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Chemical Warfare and Chemical Disarmament

Unless the current negotiations in Geneva succeed in prohibiting the development, production and stockpiling of chemical weapons, a new and more dangerous phase of the arms race may be in store

by Matthew Meselson and Julian Perry Robinson

The use in war of poison gas and other chemical weapons is prohibited by the Geneva Protocol of 1925, to which all major nations are now parties. Some nations accept the Geneva Protocol as an absolute prohibition; others, including the U.S., Britain, France, the U.S.S.R. and China, view it as a no-first-use agreement, having formally reserved the right to retaliate in kind if the Protocol is violated by an adversary. Of the member states of the North Atlantic Treaty Organization (NATO) only the U.S. and France have militarily significant stocks of chemical weapons. The continued existence of these weapons is based on their possible retaliatory role in the event of a chemical attack by the U.S.S.R.

Starting in 1976, the U.S. and the U.S.S.R. have been engaged in a series of bilateral technical discussions and negotiations in Geneva aimed at bringing about chemical disarmament, including a ban on the development, production and stockpiling of chemical weapons. (The Biological Weapons Convention of 1972 already embodies such prohibitions against biological agents, but it does not apply to chemical weapons.) The bilateral talks have achieved considerable agreement on what is to be prohibited and also on the general principle of incorporating both national and international arrangements for verifying compliance. Little progress has yet been made, however, in reaching agreement on specific verification measures.

As talks continue between the U.S. and the U.S.S.R., and concurrently within the multilateral Committee on Disarmament, which also meets in Geneva, the U.S. and its allies in NATO have embarked on a major program to enhance and modernize the protection of their forces against chemical attack. These defensive measures have found widespread support within NATO governments, which view them not only as important precautions in the present situation but also as a safeguard to be retained even if a chemical-weapons ban comes into being.

Although antichemical protection is being improved, the U.S. has not added to its stocks of the weapons themselves since 1969. The American stockpile, although substantial, is positioned mainly within the U.S. Its utility for retaliation is limited by the sizable logistic effort that would be required to deploy it to Europe under wartime conditions and by a reluctance within NATO to integrate chemical weapons into the force structures and defense planning of the alliance. Requests by the U.S. Army for funds to build production facilities for a new generation of poison-gas artillery projectiles, called binary munitions, have been rejected by Congress and the Administration partly on the ground that such action could impede negotiations for a chemical-arms-limitation treaty. Moreover, there is debate about the military value of a retaliatory chemical capability and about its possible interactions with nuclear deterrence.

In sum, the policy of the U.S. regarding chemical weapons appears to be nearing a crossroads. If a satisfactory treaty is obtained, there will be chemical disarmament. Otherwise the U.S. may decide to go ahead with the production of new chemical weapons and to make a determined effort to persuade NATO to integrate them into its defense planning. In this article we shall describe some of the technical, military and political considerations that bear most directly on the choices facing the U.S. and its NATO allies. In the wider international context there are related questions that may be no less important, but we shall not address them here.

Modern lethal chemical weapons are based on organophosphorus compounds known as nerve gases or nerve agents. They are chemically related to

NERVE GAS IS STORED as a liquid in metal containers at the Tooele Army Depot in Utah. The containers hold a total of about a million gallons of agent GB, or sarin, a high-

certain pesticides but are much more toxic. The first of these compounds, called tabun, was discovered in Germany in 1936 in the course of research on insecticides. Its military possibilities were soon recognized by the German government, which proceeded secretly to produce it and to develop production methods for a related agent found in 1938, called sarin. Although chemical weapons were used extensively in World War I, the European belligerents in World War II refrained from chemical warfare. Nerve gases in particular have never been used in combat.

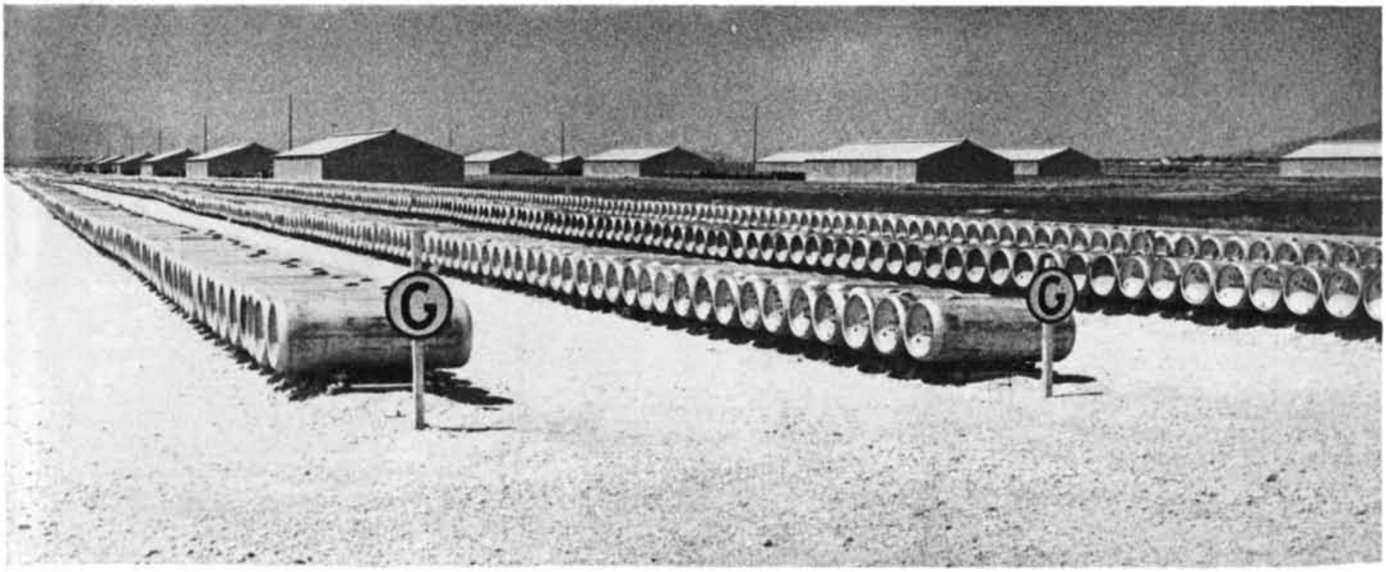
Nerve gases are stored as liquids. Depending on the volatility of the particular agent, they can be released from munitions as a cloud of vapor or as a spray of liquid droplets dispersed by explosive, mechanical or thermal means. They can enter the body by inhalation or by absorption through the skin. The nerve gas then exerts its lethal effect by binding to the enzyme acetylcholinesterase, thereby inactivating it. Blocking the enzyme causes a rapid accumulation of the synaptic transmitter substance acetylcholine, which normally is decomposed by acetylcholinesterase within milliseconds after being released at nerve endings. The buildup of acetylcholine at autonomic ganglia and effectors, at skeletal neuromuscular junctions and at synapses in the central nervous system causes a wide array of symptoms: intense sweating, filling of the bronchial passages with mucus, bronchial constriction, dimming of vision, uncontrollable vomiting and defecation, convulsions and finally paralysis and respiratory failure. Death from acute nerve-gas poisoning is caused by asphyxia, which generally will occur within a few minutes. If the dose is only marginally lethal or if it is received through the skin, however, it may take up to several hours for the victim to die. There is evidence that long-lasting neurological and psychiatric disorders can develop after sublethal exposure. Natural detoxification of nerve-gas poisoning is slow, so that the lethal dose is approximately the same whether it is received all at once or over a period of hours. Antidotes of limited effectiveness are available, but a far more effective defense against nerve gases (and indeed against all chemical-warfare agents) is provided by a gas mask and, for agents that attack or penetrate the skin, by protective clothing.

