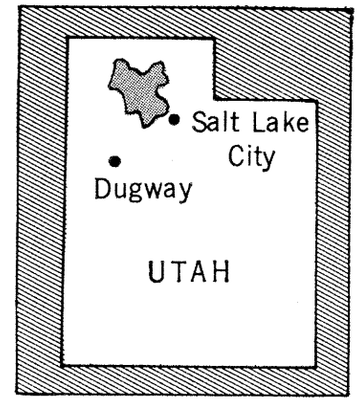
Nerve Gas: Dugway Accident Linked to Utah Sheep Kill



Nine months ago some 6000 sheep grazing in Skull Valley, Utah, were killed or sickened by a mysterious ailment that attacked the central nervous system. The sheep were located near the Dugway Proving Ground, the Army's chief site for field testing chemical and biological weapons, so suspicions were immediately aroused that the sheep had been felled by a lethal substance orginating at Dugway. These suspicions were heightened when it was subsequently revealed that Dugway had tested highly toxic nerve agents the day before the sheep became ill.

The massive sheep kill attracted to Utah a swarm of investigators from the military, from state and federal agencies, and from various universities. There were loud pledges from all concerned that there would be a no-holds-barred investigation into the question of what killed the sheep. For a time, while public interest in the incident remained high, status reports on the investigation were issued by the Army and by some of the civilian agencies involved. The Army generally took the line that, while Dugway was highly suspect, there was no conclusive proof as to what killed the sheep and further tests were necessary to establish the cause. At this writing, more than 9 months after the incident, there has still been no detailed report of what the investigation revealed. Brigadier General William W. Stone, Jr., of the Army Materiel Command, who headed the Army's investigation, has compiled a secret report on the incident, but the Army has not released an unclassified summary of this report and shows no inclination to do so. Nevertheless, it is possible, from the scattered statements the Army has made and from a variety of other sources, to piece together the outlines of what happened.

Virtually all the scientific and circumstantial evidence publicly available indicates that the primary cause of the sheep deaths was VX, a persistent nerve agent that was used in an aircraft spray test at Dugway the day before the sheep started dying. The scientific evidence will be discussed in more detail below, but, in brief, scientists have found traces of the nerve agent in the dead sheep and in nearby vegetation and snow water; they have established that the sheep were poisoned by an organic phosphate compound, of which the nerve agent is one; and they have shown that low doses of the nerve agent fed to healthy sheep will produce the same symptoms as those found in the sick Skull Valley sheep. There is evidence that the sheep ingested the nerve agent primarily by eating contaminated vegetation, and that the toxic material persisted in the area for at least 3 weeks after the incident. As a result of the unfortunate incident, a high-level advisory committee, headed by Surgeon General William H. Stewart, has recommended stringent new safety procedures for Dugway, and the Army last week adopted them *in toto*.

Accident at Dugway

How the agent escaped from Dugway may never be known beyond doubt, but investigators suggest that a combination of circumstances conspired to bring about the sheep slaughter. There was an accident during the spray test at Dugway; shortly thereafter a change in weather conditions apparently carried the agent toward the sheep and then precipitated it around them; and sheep turned out to be unusually susceptible to the agent. Had any of these factors been absent, it is conceivable—though unprovable—that there would have been no "Dugway incident."

The Army's initial reaction to news of the sheep deaths was to deny that Dugway had been doing any testing that could have caused the incident, but this posture had to be abandoned when the office of Sen. Frank E. Moss (D–Utah), revealed on 21 March that Dugway had conducted three separate nerve agent operations on 13 March, the day before shepherds first noticed the sheep were ill. The Army had supplied the information to Moss and apparently intended it to be "for official use only," but Dale O. Zabriskie, press assistant to Moss, says there was no restrictive marking on the document so he promptly released the information to Utah newsmen, much to the Army's consternation.

