Chapter 6

Ventilation and Cooling of Shelters

CRITICAL IMPORTANCE

If high-protection-factor shelters or most other shelters that lack adequate forced ventilation were fully occupied for several days in warm or hot weather, they would become so hot and humid that the occupants would collapse from the heat if they were to remain inside. It is important to understand that the heat and water vapor given off by the bodies of people in a crowded, long-occupied shelter could be deadly if fallout prevents leaving the shelter.

When people enter an underground shelter or basement in the summertime, at first the air feels cool. However, if most shelters are fully occupied for a few days without adequate ventilation, the floors, walls, and ceilings, originally cool, will have absorbed about all the body heat of which they are capable. Some shelters will become dangerously hot in a few hours. Unless most of the occupants' body heat and water vapor from sweat are removed by air circulated through a typical shelter, the heat-humidity conditions will become increasingly dangerous in warm or hot weather. One of the most important nuclear war survival skills people should learn is how to keep occupied shelters adequately ventilated in all seasons and cool enough for many days of occupancy in warm or hot weather. Methods for keeping ventilating air from carrying fallout particles into shelters also are described in Appendix A and Appendix B.

MAKING AND USING AN EXPEDIENT AIR PUMP

The best expedient way to maintain livable conditions in a shelter, especially in hot weather, is to make and use a large-volume shelter-ventilating pump. Field tests have proved that average Americans can build the expedient air pump described in Appendix B in a few hours, with inexpensive materials found in most households.

This simple pump was invented in 1962 by the author. I called it a Punkah-Pump, because its hand-pulled operation is somewhat like that of an ancient fan called a "punkah", still used by some primitive peoples in hot countries. (Unlike the punkah, however, this air pump can force air to move in a desired direction and is a true pump.) It was named the Kearny Air Pump (KAP) by the Office of Civil Defense following tests of various models by Stanford Research Institute, the Protective Structures Development Center, and General American Transportation Company. These tests confirmed findings first made at Oak Ridge National Laboratory regarding the advantages of the KAP both as a manually operated pump for forcing large volumes of outdoor air through shelters and as a device for distributing air within shelters and fanning the occupants. See Fig. 6.1.

The air pump instructions given in Appendix B are the result of having scores of families and pairs of untrained individuals, including children, build and use this air pump. They were guided by successively improved versions of these detailed, written instructions, that include many illustrations (see Appendix B). Some people who are experienced at building things will find these instructions unnecessarily long and detailed. However, shelter-building experiments have shown that the physically stronger individuals, usually the more experienced builders, should do more of the hard, manual work when shelters are built, and that those less experienced at building should do the lighter work—including making shelter-ventilating pumps. These detailed, step-by-step instructions have enabled people who never

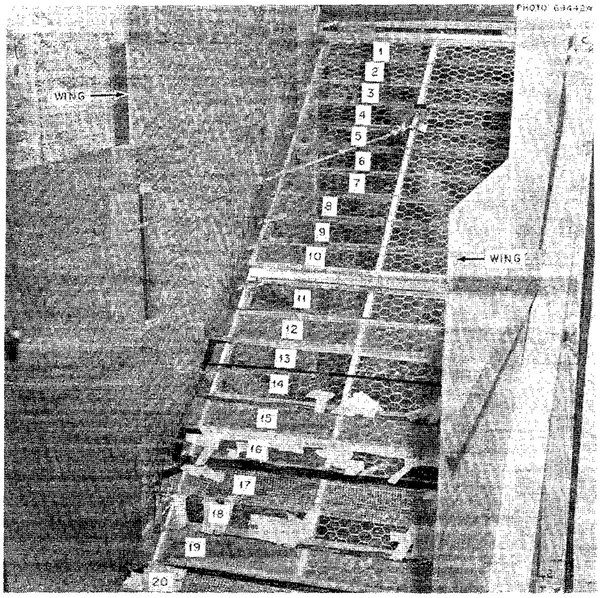

Fig. 6.1. A 6-foot KAP tested for durability at Oak Ridge. After 1000 hours of operation during which it pumped air through a room at a rate of 4000 cubic feet per minute (4000 cfm), there were only minor tears in the plastic flaps.

