shaft passes through a pump body.

8.1. Basic Description

Like valves, pumps are ubiquitous pieces of equipment. Pumps facilitate the movement of materials from one place to another and therefore are essential for any processes involving chemical transfer. They also can be used to lower the system pressure in certain chemical processing operations such as vacuum distillation. Three basic types of pumps are identified for export control by the AG: multiple-seal, seal-less, and vacuum pumps. There are a variety of designs within these categories. For example, magnetically-coupled (also known as magnetic drive or mag-drive) and canned motor drive pumps are two of the most common designs for seal-less pumps. However, other pump designs such as diaphragm pumps and bellows pumps are inherently seal-less and fall within this group.[3] This section provides brief discussions of all three of the pump types in the AG control language. It should be noted that in all cases, certain pump components are identified for control separate from complete pumps.

Global Production

- Worldwide, including:
- France
- Germany
- India
- Italy
- Japan
- The Netherlands
- Switzerland
- United Kingdom
- United States

3 Prior to the April 2005 update to the AG control specifications on pumps, canned drive, magnetic drive, bellows and diaphragm pumps were listed explicitly in the AG control language.

AG specifications give flow rates in cubic metres per hour (m^3/h), but manufacturers use a variety of units. Appendix E gives minimum flow rate specifications in other units of measurement.

8.2. Notable Features

In standard centrifugal pump designs, the motor is outside of the pump casing where the pumped fluid is contained. The motor shaft is coupled to the pump shaft and translates its rotation to the pump shaft and its attached pumping element. The point at which the rotating pump shaft penetrates the pump casing is vulnerable to leaking and requires a seal to prevent the pumped fluid from escaping. In a standard, single mechanical seal pump, there is a shaft seal composed of a ring that rotates with the pump shaft and a second fixed ring mounted to the casing (i.e., the seal surfaces move with respect to each other). Also known as a dynamic or rotary shaft seal, this seal is prone to failure; this results in leakage of pumped fluids into the environment because the seal directly contacts the chemicals being processed. Technical Note 2 of this entry clarifies the definitions of multiple-seal and seal-less pumps by stating that the seals referred to in the control are these shaft seals.[4] Such multiple-seal and seal-less pumps attempt to improve upon this shortcoming of single-seal pumps for hazardous chemical service.

Multiple-seal pumps. Multiple-seal pumps add additional mechanical seals along the pump shaft as added protection against leaks. Double mechanical seals may also be called dual or tandem seals, terms that relate to how the seals are mounted on the shaft.[5] Use of three mechanical seals (i.e., a triple seal pump) also is possible. Dual and tandem seal pumps incorporate a sealing chamber in which a barrier fluid can be injected between the two shaft seals for protection against leaks (Figure 8.A). Therefore, the presence of extra fluid connections between the motor and the chamber containing the pumped process fluid might indicate that a pump has multiple seals. However, examination of the pump's nameplate and documentation will be needed to verify technical and design information.

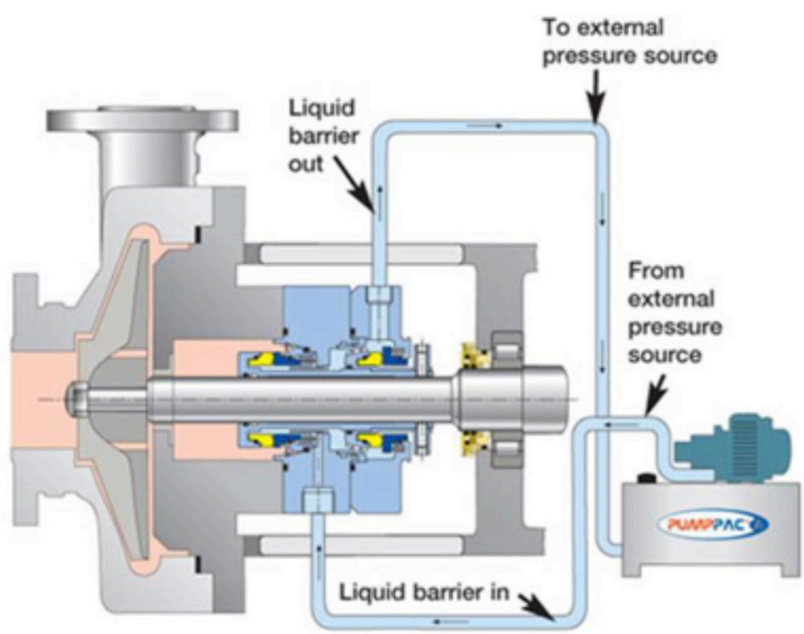

Figure 8.A. *Schematic of a tandem seal pump showing connections for barrier fluids. Two mechanical seals are mounted on each shaft. The diagram shows mechanical seals in dark blue/yellow. Two connections are used for the barrier fluid (light blue), and the pumped fluid is shown in pink.*

4 Technical Note 2 also specifies that reciprocating shaft seals are also included in the scope of the control.

5 For a detailed discussion of single and multiple shaft seals, see Grundfos, "Mechanical shaft seals for pumps"; http://www.grundfos.com/content/dam/Global%20Site/Industries%20%26%20solutions/Industry/pdf/ShaftSeal_samlet.pdf

Figure 8.B. *Magnetic drive pumps and components.*

Seal-less pumps. The term "seal-less pump" is somewhat misleading. Rather than being completely without seals, these pumps lack the shaft seals identified in Technical Note 2 – i.e., the seal where the rotating or reciprocating pump shaft enters the pump casing. Seal-less pump designs eliminate this shaft seal rather than simply reinforcing it with additional seals as in the case of multiple-seal pumps. Magnetic drive pumps and canned motor pumps (CMPs) are two designs that eliminate the need for shaft seals.[6] Inherently seal-less designs like diaphragm or bellows pumps would also fall into this category. This section will focus on magnetic drive and CMP designs, with brief mention of diaphragm pumps.

A magnetic drive pump operates by using an electric motor to drive a set of permanent magnets, which in turn drive another set of magnets attached to the pump shaft and impeller. The rotor is therefore magnet-driven rather than mechanically coupled to the motor shaft, eliminating the need for a spinning shaft to penetrate the containment shell. Magnetic drive pumps come in a variety of configurations; some examples are shown in Figure 8.B, which includes a picture of the components of a magnetic drive pump. Magnetic drive pumps might not be visually distinctive compared to sealed pumps. Pump labeling and documentation will be key to identifying these seal-less pumps and determining their control status. However, the non-metallic lining seen in pumps in Figure 8.B can be a clue that the pump in question may have sufficient corrosion resistance to meet control specifications for materials of construction.

Figure 8.C shows some examples of simple CMPs. CMPs contain the motor inside the pump's housing, eliminating the need for a rotating shaft to penetrate the pump casing. The pumped fluid provides lubrication and cooling for the motor. Due to the containment of the motor within the pump housing, CMPs often have a smooth exterior surface, as opposed to the cooling fins often seen protruding from a motor housing on other pump designs. There may also be a terminal box for motor leads and a bearing wear monitor attached to the end of the CMP opposite the fluid attachments; the terminal box can be seen in the left and centre photographs in Figure 8.C as a white cylinder protruding from the top of the pump housing. CMPs, as well as magnetic drive pumps, can also come in vertically-oriented designs.

[6] A discussion of the design and operation of magnetic drive and canned motor pumps can be found in the brochure "Nikkiso Non-Seal® Pump"; http://www.nikkisopumpsamerica.com/downloads/nikkiso/2062r10.pdf.

Figure 8.C. *Examples of canned motor drive pumps (CMPs).*

Figure 8.D. *Plastic diaphragm pump*

Diaphragm pumps completely lack a rotary shaft seal, rendering them inherently seal-less. They are also known as membrane pumps, and the terms air-operated or pneumatic might be used in product names. Diaphragm pumps use a flexible membrane to vary the volume of the pump chamber, thereby pushing and pulling fluids through the pump. The diaphragm may be operated using compressed air (air-operated) or be motor-driven (electrical). Hydraulic or magnetic drives are also possible. An example of a plastic (non-fluoropolymer) construction air-operated diaphragm pump is shown in Figure 8.D. This figure shows the distinctive shape of this pump design.

Vacuum pumps. The term vacuum pump applies to a wide range of pumps that allow sub-atmospheric pressures to be achieved in the chamber being pumped. These pumps remove gases from a sealed volume, leaving a partial vacuum. Chemical processing operations using vacuum pumps include vacuum distillation, evaporation, filtration, and drying.

Vacuum pump designs often are subdivided into three types based on their principles of operation: (1) mechanical or positive displacement pumps; (2) momentum-transfer pumps;[7] and (3) entrainment pumps. Positive displacement pumps rely on internal moving parts to create an expanding cavity on the inlet side, trap incoming gases, compress them by shrinking the cavity, and release them out the discharge side. Product names for positive displacement pumps reflect the shapes of the moving components that cause the pumping action: claw, screw, rotary lobe, rotary piston, and rotary vane are names of some common positive displacement designs. Momentum-transfer pumps move gas molecules from the inlet to the discharge side by imparting momentum to the molecules to "push" them toward the exhaust. Diffusion pumps use fluid jets to impart momentum, while turbomolecular pumps use fans. Finally, entrainment pumps reduce pressure by trapping molecules on a surface or in a vapour inside the pump. This can be accomplished through various mechanisms, such as condensation or adsorption. Diffusion pumps are sometimes considered entrainment pumps, but the designs more commonly associated with entrainment are cryopumps, sorption pumps, titanium sublimation pumps, and sputter-ion pumps.[8]

7 Common momentum transfer pumps include diffusion and turbomolecular pumps, which move pumped vapours with fluid jets or fans, respectively.

8 For detailed discussion of these entrainment pump types, see "Chapter 6 Vacuum Pumps," http://people.rit.edu/vwlsps/LabTech/Pumps.pdf

Vacuum engineers also distinguish pumps based on the sub-atmospheric pressure levels they can obtain (rough, medium, high, or ultrahigh vacuum)[1] or by the presence or absence of a sealing fluid inside the pumping chamber (wet or dry pumps, respectively).

The vacuum pumps of greatest relevance to chemical processing operations are rough or medium vacuum pumps of the positive displacement or momentum-transfer types. Wet and dry pumps are both pertinent to these applications. Therefore, this section will focus on three general pump designs commonly mentioned in the context of chemical or pharmaceutical processing:[2] ejectors, liquid ring pumps, and dry pumps. Of these, all function by positive displacement except for ejectors, which are momentum-transfer pumps with no moving parts.

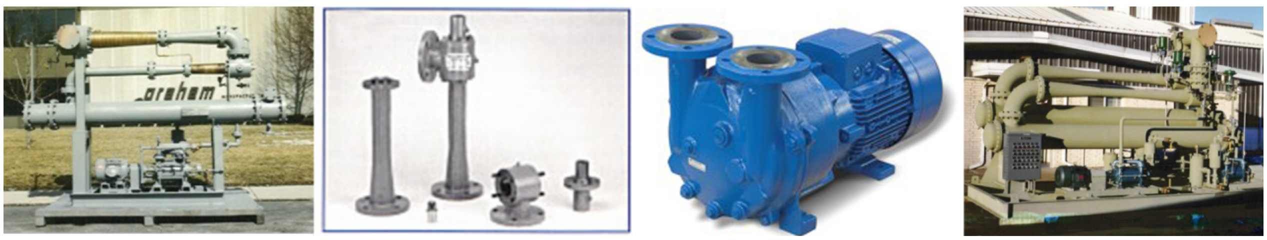

Figure 8.E. *Examples of vacuum pumps. Left: Two-stage ejector system; Centre left: Ejector components; Centre right: Liquid ring pump; Right: Combination steam ejector and liquid ring pump system.*

Ejectors: Also called jet pumps, ejectors use the flow of a motive fluid through a converging-diverging nozzle to generate the pumping action. The motive fluid is most commonly steam, but may also be another fluid like an organic solvent, air, or nitrogen. Nozzles can be fabricated from metals or plastics. Ejectors find use in numerous sectors, including the chemical, plastics, petrochemical, pharmaceutical, and pulp and paper industries. They may be single- or multiple-stage systems, and are visually characterised by their tapered converging-diverging nozzles, which are narrower in the centre than on the ends (Figure 8.E, left and centre left).

Liquid ring pumps: Liquid ring pumps are comprised of a multi-blade impeller mounted eccentrically in a cylindrical casing, i.e., offset from the casing axis. The impeller forces a sealing fluid to the casing walls, forming a liquid ring that provides sealing and heat absorption, while the impeller blades create variable-sized chambers for the pumping action. Liquid ring pumps are made of metal and are used in the same industry sectors as those mentioned above for ejectors, among others. Liquid ring pumps resemble a classic centrifugal pump, but often have both the inlet and outlet on top of the pumping chamber (Figure 8.E, centre right). Like ejectors, they can come in single or multiple-stage designs, and could be offered in hybrid pump packages with ejectors (Figure 8.E, right).

Dry pumps: Like their name implies, dry pumps do not require a working fluid or lubricant for operation. Several vacuum pump designs can run as dry pumps, namely rotary claw, rotary screw, and rotary lobe pumps.[3] Each of these designs has a pair of moving parts – in a claw, screw, or three-lobed rotor shape, respectively – that provides the changes in volume required for the pumping action. An article from *Chemical Engineering* cites use of dry pumps in the pharmaceutical, fine/specialty chemical, and semiconductor industries,[4] and the use of dry pumps for aggressive gases has been noted.[5]

1 J. L. Ryans and S. Croll, "Selecting vacuum systems," *Chem. Eng.* p. 72 (December 14, 1981)

2 Joe Aliasso, "Choose the Right Vacuum Pump," *Chemical Engineering* **106(3)**, 96-100 (1999); http://www.graham-mfg.com/usr/pdf/TechLibVacuum/222.PDF

3 Joe Aliasso, "How to make sure you select the right dry vacuum pump," *World Pumps* **2000(402)**, 26-27 (2000); http://www.graham-mfg.com/usr/pdf/techlibvacuum/228.pdf

4 Joe Aliasso, "Choose the Right Vacuum Pump"; Ibid.

5 D. Collins, "Vacuum systems for chemical and pharmaceutical processes," *Chemical Industry Digest* (June 2011); http://www.edwardsvacuum.com/uploadedFiles/Resource/Technical_Articles/Vacuum%20systems.pdf

8.3. Packaging

Pumps may be crated for shipment or strapped to pallets. Inlets and outlets should be sealed for shipping, and the units could be cushioned, for example, with foam packing. Components could be boxed or crated, but large parts might be supplied on pallets. Very large pumps may be directly strapped to flat-bed trucks for shipment. Figure 8.F shows examples of pumps ready for shipment.

