OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
NUCLEAR DIVISION
for the
U.S. ATOMIC ENERGY COMMISSION

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ANNUAL PROGRESS REPORT
CIVIL DEFENSE RESEARCH PROJECT
MARCH 1965 - MARCH 1966

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ORNL-TM-1531
PART I

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Director's Division
CIVIL DEFENSE RESEARCH PROJECT

ANNUAL PROGRESS REPORT
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MARCH 1965-MARCH 1966

NOVEMBER 1966

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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*Annual Progress Report, Civil Defense Research Project, March 1965-March 1966, Part II, ORNL-TM-1531 (Secret).

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I. FOREWORD

The Oak Ridge National Laboratory Civil Defense Research Project, jointly sponsored by the Department of Defense and the Atomic Energy Commission, has been in existence for approximately eighteen months. It consists of an interdisciplinary study of the problems of advanced civil defense systems which might be chosen for installation during the 1970's. During the first nine months of the project, the research was directed toward three objectives: the feasibility of urban blast shelters; the interaction of active and passive defense; and the sociological problems associated with substantially expanded civil and ballistic-missile defense systems. A progress report containing the results of these initial studies was prepared by the then project director, Eugene P. Wigner.*

The research program was reoriented in July 1965 toward the study in more detail of nine topics, eight of which are described in this report and its classified supplement. These subject categories, in order of their appearance in the progress report, are an investigation of post-attack food production (Chapters 1 and 2); a study of the special problems of ventilation using warm humid air (Chapters 3 and 4); the possible effectiveness of biological agents against a sheltered population (Chapter 5); the social and psychological constraints on expanded civil defense programs (Chapters 6, 7, 8, and 9); the interaction of blast waves with tunnels and entranceways (Chapter 10); the effects of mass fires on blast shelters (Chapter 11); the feasibility of advanced protective systems with dual use in crowded urban areas, with a special emphasis on economic factors (Chapter 12); and the comparative effectiveness of active and passive defense and the status of active defense system design (Chapters 13 and 14).

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*Eugene P. Wigner, Civil Defense Study Group Progress Report--September 1964-March 1965, ORNL-TM-1120 (April 30, 1965) (Confidential).

The ninth subject, the special warning and communications requirements of a tunnel-grid shelter system, is under joint study by members of the ORNL Civil Defense Research Project and the System Development Corporation, Santa Monica, California. Since intensive study of the requirements for a 25-square-mile area of Detroit was begun in February 1966, a progress report is not being included at this time in anticipation of a topical report in September 1966.

The eight topics reported here form parts of a broad framework defining a complete advanced civil defense system. They represent a portion of the area of uncertainty in the design of such a system. To illustrate their relationship to the whole, a series of problems and comments or partial solutions related to the effectiveness of advanced civil defense is listed below, following the arrangement of the chapters in this report.

1. Problem: By means of advanced civil defense systems, the government may choose to provide shelter for all citizens, with the greatest protection in the areas of greatest risk (i.e., in "target" areas). Admittedly, many more lives could be saved at a given attack level than by the present system. But would not the extra survivors merely compete for the inadequate food, increasing the probability of widespread starvation and anarchy?

Comment: Adequacy of postattack food depends on three factors: the ratio of food survival to human survival, the location of surviving food resources, and the rate of resumption of food production. The design of protective systems increasing human survival must be accompanied by the examination of the size and location of present food stocks and the trends in accumulation or depletion under present policies, as a first step toward the establishment of the requirements for a consistent federal defense policy. (Note that "defense" here means emergency preparedness activities by all federal agencies, not just the Defense Department.) The beginning of such an examination is contained in Chapters 1 and 2.

2. Problem: If a program of national shelter construction were undertaken on a gradual basis (perhaps over a ten-year period), there would obviously be a shelter deficit during this extended period which could result in the emergency use of overcrowded or poorly ventilated

spaces. Are there inexpensive ways to provide large flows of ventilating air for shelters? And can these large flows be used to cool shelters without mechanical refrigeration when the outside air is warm and humid?

Comment: As described in Chapters 3 and 4, ventilation flows as large as 30 cfm per person may provide adequate cooling even when effective temperatures exceed 85°F. Such flow rates can be established at low human "horsepower" requirements by the use of a new "punkah" air pump.

3. Problem: Improvements in the protection of people against the effects of nuclear weapons might induce an enemy to shift to different weapons of mass destruction, perhaps biological. Wouldn't such a shift negate civil defense?

Comment: Biological weapons can be formidable, but, as described in Chapter 5 in the classified supplement to this report, defense procedures are available which can substantially reduce their effectiveness.

4. Problem: If the United States were to install new strategic defense systems (ballistic missile and/or advanced civil defense), might not the reaction of foreign governments be to build up their offensive capability and maintain the same offense/defense disparity which exists today?

Comment: Although political response is obviously not as predictable as the response of structures, many sociological factors can and should be taken into consideration to minimize the probability of adverse foreign reactions to new defense programs. Such factors are discussed in Chapter 6.

5. Problem: It is easy to recall periods during which civil defense was a topic of interest, but now it is rarely discussed in the papers or in ordinary conversation. Aren't Americans opposed to civil defense and isn't research on it a waste of time?

Comment: Public opinion polls have shown a generally favorable U. S. public opinion toward civil defense for many years, but little is known about the relationship between defense attitudes and such factors as world events, educational level, specific knowledge concerning defense capabilities and level of threat, and attitudes on other issues. The work described in Chapter 7 is aimed at an improved understanding of public opinion on national security issues from which may emerge improvements in the evaluation, selection, and implementation of civil defense policies.

6. Problem: Most of us do not spend much time worrying about situations described in movies like "Dr. Strangelove." How can we expect public officials at all levels of government to dilute their efforts in their main areas of responsibility and place much emphasis on emergency planning?

Comment: A significant change in the priorities of top government officials may be one requirement before many local officials take civil defense planning seriously. A theoretical discussion of the response of officials to future threat and a recently completed case study, both designed to improve our understanding of the emergency planning process, are presented in Chapters 8 and 9.

7. Problem: Most present civil defense shelters are for protection from fallout radiation rather than blast and fire. Are the properties of blast waves from megaton weapons well enough understood to allow for blast shelter design? And if tunnels were used for blast shelters, wouldn't a failure at any point expose the entire tunnel to lethal blast waves?

Comment: Data in the unclassified report "The Effects of Nuclear Weapons" are sufficient to permit the design of blast shelters, although certain improvements in the data may be made. The special blast transmission problems introduced by tunnels can be solved by, among others, the methods described in Chapter 10.

8. Problem: Even if blast protection is adequate, mass fires may form over large urban areas. Wouldn't the heat and carbon monoxide of these fires make blast shelters uninhabitable?

Comment: Although the question is difficult and has by no means been completely answered, experimental evidence and actual experience with mass urban fires suggest that satisfactory air can generally be obtained, provided metabolic heat can be removed during the fire. Chapter 11 discusses this problem.

9. Problem: Won't the pressure to reunite families prevent separated members from taking shelter at the time of a threatened attack?

Comment: One possible answer to this question is to provide an interconnected system which will allow immediate shelter-taking followed by slower reunion. Another advantage of the system is the potential dual use of urban tunnels. Chapter 12 first explores the feasibility of a single-use tunnel-grid shelter in a section of Detroit and then discusses the potential of similar systems for peacetime as well as emergency use.

10. Problem: Can ballistic missile defense eliminate the need for civil defense?

Comment: According to Secretary McNamara in his Congressional testimony on February 14, 1966, a decision to install ballistic missile defense must be accompanied by a decision to provide at least fallout protection for all U. S. citizens. The connection between the two systems is based on the assumption that a city protected by ballistic missile defense could be indirectly attacked from upwind by fallout created by a ground-burst nuclear weapon. Advanced civil defense systems which offer significant protection from the direct as well as indirect effects of nuclear weapons would of course answer these same requirements and several others. For example, the presence of an active defense may encourage enemy airbursts as contrasted with groundbursts within the defended area, since a decrease in engagement time probably also decreases intercept probability. Such bursts would increase the relative hazard of direct versus indirect weapon effects but would offer the opportunity for a very high degree of passive protection even at the center of a target. By way of illustration, a 1-MT weapon exploded above 5000 feet or a 10-MT weapon above 11,000 feet produces peak blast pressures of 100 psi at ground zero, for which satisfactory urban shelter designs can probably be achieved. Certain classified aspects of the comparative and combined effectiveness of active and passive defense are discussed in the final two chapters. (These chapters are contained in the classified supplement.)

J. C. Bresee
Project Director

II. SUMMARIES

BIOMEDICAL ASPECTS OF CIVIL DEFENSE

Chapter 1. United States Food Supplies--Livestock
M. C. Bell

An assessment of present and postattack food resources shows that livestock is our most important source of protein, supplying 2/3 of that presently consumed in the United States. While livestock normally have less protection from nuclear attack than humans, their location, generally away from densely populated areas, gives them a greater likelihood of survival in a mixed attack against military targets and industrial areas under present civil defense protection systems. Yet an expanded shelter program could reverse the situation, especially with the current trend of concentrating livestock during feeding and marketing. Transportation by truck and rail plays an important role in moving both livestock products to consumers and livestock feed into deficit areas. Though vulnerable to radioactivity, livestock are good protectors against fallout radionuclides in human food. While varying amounts of the radionuclides of iodine, strontium, and cesium may be present in animal products, there are effective techniques for removing these from food.

