aids and maneuvering reentry vehicles for offensive forces, as well as increases in force levels, giving each side, in turn, an incentive to further improve the capabilities of its ABM systems."

Such a race would be destabilizing because it would be difficult to assess the capabilities of either country at any given time. Jack Ruina, an arms control expert at MIT, notes for example that Soviet deployment of an BMD would create great uncertainty in the United States "about possible rapid deployment of equipment from ICBM sites to urban locations and about the potential for simple technical upgrading of equipment to make it more suitable for urban defense." Taking this and other problems into consideration, the Committee for National Security, a group founded by former SALT negotiator Paul Warnke, declared last summer that the treaty barring BMD is "the single most important arms control measure achieved thus far." Defense Secretary Weinberger disagrees, however. "If we find . . . that there is a far more effective system that would require revisions in the treaty, I think it's fair to say that we wouldn't hesitate to seek those revisions," he says. "Obviously if we are able to destroy incoming missiles effectively, I don't think it's destabilizing. I think it would be extremely comforting."

The problem is that the price of this comfort could be quite high—both politically and economically. Thomas Reed, a former Air Force Secretary who is now with the White House national security council, chaired a panel on BMD for the Defense Science Board last summer. He told *Science* that although the panel concluded that a LoAD system could indeed be built, he came to a personal conclusion that it was not worth the effort. The system, he says, would require thousands of nuclear-tipped interceptors, pulling scarce nuclear materials and money away from more effective offensive weapons. "If we want to spend money on things that go bang, then maybe we should spend it on things that go bang over the Soviet Union and not us," Reed says.—R. JEFFREY SMITH

Binary Nerve Gas Production Plans Debated

Critics say existing stocks are adequate deterrents; warn of adverse reactions from both allies and Soviets

A heated debate is brewing over the Administration's proposal to resume production of nerve gas after a 13-year hiatus. At issue is a plan to spend $104 million next year on research and production of artillery shells and a bomb to deliver binary nerve gas. Binary weapons contain two nonlethal chemicals that are kept apart until the weapon is in flight, when they combine to form highly lethal nerve agents. The Army has long been pushing for replacement of its existing nerve gas stocks with binaries on the grounds that they are safer to handle and transport than conventional chemical weapons, but until now, presidents have resisted the pressure.

In 1980, however, Congress passed a $3.2-million appropriation for construction of a facility to produce binary weapons at Pine Bluff, Arkansas. Last year $20 million was approved to equip the facility. Now the Administration wants to start production of binary artillery shells—part of an overall chemical warfare deterrent program costing around $7 billion over the next 5 years, most of which would be spent on upgrading protective equipment for U.S. troops.

This year a number of members of Congress (including both Arkansas senators) have voiced strong opposition to the binary plan. Senators Gary Hart (D–Colo.) and Thad Cochran (R–Miss.) are sponsoring a measure to delete the binary production money from the armed services authorization bill, and Representative Toby Moffett (D–Conn.) has introduced a similar bill in the House.

The debate over binaries revolves around two intertwined themes. The first centers on the question of whether or not the Army's existing nerve gas munitions have deteriorated so badly that they are no longer serviceable. And the second involves the broader question of whether renewed U.S. interest in chemical weapons will have adverse political ramifications among NATO allies for what critics believe are dubious military gains.

The Administration defends its proposed chemical weapons program by pointing to Soviet capabilities in this area. The Soviets are well known to integrate a chemical war–fighting capacity into all elements of their military apparatus. Extensive evidence for this was furnished by the Soviet tanks and equipment captured during the 1973 Arab-Israeli war. In absence of a verifiable ban on chemical weapons (the Geneva Protocol of 1925, prohibiting their first use in warfare, contains no means of verification or enforcement), the Administration wants a "credible" deterrent. The purpose of having a nerve gas is not so much to inflict casualties on the enemy, since once in protective garb troops are relatively invulnerable. Rather, it is to get the other side to "suit up." Wearing bulky protective gear and performing necessary safety and decontamination measures entails a 50 percent degradation in troop performance, says the Army. Thus, if the enemy is going to make allies don protective garb, they must be made to do likewise.