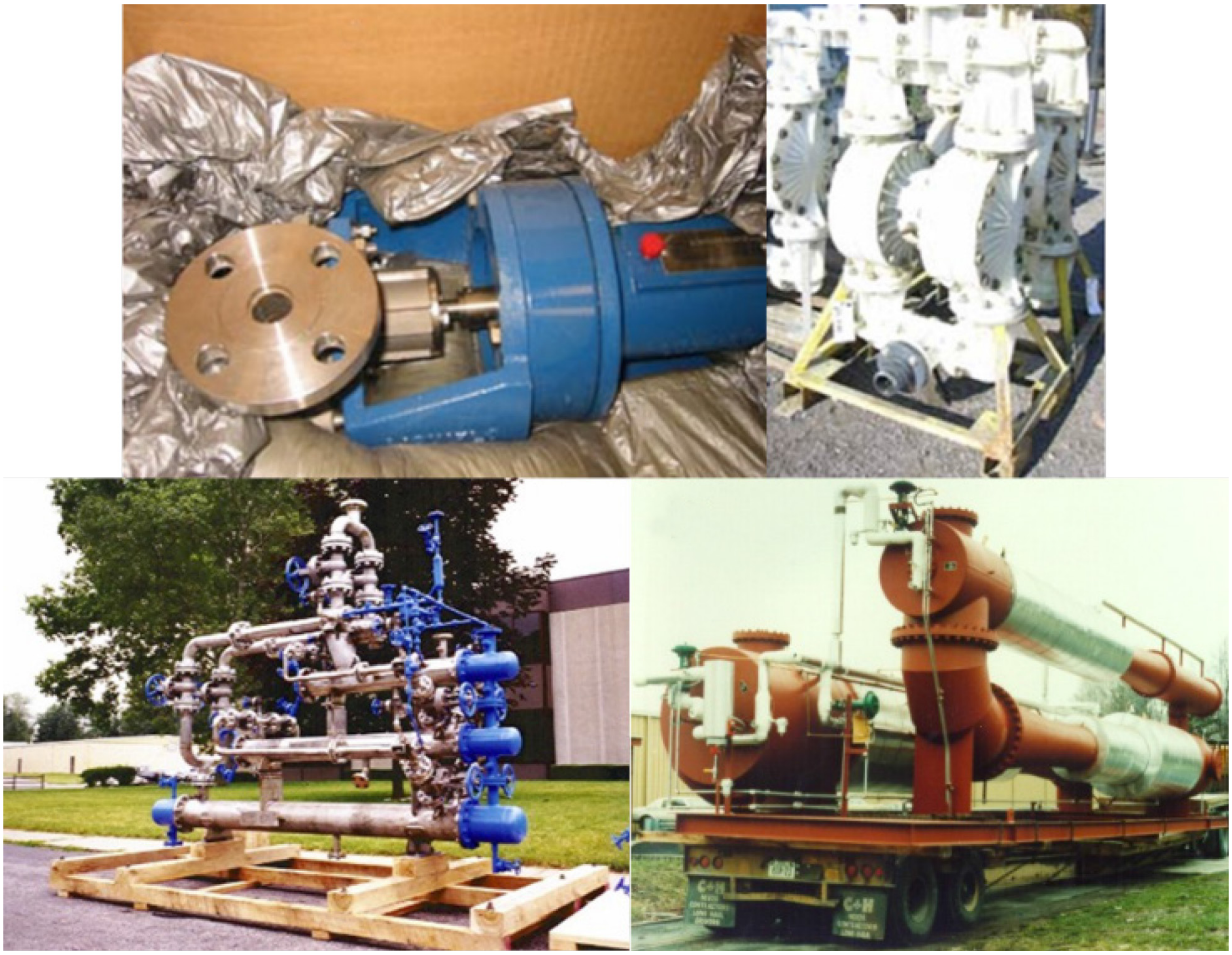

Figure 8.F. *Pumps ready for shipment. Top left: Centrifugal pump head in a box with padding; Top right: Diaphragm pump strapped to a pallet; Bottom left: Multi-stage ejector pump system on a pallet; Bottom right: Ejectors on a flat-bed trailer.*

8.4. Typical Applications

Double-seal pumps can be used for solids-containing media as well as toxic and corrosive service. Seal-less pumps like magnetic drive pumps are well-suited for handling corrosive, hard-to-seal, and otherwise hazardous liquids. Applications cited for non-metallic (fluoropolymer) magnetic-drive pumps include use in acid transfer (e.g., sulphuric, hydrochloric, hydrofluoric, and nitric) and service for caustics and chlor-alkali chemicals (e.g., sodium hydroxide, sodium hypochlorite, and chlorine dioxide). Relevant sectors and activities include chemical processing, metal plating, parts washing, circuit boards, photo processing, pharmaceuticals, food processing, wet scrubbers, and semiconductors. Fluoropolymer diaphragm pumps find use in electronics, CMP slurries, chemical, wastewater, petroleum, food, pharmaceutical, processing, mining, and general industrial applications, while fluoropolymer bellows pumps are used in the pharmaceutical industry.

Table 8 lists several applications for pumps made of corrosion-resistant materials, based on brochures from pump manufacturers.

Table 8. *Examples of pump applications associated with corrosion-resistant materials*

Material	Applications
Titanium	Resistant to heavily oxidising and chloride containing media; preferred for use in chlor-alkali processes (e.g., electrolysis; media include brine, salt water, sodium hypochlorite, or caustic soda), for pumping bleaching solutions containing chlorine, and in the manufacture of acetic acid
Zirconium	Suitable for pumping very hot highly concentrated acetic acid, other organic acids (e.g., formic acid), hydrochloric acid, and boiling concentrated aluminium chloride solution
Nickel	Used for pumping molten alkalis, for the evaporation of alkalis, and for pumping highly refined alkalis; caustic soda concentration units
PVDF	Suitable for the pumping of hydrofluoric acid at all concentrations up to the boiling point, liquids containing halogens, nitric/hydrofluoric acid pickling solutions, and for the evaporation of waste hydrochloric acid
PFA	Universal chemical resistance, with a few exceptions
PTFE	Outstanding resistance against nearly all organic and inorganic media over a wide temperature range
Silicon carbide	Well-suited for highly aggressive and highly abrasive media. Typical applications include acidic coke slurries, filter dust slurries containing acid, titanium dioxide suspensions, nickel production with large proportions of nickel chloride and copper chloride, hydrochloric acid, and solids

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9. Incinerators

Incinerators designed to destroy CW agents, AG-controlled precursors or chemical munitions, having specially designed waste supply systems, special handling facilities, and an average combustion chamber temperature greater than 1000°C, in which all surfaces in the waste supply system that come into direct contact with the waste products are made from or lined with the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight; or

(c) ceramics.

9.1. Basic Description

Global Production

- United States

High temperature incinerators can be used to destroy CW agents and decontaminate munitions that have housed them. Incineration is a common method utilised in CW disposition, and incinerators for this purpose operate at temperatures significantly higher than those of industrial incinerators.[1] Such facilities also have very stringent requirements for material handling and pollution abatement due to the severe hazards posed by CW agents.

9.2. Notable Features

The U.S. Army Chemical Materials Activity (CMA) describes the process of CW incineration in its Fact Files on Incineration Technology[2] and a fact sheet on incineration technology.[3] The CMA's incineration technology fact sheet notes that "incinerators used in the process operate at significantly higher temperatures and for longer periods of time than industrial incinerators, to ensure complete destruction of chemical agent and total decontamination of casings and munition pieces." Another fact sheet on CW incineration safety notes that these facilities are "engineered with specially designed weapons handling processes, remote-controlled incineration and disposal equipment, complex control systems and detailed procedures and training" to protect the workers, environment and the public.[4] The United States used incineration for CW destruction at Johnston Island in the Pacific near Hawaii; Anniston Army Depot in Alabama; Pine Bluff Arsenal in Arkansas; Deseret Chemical Depot in Utah; and Umatilla Chemical Depot in Oregon.[5] Photographs of some CW incineration facilities are shown in Figure 9.A.

1 U.S. Army Chemical Materials Agency, "Incineration Technology: So, just what exactly comes out of the stack?" http://www-pmcd.apgea.army.mil/fndocumentviewer.aspx?DocID=003674305 Note: this fact sheet was published under the CMA's previous name.

2 U.S. Army Chemical Materials Activity, Fact Files; http://www.cma.army.mil/factfile.aspx

3 U.S. Army Chemical Materials Agency, "Incineration Technology: So, just what exactly comes out of the stack?" http://www-pmcd.apgea.army.mil/fndocumentviewer.aspx?DocID=003674305 Note: this fact sheet was published under the CMA's previous name.

4 U.S. Army Chemical Materials Agency Fact Sheet, "Incineration: A Safe, Proven Disposal Process" http://www.cma.army.mil/fndocumentviewer.aspx?docid=003676726 Note: this fact sheet was published under the CMA's previous name.

5 U.S. Army Chemical Materials Activity, "About CMA," http://www.cma.army.mil/aboutcma.aspx

Figure 9.A. *Chemical weapons incineration facilities. Left: Umatilla, Oregon; Middle: Anniston, Alabama; Right: Johnston Atoll (now decontaminated, decommissioned, and destroyed).*

The CMA's Fact Files note that it uses three furnaces for destruction operations: a Liquid Incinerator (LIC), Metal Parts Furnace (MPF), and Deactivation Furnace (DFS). The overall facility also includes a Pollution Abatement System (PAS). Each system is described below, and images from their Fact Files are shown in Figure 9.B, as examples of systems designed for CW destruction.

- Liquid Incinerator (LIC):[6] According to the CMA Fact File, the LIC destroys liquid chemical agents drained and removed from munitions during demilitarisation, as well as agent-contaminated liquids from cleanup and decontamination activities. The LIC is composed of a primary and secondary chamber, which operate at 2700°F (~1482°C) and 2000°F (~1093°C), respectively.
- Metal Parts Furnace (MPF):[7] The MPF decontaminates metal from munitions and metal scrap and waste via high temperature in a furnace and afterburner. The furnace and afterburner operate at about 1500°F (~815°C) and 2000°F (~1093°C), respectively.
- Deactivation Furnace (DFS):[8] The DFS is a rotary kiln furnace capable of incinerating chopped rockets, explosives, propellants, and remaining chemical agents.
- Pollution Abatement System (PAS):[9] The PAS is a wet scrubber system composed of a quench tower to lower gas temperatures, a scrubber tower to neutralise acids, and a venturi, mist eliminator, and carbon filter to remove various particulates and trace materials.

The detailed specifications (e.g., temperature and materials of construction) of a given incinerator system designed for CW agent, AG-listed precursor, or munition destruction will determine its ultimate control status under the AG.

[6] U.S. Army Chemical Materials Activity, "Liquid Incinerator," Fact Files; http://www.cma.army.mil/ordview.aspx?id=21

[7] U.S. Army Chemical Materials Activity, "Metal Parts Furnace," Fact Files; http://www.cma.army.mil/ordview.aspx?id=22

[8] U.S. Army Chemical Materials Activity, "Deactivation Furnace," Fact Files; http://www.cma.army.mil/ordview.aspx?id=20#

[9] U.S. Army Chemical Materials Activity, "Pollution Abatement System," Fact Files; http://www.cma.army.mil/ordview.aspx?id=23#

Figure 9.B. *Facilities for chemical agent incineration operations. Top left: Liquid incinerator; Top right: Metal parts furnace; Bottom left: Deactivation furnace; Bottom right: Pollution abatement system.*

9.3. Packaging

Controlled incineration facilities for CW destruction would be designed for this purpose and probably shipped as sections to be constructed onsite.

9.4. Typical Applications

As previously noted, this equipment is designed for the destruction of CW agents or munitions. It is possible that such incinerators could also be used for extremely toxic chemical wastes, although the extent to which this occurs in practice was not determined.

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II. Toxic Gas Monitoring Systems and their Dedicated Detecting Components

Toxic gas monitoring systems and their dedicated detecting components as follows: detectors; sensor devices; replaceable sensor cartridges; and dedicated software therefore

(a) designed for continuous operation and usable for the detection of chemical warfare agents or AG-controlled precursors at concentrations of less than 0.3 mg/m^3; or

(b) designed for the detection of cholinesterase-inhibiting activity

II.1. Basic Description

Global Production

- Finland
- France
- Germany
- United Kingdom
- United States

Toxic gas monitoring systems are integral to the safe operation of hazardous chemical production, processing, handling, and disposal facilities, and facilities working with CW agents are certainly no exception.[10] Monitors are a subset of detection systems that have the capability to operate and sample the environment continuously – i.e., without constant human control – to immediately alert personnel to the presence of a particular agent or precursor. These near real-time, continuous air monitoring systems can alert personnel to releases in minutes, while other systems can be used in laboratory settings for longer sampling periods and to check the readings of continuous air monitors ("historical monitoring"). Toxic gas monitoring systems, certain dedicated detecting components, and related dedicated software are identified by the Australia Group for control when they meet either of two specifications: (a) continuous operation with detection at particular concentration levels of specified CW-relevant chemicals or (b) detection of cholinesterase inhibiting (i.e., nerve agent) activity.

II.2. Notable Features

Systems and Detectors Meeting Specification II.a.

Toxic gas monitoring (TGM) systems and their dedicated detecting components can have a range of appearances. In the case of those meeting AG specification II.a, they appear much like pieces of electronic equipment or electronic components, but with some notable features specific to toxic gas detection. First, the unit should have some sort of gas sampling port, and likely also electrical connections for transmission of data (although wireless units might be possible). Furthermore, visible and/or audible alarms may be present on the detectors or main control units for alerting workers to hazardous ambient levels of dangerous chemicals. A readout is likely to appear on the unit to show the concentration of the chemical detected. Although units may have a purely digital readout, there may be markings near the readout panel indicating a concentration unit (i.e., ppm) or possibly the chemical detected by the sensor. Figure II.A shows a series of toxic gas monitors for CW agents that exhibit some of these features.

In this category of TGM systems, the detection method is not specified in the control language. However, two popular detection methods for CW agents are (1) ion mobility spectroscopy (IMS), and (2) gas chromatography (GC) coupled with different types of detectors. Detectors which may be used in conjunction with GC include flame photometric detectors (FPD, or PFPD for pulsed versions) and halogen specific detectors (XSD™). Other methods of detection include surface acoustic wave (SAW), infrared (e.g., OP-FTIR), electrochemical, or photoionisation detection (PID). However, documentation will be required regardless of detection method to determine whether or not a particular unit would meet AG control specifications given that none of the

[10] For example, the U.S. Centres for Disease Control and Prevention provides a fact sheet that summarises main points about monitoring for CW agents in disposal facilities. See CDC, "Air Monitoring for Chemical Warfare Agents;" http://www.cdc.gov/nceh/demil/amcwafs.htm

relevant specifications are likely to be visually apparent.[11] This includes not only determining the detection range of the unit, but also the chemicals it can detect and whether or not it can continuously monitor the environment.

Figure II.A. *Toxic gas monitoring systems for CW agents. Left: Ion mobility spectroscopy-based system; Centre: Gas chromatography-based system (different detector options available); Right: Surface acoustic wave spectroscopy-based system.*

Some dual-use toxic chemicals that could be used as CW agents (e.g., hydrogen cyanide) and AG-controlled precursors are among the toxic industrial chemicals (TICs) used in non-CW-related industrial settings for legitimate applications. Therefore, commercial systems for TIC detection might also meet AG specifications if they have sufficient sensitivity and operate continuously. Potential CW agents and AG-controlled precursors that can be detected by commercially-available TIC sensors include arsenic trichloride, cyanogen chloride, dimethylamine, hydrogen cyanide, hydrogen fluoride, phosgene, phosphorus oxychloride, phosphorus trichloride, and phosphorus pentachloride.

Most suppliers of commercial TGM systems report detection levels in parts per million (ppm) rather than mg/m^3. The conversion between the two units requires knowledge of the molecular weight of the chemical in question. Equations II.1 and II.2 show this conversion, assuming conditions of 25°C and 1 atmosphere.[12]

$$X \text{ ppm} = (Y \text{ mg/m}^3)(24.45)/(\text{molecular weight}) \qquad (II.1)$$

$$Y \text{ mg/m}^3 = (X \text{ ppm})(\text{molecular weight})/24.45 \qquad (II.2)$$

Table II gives the ppm equivalent of the AG detection limit for potential CW agents and AG-listed precursors that could be detected by commercial TGM systems.