Chapter 2. United States Food Supplies--Grains
A. F. Shinn

The national grain situation with respect to food stocks, agricultural production, and present consumption is being explored. Research includes: a delineation of current trends in agriculture and their implications for civil defense; estimates of the vulnerability of food stocks and crops and methods and means of producing and processing them; assessment of damage to these resources from postulated attacks; and determination of the timing for resumption of normal food production and processing following attack. Conclusions from previous studies indicate: (1) that a severe shortage of either foodstuffs or processed foods is unlikely since food will survive roughly in proportion to the population; (2) that the probable bottleneck in supplying food is transportation, which depends in turn on petroleum (although the size of this problem depends on the average distance between stored food and the consumer, which could probably be substantially modified from the present situation without greatly increasing the vulnerability of the food); and (3) that a relatively greater percentage of the rural than of the urban population will survive. Since Congress has not granted legal authority to the USDA to establish a stockpile of food, the stocks acquired under price support by Consumer Credit Corporation have in essence served as the U. S. food reserves. The geographic location of stocks has been determined largely by the economy of storage with little consideration of defense needs. Grain storage in 1959 was widely dispersed and therefore relatively invulnerable to attack. However, with the current trend toward a steadily decreasing number of grain elevators, if our largest storage facilities become the major points of storage, our food vulnerability will increase. Since livestock, which provides about 66% of the protein in our diet, is vulnerable to attack, alternate sources of protein are being considered. A mixture of soy beans and grains (or the culture of fresh water fish) offers the most promise to date.

Chapter 3. Physiology of Heat Stress

C. H. Kearny

Physiological experiments were conducted at the University of Indiana to determine the effectiveness of (1) different combinations of high temperatures, relative humidities, and air velocities in maintaining a habitable shelter environment; and (2) a manually operated three-foot punkah-type overhead fan in producing these air velocities. Effectiveness, in turn, was determined by recording rectal and skin temperatures, respiratory volume, and water losses of the subjects. Results of the tests indicate that fanning a shelter occupant is of secondary importance to cooling a shelter occupant as long as a minimum requirement for air makeup and drinking water are met and as long as air is circulated sufficiently within the shelter so as essentially to equalize effective temperatures throughout, with the effective temperatures not rising much above ET 85°F; however, the punkah fan increases comfort and reduces temperature layering, thereby reducing the temperature stresses on individuals in upper bunks. At ET 85°F evaporative water consumption per person was at a rate of about four quarts a day without fanning as compared to about six quarts a day with fanning at a velocity of 75 fpm and with hotter air brought down from near the ceiling. The fall and rise in sweating rate was directly associated with sleeping and wakefulness. Only with an ET of 85°F was the beneficial effect of fanning shelter occupants obvious. In contrast, at 104° dry bulb temperature and RH 70% (ET 96°F) within the shelter, increased air velocities produced by fanning were disadvantageous because the convective heat gains were greater than the increased evaporative heat losses resulting from the higher air velocities.

The Appendix illustrates how fundamental principles of heat and mass transfer can be used to estimate the cooling characteristics of wet cylinders and thereby to provide a basis for studying the ventilation requirements for cooling people in blast shelters. The importance of the wet bulb temperature of the ambient air in the case of forced convection is demonstrated.

Chapter 4. Status of Punkah-Pump Tests at Fort Belvoir

C. H. Kearny

In connection with shelter habitability studies, punkah-pump tests were conducted at the Protective Structures Development Center with two objectives: (1) to observe the performance of a six-foot punkah-pump used as the prime air-moving device for a shelter, moving outside air through the shelter, and (2) to test other punkah-pumps as means of distributing air within and through a shelter and thus reducing longitudinal temperature gradients. A six-foot punkah-pump was placed in one of two doorways of a basement shelter and powered by a mechanical drive which simulated efficient manual operation of a punkah-pump used as an exhaust pump. The design of the punkah-pump, in contrast to that of conventional fans and blowers, takes advantage of the large available openings (such as doorways and stairways) found in typical fallout shelters. When side baffles or "wings" are fixed close to the lateral sides of the punkah-pump frame and parallel to them, they increase the pump's delivery capability but usually are not essential for adequate ventilation. With side baffles on both inlet and exhaust sides, the punkah requires less than 0.05 horsepower to pump 4600 cfm; this is only a small fraction of the horsepower needed by conventional fans to pump an equal volume of air through the shelter. To make the punkah-pump adaptable to changes in wind direction outside the shelter, it is recommended that it be made operable by both push-poles and pull-cords so that the direction in which it moves the air can be reversed *in situ*. From the standpoint both of economy and of amount of air that one man can force through a shelter by use of a punkah-pump, this type ventilating device appears to be superior to a manually powered rotary ventilating pump.

Chapter 5. The Biological Warfare Threat to a Sheltered Population

C. V. Chester

(Reported in Part II*)

SOCIOLOGICAL ASPECTS OF CIVIL DEFENSE

Chapter 6. Strategic Interaction

Davis B. Bobrow

Political and psychological variables, as well as technical and economic considerations, enter into viewpoints about continental defense systems, the adoption process of such systems, and cost/effectiveness analyses of them. Different foreign elites and elements of the American public do not react identically to possible U. S. defense decisions. Further, the political and psychological factors which influence their responses have not been expressed with sufficient precision to be handled analytically. This project seeks to make explicit the political and psychological assumptions which operate implicitly to affect the attitudes toward continental defense systems of important foreign elites and of the American public. While the initial research involves alternate theories

*Annual Progress Report, Civil Defense Research Project, March 1965-March 1966, Part II, ORNL-TM-1531 (Secret).

and approaches, it has been conducted according to a common set of criteria: (a) explicit relevance to the adoption processes of defense systems; (b) testability of findings; and (c) narrowing as soon as possible the number of specific inquiries to those with the most promise. Two important relationships central to this study are (1) the relation between the need for passive defense systems and the credibility of our deterrence policy, and (2) the relationship between the American public response to passive defense systems and the credibility of such systems. The research team of social scientists attempts to compare the psychological and political implications of four hypothetical active/passive defense postures (ranging from unilateral public freeze and arms reduction to massive active and passive defense buildup) at two points in time--adoption announcement and operational deployment.

Chapter 7. Dynamics of American National Security Attitudes
Davis B. Bobrow

The dynamics of American security attitudes are investigated through secondary analysis of over 100 national surveys conducted since the use of atomic weapons against Japan. [By "dynamics of American security attitudes," we mean (1) the components and relationships of national security beliefs of a cross section of the American population at one point in time and over the period 1945-1964; (2) the factors associated with and inferred to be responsible for (1); and (3) the projections of the components and relationships of security beliefs into the future.] This chapter deals with the reasons for the project and the tasks completed in transforming the old surveys into a data collection capable of analysis. The fruitfulness of the project depends on the assumptions that (1) American national security attitudes are relevant to U. S. defense policy; (2) certain types of analyses of U. S. national security attitudes are particularly powerful for evaluating, selecting, and implementing defense policies; (3) previous public opinion surveys are appropriate data sources for these analyses. The survey material (questionnaires, codebooks, and response data) was assembled and a system designed to implement and manage it. This system, labeled RAPID, allows for the retention of the complete question text and response categories and compiles survey volumes and indexes. The application of RAPID necessitated five tasks, which involved 113 surveys containing over 7000 question-answer units administered to well over 100,000 respondents. These tasks included producing a question package, a data package, and a support package; integrating these three packages; and assembling the master output. To handle this enormous quantity of data involved extensive and innovative use of computers. A computer manipulable events chronology for the period covered by the survey was assembled so that attitude sensitivity to different domestic and international contexts could be studied. The chronology contains all events listed in the World Almanac volume for each year, abstracted and placed in 26 categories. The categorized chronology was compared with the summary section of the New York Times "Year in Review" to check on the inclusion of major events.

Chapter 8. Determinants of Influentials' Responses to Communications About a Negative Contingency

Sue Berryman Bobrow

The purpose of this study is to describe and explain the responses of influentials to possible nuclear threat within the context of their usual responses to possible future catastrophes which come to their attention. This chapter is primarily concerned with progress toward an analytic system through which data may be economically and fruitfully gathered and analyzed. Since the events admissible for the study are restricted to that class called negative contingencies, the attributes which an event must have to fall into this category are delineated. In order to consider an influential's response to such an event it is necessary to know (1) how the threat is verbalized to the decision maker (the independent variable); (2) why he responds the way he does (the intervening variable); and (3) what responses he makes (the dependent variable). These three variables are explained in detail with a list of the possible kinds of responses which are to be considered and a list of the possible reasons for these responses. An example is given to show how these variables are being dealt with. While specific interview schedules, innovative "games," and scales for collecting data have not yet been devised, the kinds of questions necessary to elicit adequate knowledge of individual and group behavior are indicated.