Surgeon General Stewart states that two of the nerve agent operations—a demonstration firing of 155-mm shells containing nerve gases, and a disposal operation involving the burning of about 160 gallons of a persistent nerve agent—have been ruled out as possible sources of the substance that killed the sheep. The third operation, in which a high-speed aircraft dispensed 320 gallons of VX in the form of liquid droplets from two pressurized spray tanks, remains highly suspect.

The purpose of the aircraft spray test, according to statements made by Army officers at an informal briefing for the Utah congressional delegation last March, was not to test the nerve agent, which had been released hundreds of times at Dugway before, but rather to test the total disseminating system, consisting of the nerve agent, the spray tanks, and the high-speed aircraft. "You test the entire configuration before you put it on the shelf," General Stone explained at the briefing.

The Army has consistently refused to say whether anything went wrong during the test, and Colonel James H. Watts, Dugway's commanding officer at the time of the incident, has even

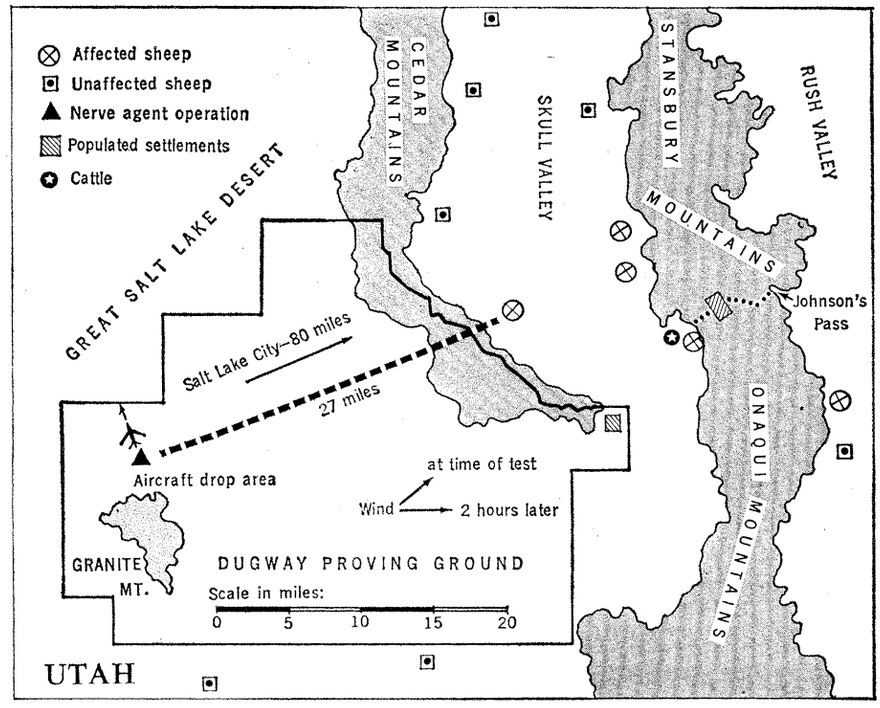
been quoted as denying rumors of a malfunction. But three sources who participated in the investigation—namely D. A. Osguthorpe, a veterinarian who acted as consultant to the Utah Department of Agriculture, G. D. Carlyle Thompson, director of the Utah State Division of Health, and Surgeon General Stewart—all confirmed to *Science* that there was, indeed, a malfunction. The malfunction resulted in the agent being released at a much higher altitude than anticipated.

The Army has publicly announced that the aircraft approached the target grid on a heading of 315 degrees true at an altitude of 150 feet (see map at right). Full details of what subsequently went wrong are not available but the following version has been pieced together from several sources.

Plans for the test called for the plane to dispense the nerve agent over the target grid, then pull up and jettison its supposedly empty tanks. But the pilot, unfortunately, has no way to shut off the tanks—they continue to discharge until they are empty. In the test on 13 March, according to investigators, one of the tanks failed to empty itself over the target grid and continued to dispense the nerve agent after the plane pulled up.