[11] However, some detectors for nerve and blister agents could bear individual letters like G or H (for G-series nerve agents or mustard gas, respectively), which would indicate a capacity to detect chemical warfare agents. Additional information on detection limits and mode of operation would still be required to determine control status with respect to the AG specifications.

[12] The CDC provides a conversion calculator online at http://www.cdc.gov/niosh/docs/2004-101/calc.html

Table II. AG detection limit (0.3 mg/m³) in ppm for selected toxic chemicals and precursors

Toxic chemical or precursor	Parts per million (ppm) equivalent of 0.3 mg/m³
Arsenic trichloride	0.04*
Cyanogen chloride†	0.1
Dimethylamine	0.2
Hydrogen cyanide†	0.3
Hydrogen fluoride	0.4
Phosgene†	0.07
Phosphorus oxychloride	0.05
Phosphorus trichloride	0.05
Phosphorus pentachloride	0.04

* Limits in ppm are rounded to one significant figure.
† Cyanogen chloride, hydrogen cyanide, and phosgene have legitimate industrial applications, but they are also listed as toxic chemicals in Schedule 3A of the CWC due to their potential for use as CW agents.

Systems and Detectors Meeting Specification II.b.

As noted in the Introduction to Chemical Weapons and Dual-Use Chemical Technology, nerve agents injure and kill their victims by disrupting nervous system function. They accomplish this by inhibiting (i.e., interfering with) the activity of an enzyme called acetylcholinesterase. TGM units meeting AG specification II.b are those designed to detect this property of nerve agents. Some methods for detecting enzyme inhibition of the enzyme cholinesterase include colourimetric and potentiometric techniques; however, from a commercial standpoint these techniques appear to be used primarily to detect cholinesterase inhibition in blood or other fluids, not for gas monitoring (i.e. for detecting exposure, not monitoring for releases of cholinesterase inhibitors). While commercial kits are available for detecting the presence of cholinesterase enzymes, no commercialised detectors of cholinesterase inhibiters in air samples were found in the course of researching this Handbook, except for basic nerve agent detector tickets or sampling papers.

Other Controlled Systems

Toxic gas monitoring systems and detectors that measure CW agents might meet the requirements for control as Wassenaar Arrangement items even if they do not meet AG control specifications. The Wassenaar Arrangement Munitions List includes “Equipment, specially designed or modified for military use, for the detection or identification of” CW agents and specially designed components for them. The Wassenaar Arrangement also lists detection systems in its Dual-Use List under 1.A.4.c, “Nuclear, biological and chemical (NBC) detection systems specially designed or modified for detection or identification of … chemical warfare (CW) agents and specially designed components therefor.” Such systems are generally not intended for facility monitoring like those controlled by the AG. See the Wassenaar Arrangement website for complete control language for these items.[1]

II.3. Packaging

Toxic gas monitors and dedicated detectors would probably be shipped like other pieces of sensitive electronic equipment. Units could be supplied in cardboard boxes or crates with internal padding like Styrofoam. The units also could be sealed in plastic bags and/or internal boxes.

[1] The Wassenaar Arrangement website can be found at http://www.wassenaar.org

II.4. Typical Applications

Toxic gas monitors detecting CW agents could be used in CW destruction or other handling facilities; in the case of dual-use toxic chemicals that could be used as CW agents (such as hydrogen cyanide or phosgene), such detectors may also find use in commercial settings. Likewise, detectors for precursors could be used in their respective industries – for example, semiconductors. See the chapter on AG-listed Chemical Weapons Precursors for examples of industrial uses of these chemicals.

However, it should be noted that the sensitivity level of toxic gas monitors required in industrial settings may vary from chemical to chemical (e.g., depending on toxicity). Therefore, the high sensitivity afforded by controlled monitoring systems and their dedicated detectors – which is applicable to all CW agents and precursors without distinction – might not be necessary for use in every relevant industry sector. Additional research will be necessary to determine the suitability of controlled monitoring systems and their dedicated detectors for specific end uses.

III. Related Technology

'Technology', including licenses, directly associated with -

- CW agents;
- AG-controlled precursors; or
- AG-controlled dual-use equipment items,

to the extent permitted by national legislation.

This includes:

a) transfer of 'technology' (technical data) by any means, including electronic media, fax or telephone

b) transfer of 'technology' in the form of technical assistance.

Controls on 'technology' do not apply to information 'in the public domain' or to 'basic scientific research' or the minimum necessary information for patent application.

The approval for export of any AG-controlled item of dual-use equipment also authorizes the export to the same end-user of the minimum 'technology' required for the installation, operation, maintenance or repair of that item.

III.1. Basic Description

Control of knowledge that would enable a CW program is a challenging but extremely important task. The AG's chemical equipment control list prescribes controls on technology directly associated with not only AG-controlled dual-use equipment, but also CW agents and AG-controlled precursors. In the context of the list, technology is defined as "specific information necessary for the 'development', 'production' or 'use' of a product. The information takes the form of 'technical data' or 'technical assistance'." All terms within single quotation marks are further defined in the list; see the Glossary for those definitions. This section provides some examples of related technology that would and would not be subject to control.[2]

There are notable exemptions from control for certain types of technology. First, such controls do not apply to information 'in the public domain' – according to the AG's definition, this means "technology that has been made available without restrictions upon its further dissemination."[3] Controls also do not apply to 'basic scientific research,' defined by the AG as "experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena or observable facts, not primarily directed towards a specific practical aim or objective." The minimum information necessary to apply for patents is also exempted. The AG further specifies that approved exports of dual-use equipment bring with them an authorisation to transfer the minimum technology necessary for the installation, operation, maintenance, or repair of the item transferred.

[2] Examples are taken from the AG's publication, "Intangible Technology Transfers;" available from the AG Secretariat.

[3] The AG further notes that "copyright restrictions do not remove technology from being in the public domain."

III.2. Examples of Related Technology

Controlled technologies related to chemicals and equipment of CW concern could take many forms, with some examples noted below. Publicly-available information about synthesis and production pathways for precursors and CW agents is not controlled and is usually not enough to master methods needed for the production of CW agents. Transfer of controlled technologies of types such as those below therefore must be scrutinized carefully, particularly with regard to the end users of the information and their intentions for using it.

- ***Training and Technical Assistance:*** Controlled technology can be transferred via training in the chemical sciences and chemical engineering, such as academic studies, specialist courses, and industry training that could be applied to the production of CW-related chemicals. Transfer of controlled technology could also occur through conferences, workshops, and scientific publications.
- ***Precursor Production Technology:*** Large-scale production schemes for dual-use precursors are often protected for commercial reasons and/or rely on knowledge resident in a particular company. Industrial-scale production often differs substantially from laboratory-scale synthesis, and such technology could pose a proliferation concern if not controlled appropriately.
- ***Development Technology for Equipment:*** Controlled technology of this type could take several forms, such as blueprints, diagrams, models, tables, formulae, engineering designs, photographs, specification manuals, procedures, instructions, books, reports, etc. The information can therefore be transferred orally or physically, including through the use of computer devices and networks. It is important to note that controlled development technology for equipment that is not state-of-the-art may still be relevant to proliferators seeking a CW production capability.

IV. Software

Controls on 'software' transfer only apply where specifically indicated in sections I and II above, and do not apply to 'software' which is either:

1. Generally available to the public by being:
   a. Sold from stock at retail selling points without restriction, by means of:
      i. Over-the-counter transactions;
      ii. Mail order transactions;
      iii. Electronic transactions; or
      iv. Telephone call transactions; and
   b. Designed for installation by the user without further substantial support by the supplier; or
2. 'In the public domain'.

III.1. Basic Description

The AG defines 'software' as "a collection of one or more 'programmes' or 'microprogrammes' fixed in any tangible medium of expression." The AG definition of a 'programme' is "a sequence of instructions to carry out a process in, or convertible into, a form executable by an electronic computer." Likewise, a 'microprogramme' is defined as "a sequence of elementary instructions maintained in a special storage, the execution of which is initiated by the introduction of its reference instruction register." Controls on software do not apply to the two instances outlined in the control list, i.e., not 'in the public domain' or generally available to the public as defined by the AG. Dedicated software for controlled toxic gas monitoring systems is an example of controlled software, since such software controls are specifically indicated in that control list entry.

The ease of software, program, and code transmission makes software controls particularly challenging, but nonetheless important. As noted by the AG in their booklet on intangible technology transfers (ITT):[4]

Consequently it is one area where "self-awareness" and "self-auditing" by scientists, engineers, programmers and other relevant staff is critical to maintaining defences against proliferators. Software is a subject which governments need to emphasise in their outreach to universities, research institutes and companies to ensure they remain aware of the potential for ITT to contribute to programs of proliferation concern.

[4] Australia Group, "Intangible Technology Transfers;" available from the AG Secretariat.

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Appendix A: Export Control List of Chemical Weapons Precursors

September 2009

Precursor Chemical	CAS No.	CWC-Schedule
Thiodiglycol	(111-48-8)	2B
Phosphorus oxychloride	(10025-87-3)	3B
Dimethyl methylphosphonate	(756-79-6)	2B
Methylphosphonyl difluoride (DF)	(676-99-3)	1B
Methylphosphonyl dichloride (DC)	(676-97-1)	2B
Dimethyl phosphite (DMP)	(868-85-9)	3B
Phosphorus trichloride	(7719-12-2)	3B
Trimethyl phosphite (TMP)	(121-45-9)	3B
Thionyl chloride	(7719-09-7)	3B
3-Hydroxy-1-methylpiperidine	(3554-74-3)	Not Listed
N,N-Diisopropyl-(beta)-aminoethyl chloride	(96-79-7)	2B
N,N-Diisopropyl-(beta)-aminoethane thiol	(5842-07-9)	2B
3-Quinuclidinol	(1619-34-7)	2B
Potassium fluoride	(7789-23-3)	Not Listed
2-Chloroethanol	(107-07-3)	Not Listed
Dimethylamine	(124-40-3)	Not Listed
Diethyl ethylphosphonate	(78-38-6)	2B
Diethyl N,N-dimethylphosphoramidate	(2404-03-7)	2B
Diethyl phosphite	(762-04-9)	3B
Dimethylamine hydrochloride	(506-59-2)	Not Listed
Ethylphosphinyl dichloride	(1498-40-4)	2B
Ethylphosphonyl dichloride	(1066-50-8)	2B
Ethylphosphonyl difluoride	(753-98-0)	1B
Hydrogen fluoride	(7664-39-3)	Not Listed
Methyl benzilate	(76-89-1)	Not Listed
Methylphosphinyl dichloride	(676-83-5)	2B
N,N-Diisopropyl-(beta)-amino-ethanol	(96-80-0)	2B
Pinacolyl alcohol	(464-07-3)	2B

Precursor Chemical	CAS No.	CWC-Schedule
O-Ethyl 2-diisopropylaminoethyl methylphosphonite (QL)	(57856-11-8)	1B
Triethyl phosphite	(122-52-1)	3B
Arsenic trichloride	(7784-34-1)	2B
Benzilic acid	(76-93-7)	2B
Diethyl methylphosphonite	(15715-41-0)	2B
Dimethyl ethylphosphonate	(6163-75-3)	2B
Ethylphosphinyl difluoride	(430-78-4)	2B
Methylphosphinyl difluoride	(753-59-3)	2B
3-Quinuclidone	(3731-38-2)	Not Listed
Phosphorus pentachloride	(10026-13-8)	3B
Pinacolone	(75-97-8)	Not Listed
Potassium cyanide	(151-50-8)	Not Listed
Potassium bifluoride	(7789-29-9)	Not Listed
Ammonium bifluoride	(1341-49-7)	Not Listed
Sodium bifluoride	(1333-83-1)	Not Listed
Sodium fluoride	(7681-49-4)	Not Listed
Sodium cyanide	(143-33-9)	Not Listed
Triethanolamine	(102-71-6)	3B
Phosphorus pentasulphide	(1314-80-3)	Not Listed
Diisopropylamine	(108-18-9)	Not Listed
Diethylaminoethanol	(100-37-8)	Not Listed
Sodium sulphide	(1313-82-2)	Not Listed
Sulphur monochloride	(10025-67-9)	3B
Sulphur dichloride	(10545-99-0)	3B
Triethanolamine hydrochloride	(637-39-8)	Not Listed
N,N-Diisopropyl-2-aminoethyl chloride hydrochloride	(4261-68-1)	2B
Methylphosphonic acid	(993-13-5)	2B
Diethyl methylphosphonate	(683-08-9)	2B
N,N-Dimethylaminophosphoryl dichloride	(677-43-0)	2B
Triisopropyl phosphite	(116-17-6)	Not Listed
Ethyldiethanolamine	(139-87-7)	3B
O,O-Diethyl phosphorothioate	(2465-65-8)	Not Listed

Precursor Chemical	CAS No.	CWC-Schedule
0,0-Diethyl phosphorodithioate	(298-06-6)	Not Listed
Sodium hexafluorosilicate	(16893-85-9)	Not Listed
Methylphosphonothioic dichloride	(676-98-2)	2B

Technical note - Chemicals are listed by name, Chemical Abstract Service (CAS) number and CWC Schedule (where applicable). Chemicals of the same structural formula (e.g., hydrates) are controlled regardless of name or CAS number. CAS numbers are shown to assist in identifying whether a particular chemical or mixture is controlled, irrespective of nomenclature. However, CAS numbers cannot be used as unique identifiers in all situations because some forms of the listed chemical have different CAS numbers, and mixtures containing a listed chemical may also have different CAS numbers.

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Appendix B: Control List of Dual-Use Chemical Manufacturing Facilities and Equipment and Related Technology and Software

February 2014

I. Manufacturing Facilities and Equipment

Note 1. The objective of these controls should not be defeated by the transfer of any non-controlled item containing one or more controlled components where the controlled component or components are the principal element of the item and can feasibly be removed or used for other purposes.

N.B. In judging whether the controlled component or components are to be considered the principal element, governments should weigh the factors of quantity, value, and technological know-how involved and other special circumstances which might establish the controlled component or components as the principal element of the item being procured.

Note 2. The objective of these controls should not be defeated by the transfer of a whole plant, on any scale, which has been designed to produce any CW agent or AG-controlled precursor chemical.

Note 3. The materials used for gaskets, packing, seals, screws, washers or other materials performing a sealing function do not determine the status of control of the items listed below, provided that such components are designed to be interchangeable.

1. Reaction Vessels, Reactors or Agitators

Reaction vessels or reactors, with or without agitators, with total internal (geometric) volume greater than 0.1 m^3 (100 l) and less than 20 m^3 (20000 l), where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) tantalum or tantalum alloys;

(f) titanium or titanium alloys;

(g) zirconium or zirconium alloys; or

(h) niobium (columbium) or niobium alloys.

Agitators designed for use in the above-mentioned reaction vessels or reactors; and impellers, blades or shafts designed for such agitators where all surfaces of the agitator that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) tantalum or tantalum alloys;
(f) titanium or titanium alloys;
(g) zirconium or zirconium alloys; or
(h) niobium (columbium) or niobium alloys.