Fig. 6.2. Behind the girl is the homemade air pump that made it possible for a family of six to live in a crowded trench shelter for more than three days. Outside the temperature rose to 93° F.

before had attempted to build a novel device of any kind to make serviceable air pumps.

(The air pump instructions given in Appendix B repeat some information in this chapter. This repetition is included both to help the reader when he starts to build an air pump and to increase the chances of the best available complete instructions being given to local newspapers during some future crisis. The instructions given in this book could be photographed, reproduced, and mass-distributed by newspapers.)

Figure 6.2 shows (behind the girl) a 20-inch-wide by 36-inch-high KAP installed in the entry trench of a trench shelter. The father of the Utah family described earlier had made this simple pump at home, using only materials and tools found in many homes—as described in Appendix B. He carried the pump on top of his car to the shelter-building site. The pendulum-like, flap-valve pump was swung from two cabinet hinges (not shown) screwed onto a board. The board was nailed to roof poles of the narrow entry trench extending behind the girl in the photograph. The pull-cord was attached to the pump frame below its hinged top and extended along one trench wall for the whole length of the shelter. Any one of the six occupants could pull this cord and easily pump as much as 300 cubic feet per minute of outdoor air through the shelter and through the insect screens over both its entrances. (Without these screens, the numerous mosquitoes in this irrigated area would have made the family's shelter stay very unpleasant.)

During the 77 hours that the family continuously occupied their narrow, covered trench, the temperatures outside rose as high as 93° F. Without the air pump, the six occupants would have been driven from their shelter by unbearable temperature-humidity conditions during the day.[8]

The photo in Fig. 6.2 also shows how the air pump hung when not being operated, partially blocking the entry trench and causing a "chimney effect" flow of air at night. There was a 10-inch space between the air pump and the trench floor, and the resulting flow of air maintained adequate ventilation in the cool of the desert night, when outdoor temperatures dropped as low as 45° F. Cool outdoor air flowed down into the entry and under the motionless air pump, replacing the body-warmed air inside the shelter. The entering cool air continuously forced the warm air out of the shelter room at ceiling height through the emergency crawlway-exhaust trench at the other end. When the weather is cool, a piece of plastic or tightly woven cloth could be hung in the doorway of a well designed, narrow shelter, to cause a flow of fresh air in the same manner.

Numerous shelter occupancy tests have proved that modern Americans can live for weeks in an adequately cooled shelter with only 10 square feet of floor space per person.[13] Other tests, such as one conducted by the Navy near Washington, D.C. during an abnormally cool two weeks in August, 1962, have shown that conditions can become difficult even when summertime outdoor air is being pumped through a long-occupied shelter at the rate of 12 cubic feet per minute, per person.[14,15] This is four times the *minimum* ventilation rate for each occupant specified by the Defense Civil Preparedness Agency (DCPA) for American shelters: 3 cubic feet per minute (3 cfm). Three cfm is about three times the supply of outdoor air needed to keep healthy people from having headaches as a result of exhaled carbon dioxide. In hot, humid weather, much more outdoor air than 12 cfm per person must be supplied to a crowded, long-occupied shelter, as will be described in the following section and in Appendix B.

MAINTAINING ENDURABLE SHELTER CONDITIONS IN HOT WEATHER

The Navy test mentioned above showed how much modern Americans who are accustomed to air conditioning could learn from jungle natives about keeping cool and healthy by skillfully using hot, humid, outdoor air. While working in jungles from the Amazon to Burma, I observed the methods used by the natives to avoid unhealthful conditions like those experienced in the Navy shelter, which was ventilated in a conventional American manner. These jungle methods include the first five of the six cooling methods listed in this section. During 18 years of civil defense research, my colleagues and I have improved upon the cooling methods of jungle people, primarily by the invention and thorough field-testing of the homemade KAP described in Appendix B.

Even during a heat wave in a hot part of the United States, endurable conditions can be maintained in a fully occupied, belowground shelter with this simple pump, if the test-proven requirements listed below are ALL met.