Amoretta Hoeber, the former Systems Planning Corporation executive who is now deputy assistant secretary of the Army for research, development, and acquisition, says that as soon as the Soviets show willingness to negotiate a verifiable ban we will promptly scuttle our new program. But our "sitting around doing nothing" for the past 13 years has enabled them to build up their side without having to make any concessions to the United States.

The government financed a big buildup of chemical munitions in the 1950's and early 1960's which terminated when President Nixon in 1969 ordered a stop to all production. But in view of the perceived Soviet threat, Administration officials argue that U.S. chemical weapons are no longer adequate.

Most of the stockpile, about half of which consists of agents (VX, Sarin, and mustard gas) in bulk storage, is located at the Tooele Army Base in Utah. The rest is in various munitions—rockets, bombs, mines, sprays, and artillery shells. Some of the stocks have deteriorated through rust and leakage. Many are

0036-8075/82/0430-0495$01.00/0

obsolete. The artillery shells, however, numbering about 3 million, are suitable for modern weapons and part of the stock is serviceable.

Hoeber stated at a briefing that only 8.7 percent of our current stock is usable, and that only 12 or 13 percent will prove serviceable when upgrading of the stockpile is complete. (The stockpile was allowed to deteriorate for most of the 1970's but since 1978 many millions have been put into refurbishment.)

Even if current artillery stockpiles were not deteriorating, the military needs munitions in the form of the "Bigeye" bomb because, according to Theodore S. Gold, the Defense Department's deputy assistant secretary for chemical matters, "we are lacking in capabilities to strike deeper tactical targets." Thus we need to be able to "force them into protective posture in depth."

The type of agent the Army plans to put in the binary artillery shells, and later the new bomb, are the same that predominate in the old stockpile: GB or Sarin, a volatile and highly lethal agent that dissipates quickly in air, and the even more lethal VX, which comes out as a viscous fluid that coats surfaces and can remain toxic for weeks. Both are stored as liquids.

Critics of the proposed program dispute almost every argument made in its behalf. Foremost among them is the tireless Matthew Meselson, the Harvard biologist who has been tracking chemical warfare activities since the early 1960's. He notes that the United States has a huge collection of munitions now because they are the result of a buildup undertaken when the U.S. military was envisaging war with both the Russians and Chinese and when nerve gases were seen as a means to inflict casualties. Now, he says, military planners recognize that chemical agents have no value as a weapon of mass warfare and are only useful to make the other side suit up. In this case, the current serviceable stockpile, which he estimates to include well over half the artillery shells, is "greatly in excess of our needs," and with proper maintenance will be good for another 20 years. He says the small stockpile based in Germany would be good for about 2 weeks of fighting, assuming that 5 percent of U.S. weapons were dedicated to shooting chemical projectiles. Meselson and Julian Perry Robinson of Sussex University have calculated that 200,000 artillery rounds would be enough to cover 5 percent of all the shooting for 30 days by U.S. troops.

Meselson has said in the past that Army officials have privately agreed with his calculations. A General Accounting Office report in 1977—before the maintenance and repair program began—also indicates that the Army has underestimated serviceable stocks. In an unclassified digest of the report, the GAO complained that the serviceability "may have been greatly understated. For example, many of the unserviceable classifications are a result of minor nonfunctional defects, such as container rust, which do not affect usability." Also, "entire production lots are classified unserviceable for a few defects." Meselson adds that some shells are classified unserviceable because of deterioration of bursters which supply the charge, even though these are easily replaced.

Although the Army claims the old munitions are no longer reliable, critics maintain that it is the new ones that pose the most uncertainty. The binary components have been laboratory-tested to see if they will mix properly, and munitions containing canisters of simulants have been test-fired, but testing with live agents is prohibited by law. The Army publicly insists this is not necessary. But William Webber, former Army Chemical Corps officer in charge of demilitarizing chemical munitions, says there is no question but that solid information about how the gas would disseminate is only obtainable from live firing.