2. Storage Tanks, Containers or Receivers

Storage tanks, containers or receivers with a total internal (geometric) volume greater than 0.1 m^3 (100 l) where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;
(b) alloys with more than 25% nickel and 20% chromium by weight;
(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
(d) glass or glass-lined (including vitrified or enamelled coating);
(e) tantalum or tantalum alloys;
(f) titanium or titanium alloys;
(g) zirconium or zirconium alloys; or
(h) niobium (columbium) or niobium alloys.

3. Heat Exchangers or Condensers

Heat exchangers or condensers with a heat transfer surface area of greater than 0.15 m^2, and less than 20 m^2; and tubes, plates, coils or blocks (cores) designed for such heat exchangers or condensers, where all surfaces that come in direct contact with the chemical(s) being processed are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;
(b) alloys with more than 25% nickel and 20% chromium by weight;
(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
(d) glass or glass-lined (including vitrified or enamelled coating);
(e) graphite or carbon-graphite;
(f) tantalum or tantalum alloys;
(g) titanium or titanium alloys;
(h) zirconium or zirconium alloys;
(i) silicon carbide;
(j) titanium carbide; or
(k) niobium (columbium) or niobium alloys

Technical note: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

4. Distillation or Absorption Columns

Distillation or absorption columns of internal diameter greater than 0.1 m; and liquid distributors, vapour distributors or liquid collectors designed for such distillation or absorption columns, where all surfaces that come in direct contact with the chemical(s) being processed are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;
(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);

(e) graphite or carbon-graphite;

(f) tantalum or tantalum alloys;

(g) titanium or titanium alloys;

(h) zirconium or zirconium alloys; or

(i) niobium (columbium) or niobium alloys.

Technical note: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

5. Filling Equipment

Remotely operated filling equipment in which all surfaces that come in direct contact with the chemical(s) being processed are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight; or

(b) alloys with more than 25% nickel and 20% chromium by weight

6. Valves

a. Valves, having both of the following:

1. A nominal size greater than 1.0 cm (3/8”), and
2. All surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry;

b. Valves, not already identified in paragraph 6.a., having all of the following:

1. A nominal size equal to or greater than 2.54 cm (1”) and equal to or less than 10.16 cm (4”)
2. Casings (valve bodies) or preformed casing liners,
3. A closure element designed to be interchangeable, and
4. All surfaces of the casing (valve body) or preformed case liner that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry;

c. Components, as follows:

1. Casings (valve bodies) designed for valves in paragraphs 6.a.or 6.b., in which all surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry;
2. Preformed casing liners designed for valves in paragraphs 6.a.or 6.b., in which all surfaces that come in direct contact with the chemical(s) being produced, processed, or contained are made from the materials of construction in Technical Note 1 of this entry.

Technical Note 1. Materials of construction for valves are any of the following:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight;

(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);

(d) glass or glass-lined (including vitrified or enamelled coating);
(e) tantalum or tantalum alloys;
(f) titanium or titanium alloys;
(g) zirconium or zirconium alloys;
(h) niobium (columbium) or niobium alloys; or
(i) ceramic materials as follows:
  1. silicon carbide with a purity of 80% or more by weight;
  2. aluminum oxide (alumina) with a purity of 99.9% or more by weight;
  3. zirconium oxide (zirconia).

Technical Note 2. The 'nominal size' is defined as the smaller of the inlet and outlet port diameters.

7. Multi-Walled Piping

Multi-walled piping incorporating a leak detection port, in which all surfaces that come in direct contact with the chemical(s) being processed or contained are made from the following materials:

(a) nickel or alloys with more than 40% nickel by weight;
(b) alloys with more than 25% nickel and 20% chromium by weight;
(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
(d) glass or glass-lined (including vitrified or enamelled coating);
(e) graphite or carbon-graphite;
(f) tantalum or tantalum alloys;
(g) titanium or titanium alloys;
(h) zirconium or zirconium alloys; or
(i) niobium (columbium) or niobium alloys.

Technical note: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

8. Pumps

Multiple-seal and seal-less pumps with manufacturer's specified maximum flow-rate greater than 0.6 m^3/h, or vacuum pumps with manufacturer's specified maximum flow-rate greater than 5 m^3/h (under standard temperature (273 K (0°C)) and pressure (101.3 kPa) conditions), and casings (pump bodies), preformed casing liners, impellers, rotors or jet pump nozzles designed for such pumps, in which all surfaces that come into direct contact with the chemical(s) being processed are made from any of the following materials:

(a) nickel or alloys with more than 40% nickel by weight;
(b) alloys with more than 25% nickel and 20% chromium by weight;
(c) fluoropolymers (polymeric or elastomeric materials with more than 35% fluorine by weight);
(d) glass or glass-lined (including vitrified or enamelled coating);
(e) graphite or carbon-graphite;
(f) tantalum or tantalum alloys;
(g) titanium or titanium alloys;

(h) zirconium or zirconium alloys;

(i) ceramics;

(j) ferrosilicon (high silicon iron alloys); or

(k) niobium (columbium) or niobium alloys.

Technical note 1: carbon-graphite is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

Technical note 2: The seals referred to in this control come into direct contact with the chemical(s) being processed (or are designed to), and provide a sealing function where a rotary or reciprocating drive shaft passes through a pump body.

9. Incinerators

Incinerators designed to destroy CW agents, AG-controlled precursors or chemical munitions, having specially designed waste supply systems, special handling facilities, and an average combustion chamber temperature greater than 1000°C, in which all surfaces in the waste supply system that come into direct contact with the waste products are made from or lined with the following materials:

(a) nickel or alloys with more than 40% nickel by weight;

(b) alloys with more than 25% nickel and 20% chromium by weight; or

(c) ceramics.

Technical Note: For the listed materials in the above entries, the term 'alloy' when not accompanied by a specific elemental concentration is understood as identifying those alloys where the identified metal is present in a higher percentage by weight than any other element.

Statement of Understanding

These controls do not apply to equipment which is specially designed for use in civil applications (for example food processing, pulp and paper processing, or water purification, etc) and is, by the nature of its design, inappropriate for use in storing, processing, producing or conducting and controlling the flow of chemical warfare agents or any of the AG-controlled precursor chemicals.

II. Toxic Gas Monitoring Systems and their Dedicated Detecting Components

Toxic gas monitoring systems and their dedicated detecting components as follows: detectors; sensor devices; replaceable sensor cartridges; and dedicated software therefore

(a) designed for continuous operation and usable for the detection of chemical warfare agents or AG-controlled precursors at concentrations of less than 0.3 mg/m^3; or

(b) designed for the detection of cholinesterase-inhibiting activity

III Related Technology

'Technology', including licenses, directly associated with

- CW agents
- AG-controlled precursors; or
- AG-controlled dual-use chemical equipment items, to the extent permitted by national legislation.

This includes

a) transfer of 'technology' (technical data) by any means, including electronic media, fax or telephone

b) transfer of 'technology' in the form of technical assistance.

Controls on 'technology' do not apply to information 'in the public domain' or to 'basic scientific research' or the minimum necessary information for patent application.

The approval for export of any AG-controlled item of dual-use equipment also authorises the export to the same end-user of the minimum 'technology' required for the installation, operation, maintenance, or repair of that item.

IV. Software

Controls on 'software' transfer only apply where specifically indicated in sections I and II above, and do not apply to 'software' which is either:

1. Generally available to the public by being:

   a. Sold from stock at retail selling points without restriction, by means of:

      i. Over-the-counter transactions;

      ii. Mail order transactions;

      iii. Electronic transactions; or

      iv. Telephone call transactions; and

   b. Designed for installation by the user without further substantial support by the supplier; or

2. 'In the public domain'.

Definition of Terms

'Basic scientific research'

Experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena or observable facts, not primarily directed towards a specific practical aim or objective.

'Development'

'Development' is related to all stages before production such as:

- design
- design research
- design analysis
- design concepts
- assembly of prototypes
- pilot production schemes
- design data
- process or transforming design data into a product
- configuration design
- integration design
- layouts

‘Export’
An actual shipment or transmission of AG-controlled items out of the country. This includes transmission of technology by electronic media, fax or telephone.

‘In the public domain’
‘In the public domain,’ as it applies herein, means technology that has been made available without restrictions upon its further dissemination. (Copyright restrictions do not remove technology from being in the public domain.)

‘Microprogramme’
A sequence of elementary instructions maintained in a special storage, the execution of which is initiated by the introduction of its reference instruction register.

‘Production’
Production means all production phases such as:

- construction,
- production engineering,
- manufacture,
- integration,
- assembly (mounting),
- inspection,
- testing, and
- quality assurance.

‘Programme’
A sequence of instructions to carry out a process in, or convertible into, a form executable by an electronic computer.

‘Software’
A collection of one or more ‘programmes’ or ‘microprogrammes’ fixed in any tangible medium of expression.

‘Technology’
Specific information necessary for the ‘development,’ ‘production’ or ‘use’ of a product. The information takes the form of ‘technical data’ or ‘technical assistance’.

‘Technical assistance’
May take forms, such as: instruction, skills, training, working knowledge, consulting services. Technical assistance includes oral forms of assistance. Technical assistance may involve transfer of ‘technical data.’

‘Technical data’
May take forms such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories.

‘Use’
Operation, installation, (including on-site installation), maintenance, (checking), repair, overhaul or refurbishing.

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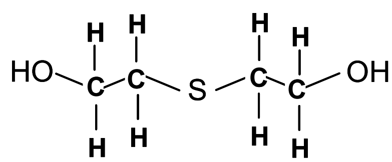
Appendix C:
Chemical Precursor Descriptions: Definitions and Resources

In this Handbook, each precursor on the AG Chemical Weapons Precursors Control List is described in four sub-sections: (1) Basic Description; (2) Notable Features; (3) Packaging; and (4) Typical Applications. In addition, a chemical structure and a list of producing countries is provided for each precursor. This section provides definitions of terms and examples of the resources used to obtain the information included in each of these sub-sections. Additional resources are provided in the Bibliography.

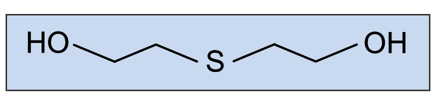
Note: The authors do not endorse or in any way attest to the accuracy of the sources referenced herein.

x. AG precursor name (where x is the precursor number on the control list for Chemical Weapons Precursors)

Each entry begins by showing the chemical structure of the precursor. The structure can provide insight into its potential use in the manufacturing of chemical weapons (CW) agents and, therefore, its proliferation risk (i.e., how chemically similar it is to a CW agent). For example, the precursor thiodiglycol with formula $C_4H_{10}O_2S$ has the full chemical structure below:



which is similar to the chemical structure for mustard gas shown in the Introduction to Chemical Weapons and Dual-Use Chemical Technology. However, for compactness, organic chemistry shorthand is used in most of the structures shown in this Handbook. In this shorthand, each carbon atom is represented by the end of a line or the intersection of two lines instead of being shown explicitly as a "C." Every carbon atom must have four chemical bonds for the molecule to be stable, so any missing bonds are assumed to be carbon-hydrogen bonds. Similarly, any nitrogen atom in an electronically neutral compound must have three bonds, and any missing bond is understood to be N-H. In this shorthand, the structure of thiodiglycol is:



x.1. Basic Description

This section begins by identifying the type of CW agent that can be made from the precursor.1 The remainder of the basic description is devoted to a table of identifiers and properties of the precursor that can be found on chemical labels and documentation; these pieces of information can assist in determining the identity of a material (and, by extension, its potential control status).

Numerous resources were used to compile this information. (Material) Safety Data Sheets (SDSs or MSDSs)[2] were used to find data on many precursors. SDSs are extremely valuable collections of physical properties, identifiers, transportation codes, and safety information for particular substances and are

[1] Sources used include Army Field Manual FM 3-11.9, "Potential Military Chemical/Biological Agents and Compounds" (January 2005); http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA457455 and D. Hank Elison, *Handbook of Chemical and Biological Warfare Agents* (Boca Raton, FL: CRC Press), 1999. See also the Bibliography.

[2] Previously known as Material Safety Data Sheets (MSDSs), the correct term for these documents is Safety Data Sheets (SDSs). However, several companies still use the outdated MSDS terminology.

often available from supplier websites if not included in a shipment.[3] In addition to manufacturer and supplier SDSs, several websites and books were used to verify information or find additional data.[4]

Each precursor has a table of identifiers and properties, with the following format:

Identifier/Property	Value
CAS#	
Formula	
Molecular Weight	
CA Index Name	
CWC Schedule	
EC#	
HS#	
UN#	
UN Hazard Placard	
Other Names	
EU CL#	
GHS Pictogram	

The sections below provide an explanation of each field in the table.

CAS#

The CAS# is a registry number assigned by the Chemical Abstracts Service. It is the most commonly-used, essentially unique identifier for a chemical substance. It takes the form XXXXXXX-XX-X, where each X is an number 0-9. The first number in the code varies in its number of digits (from two to seven), but the second and third parts always have two digits and one digit, respectively. The last digit in the CAS# is determined from the numbers that precede it, so it can be used to check whether or not a CAS# is valid. A formula for determining the validity of a CAS# can be found on the Chemical Abstracts Service website.[5]

The CAS# frequently is available as a search term in chemical information databases. This identifier is extremely valuable because chemical formulas are not always unique and multiple names can be used for many substances. However, as recognised in the Technical Note to the Chemical Weapons Precursors control list, "CAS numbers cannot be used as unique identifiers in all situations because some forms of the listed chemical have different CAS numbers, and mixtures containing a listed chemical may also have different CAS numbers."[6]

[3] The MSDS Hyper Glossary is a useful on-line glossary of SDS terms: http://www.ilpi.com/msds/ref/index.html

[4] For example, the NIST Chemistry WebBook at http://webbook.nist.gov/chemistry; *Handbook of Chemical and Biological Warfare Agents*, Ibid.; Army Field Manual FM 3-11.9, Ibid.; CRC Handbook of Chemistry and Physics, 73rd Edition (Boca Raton, FL: CRC Press) 1992-93; and *The Merck Index: an Encyclopedia of Chemicals, Drugs, and Biologicals*, 13th Edition (Whitehouse Station, NJ: Merck), 2001

[5] Check Digit Verification of CAS Registry Numbers; http://www.cas.org/content/chemical-substances/checkdig

[6] It further advises that "chemicals of the same structural formula (e.g., hydrates) are controlled regardless of name or CAS number."

Formula

The chemical formula gives the elemental composition of a substance. It is a list of its constituent elements (denoted by their chemical symbols from the Periodic Table) with the number of atoms of each element given as a subscript. In accordance with one convention, the formulas in this Handbook are written in Hill Order: carbon (C) is listed first, followed by hydrogen (H), then all other elements in alphabetical order. However, this order does not always reflect the structure of the molecule; there are often alternative sequences that better describe the connections between atoms. For example, the formula for dimethylamine in Hill Order is C_2H_7N, but the molecular structure is reflected more accurately by the order $NH(CH_3)_2$. The latter sequence is also a correct expression of the formula. It also is important to realise that the chemical formula is not necessarily a unique identifier of a substance; different chemicals can have the same molecular formula. For example, ethylamine, which is not controlled by the AG, also has the formula C_2H_7N. Therefore, additional information often will be required to confirm the identity of a substance.