Of the hundreds of organophosphorus anticholinesterases that have been considered for use in weapons three have dominated attention: their chemical names are O-isopropyl methylphosphonofluoridate (otherwise known as agent GB, or sarin), O-1,2,2-trimethylpropyl methylphosphonofluoridate (agent GD, or soman) and O-ethyl *S*-2-diisopropylaminoethyl methylphosphonothiolate (agent VX). It is estimated that about one milligram of sarin or .4 milligram of VX is the median lethal dose for man, with the lethality of soman being in between. Sarin is nearly as volatile as water and would be used primarily as an air contaminant. VX, with a volatility close to that of heavy lubricating oil, would be disseminated in sprays as a direct contact hazard or as an indirect one, through contamination of the ground or other surfaces with which people might later come in contact. VX applied at about 300 kilograms per square kilometer would create a deadly skin-contact hazard that would persist for a period of days or weeks, depending on the weather. The hazard from sarin, being primarily an airborne one, is of much shorter duration and is highly dependent on vertical and horizontal air movements and on the ambient temperature; under most conditions the amount needed to create a lethal respiratory dosage would be between 100 and 3,000 kilograms per square kilometer.

Sarin and VX are the two standard U.S. nerve gases. Soman, first prepared in Germany in 1944, is believed by Western officials to be the standard Russian nerve gas. The volatility of soman approaches that of sarin, but greater persistency can be obtained by thickening it with synthetic polymers. What the Russians are reported to call VR-55 is thought to be a stockpiled formulation of this type. Tabun (O-ethyl N,N-dimethylphosphoroamidocyanidate, also known as GA), the original but now superseded nerve gas, was said at one time to figure prominently in the chemical arsenal of the U.S.S.R.; if that is true, the stocks could still exist.

For use in regular battlefield munitions no other poisons match the nerve gases. Their toxicity and rapidity of action, their effectiveness through the skin as well as the lungs, their easy disseminability, their fairly low cost and their stability set them apart from all other chemical-warfare agents. The older agents can now be considered obsolete for the industrialized countries, although some must still be taken seriously, chiefly because substantial supplies remain available. Hydrogen cyanide is one example; *bis*(2-chloroethyl) sulfide, also known as mustard gas, is another.

The nerve gases also overshadow the



ly toxic organophosphorus compound chemically related to certain pesticides. The lethal dose of sarin for an adult human being is about a milligram. The buildings in the distance contain additional nerve-gas supplies in the form of filled munitions. The objects stacked between the warehouses are 160-gallon aircraft spray tanks, filled with another nerve gas, agent VX. Approximately 40 percent of the total U.S. stockpile of poison gas, which includes both nerve gas and mustard gas, is stored at this site and others at the Tooele depot.

category of incapacitating agents, substances intended to put soldiers out of action for a period of several hours or days but with a low probability of death or lasting ill effects. Although many candidate incapacitants have been screened, none has proved satisfactory. The anticholinergic psychotropic drug known as agent BZ (3-quinuclidinyl benzilate) was for a time stocked in standard U.S. incapacitating munitions, but its many military shortcomings, including its unpredictable tendency to elicit maniacal behavior, led to its abandonment. The only nonlethal antipersonnel weapons now in the chemical-weapons inventory of the U.S. are those employing the irritant agents CS (orthochlorobenzylidene malononitrile) and CR (dibenz[*b,f*][1,4]oxazepine). Also used by domestic police, they are classified as riot-control agents. Although the U.S. made extensive use of CS munitions in the Vietnam war and interprets the Geneva Protocol as not applying to riot-control agents, they are essentially irrelevant to combat between modern military forces because of the brevity of their effects and the protection afforded by gas masks.

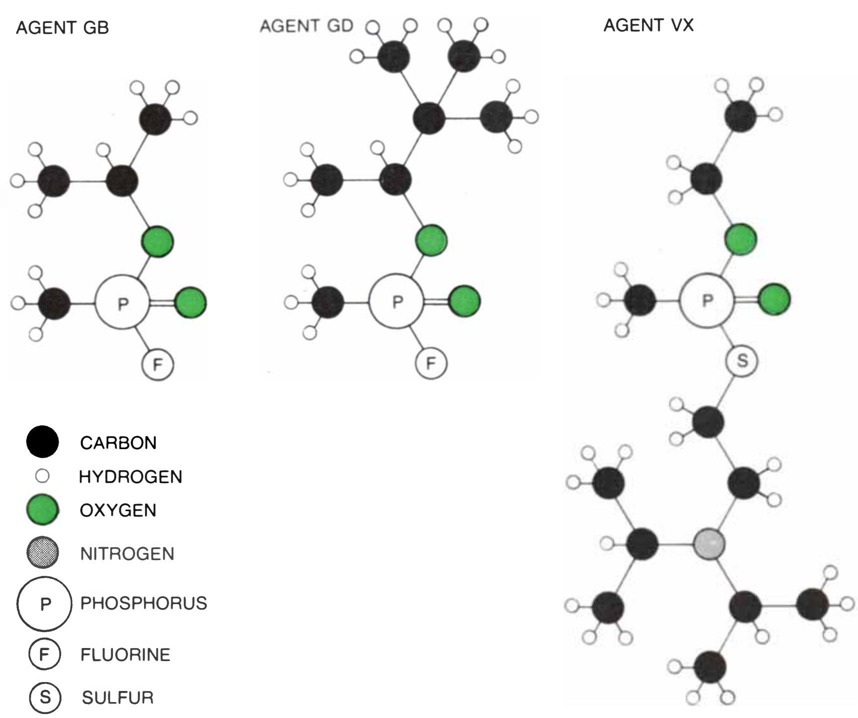
The size of the U.S. stockpile of lethal chemical munitions is classified information, but estimates can be made from open sources. Approximately 15,000 tons of sarin were produced during the period between 1953 and 1957, and some 5,000 tons of VX were made between 1961 and 1967. About 5,000 tons of nerve gas, mostly sarin, are accounted for by the destruction of obsolete munitions and surplus stocks. Of the remainder about a fourth is held in bulk-storage containers and three-fourths in munitions. Approximately 30 different types of nerve-gas munition have been approved for the operational inventories of U.S. armed forces over the past three decades, half of them having been produced in quantity. Some are now obsolete and have been or are being discarded. Remaining in the stockpile are about three million artillery projectiles (105-millimeter GB shells, 155-millimeter GB and VX shells and eight-inch GB and VX shells), several thousand 500- and 750-pound GB aerial bombs, hundreds of thousands of two-gallon VX land mines and about 1,500 160-gallon VX aircraft spray tanks. Supplies of mustard gas dating from World War II are also maintained, both in munitions and in bulk stock, the total quantity of the agent being about the same as that of nerve gas. U.S. stocks of lethal chemical munitions total approximately 150,000 tons, referring to the weight of the munitions themselves, not just the chemical agent they contain. Nerve-gas munitions comprise about two-thirds of this total.