Chapter 9. Emergency Planning and Urban Problems

Claire Nader

An urban community engaged in emergency planning with the federal government was selected and its officials and influential citizens interviewed. This city of some 400,000 persons is beset with severe social and economic problems, including unemployment, juvenile delinquency, and deteriorating race relations. This study discusses these problems, the reactions of city officials and other leading citizens to them, and the factors which determine which problems receive attention and in what order. Limitations on the choice of problems to be tackled (e.g., lack of resources, competition for those resources that are available, and the drain of leading segments of the population to the suburbs) are explored. The main points that emerge are that (1) civil defense constitutes but one strand in a complex network of problems competing for the attention of government officials and influential citizens--a problem that does not have a high priority within the network; (2) emergency planning is one of the growing number of national problems which require local, state, and federal cooperation and points to the need for appropriate organizational arrangements to be handled effectively; and (3) while local officials recognize that they will have to shoulder a major share of the responsibility for a viable civil defense program, they look for an enduring national commitment to civil defense through policy, comprehensive planning, and through adequate funding by the federal government.

CIVIL DEFENSE PROTECTIVE SYSTEMS

Chapter 10. Blast and Shock Waves

Lawrence Dresner

This chapter summarizes theoretical work on blast and shock waves carried out between May 1965 and March 1966. Propagation of plane, cylindrical, and spherical blast waves in homogeneous isotropic media is explored. To understand the blast effects of nuclear explosions one needs to know the pressure, density, and material velocity as functions of time and position. Since Brode's numerical calculations supply this information only for spherical blast waves in air--not for other geometries or other materials--the older method of piecing together a solution from the analytic solutions known to apply very near and very far from the explosion is used. The similarity theory of Taylor, von Neumann, and Sedov can be used to provide a solution near the explosion. It compares well with experimental data reported by Holzer on the time of arrival of the shock front at various positions. Far from the explosion, the fact that the shock wave is weak can be used to obtain the law of its propagation. Two practical applications are made of the theory developed, one to the decay of blast waves in tunnels, and one to the decay of blast waves from underground nuclear explosions in alluvium. The distribution of reflected pressure on the ground following an air burst is calculated and plotted. Some questions regarding the operation of blast doors, including the conditions under which steel blast doors of varying thicknesses fail, are examined; and some of the theory developed (discussed above) is applied to analyzing the operation of blast-activated blast doors.

Chapter 11. The Thermal Threat to Sheltered Populations

J. W. Strohecker

The thermal threat to a sheltered population which comes from the secondary fire effects of nuclear weapons is examined. Dangers from fire to people in shelters are heat, toxic gases, excessive carbon dioxide, and insufficient oxygen. Also, the air above a shelter may become too hot for either the operation of power generation equipment or the removal of heat from the shelter. Although considerable effort has been expended on prediction of fire spread, casualties, and damage assessment, knowledge in the field is qualitative and rather uncertain. Threats to blast shelters are discussed in some detail along with possible ways of meeting them. Fire threats to fallout shelters are considered independently with emphasis on preventing fires of major proportions from getting started by removal of sufficient combustibles from the adjacent areas ahead of time. The question of determining the optimum location for an air supply adequate for survival in a blast shelter is explored within the framework of historical fires in Germany and Hiroshima during

World War II. Areas indicated for further study include (1) continuation of experimental mass fires to provide design information for ventilation systems, (2) re-evaluation of data from major fires with emphasis on survival data, (2) evaluation of experience in burning buildings in the U. S., and (4) investigation of the feasibility of using special motor-generator sets and refrigeration systems rejecting heat to boiling water to reduce the dependence of shelters on large air and water supplies.

Chapter 12. Protected City Studies

George A. Cristy
Clifford J. Williams

The protected city concept has been expanded to include several types of protective systems applied to a number of specific cities. The single-purpose shelter approach (the tunnel-grid concept), based on the present-day design of a 25-square-mile section in Detroit, was studied and developed in detail. This concept uses a network of reinforced concrete pipes installed under city streets. Advantages of a tunnel-grid shelter include: (1) the resistance to blast damage of cylindrical structures; (2) the provision for reassembling family units in shelter; (3) the capability of sheltered movement to reduce crowding; (4) the ease with which support facilities can be duplicated; (5) the possibility of protected evacuation of a city; and (6) potential peacetime use for the tunnels. Disadvantages include possible costliness and possible vulnerability to biological agents and to blast damage should the system be breached. The dual-purpose approach has been applied in the design of six lanes of traffic under midtown Manhattan, connecting the Lincoln and Queens Tunnels and having adjoining parking facilities for 30,000 cars. Dual-use applications are also being considered for the subway portion of the new Washington Rapid Transit System and a proposed underground truck tunnel and connecting underground pedestrianways in Dallas.

Chapter 13. Active and Passive Defense Cost Ratios for Population Protection

C. M. Haaland

(Reported in Part II*)

Chapter 14. Status of Development of Ballistic Missile Defense

J. H. Gibbons

(Reported in Part II*)

*Annual Progress Report, Civil Defense Research Project, March 1965-March 1966, Part II, ORNL-TM-1531 (Secret).

II. BIOMEDICAL ASPECTS OF CIVIL DEFENSE

1. UNITED STATES FOOD SUPPLIES - LIVESTOCK

M. C. Bell

1.1 INTRODUCTION

As part of a general investigation of present and postattack food resources, studies have been in progress to assess the role of livestock. Areas considered to date include: (1) the importance of livestock products for human nutrition, (2) the distribution and possible vulnerability of livestock, (3) internal and external contamination problems, and (4) possible livestock salvage procedures.

1.2 LIVESTOCK AS A FOOD SOURCE

Each year the U. S. farmers, representing less than 1% of the world population, produce approximately 27% of the meat, 30% of the eggs, and 42% of the fluid milk in the world. Recently, 54% of agricultural cash receipts in the U. S. have come from the following five principal sources ranked in order of importance: cattle (21%), dairy products, hogs, cotton, and corn. Thus, the top three money crops are livestock and livestock products. However, demand exceeds supply, and the United States is a net importer of animal-based food.

Livestock products supply approximately 1/3 of the calories and 2/3 of the protein consumed in the United States. Additionally, cattle in particular consume many sources of nutrients which are not of direct value to man as food. Over 40% of our agricultural land is economically unsuited for anything except forage for ruminants such as cattle and sheep. The bacteria, protozoa, and yeasts living in the "fermentation vat" (rumen and reticulum) of cattle and sheep break down cellulose and other complex carbohydrates into forms which can then be utilized. These symbiotic microorganisms can also utilize nonprotein fixed nitrogen such as urea to synthesize bacterial amino acids and protein which are subsequently digested and utilized by the host animal. The ruminant animal thus becomes an important protein factory for man, supplying all of the essential amino acids to supplement other important foods such as cereals, fruits, and vegetables.

Livestock also consume agricultural by-products such as tallows, greases, tankage, meat and bone scraps, low grade wheat, wheat bran, and flour middlings, as well as other grains and grain products.

The unique importance of animal protein in the human diet was recently emphasized by the discovery of serious zinc deficiencies in people in North Africa consuming nutrients from plants only. In addition to supplying certain trace elements, livestock can effectively filter out certain others such as strontium and cesium and products in or on vegetable food. This factor will be discussed in more detail later.

1.2.1 Species and Distribution

Beef Cattle

During 1964, annual meat consumption per capita in the U. S. averaged 174 lbs and poultry consumption, 39 lbs. Beef was the largest contributor with an all time record average of 100 lbs per person.

Most of the cattle herds are located on the Western range area with other areas of the country contributing much smaller numbers. Since the center of U. S. population is east of the Mississippi, on the average, beef travels 1,000 miles from the producer to the consumer. In the fall of each year, feeder calves and yearling calves are moved into feedlots which traditionally are concentrated in areas of the country where grain is most abundant. This trend is being altered by the development of new feedlots in areas near markets. An example is the concentration of feedlots in California, many fully automated and containing tens of thousands of cattle. Even with a deficit of feed grains, cattle feeding in California is a sizeable enterprise, with 950 thousand head on heavy feed in January 1966. Since a mature beef animal supplies an average of 400 lbs of meat after slaughter, this quantity represents 20 lbs per Californian.

The number of cattle in the U. S. reached an all time high of 107 million in January 1965 (Fig. 1.1).[1] Even so, a record number of 900,000 feeder calves were expected to be imported during 1965, principally from Mexico and Canada.

Dairy Cattle

Numbers of dairy cows are declining (Fig. 1.1) while milk production per cow is increasing, with a 1965 average of 8,080 lbs of fluid milk per cow. The net result is an increase in total production of milk and a reduction in per capita consumption. Dairy cattle are distributed throughout the U. S. A. near centers of population except for a heavy concentration in Wisconsin and adjacent states.

Dairy products rank second in the principal agricultural cash commodities of the U. S. and rank first in 14 states. All of these 14 states except Minnesota are east of the Mississippi River and none are in the South.

Swine

The annual U. S. per capita pork consumption has been from 60 to 70 lbs for the last 60 years. Yearly pork production has been variable but not nearly so variable as the prices (Fig. 1.2). Swine are much more efficient converters of energy into food for man than are cattle and sheep. However, they must be fed cereal grains or similar energy sources, a higher percent of protein balanced in essential amino acids, and additional vitamins, most of which could in an emergency be used directly for human food.

Most of the swine are concentrated in the corn belt states with Iowa, Illinois, and Indiana producing almost half of the pork in the U. S. Producers in grain deficit areas ship feeder pigs into the corn-producing states for the final 3-to-4-month finishing period.