Most basement shelters and many aboveground shelters also can be kept at livable temperatures in hot weather if the cooling methods listed below are ALL followed:

- Supply enough air to carry away all the shelter occupants' body heat without raising the "effective temperature" of the air at the exhaust end of the shelter by more than 2°F. The "effective temperature" of the air to which a person is exposed is equivalent to the temperature of air at 100% relative humidity that causes the same sensation of warmth or cold. "Effective temperature" combines the effects of the temperature of the air, its relative humidity, and its movement. An ordinary thermometer does not measure effective temperature. In occupancy tests of crowded shelters when the supply of outdoor air was hot and dry, shelter occupants have been surprised to find that they felt hottest at the air-exhaust end of their shelter, where the temperature reading was lower than at the air-intake end. Their sweaty bodies had acted as evaporative air coolers, but their body heat had raised the effective temperature, a reliable indicator of heat stress. If 40 cubic feet per minute (40 cfm) per person of outdoor air is supplied and properly distributed, then (even if the outdoor air is at a temperature which is typical of the hottest hours during a heat wave in a hot, humid area of the United States) the effective temperature of the shelter air will be increased no more than 2°F by the shelter occupants' body heat and water vapor. Except for a relatively few sick people dependent on air conditioning, anyone could endure air that has an effective temperature only 2°F higher than that of the air outdoors.

(There are exceptions to this ventilation requirement when the ceiling or walls of basement or aboveground shelters in buildings are heated by the sun to levels higher than skin temperature. In such shelters, more than 40 cfm of outdoor air per occupant must be supplied. However, if a shelter is covered by at least two feet of earth, it will be so well insulated that its ceiling and walls will not get hot enough to heat the occupants.)

- Move the air gently, so as not to raise its temperature. In the aforementioned Navy test, a high speed, electric ventilating pump and the frictional resistance of pipes and filters raised the temperature of the air supplied to the shelter by 3°F. Under extreme heat wave conditions, an air supply 3°F hotter than outdoor air could be disastrous—especially if considerably less than 40 cfm per occupant is supplied, and body heat raises the air temperature several additional degrees.

- Distribute the air quite evenly throughout the shelter. In a trench shelter, where air is pumped in at one end and flows out the other, good distribution is assured. In larger shelters, such as basements, ventilating air will move from the air-supply opening straight to the air-exhaust opening. Persons out of this air stream will not be adequately cooled. By using one or more additional, smaller KAPs (also described in Appendix B), fresh air can be distributed easily throughout large shelter rooms, and the occupants will be gently fanned.

- Provide occupants with adequate drinking water and salt. In extremely hot weather, this means 4 quarts of water per day per person and 3/4 tablespoon (10 grams) of salt, including the salt in food.

- Wear as few clothes as practical. When the skin is bare, moving air can evaporate sweat more efficiently for effective cooling. Air movement can keep bare skin drier, and therefore less susceptible to heat rash and skin infections. In the inadequately ventilated Navy test shelter, 34 of the 99 initially healthy young men had heat rash and 23 had more serious skin complaints at the end of their sweaty two-week confinement, although their overall physical condition had not deteriorated.[15]

- Keep pumping about 40 cfm of air per person through the shelter both day and night during hot weather, so that the occupants and the shelter itself will be cooled off at night. In the Navy test, the ventilation rate of 7 to 12 cfm was not high enough to give occupants the partial relief from heat and sweating that people normally get at night.[15] In a National Academy of Sciences meeting on protective shelters, an authority stated: "Laboratory experiments and field investigations have shown that healthy persons at rest can tolerate daily exposures to ETs [effective temperatures] up to 90° F, provided they can get a good night's sleep in a cooler environment."[14] An effective temperature of 90° F is higher than the highest outdoor effective temperature during a heatwave in the South or in American deserts.

ADEQUATE VENTILATION IN COLD WEATHER

In freezing weather, a belowground shelter covered with damp earth may continue to absorb almost all of its occupants' body heat for many days and stay unpleasantly cold. In one winter test of such a fully occupied shelter, the temperature of the humid air in the shelter remained around 50° F.[16] Under such conditions, shelter occupants should continue to ventilate their shelter adequately, to avoid the following conditions:

- A dangerous buildup of carbon dioxide from exhaled breath, the first symptoms of which are headaches and deeper breathing.

- Headaches from the carbon monoxide produced by smoking. When the ventilation rate is low, smoking should not be permitted, even near the exhaust opening.

- Headaches, collapse, or death due to carbon monoxide from open fires or gasoline lanterns that release gases into the shelter air.