To what altitude the discharge continued is not completely clear. Colonel Watts, the former Dugway commander, has been quoted as saying the agent was released at a maximum altitude of 450 meters, or about 1500 feet. Osguthorpe, who has had access to much of the Army's data, believes the agent was carried somewhat higher. Either way, the agent was clearly within striking range of the ridge of the low-lying Cedar Mountains, which stood between the sheep and the test site. At their high point, according to the contour map distributed by Dugway, these mountains rise about 2700 feet above the Dugway flats, while at the points lying directly between the sheep and the test site, they rise only some 1200 feet above the valley. Somewhat less than 20 pounds of the VX is believed to have remained airborne after the 13 March test, according to testimony presented to a Senate appropriations subcommittee last May by Lieutenant General Austin W. Betts, chief of research and development for the Army.

At the time of the test, according to the Army, the winds at altitudes below 2300 feet were generally from the south-southwest, with gusts up to



35 miles per hour. Had this wind direction continued, the agent would have been carried up the west side of the Cedar Mountains and over barren salt flats. But there was a "weak front" in the area, reported the Army, and about 2 hours later the wind shifted and blew from the west. Betts said the wind "could have carried any very small particles of VX remaining airborne over the areas in Skull Valley and Rush Valley where sheep were later affected" Betts also said scattered showers developed during the early evening after the test (which took place at 5:30 p.m.) and he added that "one of these rain showers could have washed this airborne VX out of the air and deposited it on vegetation and the ground." Snow was reported the following morning.

On 14 March, the day after the test, sheep in several bands in Skull Valley just east of Dugway began showing signs of illness. One herder described the sheep as "crazy in the head." They generally acted dazed, held their heads tilted down and off to the side, walked in a stilted, uncoordinated manner, urinated frequently, fell down, and were unable to get up. Dugway scientists say these are not the usual symptoms associated with the nerve agent, but it was later discovered that these symptoms can be produced by low doses of the agent.

The affected herds were located in a crescent extending generally east and northeast from the Dugway site. The nearest sheep were about 27 miles from the site of the aircraft spray test and were separated from the test by low mountains. The farthest sheep were 40 to 45 miles from the test site and were located in Rush Valley, beyond a second, higher range of mountains, but near a low-lying pass through the mountains. The sheep nearest the test site were the most severely affected, while the herd in Rush Valley was touched only slightly. The course of the illness in the sheep that died was as short as 24 hours and as long as several weeks.

Investigators were initially mystified that sheep seemed to be the only animals in the area affected, Horses and cattle intermingled among the sheep showed no symptoms of illness, though chemical tests did indicate a somewhat depressed level of cholinesterase in the blood, an indication the animals had been exposed to an organic phosphate compound, a class which includes the nerve agents. Dogs and humans seemed unaffected. And while a survey of the area turned up at least 15 dead rabbits, rodents, birds, and other small wildlife, there seems to be no evidence that these small animals were killed by the nerve agent. One jack rabbit was observed to show signs of incoordination and trembling, symptoms which might indicate exposure to a nerve agent. But the Army, which had the area surveyed both before and

NEWS IN BRIEF

• **HANDLER SOLE NOMINEE**: The election of Philip Handler of Duke University to the presidency of the National Academy of Sciences (NAS), seems certain although it will not be announced officially until 15 January. Handler's name was the only one that appeared on the Academy's ballot, which was mailed to its 800 members last week. Handler was nominated in mid-October, but 2 months followed during which any 50 Academy members could have nominated other candidates.