Poultry and Turkeys[2]

Per capita consumption of chicken and turkey has almost doubled in the U. S. during the past 20 years up to a broiler consumption of 31 lbs in 1965 and turkey consumption of 7 lbs. Broiler production is concentrated in 8 Southern states, Maine, and California; these 10 states produce 82% of the U. S. total. Most of the production increase has

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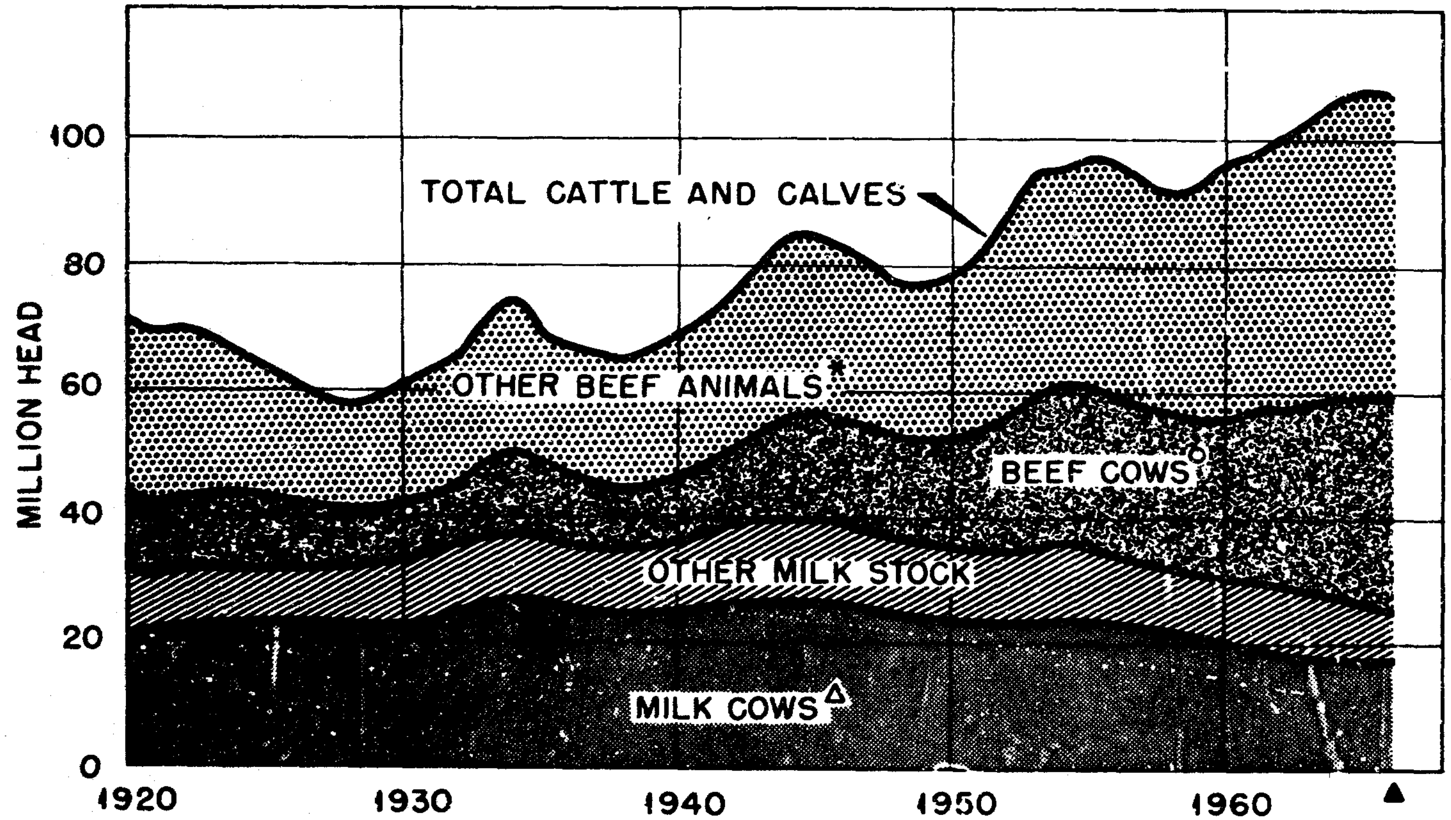

△COWS AND HEIFERS 2 YEARS AND OLDER FOR MILK
°2 YEARS AND OLDER NOT FOR MILK
*HEIFERS AND CALVES NOT FOR MILK AND ALL STEERS AND BULLS
▲PRELIMINARY

Fig. 1.1. Yearly Inventory of Cattle on Farms on January 1 Since 1920.[1]

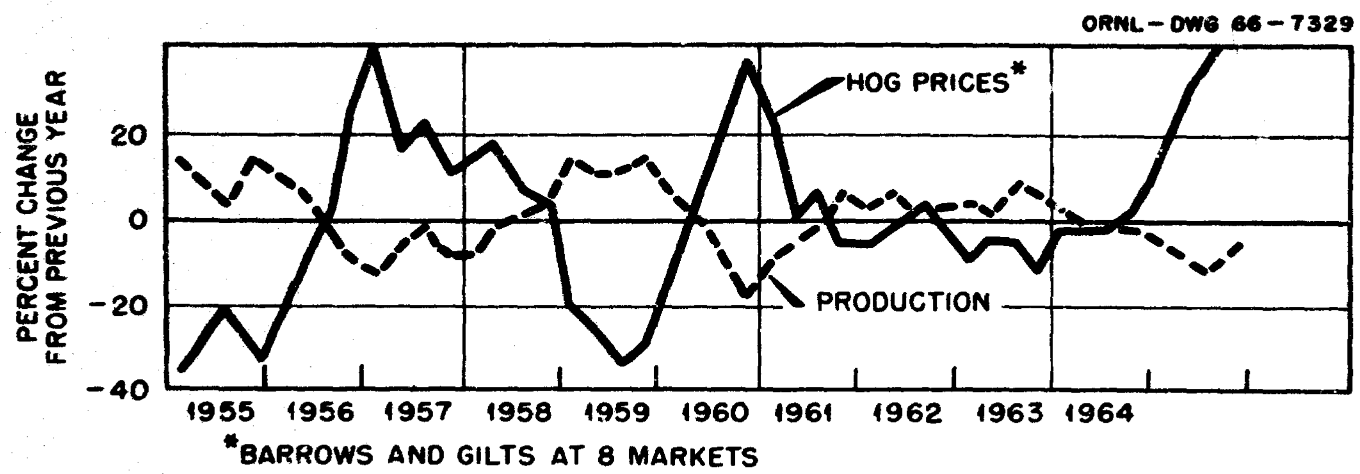

Fig. 1.2. Percentage Change in Hog Prices and Pork Production.[3]

occurred in the South. Production has increased in face of declining prices and narrowing profit margins primarily due to gains in efficiency of production and marketing. In 1948 broilers required 4.0 lbs of feed per lb of gain; this was reduced to 2.5 by 1964.

Turkey production has also been expanding but somewhat more erratically than broilers. Turkey consumption is highly seasonal with peaks at Thanksgiving and Christmas.

Egg production has increased but only about half as fast as population over the past two decades. Per capita consumption averaged 393 eggs in 1951 and is expected to drop to 307 in 1965. The total number of layers in the U. S. in 1965 was the same as in 1940 while the production per layer has increased by 60% (Fig. 1.3).[2]

Poultry are the most efficient converters of feed to meat (see Table 1.1) but require the most expensive feed, most of which is potentially directly usable as human food.

Table 1.1. Tons of Feed Consumed by Livestock in 1964 and Average Feed Conversion Values[4]

	Dairy Cattle	Beef Cattle	Swine	Poultry
Concentrates				
High protein	4.8	6.4	7.0	11.2
Total	30.5	31.4	53.7	36.2
Roughages	64.4	119.0	2.4	0.7
Feed/lb gain for meat production		8.5	3.5	2.5

1.3 VULNERABILITY OF LIVESTOCK

In general our livestock have much less protection in any given area from thermonuclear attack than our population. On the other hand, as discussed earlier in this report, livestock are more evenly distributed throughout the U. S. than people and, in general, are away from the centers of population.