Overall the weight of the U.S. stockpile of lethal chemical munitions equals about a fourth of the weight of the conventional (high-explosive) munitions the U.S. Army currently has on hand in Europe. Only a small fraction of this chemical-weapons stockpile, however, has been positioned abroad: on Johnston Island in the mid-Pacific and in West Germany. The stocks in West Germany, which are under exclusive U.S. control, are mostly ground munitions; it is said they would suffice for no more than two weeks of widespread battlefield chemical operations in Europe.

If Administration and Congressional authorization is given, the next addition to the U.S. chemical-weapons stockpile probably would be the 155-millimeter GB artillery projectile. Instead of containing actual nerve gas, it contains two nerve-gas precursors held in separate canisters. When the projectile is fired, the canisters burst and their contents react to form the nerve gas while the munition is in flight. One of the canisters could be stored and shipped separately, to be loaded into the projectile at the gun site. This built-in safety feature of binary-nerve-gas munitions is intended to provide greater operational flexibility in the storage, shipment and deployment of chemical weapons, in part by alleviating public concern about the possible unintended release of poison gas.

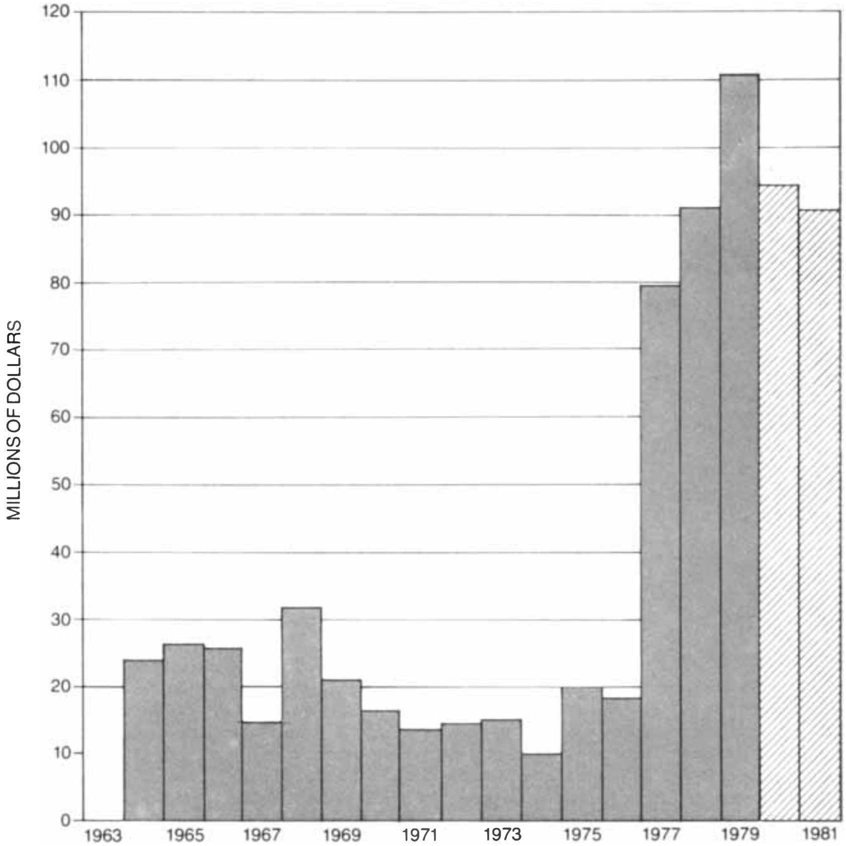
Little seems to be known outside the U.S.S.R. about the chemical weapons of that nation, either quantitatively or qualitatively. The Russians themselves have said nothing on the subject in public. Estimates of the size of the Russian stockpile that have appeared are based more on appraisals of assumed Russian military requirements than on solid evidence. U.S. defense officials have stated that little confidence can be placed in current estimates of the total size of the Russian stockpile, but that a considerable amount of it is deployed both in European forward areas and near the Chinese frontier. Part is believed to consist of nerve-gas munitions, the remainder being mostly mustard gas and hydrogen cyanide.

Whether the Russians consider their stocks to be solely retaliatory, as the Americans consider theirs, is of course not known. A buildup in Russian supplies, both of chemical weapons and of protective equipment, is said to have taken place in the late 1960's. If that is the case, the instigating decisions would have been made during the last high point of U.S. chemical-weapons procurement. According to the 1979 military-posture statement by the Chairman of the U.S. Joint Chiefs of Staff, initial-release authority for the use of chemical weapons by the Russian forces lies at the level of the Politburo: the highest council of the Soviet state.



CHEMICAL STRUCTURES of three organophosphorus anticholinesterases, or nerve gases, currently in the arsenals of the U.S. and the U.S.S.R. are given in these molecular diagrams. Reading from left to right, the compounds are O-isopropyl methylphosphonofluoridate (agent GB), O-1,2,2-trimethylpropyl methylphosphonofluoridate (agent GD, or soman) and O-ethyl *S*-2-diisopropylaminoethyl methylphosphonothiolate (agent VX). Agents GB and VX are the two standard U.S. nerve gases. Agent GD is thought to be the standard Russian nerve gas.

To a degree not approached by other categories of weapons, it is possible to protect people from the effects of chemical weapons without at the same time preventing them from engaging in most of their normal activities. Important and distinctive aspects of policy-making with regard to chemical weapons stem largely from this feature. The first and most important line of defense against chemical-warfare agents (also needed in part against radioactive fallout) is the physical protection that respirators, special clothing and air filters for collective shelters can provide. Properly fitted gas masks are capable of reducing the concentration of chemical-warfare agents in inspired air by a factor of at least 100,000. The filters contain activated charcoal for vapor adsorption and paper or some similar material for retaining particulates. To increase protection against small-molecule agents such as hydrogen cyanide, the charcoal is impregnated with copper compounds or other reactants. Gas masks currently deployed by NATO can be donned in less than 10 seconds and worn thereafter for long periods, even in sleep. The physiological stresses imposed are minor, and the psychological ones can be mitigated by training and practice. The new American mask, currently in an advanced stage of development, incorporates several refinements over the existing one. It is lighter and is designed to interface better with optical and audio equipment. The current Russian mask, although effective, is harder to don quickly than the principal NATO masks and is heavier and less comfortable.