Molecular Weight

The molecular weight is the sum of the atomic weights of all atoms in the chemical formula; it is also the mass in grams per mole (where one mole is equal to 6.022×10^{23} molecules). The term “molar mass” is a more accurate name for this latter figure, but it is numerically the same as the molecular weight.

CA Index Name

The CA (Chemical Abstracts) Index name is the name given to a substance by the Chemical Abstracts Service, which is the same organisation that assigns CAS#s. The CA Index Name can be obtained from the *Chemical Abstracts Service Registry Handbook*, which provides a chemical name and formula associated with each registry number. There are often several synonyms for a chemical, and chemical names following other conventions are provided later in the table.

CWC Schedule

This entry notes the Chemical Weapons Convention (CWC) Schedule for the chemical. A helpful overview of the Schedules is provided by Organisation for the Prohibition of Chemical Weapons (OPCW), the implementing organisation of the CWC.[7]

The CWC contains three Schedules of chemicals subject to verification measures under the treaty; toxic chemicals are listed in part A of each Schedule, with precursors under part B. Schedule 1 chemicals either have been or could easily be used as CW agents and have few, if any, legitimate uses other than protective purposes (e.g., testing protective or detection equipment). They would rarely be encountered in normal trade, and there are severe restrictions on international transfers of these chemicals. Schedule 2 chemicals can be used as CW agents or be used to make them, but they have a fair number of commercial applications. Schedule 3 chemicals are widely used and traded for many peaceful purposes. They also pose a proliferation risk due to their potential for use as CW agents or to prepare them, but it would take more chemical reactions to prepare a CW agent from a Schedule 3 precursor than a Schedule 2 precursor. Therefore, the Schedule assignment of a chemical reflects both the degree of its proliferation risk and the extent of its trade and commercial use.

7 OPCW, “Which chemicals are controlled?” http://www.opcw.org/our-work/non-proliferation/which-chemicals-are-controlled/. The Schedules and further information about trade restrictions, inspections, and declarations can be found in the CWC text on the OPCW website: http://www.opcw.org/html/db/cwc/eng/cwc_frameset.html

EC#

The EC# (European Commission Number) is a reference number for chemicals listed in the EC Inventory. The EC Inventory encompases the European Inventory of Existing Commercial Chemical Substances (EINECS), European List of Notified Chemical Substances (ELINCS), and the No-Longer Polymers (NLP) List, each of which has a different scope.[8] The EC# format is XXX-XXX-X, with all numeric digits. There are fewer entries in this registry than in that of the Chemical Abstracts Service; not all precursors have an EC#. EC#s can be found in the European Chemical Substances Information System (ESIS).[9]

HS#

The HS number is a code from the World Customs Organisation's Harmonized Commodity Description and Coding System, more commonly referred to as the "Harmonized System" or HS. These six-digit codes are harmonised internationally, providing a standardised system for classifying traded products. Individual WCO Member States assign additional digits beyond these for more specific classification and tariff rates.

For those precursors that also appear on the CWC Schedules, HS numbers were confirmed using the WCO's *Recommendation of the Customs Co-Operation Council on the Insertion in National Statistical Nomenclatures of Subheadings for Substances Controlled under the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction.*[10] For unscheduled, AG-listed precursors, HS numbers were obtained from the first six digits of national codes from the United States and Australia.[11]

UN#

UN#s (United Nations Numbers) are four-digit codes used to identify hazardous substances and articles in transport; see the Chemical Packaging and Transportation section for more information. The master list of UN Numbers is the Dangerous Goods List of the UN Model Regulations.[12] For precursors falling into generic "not otherwise specified" categories, the UN numbers were obtained from manufacturer or supplier SDSs. The Proper Shipping Name is also provided in this field.

UN Hazard Placard

As described in the Chemical Packaging and Transportation section, each UN# has an associated Hazard Class or Division that dictates what hazard diamond placards would be posted on a shipment. The respective hazard diamonds are pictured in this field.

Other Names

A chemical substance frequently is known by more than one name. There are officially-recognised nomenclature rules set by the International Union of Pure and Applied Chemistry (IUPAC) that attempt to standardise chemical names.[13] However, archaic, trade, transportation, non-English language, and other alternative names are in use in many instances. This section compiles names found to be associated with a given precursor, either in chemical information databases or from commercial sources.

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8 For more details, see "Guidance for identification and naming of substances under REACH and CLP," European Chemicals Agency; http://echa.europa.eu/documents/10162/13643/substance_id_en.pdf

9 ESIS; http://esis.jrc.ec.europa.eu/

10 Online at http://www.wcoomd.org/en/topics/nomenclature/instrument-and-tools/~/media/WCO/Public/Global/PDF/About%20us/Legal%20Instruments/Recommendations/HS/Recommendation%20CWC%202009_HS2012.ashx

11 Obtained, respectively, from http://www.usitc.gov/tata/hts/bychapter/ and http://www.dfat.gov.au/cwco/cd_rom_imp_exp_chem.html

12 The most recent version of the UN Model Regulations (officially, the UN Recommendations on the Transport of Dangerous Goods – Model Regulations) as of the writing of this Handbook is the Eighteenth revised edition published in 2013; http://www.unece.org/trans/danger/publi/unrec/rev18/18files_e.html. The respective Dangerous Goods List is found in Part 3 of the Model Regulations; http://www.unece.org/fileadmin/DAM/trans/danger/publi/unrec/rev18/English/Rev18_Volume1_Part3andApp.pdf

13 IUPAC; http://www.iupac.org/home/about.html

EU CL#

EU CL#s are the control list numbers from the European Union's Dual-Use List.[14] Those substances with EU CL #s followed by "(ML)" have a reference to military goods controls in the Dual-Use List entry.

GHS Pictogram

This section provides the hazard pictogram(s) that would appear on labels of the chemical according to the Globally Harmonized System of Classification and Labelling of Chemicals (GHS). See the Chemical Packaging and Transportation section for more information on the GHS.

x.2. Notable Features

This section describes the physical characteristics of the chemical for completeness of information. However, a chemical's appearance is not unique, and other information will be needed to make a positive identification of the chemical.

x.3. Packaging

Information about packaging of precursors for storage or shipment was gathered primarily from commercial sources of each chemical, as well as from other sources noted in the Bibliography for this Handbook.

x.4. Typical Applications

Peaceful uses of the precursor are discussed in this section. This section provides only a brief summary of commercial uses reported in various information sources. Other legitimate uses may be possible, and not all specifications (e.g., purity) of a listed precursor may be appropriate for every use listed. Therefore, additional research will be necessary to verify the validity of an end use claimed in a license application or a shipment.

In addition to manufacturer and supplier websites, sources of information for this section include those consulted for the x.1. Basic Information section, as well as those listed in the Bibliography.

Global Production

Suppliers of precursors were identified through a combination of online directories and internet searches. The availability of the precursor was confirmed by searching individual company websites. When a multinational company was found to produce a precursor, the country where production takes place is noted when known; when the country of production is unknown, the headquarters country is listed by default. It is important to recognise that, while these countries produce the respective precursor, that precursor may be available from traders located in other countries not included in the Global Production listing.

[14] The most recent version of the EU Dual-Use List, as of the writing of this Handbook, is Regulation (EU) No 388/2012 of the European Parliament and of the Council, available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:129:0012:0280:EN:PDF

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Appendix D: Glossary

Note: This Glossary contains terms found in this Handbook which may not be familiar to the reader and are not defined in the AG's own "Definition of Terms." Stated definitions derive from common knowledge and information gathered from both online dictionaries and Wikipedia.

Ablation
The removal of material from an object by an erosion-type process.

Absorption
The uptake of one phase into another, such as a gas into a liquid or a liquid into a solid.

Acetylcholinesterase
An enzyme which breaks down acetylcholine, a neurotransmitter needed for communication between nerve cells and their target organs but that normally is broken down after it transmits a signal. Nerve agents inhibit (i.e., prevent) activity of this enzyme; this in turn prevents the normal breakdown of acetylcholine, resulting in continuous stimulation of the target (e.g., muscles).

Active controls
A category of laboratory safety practice(s) which require workers to actively do something for the controls to work (e.g., use of personal protective equipment).

Active pharmaceutical ingredient
The substance in a pharmaceutical drug or pesticide that is biologically active. Also known as active ingredient (AI) and active substance (in pesticide formations).

Actuation
In the context of this Handbook, actuation refers to the opening and closing of a valve (Volume I).

Administrative controls
A category of laboratory safety practice(s) that are not physically built into a facility but are based on the policies and procedures enforced within a particular facility (e.g., escort and/or background check requirements for visitors).

Adsorption
The binding of molecules or particles to a surface. Selective adsorption of one substance in a mixture to a substrate can be used as a means of separation (i.e., in chromatographic methods).

Aerobiology
A branch of biology that studies organic particles which are passively transported by the air, such as bacteria, fungal spores, very small insects, pollen grains, and viruses.

Aerosol
A gaseous suspension of fine solid particles or liquid droplets.

Aerosolised
Existing as a gaseous suspension of fine solid particles or liquid droplets.

Affinity
An attraction or force between particles that draws them together and/or causes them to combine.

Affinity-based methods
A variety of separation processes that are based on differences in the affinity (or binding preferences) of chemicals in a mixture for different media. Also referred to as chromatographic methods.

Agent
In the context of biological weapons, an agent is a living micro-organism that is pathogenic to humans, animals, or plants. Some biological agents cause harm to animals or humans by producing chemical toxins, which are poisonous in very small quantities. For more information, see the Introduction to Biological Weapons and Dual-Use Biotechnology and the Introduction to Pathogens and Toxins.

In the context of chemical weapons, an agent is a toxic chemical that *could* be used as a chemical weapon. Precursors to CW agents are not considered to be CW in the context of this Handbook, but rather chemicals that can be used to produce CW agents. The Introduction to Chemical Weapons and Dual-Use Chemical Technology in Volume I provides a discussion of CW agent terminology and a brief overview of agent classes.

Aggregate order
An order placed with a manufacturer/supplier that is composed of a collection of individual items. In some cases, a combination of many small items may be functionally equivalent to a single larger item. For example, 10 fermenters with individual capacities of 5 litres each combine to give a total fermentation capacity of 50 litres. See the section on Small Fermenters in Volume II.

Alkaline
Related to the ability of an aqueous solution to neutralise an acid. Alkaline solutions have a pH greater than 7.

Alkyl alkanolamine
Chemical compounds that have a hydrocarbon backbone bearing both hydroxyl (-OH) and amine (-NH2, -NHR, and –NR2, where R is a carbon group) functional groups.

Alkylation
The transfer of an alkyl (i.e., hydrocarbon) group from one molecule to another.

Amoeba
A unicellular micro-organism that does not have a definite shape.

Ampoule
A small sealed vial which is used to hold a sample and protect it from environmental exposure.

Anhydrous
A substance that contains no water.

Annular
Ring-shaped. In a multi-walled piping system (Volume I), this describes the space between the inner pipe carrying the fluid being transported and the outer containment pipe.

Anteroom
An outer chamber or waiting room situated before the main work room. In Biosafety Level 3 and Biosafety Level 4 facilities, the anteroom is located between the containment work area and the regular laboratory. The anteroom typically contains facilities for changing into protective suits prior to entry into the containment work area and facilities for removing protective suits and showering after exiting the containment work area.

Antibody
Protein complex found in the blood or other bodily fluids of humans and animals. Antibodies are used by the immune system to identify and neutralise foreign objects, such as bacteria and viruses.

API
See active pharmaceutical ingredient.

Aqueous
A solution in which the solvent is water.

Arthralgia
Non-inflammatory joint pain that is a symptom of infection, disease, injury, or illness.

Atomisation
The process of converting a stream of liquid into a fine spray or aerosol.

Atomiser
A device which converts a stream of liquid into a fine spray or aerosol.

Autoclavable
Manufactured of materials designed to withstand sterilization by an autoclave, i.e. using high pressure and high temperature steam.

Axial
In a direction parallel to an axis. In the context of agitators (Volume I), axial mixing occurs along the same direction as the agitator shaft's orientation.

Bacteria
A unicellular micro-organism. With few exceptions, bacteria are independent living micro-organisms that are not dependent on another organism for replication.

Baffle
A structure inside a chemical reaction vessel (Volume I) used to disrupt the flow of its contents to promote mixing.

Base metal
The primary metal in an alloy.

Basic scientific research
The AG defines 'basic scientific research' as "experimental or theoretical work undertaken to acquire new knowledge of fundamental principles of phenomena or observable facts, not primarily directed towards a specific practical aim or objective."

Batch operation
A method of operation which requires distinct 'start' and 'end' points to the process. Data or products are collected at the end of the process as part of individual batches. Following collection, the process may be restarted.

Binary fission
Reproduction of a bacterium where the micro-organism divides itself into two independent cells.

Biodegradation
The chemical dissolution of materials by micro-organisms or other biological means, returning the material to the form of components found in nature.

Biological weapon
A weapon that delivers toxins or micro-organisms, such as viruses and bacteria, with the intent of deliberately inflicting disease and destruction among people, animals, or agriculture.

Biopesticide
A form of pesticide based on micro-organisms or natural products.

Bioreactor
An apparatus used to carry out any kind of bioprocess. See fermenter, chemostat, and continuous flow stirred tank reactor. See also the section on Fermenters in Volume II.

Bioremediation
Any process using micro-organisms, fungi, green plants, or their enzymes to return a natural environment altered by contaminants to its original condition.

Biovar
A group of strains which are distinguishable from other strains of the same species on the basis of their physiological characteristics.

Biphasic disease
A disease which has two distinct phases. For example, patients who are infected with *Omsk haemorrhagic fever virus* can experience biphasic expression of the disease. Initially, patients experience symptoms typically associated with mild viral haemorrhagic fever. After symptoms subside and the patient seems to have recovered from the virus, a second set of symptoms including fever and encephalitis can develop.

Blister agent
See Vesicant

Blood agent
A type of chemical weapons agent that acts by interfering with oxygen transport from blood to body tissues (e.g., hydrogen cyanide and cyanogen chloride). See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Blood fraction
An end product of separating blood (by centrifugation) into its component parts. These blood fractions include blood plasma, white blood cells, and red blood cells.

Blood plasma factor
Blood plasma factors are proteins that regulate the ability of blood to clot and are very important in the process of minimising blood loss after a wound.

Brackish water
Water that is higher in salt content than freshwater but lower in salt content than ocean water. This occurs naturally in tidal estuaries where fresh and salt water mix.

Bung hole
A hole bored in a liquid-tight barrel to remove contents.

Carbide
A compound of carbon with another element, namely an element that attracts electrons more strongly than carbon does. Silicon carbide and titanium carbide are two examples and are considered ceramics.

Carboy
A rigid container with a typical capacity of 20-60 litres (5-15 gallons). Carboys are primarily used for transporting fluids.

CAS number
A unique registry number assigned to each chemical by the Chemical Abstract Service (CAS). See Appendix C in Volume I for more details.

Catalyst
A substance that causes a chemical reaction to happen more quickly.

Caustic
Able to burn or corrode organic tissue by chemical action.

CDA
See Controlled droplet application

Centrifugal force
Force generated by rotation and experienced as outward force away from the centre of rotation.

Centrifugal separator
Also called a centrifuge. A machine used to separate components with varying density using the centrifugal force generated by high-speed rotation. See the Volume II section on Centrifugal Separators.

Ceramic

An inorganic, nonmetallic solid. Ceramics are generally known for their corrosion resistance, strength, hardness, and high thermal conductivity.