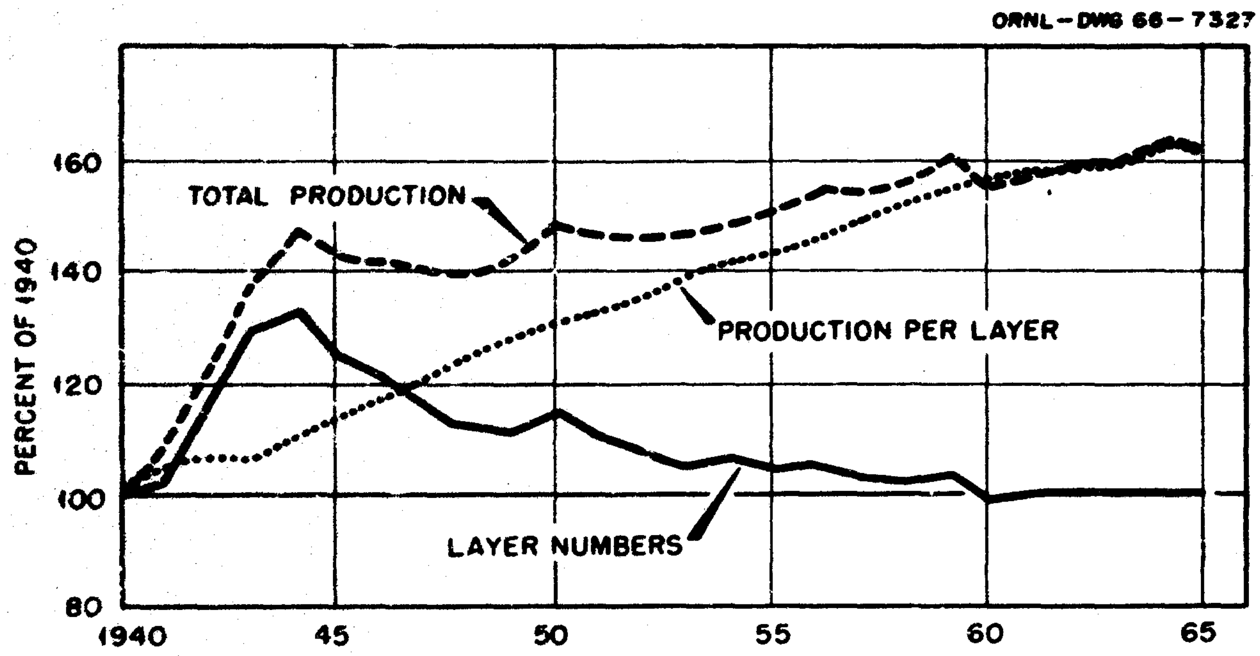

Fig. 1.3. Changes in Egg Production Since 1940.[2]

This means that with present civil defense protection systems an antipopulation attack on the U. S. would probably result in more livestock survival than population survival. With a full-fallout-shelter program and a population-avoidance military attack, the reverse would probably be true. An advanced civil defense system to protect urban populations (as described in Chapter 12) might perform well enough against a future city attack to ensure more human than animal survival. Vulnerability studies are planned of at least these three cases.

Our most vulnerable and most used source of protein is in our beef cattle. Most cattle live their lives with no protection from fallout or from the elements of nature. A good example of the sub-lethal effects of fallout on cattle was furnished by the group of cattle exposed near Alamogordo, New Mexico, in July 1945. Scar tissue, greying of hair, and, after many years, carcinoma of the skin was evident.[5] Beef cattle on pasture would also be subjected to internal beta and gamma radiation from ingested forages.

The size of feedlots for finishing cattle is increasing with up to 50,000 head in one unit in Greely, Colorado. Marketing of livestock is also being increasingly concentrated with over 50% of the total cattle marketed in the six markets of Omaha, Chicago, Sioux City, South St. Paul, Kansas City, and St. Joseph.

Transportation, both truck and rail, plays an important role in moving livestock products to the consumer as well as in moving livestock feeds into feed deficit areas. Many beef and swine producers grow and store grain and roughages sufficient for the entire year, buying only supplements of protein, vitamins, and minerals. On the other hand, many broiler producers buy all their feed as a complete mix delivered from one to three times each week, maintaining only a few days' supply of feed. Dairy animals around large cities depend on shipment of hay and dairy feed into the area throughout most of the year.

Poultry can survive almost twice as much gamma irradiation as other meat producers, but they are more vulnerable to a temporary lack of feed and water. The life cycle in broiler production is very short with a chick becoming a market bird in only 8 weeks compared with a pig requiring 5 months and beef steer 12 to 18 months to usual market weight.

On the other hand, cattle and sheep require less expensive feed, which in an emergency could be entirely from roughages and other products not used for human consumption. As was mentioned earlier, ruminants are generally less efficient converters of feed grain into meat than are hogs and poultry, but the demand for beef in the present U. S. diet is so great that almost half of the meat consumed is from beef and much of this beef is grain fed.

1.4 ANIMAL METABOLISM OF RADIONUCLIDES

1.4.1 Introduction

Of the over 200 radioisotopes from nuclear fission and from induced radioactivity in surface bursts, there are only three which are significant internal hazards to postattack food production from livestock. These are radioisotopes of iodine, strontium, and cesium. Radioactive iodine is absorbed and concentrated in the thyroid gland. Strontium-89 and -90 are metabolized like calcium, deposited in bone, and secreted in milk. Cesium-134 and -137 react like potassium and are generally distributed in tissue, especially in muscle.[6]

1.4.2 Iodine

Of the three hazardous radionuclides, iodine is the only element which is an essential nutrient required for animals. It is especially important for reproduction and for growth of young animals.

Radioiodine is one of the most abundant radionuclides in early fallout; it is absorbed and concentrated in the thyroid gland with only a trace found in meat. Fortunately, ^{131}I (the most important radioisotope of iodine after 12 days following a nuclear explosion) decays rapidly with an 8-day half-life into a nonradioactive product. Around 15% of the soluble dietary radioiodine is deposited in the thyroid, from which a portion is secreted in the hormone thyroxine which regulates body metabolism. The fetus and growing young animals are much more susceptible to radiotoxicity from radioiodine than are mature animals.

Growth is retarded in young, while older animals show little effect of overexposure except lethargy. Milk production may be resumed in a dairy animal by feeding the synthetic hormone protamone or by giving thyroxine. In any case, dairy animals could be useful for meat even if the thyroid were destroyed and supplemental hormones were not available.

1.4.3 Radiostrontium

Strontium-89 and -90 are deposited along with calcium and phosphorus in bone. These beta emitters are more difficult to detect in an animal than are iodine and cesium, but they may be assumed present if the other two are. They react more like calcium than phosphorus and are deposited in the apatite bone crystals. Tracer experiments show that a greater percentage of calcium is absorbed from food than strontium and more absorbed strontium is re-excreted than calcium, giving a discrimination factor of four for calcium versus strontium in bones and eight for calcium versus strontium in milk.

Strontium-89 has a physical half-life of 43 days with a biological half-life* of 18 days when deposited on forage.[7] Strontium-90 has a physical half-life of 28 years. Although ingestion of massive doses of radiostrontium (up to 70 millicuries in cattle) by even a large beef animal can cause death in a few weeks, a fresh fallout field containing sufficient strontium activity to allow such ingestion would be accompanied by lethal gamma fields. Aged fallout could theoretically have lethal quantities of ^{90}Sr without lethal gamma, but weathering could be expected to remove most of the fallout particles from forage. Thus, prompt livestock deaths from radiostrontium ingestion alone should not be expected.

From the standpoint of the postattack food problem, the principal radiostrontium hazard is from the ingestion by young humans of the radioactivity in milk. Purification methods are described later. Since strontium in meat animals is concentrated in the bone, normal slaughtering and meat cutting methods produce human food adequate for emergency use.

*The biological half-life of an isotope is the measure of the disappearance rate from an organism based on both physical decay and biological excretion.

1.4.4 Radiocesium

Cesium-137 and -134 are readily absorbed by livestock and are distributed throughout the muscle tissue of animals as is potassium. The physical half-lives for ^{137}Cs and ^{134}Cs are 28 years and 2 years, respectively. Biological half-lives vary with the diet and species, but are usually between 20 and 100 days.[8]

As was the case with strontium, fresh fallout which would provide lethal internal contamination of radiocesium to a grazing animal would also be accompanied by a lethal penetrating external radiation field; thus the principal hazard in postattack food is uniform contamination of meat.

1.5 TREATMENT OF CONTAMINATED ANIMAL PRODUCTS

1.5.1 Meat

Meat from animals given tracer levels of ^{131}I contains negligible radioactivity. As was mentioned earlier, meat from animals fed large doses of radiostrontium and slaughtered by usual methods contains little strontium.

Radioactive cesium reacts quite differently from strontium since more than half absorbed by animals is distributed throughout muscle tissue. Some radioactive cesium is released in cooking meat, and more than 50% is released into juices from stew meat.[9] A more effective method of getting rid of it is by soaking meat in water. Water flowing slowly over 1-inch cubes of beef contaminated with radiocesium removed 81% of cesium in 12 hours and 99% in 60 hours. Considerable loss of color was evident along with a loss of 6% nitrogen, but taste tests have shown that the meat was still edible and palatable.[10]

1.5.2 Milk

Milk is the main source in our diet of ^{90}Sr and ^{137}Cs from previous nuclear weapons tests. Removal of these ions and ^{131}I can be effected by use of ion-exchange resins as was shown by early test tube experiments.[11,12] These procedures have now been adapted to a full-scale milk processing plant.[13] Tests show that milk treated with ion-exchange resins is not altered in nutritive value and is an acceptable food for man and animals.

1.5.3 Eggs

Removal of ^{131}I from eggs is easiest by cold storage and radioactive decay. Over 99% of ^{90}Sr in eggs is deposited in the shell and is not released into the edible portion even with boiling. No data are available in the literature on techniques for ^{137}Cs removal from eggs.

1.6 SUMMARY

Livestock products provide most of the farm income in the U. S. and production efficiency is continually increasing. Livestock are good protectors against radionuclides from fallout in human food since most radionuclides are not absorbed by animals. However, livestock are sensitive to radiation and are our most vulnerable food source. The most hazardous radionuclides in livestock products are iodine, strontium, and cesium. Procedures are available for removing dangerous quantities of radioactivity from most animal products.