• **DARTMOUTH MED SCHOOL**: Dartmouth College, which in May announced a decision to offer a full 6-year medical program, starting in the junior year and leading to a doctor of medicine degree, has been awarded a $750,000 grant from the Commonwealth Fund for this purpose. The new medical school, which will have 53 students in its first-year class in 1969, expects to have a total enrollment of about 160 by 1973. (Dartmouth now has 96 students in its 2-year basic medical education program.) The new medical school will be operated on an 11-month basis and will offer a curriculum stressing early clinical training. Dartmouth officials told *Science* that the new medical school will require about $28 million in additional funding; $8 million will be for new facilities and about $20 million in endowments will provide the necessary additional operating expenses. For the past 54 years, Dartmouth offered only the 2-year medical program; its graduates completed their degrees elsewhere.

• **YALE AFRO-AMERICAN MAJOR**: Yale will be the first major American university to offer an Afro-American major, which would include such subjects as Negro history and literature and the political effects of violence. Yale's decision to initiate the new program followed a request last winter by many of Yale's 110 Negro undergraduates to develop an Afro-American curriculum. A student-faculty committee approved the plan after a 9-month study. Sidney Mintz, chairman of the faculty committee, told *Science* the program will be in effect next fall and that the majors will be linked to a strong disciplinary base, such as political science or history.

• **R&D SPENDING**: The nation is expected to spend about $26 billion for research and development in the United States in 1969, which represents a 3.6 percent increase over last year. A Battelle Memorial Institute report from Columbus Laboratories shows, however, that this 3.6 percent increase represents "a distinctly slower" rate of growth than in recent years. Battelle estimates that the funding by industry will be up by $725 million, or about 8.7 percent, while federal expenditures are expected to remain at the current level of about $15.6 billion. Funding by colleges, universities, and nonprofit institutions is also expected to rise by about $98 million, or 11.7 percent for universities, and $25 million, or 9.3 percent, for nonprofit institutions. Of the total expenditure, Battelle estimates that the government will spend about $15.6 billion, or about 60 percent of all R&D funds; industry about $9 billion, or about 35 percent; colleges and universities about $938 million, or about 3.6 percent; and nonprofit institutions, about $295 million, or about 1.1 percent.

• **FORDHAM NAMES NEW PRESIDENT**: Fordham University, an 11,000 student Jesuit institution in New York, has named a new president, the Rev. Michael P. Walsh, and enlarged its board of trustees to include, for the first time, laymen and non-Catholics. It is said that the composition of the university's ruling body has been changed so that the church-related university might qualify for direct financial aid from New York State and the federal government. The new enlarged board of trustees consists of 15 laymen (some five of whom are non-Catholic) and 11 Jesuits. Previously Fordham's board of trustees consisted of nine Jesuit priests.

• **NEW PUBLICATIONS**: A report of the National Institutes of Health shows that the federal government provided two-thirds, or $1.5 billion, of the $2.3-billion total funds spent for biomedical research in 1967; *Resources for Medical Research Report No. 12,* "Dollars for Medical Research, 1965–67," may be obtained for $1.25 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

after the test, maintains that the rodent population remained essentially unchanged.

Why were sheep the only animals affected? The answer seems to lie partly in the fact that sheep are more susceptible to the agent than many animals, partly in the fact that sheep had greater access to contaminated food than most animals.

Dugway scientists stated at the time of the incident that not much was known about the effects of the nerve agent on sheep. But during the course of the investigation, according to Surgeon General Steward, it was learned that sheep are "peculiarly responsive" to the nerve agent and succumb to "much lower doses" than would harm a human being, even a child. Moreover, sheep, it seems, die easily once they become sick. Robert H. Huffaker, a Public Health Service veterinarian who participated in the investigation, believes the first sheep that died may have been killed by the nerve agent, but those that died later succumbed to such secondary causes as starvation. "Sick sheep like to die," he says. "You won't find them crawling a mile to a waterhole on a broken leg."