Chemical neutralisation

A chemical weapons destruction method that involves the mixing of CW agents with hot water or hot water and sodium hydroxide to convert the agents into less harmful chemicals.

Chemical reaction

A process that transforms one set of chemical molecule(s) to another with distinctly different chemical identities.

Chemical synthesis

A sequence of chemical reactions conducted to obtain a product, or several products. Often this involves the construction of complex chemical compounds from simpler ones.

Chemical weapon

In the context of this Handbook, a toxic chemical loaded into a delivery system such as a munition - i.e., a complete device for exposing a population to a substance that can cause death or other injuries through its chemical action.

Chemical weapons agent

A toxic chemical that could be used as a chemical weapon. See the Introduction to Chemical Weapons and Dual-Use Chemical Technology in Volume I for an extensive discussion of CW agent-related terminology.

Chemostat

A bioreactor in which constant growth conditions for micro-organisms are maintained over prolonged periods of time by supplying the reactor with a continuous input of nutrients and continuous removal of growth medium and waste products. See the section on Fermenters in Volume II.

Chlor-alkali

An industrial process involving the electrolysis of brine (salt water) to generate other chemicals; products can include hydrogen gas, chlorine, sodium hydroxide (caustic soda), sodium chlorate, and/or sodium hypochlorite (bleach), depending on the specific methods used.

Chloroplast

Specialised sub-cellular compartment within plant or algae cells where photosynthesis takes place.

Choking agent

A type of chemical weapons agent that acts by damaging lung tissue, leading to pulmonary edema. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Cholinesterase inhibition

The inhibition of the breakdown of acetylcholine. See acetylcholinesterase.

Chromatographic methods

Laboratory techniques used to separate mixtures. See Affinity-based methods.

Chromosome
A mixture of nucleic acid (DNA or RNA) and protein located in the nuclei of cells.

Clarify
To make a liquid clear or pure, usually by freeing it from suspended matter.

Clean room
A room with a controlled environment and constant, highly filtered airflow. It has a very low level of pollutants, dust, airborne microbes, aerosol particles, or chemical vapours. Biosafety level 3 and Biosafety level 4 facilities (see Volume II) are examples of clean rooms, but clean rooms are also widely used in the electronics industry or in any application where dust elimination is required.

Colourimetric
A technique in which the concentration of a chemical element or compound in a mixture is determined by measuring a colour change or the absorption of light in a particular colour range.

Commensalism
An association between two organisms in which one benefits and the other derives neither benefit nor harm.

Condensation
The change of a physical state of matter from a gas into a liquid.

Condenser
A device used to remove heat from a liquid or vapour, causing it to cool and transform to a solid or liquid, respectively.

Conjunctivitis
Inflammation and/or infection of the eye and inner surface of the eyelids.

Controlled droplet application
A spraying technology that produces an aerosol of uniform droplet size. This technology allows droplet size to be altered to known droplet diameters so one can achieve the “optimum” size for an intended application.

Copolymer
A polymer derived from more than one type of monomer.

Corrosive
A characteristic of a chemical that will destroy or damage other substances with which it comes into contact.

Cross-flow filtration
A filtration technique where the material to be filtered passes tangentially across (not perpendicular to) the filter surface, minimising fouling and clogging of the filter. Also called tangential flow filtration. See the Volume II section on Cross (tangential) Flow Filtration.

Crystallisation
The process of forming solid crystals from a gaseous or liquid solution.

Culling
The process of removing animals from a group based on specific criteria. For the purposes of the AG Handbook, culling is a containment strategy that refers to the slaughtering of animals affected with or potentially exposed to controlled pathogens to prevent further spread of the disease.

Cultivar
A race or variety of plant that has been created or intentionally chosen and maintained in a population through cultivation. For example, farmers may preferentially grow a particular cultivar of rice that produces a higher crop yield or is more resistant to environmental stressors (e.g., temperature).

Cyanobacteria
Bacteria that obtain nutrients through photosynthesis. These bacteria are also known as blue-green algae.

Dead-end host
Any host from which a pathogen cannot escape to continue its life cycle. Once in a dead-end host, the pathogen is not transmissible from that host to another organism.

Decanter centrifuge
A type of centrifuge that features a horizontal spinning metal bowl encased in another metal housing. A scroll or screw conveyor within the bowl rotates at a different speed than the bowl and removes separated solids for discharge. See the Volume II section on Centrifugal Separators.

Dehydration
In the context of freeze- or spray-drying, dehydration refers to the removal of water or other fluids from a solid by evaporation. See the Volume II sections on Freeze-Drying Equipment and Spray-Drying Equipment.

Demilitarisation
The reduction of a nation's armed forces, weapons, and/or military vehicles to an agreed minimum. In the context of this Handbook, demilitarisation is used to refer to the destruction of CW agents, precursors, and/or munitions.

Density
Mass per unit volume. Density is a measure of the "heaviness" of an object when comparing it to another object of a similar volume.

Development
In reference to development technology, the AG defines 'development' as "related to all stages before 'production' such as: design, design research, design analysis, design concepts, assembly of prototypes, pilot production schemes, design data, process or transforming design data into a product, configuration design, integration design, and layouts."

Dewatering
The process of removing water from a solid by centrifugation or filtration.

Diaphragm
A flexible membrane. In the context of the AG, this refers to a type of seal-less pump that uses the reciprocating action of a diaphragm to cause the pumping action (Volume I).

Disinfection
Destruction of pathogenic and other types of micro-organisms. Disinfection is less lethal than sterilization because it destroys most recognised pathogenic micro-organisms but not necessarily all microbial forms (e.g., bacterial spores).

Disk stack centrifuge
This centrifuge design features a prominent conical metal bowl with at least three connections – one feed inlet and two outlets. The inside of the metal bowl contains not only the spinning part of the centrifuge, but also a stack of disks to assist the separation. See the Volume II section on Centrifugal Separators.

Dissolution
The process of a solute forming a solution with a solvent.

Distillation
A separation technique based on differences in boiling points between different components of a chemical mixture. See the Introduction to Chemical Weapons and Dual-Use Chemical Technology in Volume I for more details.

DNA
An acronym for deoxyribonucleic acid. DNA is a self-replicating material present in nearly all living organisms that carries a species' genetic information.

Dopant
A trace impurity element that is inserted into a material in order to alter the electrical or optical properties of that material. Also known as a doping agent.

Downcomer
In the context of distillation columns, a pipe used to facilitate the movement of liquid to lower sections of the column. See the Volume I section on Distillation or Absorption Columns.

Drift spraying
A spraying application where the particles generated are intended to "drift" for an extended period of time, covering a wide area. Drift spraying typically uses smaller particles.

Dual-use
Dual use refers to the potential of products and technologies with peaceful civilian purposes to be used in WMD-related applications.

Dystonia
A neurological movement disorder characterised by sustained muscle contractions, which result in repetitive movements and uncontrollable twisting.

EC number
The European Commission (EC) Number is a reference number for chemicals listed in the EC Inventory. See Appendix C in Volume I for more details.

Eccentrically
Describes the motion of a disk or wheel having its axis of revolution displaced from its centre so that it is capable of imparting reciprocating motion. In the context of this Handbook, this refers to the orientation of liquid ring pump impellers which are mounted offset from the casing axis.

Effluent
Liquid or gas that flows out from a larger body of liquid or gas.

Elastomer
A polymer with the elastic properties of natural rubber.

Electrochemical detection
A sensitive and selective detection technique that is based on oxidising or reducing parts of a chemical's structure.

Electrolysis
A method of using a direct electric current to drive a chemical reaction.

Electronegativity
A property describing the tendency for an atom or group of atoms to draw electrons toward itself. An atom that is more electronegative than its neighboring atoms in a molecule will attract more electrons toward it.

Elution
The process of removing an adsorbed component from a substrate by washing with a solvent to which the component has more affinity than the adsorbent.

Emulsion
A mixture of two or more immiscible liquids, which cannot form a homogeneous solution.

Encephalitis
Inflammation and swelling of the brain.

Encephalomyelitis
Inflammation and swelling of the brain and spinal cord.

Endemic
Commonly found within a particular population or in a certain geographic area.

Engineering thermoplastics
A group of plastic materials that have better mechanical and/or thermal properties than other commonly used plastics. Engineering thermoplastics are generally used in applications which require higher performance in the areas of heat resistance, chemical resistance, impact, fire retardancy, or mechanical strength.

Entrainment pump
A type of pump that functions by moving the process fluid via the movement of another fluid.

Enzyme
Biological molecules, usually proteins, which can cause specific chemical changes to a separate molecule.

Excipient
An inactive substance mixed with the "active" material (e.g., an active pharmaceutical ingredient or a pathogen) to be dried and preserved. Excipients typically improve the preservation of biological material without disrupting its activity.

Exotoxin
A toxin naturally secreted by certain bacteria. By contrast, an endotoxin is a toxin produced by bacteria that is only released when the bacteria breaks apart and dies.

Extraction
The process of removing something from a mixture or compound. In the context of purification, this term often refers to extraction of a desired compound from a mixture through the use of immiscible solvents. See the discussion of purification in the Volume I section Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Extrusion
In the context of this Handbook, a method of encapsulation whereby the material to be coated is drawn through a nozzle to form microcapsules. Several types of extrusion methods are practiced, differing by nozzle configuration and coating method. See the Volume II section on Encapsulation Equipment and Technology.

Family
The next taxonomic category above genus, usually ending in –idea (animals) or –aceae (plants).

Feedstock
A raw material or solution from which a product is made. In spray-drying, feedstock refers to the liquid to be atomised and dried into powder. See the Volume II section on Spray-Drying Equipment.

Fermenter
A bioreactor which enables optimal fermentation conditions to be maintained, allowing addition of nutrients, removal of products and insertion of measuring and/or control probes as well as other necessary equipment (e.g. for heating, cooling, aeration, agitation, sterilization, etc.) under sterile conditions. See the Volume II section on Fermenters.

Filtrate
Following a filtration process, the part of a solution that is considered "filtered."

Flame photometric detector
A detector used to detect compounds containing sulphur or phosphorus utilising chemiluminescent reactions. It can also be used to detect certain metals.

Flocculant
A substance added to a suspension to clarify it by enhancing the aggregation of the suspended particles, causing them to drop out of the solution.

Fomite
A living or inanimate object that may be contaminated with infectious organisms and facilitate their transmission to a susceptible host.

Fouling
The accumulation of unwanted solid material on a filter, which decreases performance of the filter.

Fungi
A group of unicellular and multicellular organisms (e.g., molds, yeast, and mushrooms) that feed on organic matter as their source of nutrients.

Fungicide
A chemical substance that kills or inhibits the growth of fungi.

G-series nerve agent
A group of nerve agents so named because German scientists were the first to synthesise them. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Galvanised
The process by which a zinc coating is added to iron or steel to prevent rusting.

Gas chromatography
A chromatographic method used to separate and analyse mixture components by vapourising the mixture and passing it through a column with coated walls or packing. Different mixture components have different affinities for the wall or packing material, which affects the speed at which they travel through the column.

Gas tight
A measure of airtightness defined as preventing the passage of gas or aerosols, up to a particular pressure rating and over a particular length of time.

Gastroenteritis
Inflammation of the lining of the intestines that can be caused by a pathogen. Symptoms can include abdominal pain, diarrhea, vomiting, headache, fever, and chills.

Genetically modified
An organism that has intentional changes introduced into its genetic material (DNA or RNA).

Genome
The entirety of an organism's hereditary information found in a cell and encoded by DNA or RNA.

Genus
A taxonomic category that ranks above species and below family.

Germicidal
The capability to kill or reduce germs, especially pathogenic micro-organisms.

Germination
The process by which plants, fungi, and bacteria emerge from seeds and spores and begin to grow.

Graphite

A form of carbon that can exhibits high corrosion-resistance and excellent thermal conductivity.

Halogen specific detector

A selective detector for halogenated compounds (i.e., compounds containing fluorine, chlorine, and/or bromine).

Hazard Class

A designation assigned to each entry in the UN Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. The Hazard Class assigns material to a general category of chemical or physical hazards (e.g., Hazard Class 3 indicates flammable liquids). See the Volume I section on Chemical Packaging and Transportation.

Head

An end cap on a chemical reaction vessel or heat exchanger that provides ports for connection of piping or instruments. See the Volume I sections on Chemical Reaction Vessels or Reactors and Heat Exchangers or Condensers.

Heat transfer area

The total area in a heat exchanger or condenser over which thermal transfer occurs (e.g., the surface area of the tube bundle in a shell and tube heat exchanger design). See the Volume I section on Heat Exchangers or Condensers.

HEPA

See High Efficiency Particulate Air.

High Efficiency Particulate Air

A type of air filtration system or filter rated to remove at least 99.7% of airborne particles 0.3 µm in diameter.

High vacuum

Describes a pressure range lower than medium or low vacuum systems; high vacuum pumps are able to pump more molecules out of a chamber than medium or low vacuum pumps, giving a “high” degree of vacuum. Definitions for the pressure range can vary, but are often in the 1×10^{-1} to 1×10^{-7} Pascal range.

Host

An organism that is susceptible to or harbours a pathogen under natural conditions.

Host cell

Viruses lack the ability to reproduce or replicate on their own. Therefore, viral replication depends on using the replication machinery of another cell. The cells that viruses use to reproduce are called host cells.

Host range

The geographical and/or species distribution that is susceptible to an infectious agent under natural conditions.

Hygroscopic

The ability of a substance to draw and retain water molecules from the surrounding environment.

IBC
See Intermediate bulk container.

Immiscible
Unable to form a uniform solution or mixture when combined.

Impervious
Describes a characteristic of a substance that does not allow liquids to pass through it.

Impregnated
Describes a material in which another substance is embedded throughout to reduce porosity (i.e., block pores so that fluids do not penetrate the material).

In situ
Latin phrase meaning "in the place." In biology, *in situ* refers to examining an event exactly in the place it occurs. Thus, "*in situ* steam sterilization" of a fermenter refers to steam sterilization that takes place inside the fermenter.

In the public domain
The AG defines 'in the public domain' as "technology that has been made available without restrictions upon its further dissemination. (Copyright restrictions do not remove technology from being in the public domain)."

Incapacitant
A chemical (e.g., tear gas) used to temporarily incapacitate individuals. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Incineration
The destruction of chemicals or other materials by burning at very high temperatures.

Industrial scale
Refers to production or manufacturing on a large (often commercial) scale or equipment that is capable of enabling large scale production (e.g., a 1000 litre fermenter would be considered a piece of industrial scale equipment, while a 5 litre fermenter would be considered laboratory scale). This is the opposite of laboratory scale.

Infection control zone
An area of infection control, usually a room in a hospital, most frequently used to isolate a patient with an illness easily spread by physical contact or through the air. This is accomplished by HEPA filtering the air and making air flow into the room (negative pressure). An infection control zone can also protect a patient from infection by setting filtered air to flow out of a room (positive pressure).

Infectivity
The ability of a pathogen or a biological agent to establish an infection.

Inhibition

The process of stopping or retarding a chemical reaction (e.g., inhibition of acetylcholinesterase by a nerve agent).

Inoculation

The process of introducing a pathogen into a living organism. When referring to production of large quantities of a pathogen (e.g. growing bacteria in a fermenter), it can also refer to the process of introducing a pathogen to suitable media to facilitate growth.