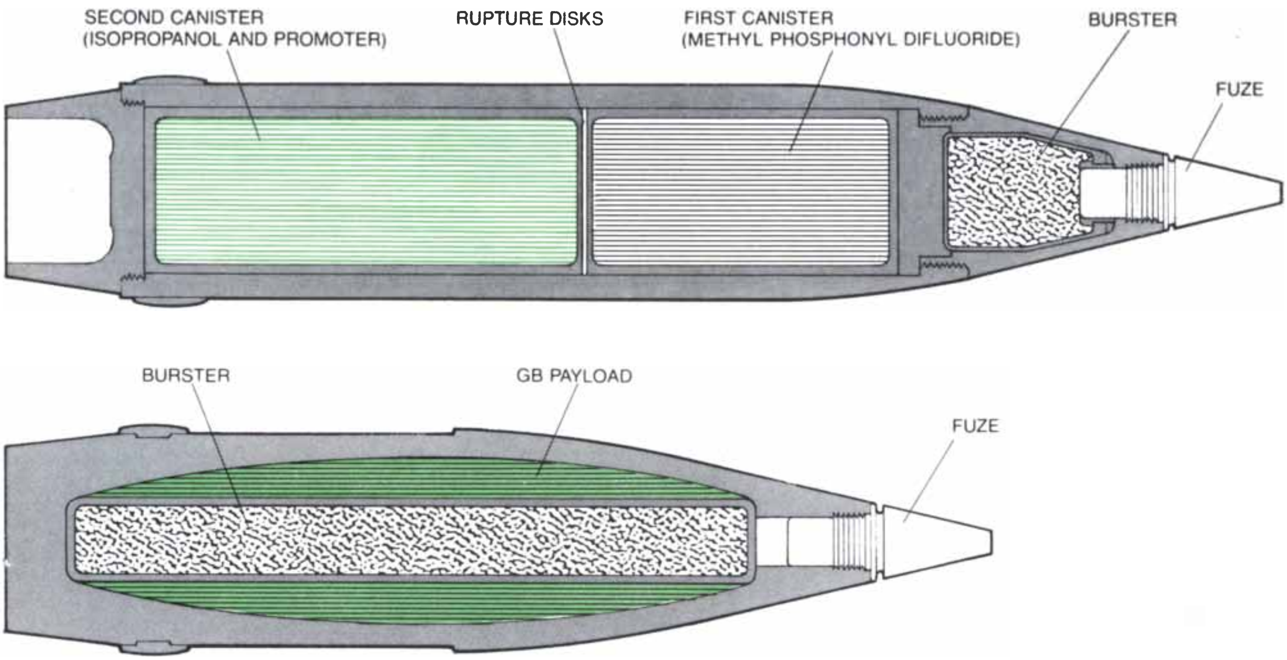
U.S. EXPENDITURES for protective equipment against chemical attack have increased sharply in recent years as this country and its allies in the North Atlantic Treaty Organization have sought to improve the anti-chemical-warfare capability of their forces in Europe. Bars are based on constant 1973 dollars. Hatched bars indicate approximate planned levels of spending.

All U.S. Army forces in Europe are equipped either with the British Mark 3 protective suit or with its more recently issued American counterpart. Each suit is a disposable two-piece overgarment, which for full protection is worn with butyl-rubber gloves and overboots. The American suit weighs four pounds and is water-repellent and permeable to air. The outer layer of its two layers of fabric is wear-resistant and treated to be rapidly wettable by droplets of nerve gas in order to accelerate their evaporation. Penetrating vapor is adsorbed by activated carbon bonded to the unexposed surface of the inner layer. Because the material can "breathe" and pass perspiration, it interferes little more than ordinary clothing with the ability of its wearer to shed heat. At temperatures usually encountered in central Europe the degradation of combat performance in full protective gear attributable to heat stress is minimal. At temperatures higher than 75 or 80 degrees Fahrenheit, however, any periods of heavy exertion must be limited to about an hour or else protection must be partly relaxed, for example by removing the gloves and unzipping the front of the protective jacket. Current Russian protective garments are made of air-impermeable rubberized fabric. At 60 degrees F. they can be worn for about four hours before heat stress builds up to casualty levels; above 70 degrees F. the tolerance time is less than half an hour. The Russians are said to be working on an improved suit.

For armored fighting vehicles collective rather than individual protection can be provided. The latest Russian and European NATO tanks have seals and positive-pressure filtered-air supplies so that their crews are fully protected without having to wear masks. The Russian forces appear to be relying increasingly on this method for the armored personnel carriers and combat vehicles in which their infantrymen would move during battle. The American preference is to provide armored vehicles with a central pressurized supply of filtered air to which individual respirators can be connected, making it possible to operate with the hatches open and allowing soldiers to enter and leave the vehicle; full collective protection is limited to vehicles such as "command, control and communications" vans and certain mobile missile units. Collective protection is also available on both sides for fixed installations, including command posts and temporary shelters through which front-line units can be rotated for medical care and rest.

NATO troops are trained to put on their masks and other protective equipment in response to commanders' orders, warnings given by chemical-agent-detection personnel or individual detection by a variety of means, including the sensing of characteristic symptoms such as a runny nose, dimming vision and tightness in the chest. The capacity for determining the proper degree of protection is being enhanced by the deployment of sensitive automatic field alarms for nerve gases. Such alarms are important because nerve-gas contamination at casualty-threatening levels may be undetectable by the unaided human senses. One of the latest alarms to enter service is a 30-pound British device that monitors the voltage across an electrochemical cell in which covalently immobilized cholinesterase is continuously irrigated with a solution of butyrylthiocholine substrate; nerve gas in the sampled air inhibits the enzyme, just as it would in the human body, resulting in a drop in the thiocholine level, which triggers the alarm.

Gas masks and protective clothing can provide effective protection against nerve gas. If they should be circumvented, a second line of defense—the self-administration of antidotes—is available to the individual. Antidotes would come into play when protective equipment had not been donned promptly enough or when it had become



ARTILLERY SHELLS designed to deliver the nerve gas GB in different ways are shown in these cutaway drawings. The 155-millimeter projectile at the top is the newer binary-type munition now ready but not yet authorized for production; the one at the bottom is its stockpiled nonbinary equivalent. In the binary version one of the two canisters containing the ingredients to form GB can be stored and shipped separately, to be loaded at the gun site. When the projectile is fired, the contents of the two canisters mix and react to produce the lethal agent. The binary feature provides greater insurance against unintended release of nerve gas and facilitates possible disposal. The heavier casing and central burster of the nonbinary round provide substantial fragmentation effects. Although the binary shell holds more chemical, only about 70 percent of its payload ends up as GB; the other main product of the chemical reaction is hydrogen fluoride.

damaged. They would also be necessary in the more remote eventuality that the sorptive capacity of respirator filters or protective suits had become saturated under circumstances not allowing immediate replacement. The most widely available antidote is atropine, which blocks acetylcholine at autonomic receptors, used in conjunction with an oxime compound that can displace bound nerve gas from inhibited acetylcholinesterase. Compact autoinjectors are issued to be self-administered as soon as the symptoms of nerve-gas poisoning begin to be felt. The formulation used in current American and Russian autoinjectors, referred to as TAB, consists of trimedoxime, atropine and a second antagonist of acetylcholine, benactyzine. This antidote can save the lives of people receiving somewhat more than the median lethal dose of nerve gas, and it can reduce the severity of symptoms due to sublethal doses.