The Army has stated that the sheep were apparently affected by eating contaminated vegetation, and feeding experiments conducted by the Agriculture Department's Poisonous Plant Research Laboratory in Logan, Utah, lend substance to this theory. When Logan scientists fed forage from the affected areas of Skull Valley to healthy sheep, the sheep showed a marked depression of cholinesterase activity (a sign of possible nerve agent exposure) and some of them developed symptoms identical to those observed in the sick Skull Valley sheep. In contrast, sheep placed in the affected areas but muzzled and fed only hay and water brought in from outside showed no signs of toxicity, though some investigators doubt it.

There was speculation early in the investigation that the sheep may have been sickened by licking contaminated snow, and since at least one laboratory has identified traces of the nerve agent in snow water, this may remain a possible source of the poison.

The toxic substance seems to have persisted in the area for at least 3 weeks after the incident, possibly longer. Logan scientists placed three different groups of normal sheep in the affected area on 19 March, 1 April

and 4 April and all groups developed illness identical to that of the sheep in the initial outbreak. By 3 months after the incident, however, the poison had apparently dissipated. Healthy sheep fed forage collected from the affected area on 12 June, and on several occasions subsequently, showed no signs of illness.

The massive sheep kill has raised questions about the potential danger to human life. Alvin Hatch, manager of the ranch that suffered the greatest losses, told *Science* his herders often obtain their water by melting snow, though at the time of the incident they were carrying a water supply. Since the nerve agent has been identified in snow water, Hatch speculates that his herders may have had a "narrow escape."

There were also reports that one of the sheepherders and two Agriculture Department scientists who autopsied the dead sheep developed headaches, nausea, dizziness, and diarrhea, but an Agriculture Department report, dated 15 July, says "there was no confirmation that these (symptoms) were directly associated with the cause of illness in the sheep." The Public Health Service and the Army tested the vast majority of humans in the affected areas and found no evidence of nerve agent effects. Whether humans escaped harm primarily because the level of nerve agent present was too low to affect them, or because they did not wander around the range munching vegetation, is not clear from the information available to *Science*.

Has Gas Escaped Before?

Dugway has had no off-base chemical monitoring system, so it is impossible to tell whether any significant amounts of lethal agent have escaped in the past. The advisory committee headed by the surgeon general states that the March sheep kill "provided the first off-post event which was suspected of being connected to Dugway operations," but such a statement does not rule out the possibility that nerve agents may have escaped previously and simply failed to strike populated areas. Fay Gillette, sheriff of Tooele County, Utah, for the past 22 years, told *Science* that on several occasions some 6 or 7 years ago he received "confidential calls" from Dugway, generally in the evening, asking him to patrol U.S. Highway 40, 35 miles north of Dugway, and tell people who were stopped along the side of the road to get moving. "They never told me why and I never asked them," says Gillette. Seymour M. Hersh, author of a recent well-reviewed book on chemical and biological warfare, spent 3 weeks in Utah investigating the Dugway incident and concluded that "this is not a freak event—there have been other similar occurrences at Dugway." Hersh says he has detailed his findings in an article scheduled to appear in *Esquire* magazine.

Army Isn't Talking

The weight of circumstantial evidence —the accident at Dugway, the weather conditions, the location of the affected herds—strongly suggests Dugway was the source of the substance that killed the sheep. But even stronger evidence was turned up by scientists who participated in the investigation. Unfortunately, complete information on the scientific findings is apparently known only to the Army, and the Army isn't letting its scientists say much. *Science* requested an interview in August with Mortimer A. Rothenberg, Dugway's chief scientist, and Rothenberg agreed, subject to approval by his superiors. Such approval was denied.

The Army told *Science* it could submit questions to Dugway in writing, so four questions were mailed in on 22 August. More than 3 months passed before the answers came back. Even then, the answers were, in some respects, incomplete and ambiguous.

Fortunately, the Army is not the only source of information on the investigation. Dozens of civilian specialists from federal and state agencies and from various universities participated in aspects of the investigation, and some were actually on the scene in Skull Valley before the Army even knew any sheep had died. After considerable prodding, *Science* was able to obtain reports from the two major federal agencies involved, the Public Health Service and the Agriculture Department. From these reports, and from the few public statements made by the Army, it seems clear that the preponderance of scientific evidence has implicated the nerve agent as responsible for the sheep deaths.