Critics also say that the dangerousness of the current stockpile has been overestimated, noting there have been no major accidents.

Another major item of contention relates to plans for basing the new munitions. The United States' European allies are dead set against having any additional chemical stocks based on their turf. (Germany, Norway, Holland, and Denmark refuse even to train their troops in defensive chemical measures.) Critics contend that the United States' chemical arsenal is useless as a deterrent if it is going to be based in Pine Bluff. Gold's response is that "a credible stockpile in the United States has significantly more value than no credible stockpile anywhere." Hoeber is more aggressive: she said that basing in the United States actually gives the U.S. deterrent more "flexibility" because then we could ship it anywhere in the world as needed.

But critics say it would take so long to get the stuff over to Europe that it would be useless. Meselson, for example, calculates that to bring over 5000 agent tons—enough for several months of combat—would require the fulltime services of 2000 C141-B transport planes (of which the United States has 234) and 3000 semitrailer trucks for 12 days. Hoeber, questioned about airlift capability, responded, "I have to be an optimist on this." If top priority is placed on chemical transport, she estimated it would only take 24 hours to bring the munitions over. (*Science* was unable to find out whether she envisaged the airlift occurring at the outbreak of hostilities with the U.S.S.R. or after they had launched a gas attack.)

U.S. Air Force

U.S. troops undergoing chemical warfare training in Germany, 1980.

Another matter on which there are major differences in perception is the matter of civilian casualties. Once both sides are suited up, chemicals exert their main effects on the unsuited. Meselson and Robinson have estimated that the ratio of civilian to military casualties would be 20 to 1. Sarin, they said, which is carried by the wind, could potentially inflict casualties for days and could kill people 20 kilometers or more downwind. And VX could make terrain uninhabitable for weeks. Hoeber at her briefing said that civilian casualties are the inevitable side-effect of any war, and the civilian casualty question had been "much misunderstood." She said such casualties would occur only in immediate areas of combat. Sarin dissipates "in minutes" or at most hours in cold weather. Since the persistent VX sticks to the ground she didn't see this as a civilian problem at all.

Experts also differ considerably about the degree to which "suiting up" affects the performance of fighting men. Although the Army says there would be 50 percent performance degradation, Meselson says that in the cool summer temperatures prevailing in central Europe degradation would be about 30 percent and much less in temperatures below 70 degrees. Everyone agrees, however, that the estimates are extremely

uncertain, and that the Russians would have a harder time in their rubber-based suits than the allies in their lighter, charcoal-based equipment.

The debate over binaries is somewhat confused by the fact that criticisms of the new program are intermixed with criticisms of the whole concept that U.S. chemical capabilities can deter the Russian use of chemicals.

Saul Hormats, 37-year veteran of Edgewood Arsenal, now retired, is one critic who believes there is no point in having an in-kind deterrent at all. First of all, say Hormats and others, U.S. build-up of chemical deterrent may undermine the nuclear deterrent by causing Soviets to doubt NATO willingness to go nuclear if necessary. (The other side of that argument is that chemicals offer more escalatory flexibility and could buy a delay before the nuclear option was invoked.) He says history shows that any Soviet invasion of Europe would be a massive one with millions of soldiers. If, in the event of a stalemate, they decided to push through with a nerve gas attack, they would have 4 or 5 hours to inflict casualties before allies had a chance to go into a protective posture. Any counterattack would be against a fully protected enemy and would only be "symbolic." Then, says Hormats, since gas only works against unprotected soldiery, the Russians could immediately revert to normal high explosives, thus enjoying a significant temporary advantage over allied troops while they still had a portion of their munitions tied up with ineffective chemical agents.

One rationale given for maintaining a deterrent stockpile is historical: the Defense Department claims the reason the Germans never used gas in World War II was because they knew the allies could retaliate. Hormats disputes this. He says that when he was at Edgewood during the war a group of seasoned military men from the United Kingdom spent months field testing and puzzling over the uses of chemical munitions. They concluded that they had no decisive military function and their only purpose would be to slow down the battle, thus ultimately creating more casualties. He says talks with German officials after the war indicated that the Germans had arrived at the same conclusion. The real fear Europeans had during the war was of massive gas attacks on cities. But that notion has been retired with the advent of strategic nuclear weapons.