Severer intoxication, up to several median lethal doses, can be countered only if positive-pressure artificial respiration is also applied. Prophylactic use of oximes or reversible inhibitors of acetylcholinesterase such as pyridostigmine (administered by means of pills swallowed a short time before nerve-gas exposure) may improve the prognosis. Notwithstanding the advances in therapy and prophylaxis that now seem possible, however, it is doubtful whether these medical defenses would significantly reduce casualties in the sense of soldiers put out of action, although they could certainly save lives and bolster morale.

The third principal component of antichemical protection consists of equipment and procedures for decontamination. Soldiers are provided with kits for decontaminating their skin and personal equipment. The other main requirement is a capacity for ensuring that crucial combat and support equipment remains usable. The contamination that must be countered is that which because of its density or location would otherwise overstress the protection of the operators or be transferable to critical clean

	NONCHEMICAL SHELLS		NERVE-GAS SHELL (GB)			
	FRAGMENTATION SUBMUNITION SHELL	AIRBURST HIGH-EXPLOSIVE SHELL	TARGET PERSONNEL UNPROTECTED	TARGET PERSONNEL CARRYING BUT NOT WEARING GAS MASKS AT START OF ATTACK	TARGET PERSONNEL WEARING GAS MASKS BUT NOT PROTECTIVE CLOTHING	TARGET PERSONNEL WEARING GAS MASKS AND PROTECTIVE CLOTHING
TARGET PERSONNEL ON THE ATTACK	1	4	1	2	74	(CASUALTY LEVEL EXCEEDING A FEW PERCENT WOULD BE UNATTAINABLE)
TARGET PERSONNEL ON THE DEFENSIVE	4	51	1	66	74	

NUMBERS OF VOLLEYS of different projectiles that would have to be fired by a battalion of 18 155-millimeter howitzers in order to inflict casualties of about 30 percent on a platoon-size target (with a radius of 150 meters) in open terrain at a distance of 10 kilometers are estimated in this table. The figures take into account the differences between attackers and defenders with respect to their posture, breathing rate and time required to don their gas masks once the shells have started to fall. The fragmentation submunition shell, one of a family of new munitions called Improved Conventional Munitions (ICM) by the Army, detonates at a height of about 50 meters, releasing a cluster of 88 small antipersonnel bombs. For the nerve-gas shells the number of volleys required would vary over at least an order of magnitude depending on the weather. The figures given here are midrange ones: for a cool, dry, overcast day with a gentle breeze.

areas. This task can be accomplished with portable dispensers and scrubbers, which can apply decontaminating agents to door handles, gunsights, machine controls, entryways and the like. Effective decontaminants are available in the form of oxidizing agents, such as bleaching powder. Also available, although perhaps less critical, is large-scale decontamination equipment for use in logistical centers and staging areas. The Warsaw Pact nations have deployed large numbers of vehicles for chemical and radiological decontamination, including the TMS-65 turbojet-powered large-volume dispenser, first observed in the 1960's, which is said to be capable, when it is used in pairs, of decontaminating the outer surfaces of a tank in less than three minutes.

The new protective items now being deployed by NATO in Europe are greatly increasing the capacity of the NATO forces for operating effectively on contaminated battlefields and for preserving support and resupply functions. Equipment, however, is only a part of what is needed. An adequate defense must also embody a detailed and widely diffused understanding of the problems involved, thorough training and exercising of personnel, and an organization efficient enough to operate smoothly under the chaotic conditions of war, which large-scale chemical operations would undoubtedly aggravate.

All the major NATO and Warsaw Pact armies provide training for antichemical protection at the individual level, but there are many tasks that must be done by groups requiring special equipment and expertise. These requirements overlap those for biological and radiological defense, and all three tasks (nuclear, biological and chemical) are generally organized together under the abbreviation NBC. The American practice is to assign such tasks to teams under local field command, down to and including the company level, with key personnel in each team receiving more specialized NBC training. A typical U.S. Army company of between 100 and 130 men includes an NBC Defense Team to which 15 or more men are assigned, most of whom usually have other duties as well. The team includes separate groups assigned to chemical detection, radiological monitoring and decontamination. In addition there are career chemical-specialty troops attached to brigades and higher command levels, such as the NBC Defense Companies authorized for each U.S. combat division and corps support command. The Russian organization, which resembles that of the West German army, places much more emphasis on career NBC troops organized as a separate branch, of whom there are estimated to be approximately 80,000.

Antichemical defense procedures are

PROTECTIVE GEAR designed to defend soldiers against a chemical attack is modeled by a U.S. infantryman in this photograph released recently by the Army. The gas mask, a new style now in an advanced stage of development, incorporates filters made of activated charcoal for vapor adsorption and glass fiber for particle retention. The protective suit, a disposable two-piece, multilayered overgarment, is lightweight, water-repellent and permeable to air. The outer layer of fabric is chemically treated to be rapidly wettable by droplets of nerve gas in order to accelerate their evaporation; penetrating vapor is adsorbed by a layer of activated charcoal bonded to the inner fabric layer. For full protection the suit is worn with butyl-rubber gloves and overboots. Adhesive-backed strips of detection paper are placed on the arm, wrist and ankle. All U.S. troops in Europe are equipped with gas masks and protective clothing.

routinely practiced during Warsaw Pact maneuvers. Evidence of such close attention to protection has been available to NATO since the 1950's, not least in the pages of Russian military journals. Russian-supplied protective equipment of many kinds was found among Israeli-captured Arab materiel after the Six-Day War of 1967, indicating that the equipment was standard Russian issue. Similar NBC materiel was captured during the October War of 1973. In neither case were any chemical munitions found.

In 1974, citing the October War findings, the U.S. Army announced that it was assigning a high priority to antichemical preparedness, and it is now engaged in a $1.5-billion program intended to provide by the mid-1980's a greatly improved capability for withstanding chemical attack and for conducting operations in a toxic environment. Battle-training exercises are routinely held in full protective gear. Similarly, the Air Force has begun a program, estimated to cost $234 million and due for completion by 1984, to improve the chemical defenses of its European air bases. These programs are rapidly bringing the quality of the antichemical protection of U.S. forces in Europe up to or beyond that of those allied forces that have long given it priority, particularly the British, Canadian, French and German forces. NATO itself has embarked on an alliance-wide program to smooth out disparities and upgrade overall antichemical defenses.

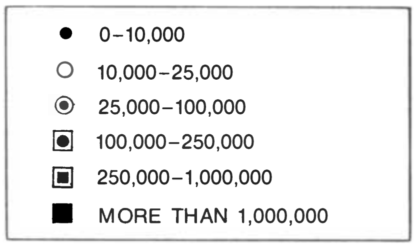
Even with the advanced methods of chemical protection now available, a sufficiently determined chemical attack would still make an impact, not only in casualties among troops caught off guard or with defective or improperly used protective equipment but also in the degradation of mission performance imposed by the protective measures themselves. The better the protective posture of a fighting unit is, however, the less economical would the use of chemical weapons against it become in comparison with other weapons. For causing casualties the principal non-nuclear competitors with nonpersistent agents such as sarin are flame-producing munitions and airburst high-explosive or fragmentation munitions against troops in the open and fuel-air explosives against dug-in troops; competitive with persistent agents such as VX for "area denial" are the many varieties of scatterable mine, including those deliverable by artillery. Although side-by-side comparisons of these different munitions have apparently not been undertaken in any great detail, the existing munitions-expenditure tables for each one provide a rough guide. For unprotected or unprepared troops the casualty effects of chemical weapons can be competitive with those of conventional weapons, but this is not the case for an attack on prepared troops with good antichemical protection, particularly when the comparison is with the much more effective newer types of conventional antipersonnel weapons now being deployed. Soldiers wearing antichemical protective equipment are far more vulnerable to conventional attack than they are to attack with chemicals. Moreover, it must also be taken into account that, at least for NATO, resources devoted to chemical weapons contribute nothing to firepower unless the other side chooses to use chemicals first.