The most convincing evidence comes from chemical tests conducted by the National Communicable Disease Center in Atlanta, a branch of the Public Health Service. Chemists at NCDC used gas chromatography, infrared spectroscopy and mass spectrometry in an effort to find traces of nerve agent in the dead sheep or in such environmental materials as snow and grass. In a report to Utah's health director, dated 29 April, NCDC said unequivocally that chemists found traces of the nerve agent. The report's "summary of chemical results" states that:

"—Water and forage from Skull Valley as well as blood and liver from ill sheep showed an agent which proved to be identical in chemical composition to a sample of the test agent supplied by Dugway.

"—Rumen contents from ill sheep showed the same response on instruments as the authentic test agent furnished in water by Dugway, that is, hydrolysis products of test agent.

"—Infrared chromatograms of test agent, hay, and water extracts showed similar scans indicating identity of agents under study.

"—Mass spectrometry of test agent hay and water isolates *prove beyond doubt* [italics added] that these responses are in fact identical and can only be attributed to the same chemical."

Confirming Tests at Dugway

Confirming chemical tests seem to have been conducted in Dugway's laboratories, though the Army is much less emphatic in asserting that it definitely detected traces of the nerve agent. General Betts, the Army's R & D chief, testified last May that Dugway's chemical analysis of large samples of vegetation from the affected area had proceeded "to the point where it was considered possible that traces of VX or a similar organic compound were very likely present." More recently, in a 25 November response to the questions posed by *Science*, the Army said that "traces of agent or agent-like material were found in samples of vegetation collected at several periods of time after the March 13th incident."

The chemical tests were conducted with great difficulty, for they required instruments capable of detecting minute traces of the nerve agent and considerable sophistication in interpreting the results. Army scientists initially analyzed several hundred samples of water, soil, snow, vegetation, and wool from Skull and Rush Valleys and found no evidence of VX. Only after "very large samples of vegetation" were analyzed did the Army conclude that the agent might "possibly" be present. Meanwhile, the Agriculture Department initially thought it had detected "some similarity" between decomposition products of the nerve agent and substances in

the tissues from affected sheep, but later concluded that the similarity was caused by products normally found in sheep tissue and was not significant. Agriculture officials say they also had problems with their instruments. In all, according to the Army, several thousand samples of environmental materials from a 100-square mile area were analyzed by various agencies in the effort to determine what killed the sheep.

Army Still Skeptical

As a result of the inherent difficulties of the analysis, some Army scientists are said to remain unconvinced that the nerve agent has been unequivocally identified. Nevertheless, NCDC Atlanta remains confident of its results, and no one has publicly challenged the seemingly conclusive findings. Surgeon General Stewart told *Science* that, at the time of the incident, NCDC had "better equipment than Dugway to detect very low levels" of the nerve agent.

In addition to tests identifying the nerve agent itself, there is considerable evidence, apparently undisputed, that the sheep were poisoned by an organic phosphate compound. These compounds are found in nerve agents, many common pesticides, and some noxious plants as well. They interfere with the action of the enzyme cholinesterase at nerve endings, and a depressed level of cholinesterase is thus considered a rather specific indication that an organic phosphate is involved. Numerous investigators have reported a severe depression of cholinesterase in the blood of the affected sheep. Moreover, the Agriculture Department has reported finding a cholinesterase depressing substance in snow collected from the area of the sheep kill. Thus it seems clear that the sheep were subjected to an organic phosphate poison, and since the investigation turned up no evidence that death was caused by poisonous plants or pesticides, the most likely culprit among the organic phosphates is the nerve agent tested at Dugway.