NATURAL VENTILATION

Enough air usually will be blown through an aboveground shelter if sufficiently large openings are provided on opposite sides and if there is any breeze. But if the weather is warm and still and the shelter crowded, the temperature-humidity conditions soon can become unbearable.

Adequate natural ventilation for belowground shelters is more difficult. Even if there is a light breeze, not much air will make a right-angle turn and go down a vertical entry, make another right angle turn, and then flow through a trench or other shelter partially obstructed by people and supplies.

In cool weather, occupants' body heat will warm the shelter air and make it lighter than the outdoor air. If a chimney-like opening or vent-duct is provided in the ceiling, the warmed, lighter air will flow upward and out of the shelter, provided an adequate air-intake vent is open near the floor. An Eskimo igloo is an excellent example of how very small ventilation openings, skillfully located in the ceiling and at floor level, make it possible in cold weather for chimney-type natural ventilation to supply the 1 cfm per person of outdoor air needed to prevent exhaled carbon dioxide from becoming dangerously concentrated.

In warm weather, chimney-type natural ventilation usually is inadequate for most high-protection-factor shelters that are fully occupied for days. And in hot weather, when as much as 40 cfm per occupant is required, body-warmed shelter air is no lighter than the outdoor air. Chimney-type ventilation fails completely under these conditions.

SAFE SHELTER VENTILATION WITHOUT FILTERS

Numerous tests have shown that the hazards from fallout particles carried into shelters by unfiltered ventilating air are minor compared to the dangers from inadequate ventilation. A 1962 summary of the official standards for ventilating systems of fallout shelters stated: "Air filters are not essential for small (family size) shelters..."[17] More recent findings have led to the same conclusion for large fallout shelters. A 1973 report by the Subcommittee on Fallout of the National Academy of Sciences on the radioiodine inhalation problem stated this conclusion: "The opinion of the Subcommittee is that inhalation is far less of a threat than ingestion [eating or drinking], and does not justify countermeasures such as filters in the ventilating systems of shelters."[18]

In warm weather, it is essential to pump enough air through very small shelters like the one shown in Fig. 6.3. The photograph shows a man inside a Car-Over-Trench Shelter that provides fallout protection about four times as effective as that given by the average home basement. The shelter was completed by piling earth inside and around the car that had been driven over the narrow trench. The shielding earth around the car's sides was piled against polyethylene film taped to the sides, to keep earth from going under the car. In warm or hot weather such a shelter cannot be occupied for long without forced ventilation.

Fig. 6.3. Pulling a small, stick-frame KAP to keep temperatures endurable for occupants of a Car-Over-Trench-Shelter.

Fallout particles that reach the earth within the first 24 hours after an explosion are so large and fast-falling that virtually all of them would be deposited on the ground. They would not fall into a properly designed shelter, especially one with a low-speed air intake. Particles small enough for a person to breathe into his lungs generally take several days to fall from where they are first carried, miles high in a mushroom cloud. By the time these small fallout particles are near the earth, the generally westerly winds blowing around the world at high altitudes would have carried them to Europe, or Asia, or back around the earth to North America. After days-to-weeks of wide dispersal and radioactive decay, such small particles would constitute a minor health hazard compared to other injurious conditions that would afflict an unprepared people subjected to a large-scale nuclear attack.

When sand-like fallout is being deposited, the occupants of small expedient shelters should decide whether to restrict or stop ventilation. If it is windy outside, some of the sand-like particles may be blown into a small open shelter. Ventilation should not be restricted long enough to cause serious overheating or headaches from exhaled carbon dioxide. As in a sand storm, breathing through a dust mask or towel would be helpful to avoid getting fallout particles into one's nose and mouth. Likewise, if a house is burning dangerously close to a separate, earth-covered shelter, closing the shelter's ventilation openings for an hour or two usually will prevent the entry of dangerous concentrations of carbon monoxide, carbon dioxide, or smoke. (Most houses will burn to the ground in less than two hours.)

When an attack is expected, an occupied shelter should be kept as cool as practical by pumping large volumes of outdoor air through it. This also will assure that the air is fresh and low in exhaled carbon dioxide. Then, if a need arises to stop or restrict ventilation, the shelter can be closed for longer than could be done safely otherwise.