Much more difficult to assess than the casualty effects of chemical weapons is the degree to which antichemical protection degrades mission performance. Large-scale controlled tests adequately designed to provide the necessary data have only recently begun in the U.S. There is bound to be some degradation, and for some missions it would be worse than it would be for others. Current estimates range from near zero, as in a recent British exercise at an air base in Germany measuring tactical aircraft turnaround times with the air and ground crews fully protected, to more than 30 percent for some unspecified types of front-line mission cited in the testimony of Department of Defense officials before Congress.

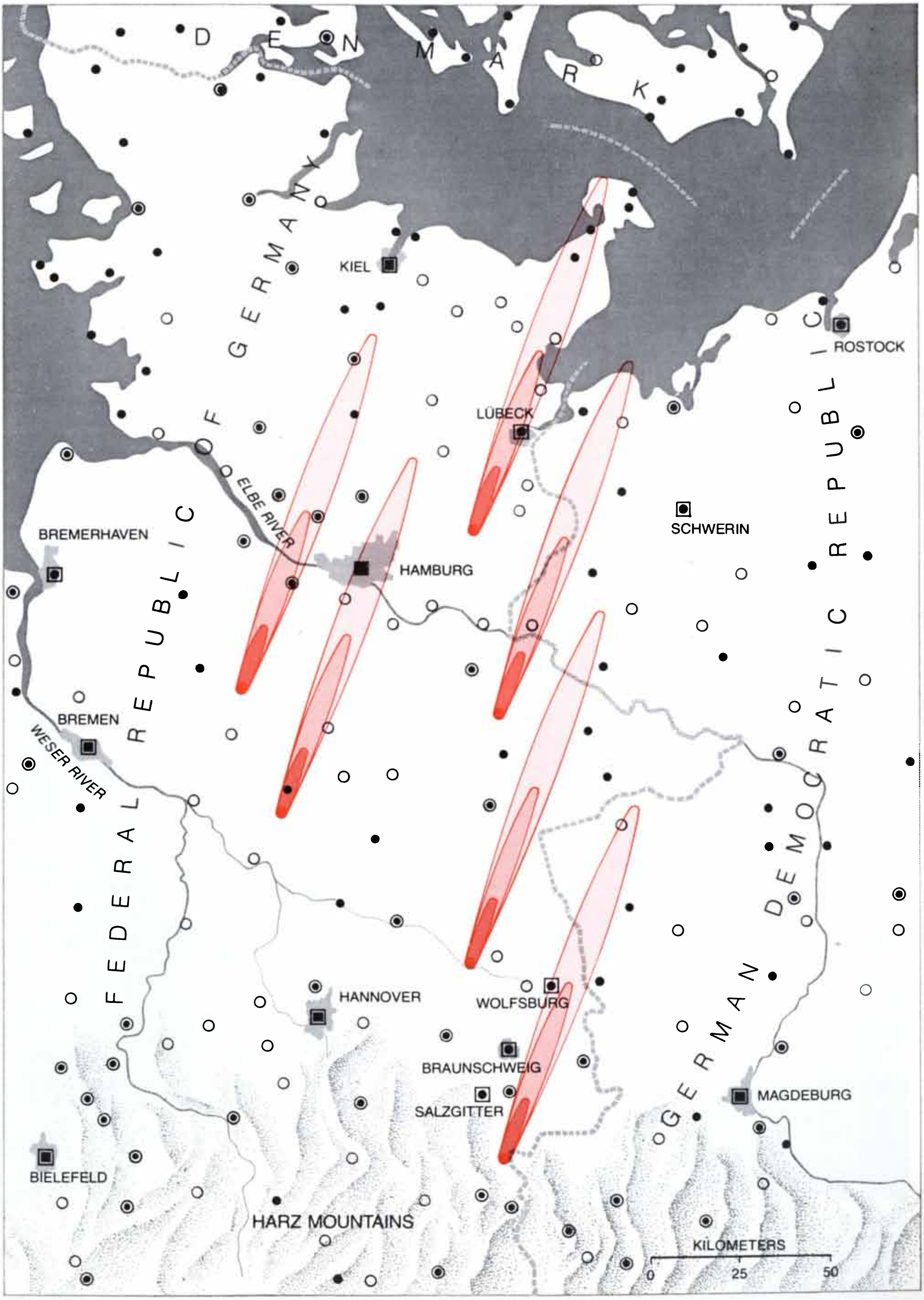
Since civilians are unlikely to be provided with protective equipment and trained in its use to the same extent as combat units, noncombatants stand to suffer more severely from the effects of chemical attack. Existing chemical weapons are not designed for strategic purposes, and military doctrine does not envision intentional chemical attacks on civilians. Clouds of nerve-gas vapor could drift long distances downwind of a battlefield before becoming harmless, however, and terrain contaminated by nerve gases may remain hazardous long after fighting in the region has ended. Battlefield chemical weapons thus carry with them an immense potential for causing civilian casualties. It can be estimated that on-target sarin contamination intended to cause 20 percent casualties among soldiers carrying respirators but not at first wearing them could, under weather conditions frequent in central Germany, kill unprotected people 20 kilometers or more downwind and seriously incapacitate people out to about twice that distance. Civilian casualties on the order of millions could result from battlefield chemical warfare in Europe.

Quite apart from the purely military factors determining the utility of chemical weapons there are within NATO major political considerations limiting their deployment and use. The U.S. and France are alone among the NATO allies in possessing them. Italy (like Bulgaria, Hungary and Romania in the Warsaw Pact) is under international treaty constraints limiting the acquisition of chemical weapons. West Germany, also limited by treaty, has renounced them altogether in perpetuity and, as the sole European repository of U.S. stocks, is a reluctant host. In an official White Paper the West German armed forces have disavowed any intention either now or in the future of seeking access to the stocks or of training combat units in the use of chemical weapons.