Further evidence implicating the nerve agent comes from feeding experiments at Dugway. When healthy sheep were fed small doses of VX, they developed essentially the same symptoms as the sick sheep in Skull Valley.

Army scientists are not convinced, however, that VX was the only cause of the sheep deaths. In its 25 November response to *Science* the Army said: "Although minute quantities of the agent were detected off-post, the results from these investigations have not provided conclusive evidence that nerve agent by itself caused sickness or death in the sheep. The answer is still unknown and may never be determined. The evidence suggests a combination of factors or effects." The Army is currently conducting experiments to determine whether the toxicity of the nerve agent is increased synergistically by the action of pesticides, noxious plants, trace elements in the soil, or the condition of sheep following the rigors of trailing and lambing. Thus far the Army has concluded that there is no synergism when sheep are fed both nerve agent and heptaclor, a pesticide which has been found in portions of Skull Valley.

Though Brigadier General John G. Appel, who has immediate command over Dugway, was quoted on 6 December as denying that the nerve agent caused the sheep deaths, the Army has accepted legal rsponsibility by paying $376,685 to one rancher for the loss of 6249 sheep (4372 dead, 1877 others sickened) as well as a lesser amount to some Indians who lost a small number of sheep. According to an Army letter to members of Congress, such compensation is proper, under the Military Claims Act, "where the Army's activities contributed to the loss."

New Safety Rules

The sheep kill incident has caused the Army to tighten up the safety procedures used in testing persistent lethal chemical agents at Dugway. On 5 July, Secretary of the Army Stanley R. Resor announced the formation of a high-level advisory committee, headed by the Surgeon General, to review the safety of chemical testing at Dugway. Last week, the committee's recommendations were released, and Resor announced that every single one had been ordered adopted.

The new regulations state that high-speed aircraft must maintain "positive control" over the dissemination of lethal agents and that no release of such agents shall be made above 300 feet. They also prohibit testing when wind speed exceeds 15 miles per hour, or when thunderstorms are occurring or predicted within 100 miles of the lethal cloud.

One of the most significant new rules requires that Dugway release agents in such a way that the agent cloud remains in the barren salt flats area north and northwest of the test site and does not cross heavily traveled U.S. Highway 40, to the north, for at least 3 hours (by which time the cloud would presumably have dispersed to the point where it is harmless). Heretofore, Dugway has not worried much about the direction of travel of the cloud and has counted on dilution of the cloud to render it nonhazardous. To carry out the new rules, Dugway will have to extend its ability to predict downwind behavior of the cloud from the present range of a few miles to "several tens of miles."

Another significant regulation requires Dugway, for the first time, to establish a monitoring system to detect the entry of chemicals into the environment outside the proving grounds. The system will consist of air samplers to sound an immediate alarm (though there is some question whether such samplers can be made sensitive enough) as well as ecological surveys to detect penetration of chemicals into local animal populations, both domestic and wild.

Utahns Not Worried

Although the sheep death incident caused concern throughout the nation, the people of Utah and their community leaders did not seem particularly worried. The incident was not treated as front-page news by the Salt Lake City papers, and the Tooele Chamber of Commerce actually passed a resolution expressing confidence in Dugway, presumably because Dugway contributes heavily to the local economy. Moreover, there was virtually no reaction from Utahns when the Army revealed that lethal nerve agents, which had aroused a storm of protest in Denver, would be transferred in part from Denver to the Tooele Army Depot.

The Army has consistently said there was no negligence on the part of anyone at Dugway, so the sheep slaughter was presumably the result of inadequate safety regulations rather than a failure to follow prescribed regulations. Surgeon General Stewart told *Science* that Dugway was operating "on a set of assumptions that had worked in practice for so long that the assumptions became truths." In retrospect, the Army can clearly be blamed for a lack of caution in handling the deadly nerve agents, as well as a lack of candor in informing the public about the cause of the incident.—PHILIP M. BOFFEY