Inoculum

The biological sample used as starting material for growth of micro-organisms or viruses. Inocula are used for legitimate production of pharmaceutical or bacterial products (such as vaccines, insulin, or ethanol), but also can be used for illegitimate production of a biological weapon agent or toxin.

Intangible technology transfers

Transfers of technologies which are not physically tangible or tactile (e.g., software, program, and code transmission). A publication is available from the AG Secretariat that further describes these transfers.

Interfacial polycondensation

A method used to produce microcapsules, in which a chemical reaction occurs at the interface between a droplet and the liquid in which it is suspended, resulting in the formation of a capsule surrounding the remaining compound. See the Volume II section on Encapsulation Equipment and Technology.

Interferon

A protein made and released by cells in response to the presence of a pathogen, that can include viruses, bacteria, other parasites, or even cancerous cells. Interferons are communication signals between cells that trigger protective actions of the immune system to destroy pathogens or cancerous cells.

Intermediate bulk container

A reusable industrial container designed for the storage and transport of bulk substances (e.g., food, pharmaceuticals, and chemicals).

Inter-modal container

See ISO container

Ion mobility spectroscopy

An analytical method used to separate and identify ionised molecules in the gas phase based on differences in their mobility in a carrier gas.

ISO container

ISO containers are designed for transport by more than one mode (e.g., truck and rail); hence they are also known as inter-modal containers. There are several standard types of ISO containers. Tank-style ISO containers are used to transport chemicals and are composed of a tank mounted inside a rectangular metal rack. For example, see Figure 45.C in the Volume I Chemical Weapons Precursors entry on sodium cyanide.

ITT

See Intangible technology transfers

Jacketed
Describes a vessel design in which there are separated inner and outer walls; fluid can be circulated between the walls for temperature control. See the Volume I section on Chemical Reaction Vessels or Reactors.

Laboratory scale
Refers to experiments conducted on a small scale or items of a size appropriate for such experiments (e.g., a 5 litre fermenter would be considered laboratory scale, while a 1000 litre fermenter would be considered industrial scale). This is the opposite of industrial scale.

Laryngitis
Swelling, irritation, and/or inflammation of the larynx (voice box). This is usually associated with hoarseness and/or loss of voice.

LC_{50}
The concentration of a chemical, pathogen, or toxin in air needed to kill 50% of exposed and unprotected animals via inhalation.

LD_{50}
The amount of liquid or solid needed to kill 50% of exposed and unprotected animals. Typically expressed as milligrams (mg) of chemical, pathogen, or toxin per kilogram (kg) of animal body weight. LD50 values can be reported for any route of exposure such as dermal, oral, inhalation, or injection.

Lentogenic
Describes the virulence of a virus that causes a mild or minor infection in its host.

Lighter than air vehicle
An aerospace vehicle that derives its primary means of staying aloft from use of an envelope or balloon filled with a gas lighter than air (e.g. helium).

Low vacuum
Describes a pressure range higher than medium or high vacuum systems; low vacuum pumps pump fewer molecules out of a chamber than high or medium vacuum pumps, giving a “low” degree of vacuum. Definitions for the pressure range can vary, but are usually just below atmospheric pressure in the 1×10^5 to 3×10^3 Pascal range.

Lyophilisation
A dehydration process used to stabilise nearly any perishable material in order to increase its shelf life and reduce its sensitivity to environmental stresses. Also known as freeze drying. See the Volume II section on Freeze-Drying Equipment.

Lyophiliser
Another name for a freeze dryer. See the Volume II section on Freeze-Drying Equipment.

Manifold
A chamber having several outlets through which liquid or gas is distributed or gathered.

Manway
A port or opening through which a human can pass. See the Volume I section on Chemical Reaction Vessels or Reactors.

Material Safety Data Sheet
See Safety Data Sheet

Media
Liquid or solid material containing nutrients needed to grow micro-organisms.

Medium vacuum
Describes a pressure range lower than low vacuum systems, but not as high as high vacuum systems; medium vacuum pumps are able to pump more molecules out of a chamber than low vacuum pumps but not as many as high vacuum pumps, giving a "medium" degree of vacuum. Definitions for the pressure range can vary, but are often in the 3×10^{3} to 1×10^{-1} Pascal range.

Meningitis
An infection and inflammation of the protective tissues surrounding the brain and spinal cord.

Meningoencephalitis
A medical condition that simultaneously resembles both meningitis (inflammation of the protective tissues surrounding the brain) and encephalitis (inflammation of the brain).

Mesogenic
Describes the virulence of a virus that causes moderate to severe infection in its host.

Micro-organism
A micro-organism or "microbe" is an organism that is too small to be seen with the human eye. Microorganisms are very diverse and include bacteria, fungi, protists, microscopic plants (green algae), and microscopic animals (e.g., plankton). Most micro-organisms are single cell organisms. Viruses meet the size definitions of micro-organisms, but they are considered non-living when separated from the host they require for replication. Although most micro-organisms in the environment are not harmful, some are especially dangerous, causing lethal or severely debilitating diseases to humans, animals, or plants. Many disease causing micro-organisms can pose a biological weapons threat. See the Volume II Introduction to Pathogens and Toxins.

Microprogramme
The AG defines a 'microprogramme' as "A sequence of elementary instructions maintained in a special storage, the execution of which is initiated by the introduction of its reference instruction register."

Midge
A small flying insect that closely resembles a mosquito.

Miscible
Capable of being mixed to form a uniform solution or mixture.

Mist eliminator
A device designed to separate liquid droplets from a gas phase.

Mole
A unit of measurement in chemistry defined as 6.022×10^{23} electrons, ions, atoms, or molecules.

Momentum-transfer pump
A pump that moves gas molecules from the inlet to the discharge side by imparting momentum to the molecules to "push" them toward the exhaust.

Monoclonal antibody
Globular proteins found in blood or other bodily fluids of humans and animals. They are used by the immune system to identify and neutralise foreign objects, such as bacteria and viruses.

Monomer
A term applied to a molecule or that can react with itself or other monomers to form a polymer.

Morbidity rate
A measure of the frequency of occurrence of disease in a defined population during a specific period of time. For a specific disease, the morbidity rate describes the average percentage of diseased individuals given the total number of individuals exposed to a pathogen.

Mortality rate
A measure of the frequency of occurrence of death in a defined population during a specific period of time. For a specific disease, the mortality rate describes the average percentage of deaths given the total number of individuals infected.

MSDS
See Safety Data Sheet

Multi-fluid nozzle
A device used, primarily in pharmaceutical spray dryers, to atomise a liquid feedstock by contacting the liquid feed with pressurised gas. The interaction of high velocity gas and low velocity liquid leads to the atomisation of the liquid. See the Volume II section on Spray-Drying Equipment.

Mutation rate
A measure of the rate at which changes occur in DNA or RNA over a specific period of time.

Nameplate
A label or engraving affixed to the outside of industrial equipment that typically provides important information such as the manufacturer name and model number.

Necrotic
Describes death of cells or tissues that generally occurs through injury or disease.

Negative pressure

Pressure within a system that is less than that of the environment surrounding it. Consequently, a leak in a negatively pressurised system will not allow air to escape into the surrounding environment. Biological Safety Cabinets designed to protect workers from exposure to biological agents operate under negative pressure relative to their larger environment. See the Volume II section on Protective and Containment Equipment.

Nerve agent

A group of CW agents that inhibit the action of the enzyme acetylcholinesterase. Inhibition of acetylcholinesterase causes continuous stimulation of target organs, which primarily include muscles. Physical symptoms of nerve agent exposure include pupil constriction, muscle paralysis, and death due to respiratory failure – all due to the muscles' inability to relax or stop constricting. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Neurotoxin

Toxins that target the nervous system and disrupt signaling that allows neurons to communicate effectively with other neurons and their target organs, such as muscle.

Neurotransmitter

A chemical produced in nerve cells that transmits signals between nerve cells.

New World

The geographic part of the world referring to North and South America.

Nucleic acid

A large macromolecule that encodes genetic information in the form of DNA or RNA. See also Oligonucleotide.

Old World

The geographic part of the world referring to Europe, Asia, Africa, and Australia.

Oleochemistry

The study of vegetable oils, animal oils, and fats.

Oligonucleotide

A short polymer of nucleotides (also called DNA bases), typically from 20 to 200 nucleotides. Oligonucleotides are short pieces of DNA.

Ore floatation

The process by which valuable minerals are separated from invaluable or less valuable materials by grinding the ore into small particles and submerging in water. Materials are separated based on how they float or are suspended in the solution.

Organophosphorus

Describing organic compounds containing carbon-phosphorus bonds.

Overwintering

To last through or pass the winter. Although many pathogens are susceptible to temperature extremes, *Synchytrium endobioticum* that causes potato wart will stay viable in the soil for up to 30 years.

Oxidant

Also known as an oxidising agent, an oxidant is the compound in an oxidation-reduction reaction that accepts an electron from another compound.

Oxide

A compound that contains oxygen and one other element.

Packing Group

A designation assigned to entries in the UN Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. The Packing Group designates the risk level of an item intended for shipment. Specific shipping requirements for an item may vary based on Packing Group assignment (e.g., certain items may have an increased risk level and Packing Group assigned for shipments with larger quantities). See the Volume I section on Chemical Packaging and Transportation.

Particulate

A general term for tiny pieces of solid or liquid matter associated with the atmosphere. Often the tiny pieces are suspended as an aerosol.

Passive controls

A category of laboratory safety practice(s) that are built into a facility and do not require active participation from employees to work (e.g., air monitoring devices).

Pathogen

An infectious agent or micro-organism that causes disease in its host. The Australia Group Common Control Lists list pathogens that cause disease in humans, animals, and plants. See the Volume II sections on Human and Animal Pathogens and Toxins and Plant Pathogens.

Pathogenic

Disease causing.

Pathogenicity

The potential of a particular micro-organism to cause disease. Often, pathogenicity is characterised by the mechanism of infection, whether the micro-organism produces a toxin, and the ability of medical treatment to reverse the disease.

Peptide

A short polymer of amino acids. Thus “polypeptide” is a small protein.

Periodic Table

A table that organises elements based on their atomic number, electron configuration, and similar chemical properties.

Phase
The physical state of a substance (e.g., liquid, solid, or gas). Transitions between physical phases do not involve a change in the chemical composition of the material.

Phase separation
A process used to form microcapsules, which occurs when the compound used to form the coat of the microcapsule is induced to change phases from liquid to solid and coat the core material as a result. See the Volume II section on Encapsulation Equipment and Technology.

Phosphorylating
Phosphorylation is the chemical addition of a phosphate group (PO_4) to a molecule.

Photoionisation detection
A type of gas detector that measures volatile compounds in very small concentrations by ionising them and detecting the resulting electric current.

Photosynthesis
A process used by plants and other organisms to convert light energy into chemical energy.

Pickling
The process of removing impurities (e.g., rust) from the surface of metals using a solution containing strong acids.

Pilot scale
A scale that facilitates the transition from laboratory scale to industrial scale production. Pilot scale equipment is intermediate in size between laboratory and industrial scale equipment.

Plasmid
A small circular DNA molecule.

Plasticiser
Additives that increase the fluidity and plasticity of a material.

Polymer
A large molecule that contains multiple repeating subunits or monomers. Large polymers are also known as macromolecules.

Polysaccharide
A polymer of carbohydrates used to store energy or provide structure. Examples include starch or cellulose.

Pore
A hole in a filter membrane that allows passage of items smaller than the pore size through the filter. See the Volume II section on Cross (tangential) Flow Filtration Equipment. May also refer to a hole found in the surface of a plant (see stomata) or holes in a bulk material's structure (see impregnated).

Positive displacement pump
A class of pumps that rely on internal moving parts to create an expanding cavity on the inlet side, trap incoming gases, compress them by shrinking the cavity, and release them out the discharge side.

Positive pressure
Pressure within a system that is greater than that of the environment surrounding the system. Consequently, a leak in a positively pressurised system will allow air into the surrounding environment. Suits designed to protect workers from exposure to biological agents have a tethered air supply operating under positive pressure. See the Volume II section on Protective and Containment Equipment.

Potentiometric
Describing a type of chemical analysis used to determine the concentration of a particular component of a solution by measuring the voltage of the solution.

Precursor
A chemical that can be used to produce another chemical via chemical reaction. In the context of the Handbook, this term refers to a chemical that can be used to make a CW agent. Also generally known as a reactant.

Pressure nozzle
A device used to atomise a liquid feedstock by forcing the liquid to exit a small diameter opening under high pressure. See the Volume II section on Spray-Drying Equipment and Spraying and Fogging Equipment.

Probiotic
A micro-organism that is believed to provide health benefits when consumed.

Product lot
A specific batch of material from a single manufacturer, typically identified by a unique identification number.

Production
The AG defines 'production' as "all production phases such as: construction, production engineering, manufacture, integration, assembly (mounting), inspection, testing, and quality assurance."

Programme
The AG defines a 'programme' as "A sequence of instructions to carry out a process in, or convertible into, a form executable by an electronic computer."

Proper Shipping Name
A name assigned to each entry in the UN Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. See the Volume I section on Chemical Packaging and Transportation.

Protist
A catch-all taxonomic kingdom for unicellular living organisms. Protists are grouped in their own kingdom because member species are too genetically different to be considered plants, animals, fungi, or bacteria.

Proton scavenger
A compound that reacts with free protons in a solution to form a compound that will not undergo further reaction.

Pulmonary edema
The accumulation of fluid in the lungs that leads to shortness of breath and can lead to respiratory failure.

Purification
The process of isolating a desired chemical product from a mixture of substances.

Race
In the context of plant biology, a group of plants having similar characteristics that distinguish them from other plants within the same species. For example, the plant pathogen *Ralstonia solanacearum*, race 3, biovar 2 is controlled by the AG, but other races and biovars are not. The species is divided into race based on the host range and further subdivided into biovar to distinguish between subtle differences in metabolic pathways that contribute to the pathogenicity of the agent.

Radial
Radiating from a central point. In the context of agitators (Volume I), radial mixing occurs perpendicular to the agitator shaft's orientation (i.e., outward from the shaft).

Reactant
Also known as a precursor, reactants are combined and undergo a chemical reaction to generate a desired chemical known as the product.

Reboiler
A heat exchanger used to provide heat to an industrial scale distillation column.

Recombination
The process by which pieces of an organism's genome (DNA or RNA) is broken and rejoined.

Reflux
The portion of condensed vapour returned to the column during distillation.

Reservoir
The habitat in which a pathogen normally lives (e,g., animals, humans, or the environment).

Retentate
In a filtration process, the part of a solution that does not cross the membrane.

Reverse osmosis
A filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. As a result, the solute is retained on the pressurised side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective," this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely. Reverse osmosis is

most commonly known for its use in purifying drinking water from seawater, removing the salt and other substances.

RNA
An acronym for ribonucleic acid. RNA is a genetic material present in all living cells. RNA acts as an intermediary carrying instructions from DNA to synthesise proteins in the cell. Some viruses have RNA as the primary carrier of genetic information in place of DNA.

Rotary atomiser
A device used to atomise a liquid feedstock by contacting the liquid with a spinning wheel containing tiny holes for atomised particles to exit. The design of the wheel and its rotational speed dictate the final properties of the resulting aerosol. See the Volume II sections on Spray-Drying Equipment and Spraying and Fogging Systems.

Rough vacuum
See low vacuum.

Safety Data Sheet
A document identifying hazards posed by a chemical and measures to mitigate them.

Sanitary connection
A type of fitting that is durable and easily cleaned to promote sanitary conditions in biological processing.