The arguments advanced for NATO's maintaining a chemical retaliatory capability vary, according to whether it is supposed the Russians employ chemicals in an otherwise conventional war or whether instead nuclear weapons are also in use. In the event of a major Russian conventional attack on Europe a NATO capability for retaliating in kind is seen as an important, yet minimally escalatory, deterrent against a Russian initiation of chemical warfare. It is considered that NATO retaliation would be seen by the Russians as substantially offsetting any gain from their use of chemi-



POTENTIAL CIVILIAN CASUALTIES resulting from a hypothetical chemical attack on a battlefield in north-central Europe are suggested by the equal-dosage contours of this map. The solid colored dots represent battalion-size targets (a square kilometer or less in area), each attacked with GB bombs releasing a total of six tons of nerve gas per target, a quantity intended to inflict about 20 percent casualties on troops carrying but not at first wearing gas masks. The weather is assumed to be cool, dry and overcast with a gentle southwesterly breeze. Most people within the light-color areas would be poisoned, although not fatally; their vision would be affected, and they would suffer protracted eye pain, headache and difficulty breathing. Within the medium-color areas unprotected people would be incapacitated for a period of days. The innermost, dark-color areas are those in which people would be severely poisoned; only young adults near the outer fringes of each area would have a good chance of surviving, and many of them would be brought to the brink of death, collapsed and in convulsions. Under more stable atmospheric conditions, for example at night with clear or partially clear skies, all the areas would be several times larger; under less stable conditions, for example in warm, sunny weather, they would be smaller. Normally there would be wind fluctuations over the 10-hour period considered here, altering the shape of the equal-dosage contours. The six attacks illustrated would release only a fraction of a percent of the total amount of nerve gas that could be expended in a large-scale chemical war in Europe.


DENMARK
FEDERAL REPUBLIC OF GERMANY
GERMAN DEMOCRATIC REPUBLIC
KIEL
ROSTOCK
LÜBECK
SCHWERIN
ELBE RIVER
BREMERHAVEN
HAMBURG
BREMEN
WESER RIVER
HANNOVER
WOLFSBURG
BRAUNSCHWEIG
SALZGITTER
MAGDEBURG
BIELEFELD
HARZ MOUNTAINS
KILOMETERS
0
25
50

cals. Moreover, since such a NATO response would be only a continuation of what the other side had started, the NATO retaliatory threat would be credible where the much more escalatory threat of nuclear retaliation might be less so. It is further argued that if deterrence fails, NATO forces can discourage escalation of the extent and intensity of the use of chemicals and possibly end it by being able to use their chemicals to match the effect of chemical strikes at each level, both on the battlefield and in rear support areas.

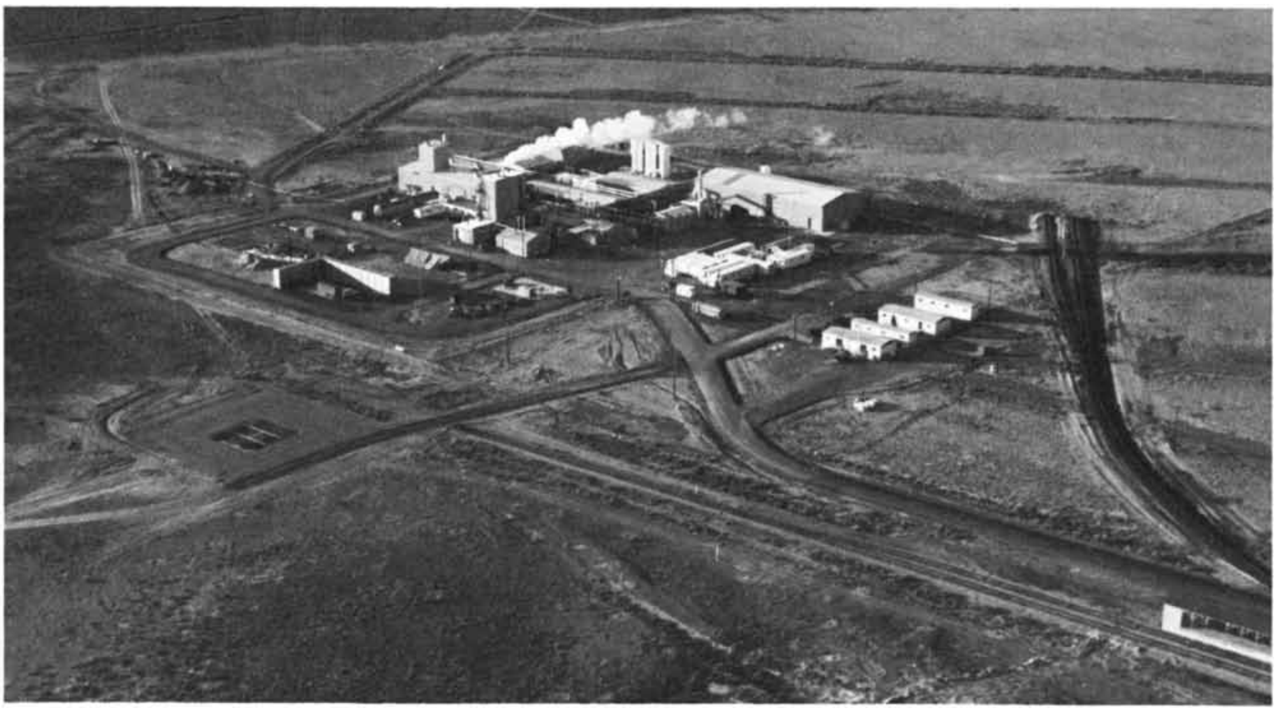
U.S. doctrine on chemical weapons promulgates these ideas in current field manuals as follows: "The objective of U.S. policy is to deter the use of chemical weapons by other nations. If this deterrence fails, and the use of chemical weapons is authorized by national command authorities, the primary objective is to achieve early termination of chemical-warfare operations at the lowest level of intensity."

Under the different assumption that nuclear weapons are already in use, the antiescalation benefits seen for a chemical retaliatory capability largely disappear. The utility of chemical retaliation would then hinge on its battlefield effectiveness in inflicting casualties and imposing delays on enemy military units.

The deterrent value and the de-escalating potential of NATO's chemical weapons have been questioned both in terms of immediate military effectiveness and in relation to broader strategic considerations. If the Russians were to use chemical weapons in support of a conventional offensive, NATO retaliation in kind at the same level would compel the Russian forces to adopt more stringent antichemical precautions than their own chemical attack had necessitated. This effect might or might not have some significance in determining the overall outcome, but its possibility, it is argued, would hardly be likely to be seen by the Russians as offsetting the immediate gains that recourse to chemicals could promise. An initial chemical strike, in contrast to a retaliatory one, might have a substantial probability of catching opposing forces at a low level of antichemical protection and would hold out a correspondingly greater prospect of major tactical impact. It is therefore maintained that NATO's chemical weapons would add little to the deterrence of chemical warfare unless the retaliation threatened were highly escalatory: heavy enough to overwhelm Russian front-line protection or deep enough to reach targets in the Russian rear.

Serious liabilities for NATO would, it is argued, be attached to such a response, however, thereby reducing its credibility. The extension or intensification of the battlefield use of chemical weapons could slow NATO counteroffensives and greatly increase civilian casualties. Longer-range chemical attacks, with effects intrinsically difficult to predict or control, would carry a serious risk of precipitating nuclear or other escalatory responses that NATO might prefer to avoid or to preserve as its own initiative. The retaliatory options available in a chemical-warfare capability of this kind would, in terms of potential target effects, overlap those afforded at present by NATO's nuclear weapons, so that the deployment of chemical weapons could be perceived by the Russians as a sign of diminished resolve to use nuclear weapons. Increased reliance on chemical retaliation to deter a Russian chemical attack could then carry a cost of reduced capacity for deterring war itself.