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2. UNITED STATES FOOD SUPPLIES - GRAINS

A. F. Shinn

2.1 INTRODUCTION

2.1.1 Purpose of the Study

The mission of the agricultural team, whose work was initiated in the autumn of 1965, is fivefold:

1. Evaluation of the present-day national food situation with respect to food stocks, agricultural production, and current consumption.
2. Delineation of current trends in agriculture and their implications for civil defense.
3. Estimations of the vulnerability of food stocks, crops, food production, and processing capacities.
4. Assessment of damage to food stocks, crops, and food-producing and processing capacities from postulated attacks.
5. Determination of the timing for resumption of normal food production and processing following attack.

2.1.2 Status of the Study

The literature and statistical data requisite for our first two goals above have been assembled and analyzed and currently are being prepared for an ORNL Technical Memorandum. Highlights from this TM report are contained in this chapter.

Work on goals three and four is in progress, having started with a briefing by government officials in charge of vulnerability and damage assessment studies of agriculture. These computer studies were carried out jointly by the National Resource Evaluation Center and the ASCS (Agricultural Stabilization and Conservation Service) agency of the U. S. Department of Agriculture. No work has been done on the fifth goal.

2.1.3 Organization of the Data

The important literature dealing with nuclear attack and agriculture is first cited, then statistics on present stocks of food and production and consumption of food are given in graphical and tabular form. Finally, the civil defense implications of the reduction in our food reserves, the vulnerability of our livestock to attack, and certain alternate sources of protein in a postattack period are discussed.

2.1.4 Previous Studies

Stanford Research Institute has published studies on postattack survival of food stocks and food production capacity,[1] postattack farm problems,[2,3,4] and postattack food processing and distribution.[5] Mitchell[6] has explored ecological problems in postattack agriculture, and the Postattack Recovery Panel of Project Harbor has recommended measures in agriculture to facilitate recovery from attack.[7] Other studies in the field include that of Ayres on the effect of nuclear wars on special aspects of agriculture [8] and the engineering study of the vulnerability and postattack repair of eight major segments of the food industry by Advance Research, Inc.[9] Extensive, detailed studies on vulnerability and damage assessment in the agricultural industry have been carried out jointly by the National Resource Evaluation Center of the Office of Emergency Planning and the Agricultural Stabilization and Conservation Service of the U. S. Department of Agriculture.[10] Pettee has estimated the need for a U. S. emergency stockpile of processed food.[11]

Some conclusions from these previous studies are listed below:

1. Under past and current civil defense programs, a severe shortage of both raw and processed food stuffs is unlikely because food manufacturers are both numerous and well dispersed.[9,10]
2. The probable bottleneck in supplying food is transportation which depends, in turn, on petroleum supplies.[9]
3. Food will survive in approximate proportion to the population which will consume it (under current defense programs) although temporary deficits will occur in some areas.[10,11]

4. A relatively greater percentage of rural population will survive than urban population.[10]
5. There is no prospect for a <u>nationwide</u> deficit of processed food because the preattack stockpile, necessary for bringing the nation as a whole through the first postattack year,[11] already exists. However, local deficit areas will likely occur.

The conclusions are based on data from the Censuses of Agriculture for 1954 and 1959 and the existence of large yearly carry-overs of food in the '50's and early '60's. An extensive blast shelter program would be expected to modify all five conclusions.

2.2 THE NATIONAL FOOD SUPPLY

2.2.1 Commodity Carry-over, Reserve, and Surplus

The three terms carry-over, reserve, and surplus have been used more or less interchangeably with respect to the amounts of commodities on hand. Carry-over has an unequivocal meaning and is the amount of a farm commodity remaining after a marketing year is completed and before sizeable amounts of the new crop are marketable. Both "reserve" and "surplus" have been used imprecisely. A commodity reserve is supposed to be that amount of carry-over necessary to supply the usual continuous demand (food processing, exports, etc.) until the next crop is available and to hedge against potential inadequate crop production. Unfortunately, there is no general agreement on the crop quantities which should be identified as "reserve." A commodity surplus is the amount by which stocks exceed the hypothetical commodity reserve level. Customarily, the entire commodity stocks are called "reserves" when they are equal to or less than this ill-defined commodity reserve level; and the entire stocks are called "surpluses" when they exceed the commodity reserve level.

2.2.2 Commodity Reserve Levels

In 1964, the Subcommittee on Food and Fiber Reserves for National Security, National Agricultural Advisory Commission, suggested tentative figures for use in solving the "reserve definition" problem mentioned in the previous section and developing realistic present-day commodity reserve levels (see Table 2.1.). These figures were derived from an earlier study by an agricultural committee headed by Senator Allen J. Ellender of Louisiana. President Johnson recommended in his message to Congress of February 10, 1966, that legislation be framed to establish appropriate commodity reserve levels.[12] On February 14, 1966, Representative Harold D. Cooley (North Carolina), Chairman of the House Committee on Agriculture, introduced a bill (H.R. 12784) to authorize the Commodity Credit Corporation (CCC) to establish and maintain reserves of agricultural commodities to protect consumers and for other purposes. The Senate companion bill is S.2932.[13] Neither bill mentions civil defense.

2.2.3 Commodity Credit Corporation

Functions[14]

The Commodity Credit Corporation is an agency of the United States assigned to the Department of Agriculture. Its programs are administered by the Agricultural Stabilization and Conservation Service which supplies both personnel and facilities for this purpose. Its major activities include price support and production stabilization for commodities such as cereal and feed grains, cotton, soybeans, milk, and tobacco. The CCC may encourage production adjustments and maintain farm income by making payments for diverting cropland from the production of feed grains and wheat to conservation uses. Commodities acquired under the price support program are stored in commercial or CCC facilities pending their disposition through domestic and export sales, transfers to other government agencies, donations for welfare use, and the Food for Peace program, Public Law 480.

Stocks

Congress has never granted legal authority to the U. S. D. A. to establish a stockpile of food. Hence, the stocks acquired under price support by CCC have in essence served as our food reserves.

The fluctuations in quantities of ten major foods held by the CCC from 1954 to 1966 are shown in Figure 2.1.[15,16] The graph shows a general decline in CCC holdings during the last few years. Trends at

Table 2.1. C.C.C. Stocks of Major Food Commodities

Commodity	Peak Quantity: Quantity (Millions)	Peak Quantity: Man-Days of Food*	N.A.A.C. Discussion Levels: Quantity (Millions)	N.A.A.C. Discussion Levels: Man-Days of Food*	Estimated Stocks as of March 31, 1966: Quantity (Millions)	Estimated Stocks as of March 31, 1966: Man-Days of Food*
Wheat	1400 bu (June 1961)	215	630 bu	97	584 bu	90
Rice	35 cwt (July 1956)	8	9 cwt	2	5 cwt	1
Feed Grains (67% corn, 15% oats, 11% sorghum, 7% barley)	85 tons (Sept. 1961)	383	45 tons	203	45 tons	203**
Soybeans	88 bu (Aug. 1959)	17	100 bu	19	45 bu	9
Butter	508 lb (Aug. 1954)	3	100 lb	0.6	0.7 lb	0.003
Cheese	580 lb (Sept. 1954)	1.5	380 lb	1	0 lb	0
Milk, dried	848 lb (May 1963)	2	530 lb	1.5	68 lb	0.2
TOTALS	- - -	~630	- - -	~324	- - -	~303

*Bases: 3000 calories per person daily for 195 million U. S. population.