Scrubbing
The process of chemically removing impurities from a gas.

Sedge
A plant that resembles grass and grows in moist environments.

SDS
See Safety Data Sheet

Shaft seal
A seal located where a rotating or reciprocating drive shaft passes through a pump body.

Skimming
The process of separating a liquid or solid from the top of a liquid, e.g. in the removal of cream from milk.

Software
AG defines 'software' as "a collection of one or more 'programmes' or 'microprogrammes' fixed in any tangible medium of expression."

Solubility
The ability of a substance to dissolve in a given solvent (usually a liquid) and form a homogeneous solution.

Solvent
The liquid or other substance in which a solute is able to be dissolved to form a solution.

Solvent purification/reclamation
The process of purifying and isolating a previously-used solvent in order to recycle it for reuse.

Souring
In the context of laundry, an acidic solution used to neutralise alkalinity in textiles.

Spastic paralysis
A condition in which muscles undergo persistent spasms and exaggerated reflexes because nervous system control of the muscles has been disrupted or altered.

Species
A group of living organisms with similar characteristics that is capable of exchanging genetic material and interbreeding. It is a taxonomic unit that ranks below a genus.

Spore
An inactive form of a micro-organism, particularly a bacterium or a fungus, that can survive for a long time in harsh environmental conditions. Spores can reactivate upon exposure to an environment that supports growth (e.g., an environment containing water and nutrients).

Sporulation
The process by which bacteria or fungi form spores.

Spray chilling
Also known as spray congealing, a method of producing microcapsules by atomising a solution of core and matrix materials into a stream of cold gas, solidifying liquid droplets into particles.

Steam distillation
A type of distillation used for temperature sensitive materials. Steam distillation introduces water or steam into the system to lower the boiling points of compounds, allowing them to evaporate and separate at lower temperatures.

Sterilizable
Manufactured of materials capable of withstanding processes used to kill all micro-organisms. Typically, this means construction of materials that withstand high pressure and high temperature steam.

Sterilization
A validated process used to render a product free of all forms of viable micro-organisms. Sterilization is more powerful than disinfection because it destroys all microbial forms of micro-organisms (e.g., bacterial spores and bacteria).

Stomata
A pore found on the surface of a plant that is used to control gas exchange.

Strain
A highly specific taxonomic rank used to describe a group of organisms of the same species with similar characteristics that are distinct from other members of the same species.

Sublimate

To transition a substance from the solid phase to the gas phase without passing through an intermediate liquid phase.

Surface acoustic wave spectroscopy

In the context of chemical detection, the detection of gases through selective absorption by measuring acoustic vibrations that change based on the chemical absorbed.

Surfactant

A compound that decreases the surface tension between a liquid and a solid or between two liquids. Surfactants can be used, for example, as emulsifiers, detergents, wetting agents, or dispersants.

Taxonomy

The branch of science concerned with classification, especially of organisms. Biological classification is a method used to group organisms with other similar organisms. The groups most typically used to classify organisms are (from largest to smallest): domain, kingdom, phylum, class, order, family, genus, and species.

Technical assistance

The AG definition of 'technical assistance' states: "may take forms such as: instruction, skills, training, working knowledge, consulting services. Technical assistance may involve transfer of 'technical data'."

Technical data

The AG definition of 'technical data' states: "may take forms such as blueprints, plans, diagrams, models, formulae, tables, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories."

Technology

The AG defines 'technology' as "specific information necessary for the 'development', 'production' or 'use' of a product. The information takes the form of 'technical data' or 'technical assistance'."

Terminal diffuser

A type of HEPA filter system that does not integrate the fan and the HEPA filter in the same unit. In a terminal diffuser setup, the fan and HEPA filter are connected by tubing or ducting.

TIC

See Toxic industrial chemical

Tissue culture

The growth of cells or tissues outside of an organism, often in a Petri dish, flask, or bioreactor. Cultured cells may be used to grow viruses.

Tote bin

Containers used for shipping bulk quantities of chemicals and other materials.

Toxic

Containing poison or being poisonous in a way that is capable of causing serious harm or death.

Toxic chemical

The CWC defines a 'toxic chemical' as "any chemical which through its chemical action on life processes can cause death, temporary incapacitation or permanent harm to humans or animals. This includes all such chemicals, regardless of their origin or their method of production, and regardless of whether they are produced in facilities, in munitions or elsewhere."

Toxic industrial chemical

Industrial chemicals that are manufactured and used in large quantities but that pose dangerous chemical or physical hazards.

Toxicity

The potency or degree to which a substance or compound that is toxic can damage an organism.

Toxicology

A branch of biology and medicine concerned with the study of the adverse effects of chemicals on living organisms.

Toxin

A poisonous substance produced by living cells or organisms. Toxins can be small molecules, peptides, or proteins that are capable of causing disease on contact with or absorption by body tissues. Toxins vary greatly in the severity of their effects, ranging from minor and short-acting to almost immediately deadly.

Transcribe

To convert information encoded in DNA into RNA. Transcription is the process of converting the genetic information contained in DNA into RNA. This is a necessary intermediate step required for protein production.

Translate

To convert information encoded in RNA into protein. Translation is the process by which a cell uses RNA as the blueprint for protein synthesis.

Transposon

A DNA sequence that has the ability to change position within a genome. Transposons are also known as jumping genes and are common in plants.

UAV

See Unmanned aerial vehicle

UN number

Four-digit codes used to identify hazardous substances and articles in transport. The master list of UN Numbers is the Dangerous Goods List of the United Nations Recommendations on the Transport of Dangerous Goods. See the Volume I section on Chemical Packaging and Transportation.

Unmanned aerial vehicle

An aircraft that flies without a human pilot on board the vehicle.

Ultrahigh vacuum

Describes a pressure range lower than high vacuum systems; ultrahigh vacuum pumps are able to pump more molecules out of a chamber than high vacuum pumps, giving an "ultrahigh" degree of vacuum. Definitions for the pressure range can vary, but are often in the 1×10^{-7} to 1×10^{-10} Pascal range.

Ultrasonic nozzle

A device used, primarily in pharmaceutical spray dryers, to atomise a liquid feedstock by subjecting the liquid feed to high frequency vibrations. See the Volume II section on Spray-Drying Equipment.

Use

The AG defines 'use' as the "operation, installation, (including on-site installation), maintenance (checking), repair, overhaul or refurbishing."

V-series nerve agent

A type of nerve agent first discovered in the 1950s. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Vaccine

A biological preparation that enhances the vaccinated subject's immunity to a particular disease. A vaccine stimulates the subject's immune system with a weakened pathogen so the immune system becomes prepared to recognise and destroy the virulent disease-causing pathogen.

Vacuum

A vacuum technically is a space devoid of matter. In the context of pumps, vacuum pumps reduce pressure in a chamber by removing air from it, i.e. reducing the amount of matter it contains. There are different levels of vacuum that are associated with different pressure ranges (and, by extension, amounts of matter); see Glossary entries on rough, low, medium, high, and ultrahigh vacuum.

Vacuum distillation

A method of distillation where the pressure above a liquid mixture intended for distillation is reduced to less than its vapour pressure. This allows separation of compounds at temperatures below their usual boiling points and/or improved separation of compounds that normally have very similar boiling points.

Vector

A living intermediary (e.g, mosquitos, ticks, and fleas) that carries a pathogen from a reservoir to a susceptible host. In the context of genetic elements, the term vector refers to plasmids used in molecular biology to carry a desired DNA sequence into a target cell."

Velogenic

Describes the virulence of a virus that generally causes lethal infection in its host.

Venom

A toxin – or more typically a mixture of toxins – produced by certain types of animals that inject it into their victims by means of a bite, sting, or other sharp body structure.

Venomous

Capable of producing toxin/venom and capable of inflicting a poisoned wound.

Venturi
A type of jet ejector pump that produces a vacuum using the Venturi effect; fluid pressure is reduced by forcing the fluid through a constricted section of a pipe.

Vesicant
Also known as blister agents, vesicants cause large and often life-threatening blisters on moist tissues. See the Volume I Introduction to Chemical Weapons and Dual-Use Chemical Technology.

Viability
The ability of a micro-organism to survive, grow, and reproduce.

Virulent
Describes a disease or toxin that creates extremely severe or harmful symptoms in its host.

Virus
An infectious agent generally composed of genetic material packaged within a protein coat. Viruses must infect host cells in order to replicate, burst out of the host cell, and spread the infection.

Viscosity
The property of a liquid that describes its resistance to flow. Liquids with high viscosity tend to be thick, sticky, and do not flow easily.

Volatility
A measure of the tendency of a substance to vapourise or turn from a liquid phase to a gas phase.

Vulcanisation
The process of converting rubber and related compounds into more durable materials by adding materials that cross-link (connect) polymer chains together.

Weir
An internal structure within a distillation column tray that keeps an appropriate level of liquid in the tray for effective separations.

Wetted surfaces
Surfaces coming into direct contact with processed or contained chemicals. For the purposes of AG control specifications on dual-use chemical equipment, these are the surfaces of chemical processing equipment that must be made of corrosion-resistant materials.

Xylem
A vascular tissue in plants used to transport water and minerals.

Zoonotic
Describes a pathogen that is capable of being transmitted from animals to humans or from humans to animals. The latter is sometimes referred to as reverse zoonosis.

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Appendix E:
Unit Conversions

Many AG control specifications for dual-use biological and chemical equipment include units of measurement. Equipment manufacturers use a variety of units that may not be the same as those specified in the control lists. The tables below provide control specifications that appear in the AG chemical equipment control list and the biological equipment control list in a variety of different units. The applicable controlled commodity is noted in each table. All units stated in the AG control language are shown in ***bold and italics***. Non-exact conversion factors are provided above the tables to four decimal places; calculations in the tables that use these non-exact conversion factors are rounded to the nearest 0.1. Numbers are shown in scientific notation (a x 10^b) when the value is <0.01.

It should be noted that any conversions of a control specification into units other than those in the AG control language are not official AG control specifications and in many cases are simply approximations. Conversions are provided here informally for reference purposes only and not for use in official control determinations.

Length/Diameter

1 metre (m) = 100 centimetres (cm) = 39.3701 inches (in) = 1 x 10^6 micrometres[1] (µm)

Metres (m)	Centimetres (cm)	Inches (in)	Micrometres (µm)	Applicable AG Commodity	Handbook Volume
1x10^{-5}	1x10^{-3}	3.9x10^{-4}	***10***	Spray-drying equipment and Awareness Raising Guidelines: Encapsulation	II
5x10^{-5}	5x10^{-3}	2.0x10^{-3}	***50***	Spraying or fogging systems	II
0.01	***1***	***⅜***	10,000	Valves	I
0.0254	***2.54***	***1***	25,400	Valves	I
0.1	10	3.9	100,000	Distillation or absorption columns	I
0.1016	***10.16***	***4***	101,600	Valves	I

[1] The term micrometre is used synonymously with the term micron in AG control language.

Appendix E: *Unit Conversions*

Surface Area

1 square metre (m^2) = 10.7639 square feet (ft^2)

Square Metres (m^2)	Square Feet (ft^2)	Applicable AG Commodity	Handbook Volume
0.15	1.6	Heat exchangers or condensers	I
0.2	2.2	Cross flow filtration equipment	II
1	10.8	Cross flow filtration equipment	II
20	215.3	Heat exchangers or condensers	I

In addition:
1 m^2 = 10,000 cm^2
1 ft^2 = 144 in^2

Volume

1 cubic metre (m^3) = 1000 litres (l) = 35.3147 cubic feet (ft^3) = 264.1721 U.S. gallons (US gal)

Cubic Metres (m^3)	Litres (l)	Cubic Feet (ft^3)	U.S. Gallons (US gal)	Applicable AG Commodity	Handbook Volume
0.02	***20***	0.7	5.3	Fermenters and Awareness Raising Guidelines: Fermenters	II
0.1	***100***	3.5	26.4	Reaction vessels and Storage tanks, containers, or receivers	I
1	1000	35.3	264.2	Aerosol inhalation chambers	II
20	***20,000***	706.3	5283.1	Reaction vessels	I

In addition:
1 m^3 = 1,000,000 cm^3
1 ft^3 = 1728 in^3

Flow Rate[2]

1 cubic metre per hour (m^3/h) = 1,000 litres per hour (l/h) = 16.6667 litres per minute (l/min) = 0.5886 cubic feet per minute (CFM) = 4.4029 U.S. gallons per minute (GPM)

Cubic Metres per Hour (m^3/h)	Litres per Hour (l/h)	Litres per Minute (l/min)	Cubic Feet per Minute (CFM)	U.S. Gallons per Minute (GPM)	Applicable AG Commodity	Handbook Volume
0.1	***100***	1.7	0.1	0.4	Centrifugal separators	II
0.12	120	***2***	0.1	0.5	Spraying or fogging systems	II
0.6	600	10	0.4	2.6	Pumps	I
5	5000	83.3	2.9	22.0	Pumps	I

Temperature

273 Kelvin (K) = 0 degrees Celsius (°C) = 32 degrees Fahrenheit (°F)[3]

Kelvin (K)	Degrees Celsius (°C)	Degrees Fahrenheit (°F)	Applicable AG Commodity	Handbook Volume
273	***0***	32	Pumps	I
1273	***1000***	1832	Incinerators	I

Mass

1 kilogram (kg) = 2.2046 pounds (lb)

Kilograms (kg)	Pounds (lb)	Applicable AG Commodity	Handbook Volume
10	22.0	Freeze-drying equipment	II
1000	2204.6	Freeze-drying equipment	II

[2] For pumps, these flow rates reflect measurements taken under standard temperature (273 K (0° C)) and pressure (101.3kPa) conditions.

[3] Conversion between degrees Celsius and degrees Fahrenheit uses the following formula: °F = (9/5)°C+32

Evaporation & Condensation Capacity

1 kilogram per hour (kg/h) = 24 kilograms per 24 hours (kg/24h) = 2.2046 pounds per hour (lb/h)

Kilograms per Hour (kg/h)	Kilograms per 24 Hours (kg/24h)	Pounds per Hour (lb/h)	Applicable AG Commodity	AG Volume
0.4	9.6	0.9	Spray-drying equipment	II
0.4	***10***	0.9	Freeze-drying equipment	II
41.7	***1000***	91.9	Freeze-drying equipment	II
400	9600	881.8	Spray-drying equipment	II

Pressure

1 kilopascal (kPa) = 0.0099 atmospheres (atm) = 7.5001 mm Hg = 7.5001 torr (Torr) = 0.1450 pounds per square inch (psi) = 4.0146 inches of water gauge (in w.g.)

Kilopascals (kPa)	Atmospheres (atm)	Millimetres of Mercury (mm Hg)/ torr (Torr)	Pounds per Square Inch (psi)	Inches of Water Guage (in w.g.)	Applicable AG Commodity	AG Volume
101.3	1.0	759.8	14.7	406.7	Pumps	I

Detection Level

Conversion between mg/m^3 and ppm (parts per million) requires knowledge of the molecular weight of the chemical in question. See the Volume I section on Toxic Gas Monitoring Systems and their Dedicated Detection Components for a table of detection levels by chemical and further details on this calculation.

Appendix F: Bibliography

The following represents an edited compilation of key references and websites from government agencies, non-governmental organisations, scientific societies, and scientific publications. Further information on specific AG-listed commodities may be found in the text and footnotes of individual commodity entries.

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