The politics of the current situation are somewhat puzzling. A 1980 Defense Science Board study of chemical warfare, which endorsed the binary program, may have added some legitimacy to the idea. The suspected use of chemical agents in Southeast Asia and Afghanistan is widely believed to be an additional influence, although Administration officials insist there is no connection.

The military-minded Reagan Administration appears to be engaging in unilateral logic rather than responding to larger political and military considerations. It shows no concern that bad-mouthing the existing chemical arsenal will persuade the Soviets that the United States now lacks a credible deterrent. Nor does it appear to take seriously the concerns of critics that a new round of nerve gas production will jeopardize the ability of European governments to hold together support for modernization of Theater Nuclear Forces (the cruise and Pershing II missiles scheduled for deployment in Europe). There are already signs of a backlash—the ruling German Social Democratic Party has passed a resolution asking their government to kick out the nerve gas stocks now based in Germany.

The binary program also makes a questionable fit with NATO policies on chemical warfare. Although NATO has been greatly concerned about upgrading its chemical protective posture, Julian Perry Robinson has written that the diversion of resources into poison gas manufacture "would run directly contrary to current trends in NATO armament, where the emphasis is on greater precision, greater kill probability, and reduced collateral damage."

Finally, there is the question as to whether American activities will lead to a renewed chemical arms race with the Russians. Says former Ambassador James Leonard, who participated in the chemical warfare talks before they stalled in 1980, "we get a lot of credit for refraining from building these things," and the Soviets are sure to respond with stepped-up activities. The Administration does not seem to feel that a binary program will be seen by the Soviets as particularly threatening. Says Hoeber, quoting former Defense Secretary Harold Brown: "Whenever we build up the Soviets build up, and whenever we don't build up they build up."

The Administration's position on chemical weapons, as on nuclear ones, is that the only way to gain Soviet cooperation is to threaten to do something they don't like. But despite Soviet statements indicating willingness to resume the chemical talks that broke down in 1980, the Administration has made no move to initiate further bilateral negotiations.

—CONSTANCE HOLDEN

NRC Reports on Ginna Nuclear Plant Accident

According to investigators from the Nuclear Regulatory Commission (NRC), the ultimate cause of the radioactive steam leak at the Robert E. Ginna plant last January may have been poor workmanship. At a briefing for the NRC on 14 April, the authors of a 300-page staff study (NUREG-0909) reviewed what they had found at Ginna. They focused in some detail on a collection of metal debris in the plant's steam generators.

The accident began at 9:28 on the morning of 25 January when one of the thousands of small pipes that carry hot, radioactive water through the steam generator burst without warning. Small pipes such as this, used to circulate heat from the reactor into the steam generator, have caused problems in many pressurized water reactors. The tubes are subject to corrosion, denting, and pitting. The Rochester Gas and Electric Company, like other plant owners, has had to spend a lot of time and money maintaining Ginna's steam system. Sludge must be removed regularly to keep corrosion to a minimum. Weak tubes must be reinforced with metal sleeves. Tubes damaged beyond repair must be plugged.

During one of the periodic maintenance sessions several years ago, it appears, a workman allowed a piece of steel plate to fall into the bottom of one of Ginna's steam generators. There it stayed until the accident in January. The NRC report says that this metal plate (about 4 by 6 inches) matches a section of plate which was repaired in 1975. After falling down among the tubes, it may have rattled around in the vessel, agitated by strong eddies of boiling water.

This was not the only debris in the steam generator. The NRC also found two long sections of severed tubing (30 inches long), a small rectangular piece of steel, a strip of metal, a piece of wire, and three tube fragments. Moreover, in the other steam generator, the one not involved in the accident, inspectors found a small rectangle of steel, a metal rod that looked like the used stub of a welding electrode, and a piece of wire. Although the NRC report gave no firm conclu-

0036-8075/82/0430-0498$01.00/0