**Assumes no use of feed grains for animals.

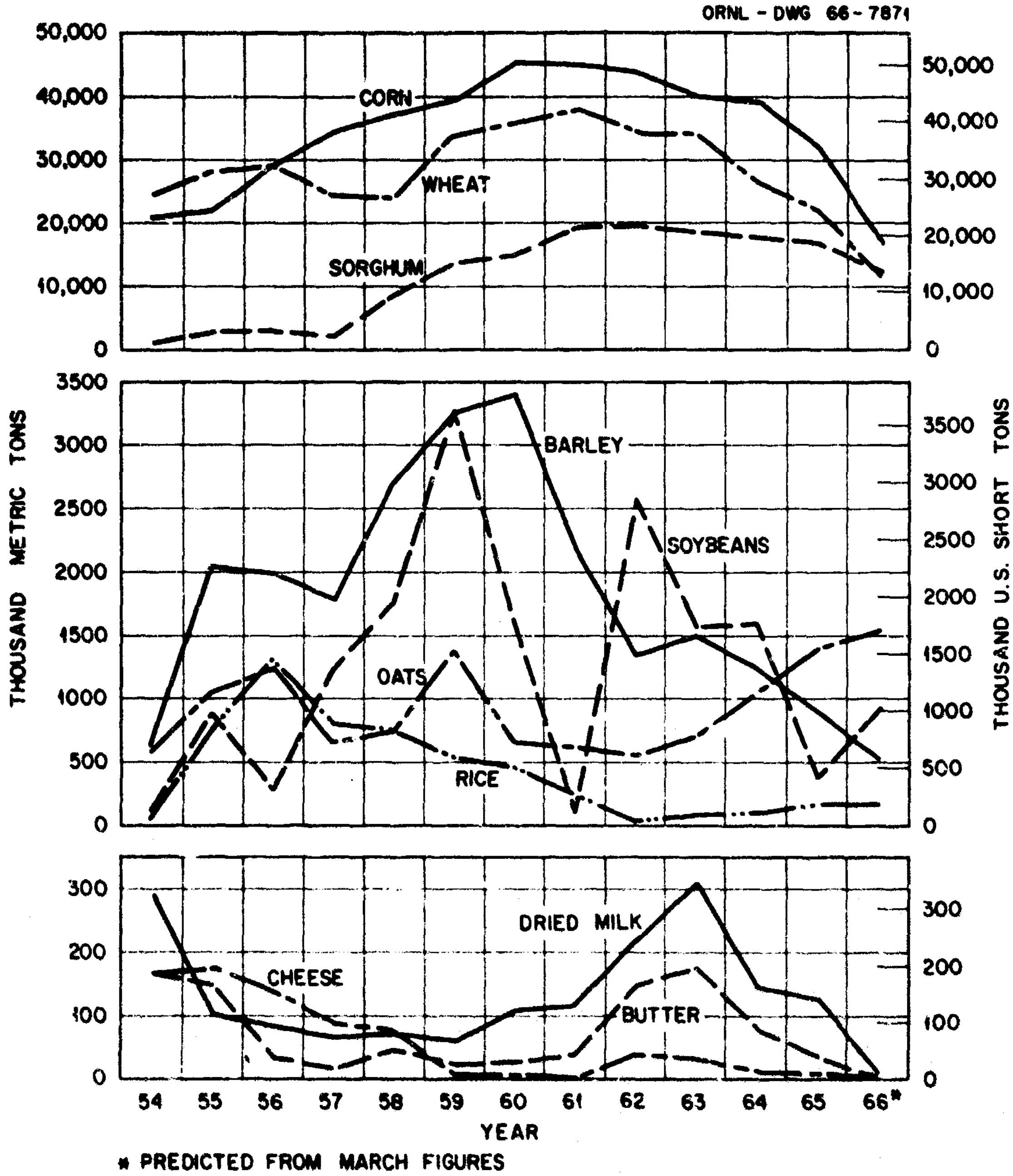

Fig. 2.1. Fluctuation of CCC Stocks - April 30, 1954-1966.[15,16]

this writing indicate further drops in CCC holdings of grains and dairy products during 1966. In Table 2.1 the peak quantities of ten major food commodities held by the CCC are compared with quantities held as of March 31, 1966,[17] and with those suggested by the National Agricultural Advisory Commission[18] for discussion purposes in development of commodity reserve levels.

Geographic Location of Stocks

The geographic location of stocks has been largely determined by the economy of storage without regard to defense considerations. Fortuitously, grain storage was in 1959 widely dispersed at some 20,000 locations[10] and was, thus, relatively invulnerable. Country elevators for grain storage have steadily decreased in number since the Census of Agriculture for 1959.[19] If this trend continues, and if our largest storage facilities become the major points of storage as stocks decline, then stored reserves obviously would be much more vulnerable than studies based upon the 1959 data would indicate.

Figure 2.2 shows the locations of each of the thirty U. S. grain elevators with a storage capacity of more than ten million bushels.[37] Only two of them--those in Enid, Oklahoma, and Hutchinson, Kansas--are not listed as targets in the approximately 9,000-megaton attack on 303 cities given by Martin and Latham.[20] The total storage capacity of these elevators is 1,364,000,000 bushels, or about the size of our annual wheat production. The two granaries not targeted have a capacity of 118,125,000 bushels, or 8.7% of the total. The total off-farm capacity for grain storage in the U. S. as of January 1, 1966, was 5,463,160,000 bushels.[21]

2.3 FOOD STOCKS AS OF JULY 1, 1965

The major sources of food are diagramed in Fig. 2.3. The size of these sources is estimated in number of days of food for each person of the population as of July 1, 1965, based on a daily consumption of 3000 calories.* The statistics on the food supply came from official government sources.

*The daily per capita consumption in 1964 was 3170 calories (U. S. D. A., Economic Research Service, National Food Situation, NFS-114, p. 22, November 1965).

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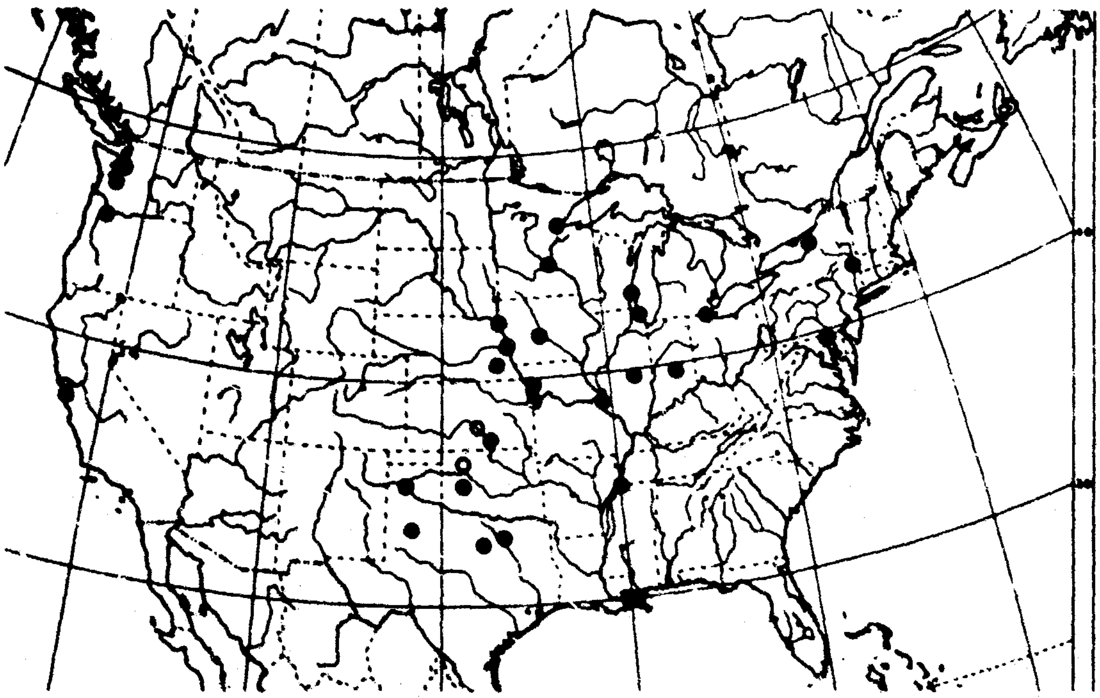

Fig. 2.2. Grain Elevators with More Than Ten Million Bushels Capacity, January 1, 1965.

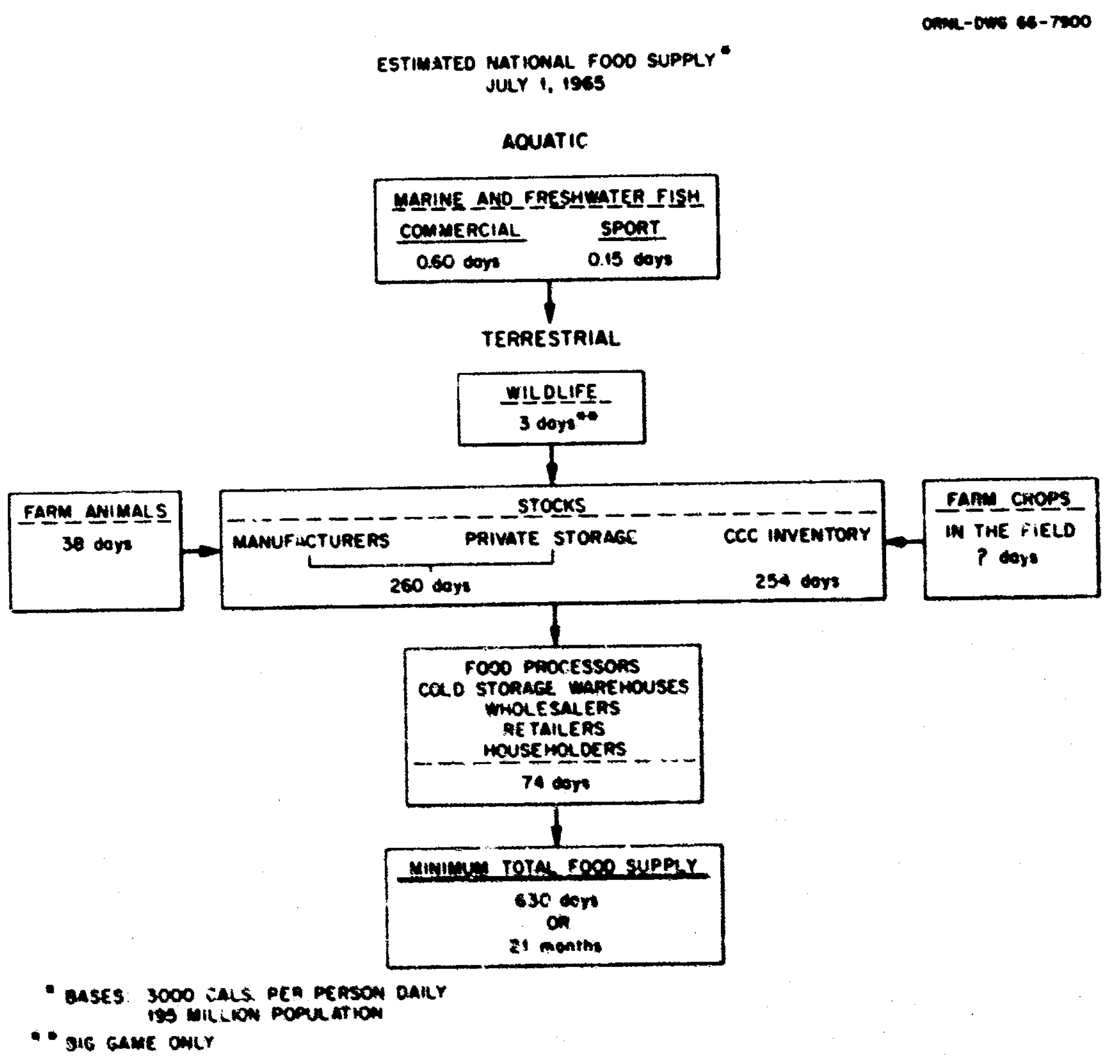

Fig. 2.3. Estimated National Food Supply, July 1, 1965.