As it happens, the latter considerations are for the present largely academic since the chemical weapons NATO has available in Europe are sufficient only for rather limited retaliation. The leading NATO allies have made it clear that they are unwilling to countenance any expansion of the stocks, whether through procurement actions of their own or by expanding the chemical-depot facilities available to the U.S. Domestic political considerations have been influential, but it is also recognized that the resources needed to expand and modernize the NATO stocks, possibly by deploying binary munitions, would represent a substantial drain on other NATO programs, such as the present upgrading of conventional military ca-



DISPOSAL FACILITY for the destruction of chemical weapons that have become unserviceable was built recently at the Tooele Army Depot. Agent GB is decomposed here by hydrolysis in alkaline solution, agent VX is decomposed by chlorination and mustard gas is destroyed by incineration. The disposal of unserviceable stocks of lethal chemical weapons currently under way is expected to take seven years and to consume a few percent of the U.S. stockpile. The facility serves as a prototype of the installations that would be needed for the larger-scale elimination of chemical-weapons stockpiles in the event that a chemical-disarmament treaty comes into being.

pabilities. There is also fear that if an expanded chemical retaliatory capability were ever to be used, the consequence would be a stalemate on the battlefield, as in World War I, with attendant greatly increased casualties and destruction in Europe.

Maintaining a chemical retaliatory capability and entering into an agreement to limit chemical arms are alternative approaches to the same objective: the minimizing of the threat presented by the chemical weapons of one's adversary. Only arms limitation, however, seeks to remove the opponent's weapons and to reverse the usual cycle whereby the military programs of one side act to drive those of the other. Moreover, only arms limitation addresses the problem of the possible proliferation of chemical weapons to conflicts and confrontations between parties other than the NATO and Warsaw Pact countries. Both approaches entail risks. Maintaining chemical weapons perpetuates the already existing threat and may augment it. Entering into an arms-limitation agreement may in the worst case expose NATO to an undiminished threat while denying NATO a chemical capability of its own. Both approaches are subject to important political constraints, quite apart from the constraints imposed by the purely military strengths and weaknesses of the weapons themselves. On the one hand there are political limits to the measures attainable for verification of compliance with an agreement. On the other there are political constraints on the nature and effectiveness of the chemical retaliatory force NATO can maintain. These constraints are rooted not only in public opinion but also in the national-defense policy of key NATO allies, such as West Germany.

Nevertheless, there are two essential factors that give NATO considerable flexibility in shaping its policy for chemical weapons. One of these factors is the greatly improved chemical-protective posture now coming into being in Europe. This factor limits the threat to NATO forces created by Warsaw Pact chemical weapons, both in the present situation and in the environment of an arms-limitation agreement, should the other side retain or produce chemical weapons in violation of the agreement. The other factor allowing flexibility in NATO policymaking is the wide range of modern conventional weapons and nuclear weapons, which overlap and overshadow the capabilities of chemical weapons, both for deterrence and for combat. These considerations help to set the boundary conditions within which the current bilateral talks between the U.S. and the U.S.S.R. on chemical disarmament proceed.

At the Moscow summit meeting of July, 1974, President Nixon and Secretary Brezhnev declared they had agreed to consider a joint initiative on the prohibition of chemical weapons. This agreement was reaffirmed by President Ford and Brezhnev at Vladivostok that November, and it led in August, 1976, to the start of the current bilateral negotiations in Geneva. By the end of the 10th round of the talks, in August, 1979, agreement had been reached that both lethal chemical weapons and incapacitating ones should be included within the scope of a chemical-weapons convention, and that highly toxic chemicals (and precursors) of types and in quantities having no justification for purposes other than chemical warfare should also be prohibited, subject to certain additional criteria intended to facilitate verification. It is also agreed that on ratifying the convention states should declare their chemical-weapons stockpiles and means of production, and that verification of their elimination within a specified period should be based on a combination of national and international measures, including a provision for requesting on-site inspection to investigate suspected violations. Although these agreements represent substantial progress, critical negotiations still lie ahead, since little accord has yet been reached on the particular information to be provided in the required declarations or on the pivotal issue of the specific methods to be used for verifying the destruction of chemical weapons and the elimination of production facilities.

Existing means of surveillance, including a variety of procedures for intelligence gathering and evaluation, have an important if limited ability to detect chemical-warfare activities in the Warsaw Pact region. Such national verification procedures by themselves are considered by the U.S. and other NATO countries to be inadequate for monitoring compliance with a chemical-disarmament treaty. It is not necessary, however, that a verification system be able to detect all the activities and facilities that go into creating or maintaining a chemical-warfare establishment. What is required is a high likelihood of detecting chemical-warfare preparations on a scale large enough to constitute a major military threat. It is important to note in this regard that the effectiveness of verification measures is enhanced by a high level of chemical defense. Good defense greatly raises the scale of chemical-warfare preparation needed to constitute a major military threat, making concealment more difficult and intrusive inspection less necessary.

Although historically there is wide divergence between the approaches of the U.S. and the U.S.S.R. to problems of verification, the agreed concepts of declaring chemical weapons and means of production and of using a combination of national and international measures to verify their elimination may provide the basis of a convention acceptable to both sides. One approach for reliably verifying the destruction of declared weapons and chemicals would be to transport them to a site or a few sites chosen by the possessor where the destruction would be carried out under international observation. Even with automated disposal techniques this process would require several years, during which the participants might take various measures to assure themselves that the agreement was being implemented as expected. The elimination of declared production facilities could be monitored by satellite reconnaissance, following limited on-site visits to ascertain that the facilities were of the types declared. These procedures would guarantee the elimination of large quantities of chemical weapons and sizable production facilities. The problem of verifying the absence of undeclared stocks or facilities could be addressed by carefully designed measures based on the already agreed right to request on-site inspection where other means had indicated questionable activities.

The search for political accommodation within these possibilities and the various others that can be conceived for a chemical-arms-limitation agreement has developed a pace of its own, albeit one that is governed by changes in the broader course of international relations. If the U.S. and the U.S.S.R. are able to come to terms on chemical warfare, the next step would be to present a proposal for a multilateral agreement to the Geneva disarmament conference. The exploratory negotiations and technical study that have been continuing there for the past 11 years could then finally result in a chemical-weapons treaty with wide international support, but it will clearly be some time before the ultimate success or failure of these endeavors becomes apparent. Meanwhile there is a danger that the existing constraints against chemical warfare will weaken and that additional countries will move to acquire chemical weapons, as is emphasized by the recent unconfirmed but troubling allegations of the use of poison gas in Afghanistan and Southeast Asia.

What is at stake in the negotiations goes beyond the problem of dealing with the threats chemical weapons currently present to the security of nations. Mankind has entered a period of rapid and accelerating understanding of the fundamental biochemical and cellular processes of life. As this knowledge expands, so too will the range of its possible applications for good and ill. In the long run the existence of a chemical-disarmament treaty in addition to the present biological one could help to establish the principle that the increasingly profound knowledge of life processes be directed solely to beneficial purposes.