The days of food were calculated for raw commodities after taking into account factors necessary for their conversion to consumable form[22] and data on their caloric content[23] in combination with the two bases given in Fig. 2.3.

MARINE AND FRESH WATER FISH supply 0.75 days, or half the annual catch by commercial and sport fishermen.[24] It is somewhat surprising to see that sport fishing yields about 20% of our edible fish. WILDLIFE, as big game alone, can supply more than three days of food and could well be an important supplement in an emergency.[25] Thirty-eight days of food (one-half the 1965 slaughter) is supplied by FARM ANIMALS, primarily cattle (15 days), hogs (19 days), and poultry (4 days). STOCKS were calculated from CCC figures[26] and USDA data,[27] and consist mostly of corn (263 days), wheat (125 days), and sorghum (95 days). Studies by the USDA provided the bases for estimates given for FOOD PROCESSORS, COLD STORAGE WAREHOUSES, WHOLESALERS, RETAILERS, and HOUSEHOLDERS.[28]

The estimate of the total food supply is a minimum one because no figure is included for the substantial amount of FARM CROPS in the field. Approximately 2-1/2 months of the total supply are in the form of processed, ready-to-eat food. This quantity is considered adequate to tide the country over the period of industrial repair following attack until the time when food processing is resumed.[11]

2.4 PROTEIN PRODUCTION IN A POSTATTACK PERIOD

2.4.1 Introduction

Livestock provides about 66% of the protein in the American diet and is our most vulnerable source of protein (see Chapter 1). Two studies have concluded that 60% or more of our livestock would survive various nuclear attacks.[3,10] It is likely that survival from possible biological attack might be lower than that, but no studies on this have been published in unclassified literature. Because of the importance of good quality protein in the diet, it seems appropriate to consider alternate sources.

2.4.2 Alternate Protein Sources

Ideally, alternate protein sources should meet several criteria: (1) familiarity to consumers, (2) production possible with current technology, (3) high total production possible, (4) production widely dispersed, (5) vulnerability to attack--minimal, (6) processing simple and minimal, and (7) costs lower than livestock. By these criteria, grains, soybeans, and freshwater fish are good candidates. The only unorthodox source of protein that scores reasonably well is algal culture.

Grains

Wheat, corn, and sorghum comprise our major grain reserves. The protein of no one of them alone is a satisfactory substitute for meat protein. But if a small percentage of the amino acid lysine is added to wheat flour, the value of the protein will be greatly enhanced and essentially comparable to that found in meat.* However, the cost of doing this may be too high to be practical. Properly proportioned blends of these three grains might give a mixture with protein almost as valuable as that of meat, but nutritionists have been able to achieve better amino acid balances with blends of grains and oilseed cake or grains and leguminous beans. Incaparina, developed by Dr. Nevin Scrimshaw, is such a blend, and its formula is shown in Table 2.2.[29]

Table 2.2. Formula of Incaparina, A Blend of Grains with Proper Amino Acid Balance

	Incaparina (Vegetable Mixture 9 B)
Maize	29%
Sorghum	29%
Cottonseed	38%
Torula Yeast	3%
$CaCO_3$	1%
Vitamin A	4500 IU per 100 gms

*Some commercial bread contains 0.45% added lysine, based on the weight of wheat flours used in the bread, which more than doubles the nutritional value of the protein.

Soybeans

A mixture of three parts of a cereal grain with one part of a processed, leguminous bean (peanut, chick pea, lima, soybean, etc.) flour will give a nutritionally adequate protein mixture.[30] The beans supply the lysine which is inadequate in the cereal, and the cereal supplies the methionine which is inadequate in the beans. Soybeans are the only beans which could be produced in sufficient quantity for mixture with our grain reserves. Both General Mills and the Meals for Millions Foundation already produce cheap, soybean-based Multi-Purpose Food.[31,32] Six ounces of it supply the daily requirements of protein, minerals, and vitamins necessary for a 154-pound man.[33]

There is not sufficient carry-over of soybeans to be mixed with our carry-over of wheat. The 1965-66 carry-overs of soybeans[34] and wheat are predicted to be about 48 million bushels and 500 million bushels, respectively. Thus, about a four-fold increase in soybean carry-over would be necessary to match the wheat carry-over.

It is interesting to compare the 1965-66 carry-over of soybeans and wheat with the annual production. The 48 million bushels of soybeans represent about 1/16 of the 1965 annual production of 840 million bushels, while the 500 million bushels of wheat represent almost 1/2 of the annual production of 1300 million bushels. Obviously the "reserve" of soybeans is quite low and does not represent much protection against normal crop failure. One would hope that future defined commodity reserve levels would promote the establishment of an adequate soybean crop reserve.

Freshwater Fish

The production of freshwater fish in inland waters could give a small but relatively invulnerable source of excellent protein. An annual production of two billion pounds* of catfish is possible if these or similar fish are raised in the nearly two million acres of rice lands** in the five major rice-producing States.[35] The 1.75 million acres[36] of farm ponds in the U. S. might yield another one billion pounds of fish. These two sources alone exceed the annual commercial harvest of edible fish. The additional great potential of raising fish in lakes and reservoirs has not yet been estimated.

*One billion pounds of whole, raw fish supplies 0.52 days of food (3000 calories daily consumption for 195 million people).[22,23]

**Assuming rice and fish raised alternately.

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3. PHYSIOLOGY OF HEAT STRESS*

C. H. Kearny

3.1 PURPOSE

Almost every shelter test, as well as most current shelter physiological research, has involved the determination of heat stresses to which persons living under essentially still-air shelter conditions are subject.** Furthermore, there exists considerable difference of opinion regarding the importance of high local air velocities, both as regards the survival of shelter occupants under severe temperature conditions and as regards their well-being. Therefore to obtain more data concerning the necessary air movement over the body surface of a shelter occupant for prolonged survival in conditions of high temperatures and relative humidities, the Oak Ridge National Laboratory entered into a contract with a physiological laboratory with many years of experience in the field of hot-weather environmental research, the Department of Anatomy-Physiology of Indiana University.

The air velocities maintained over the test subjects were primarily those produced by a manually operated three-foot punkah-pump used as an overhead fan. Testing the effectiveness of this air-moving device from a physiological point of view was an objective of this study.

The quite complex details of this investigation are contained in the final report by Drs. Mukul R. Banerjee and Robert W. Bullard of Indiana University. The following summary includes only those results which appear most relevant to the development of minimum-cost solutions to current shelter environmental problems.

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*Review of work performed under subcontract number 2544 with Indiana University, Bloomington, Indiana.

**That is, the net ventilation rates through shelters, combined with the cross sectional areas for flow, result in very low local velocities. An evaluation of the importance of fanning shelter occupants (as distinguished from quite uniformly distributing the air within the shelter) is the subject of this report.

3.2 TEST PROCEDURES

The experiments were carried out in an uninsulated climatic chamber. In these tests the preheated chamber was occupied by only one test subject at a time, each for a 4-hr period. The instrumentation of the 8-1/2-by-5-3/4-by-10-ft (length/width/height) test chamber is shown in Fig. 3.1.

In order to minimize the temperature increase of air passing through the test chamber, a constant flow of 30 cfm was used. A flow of 30 cfm limits to about 2°F the rise in effective temperature of the air in the shelter, as compared to the effective temperature of the outside air, provided the air is well distributed within the shelter.

When the punkah-pump was not fanning the subject, air velocities in the central part of the room were too slow for the Hastings Air Meter to measure and were recorded as less than 5 fpm.

Four healthy young men served as test subjects. They were dressed only in cotton underwear shorts and rested on a 1/4-x-1/4-in. nylon net reclining chair which was 10-1/2 in. above the floor. Thermocouples attached to the test subject recorded rectal, tympanic membrane, and skin temperatures from the forehead, arm, and calf. A 6-cu-ft spirometer was used to determine respiratory volume, and water losses were determined every hour by weighing the subject.

The experiments were conducted in two phases:

A. First phase--designed to determine the effectiveness of different combinations of temperatures, humidities, and air velocities over the test subjects' skins in maintaining habitable shelter environments. This phase consisted of four experiments, each involving four test subjects.

Experiment Number	Dry Bulb Temperature (°F)	R.H. (%)	Effective Temperature (°F)
1	96	50	85.0
2	96	70	89.5
3	104	50	90.5
4	104	70	96.0

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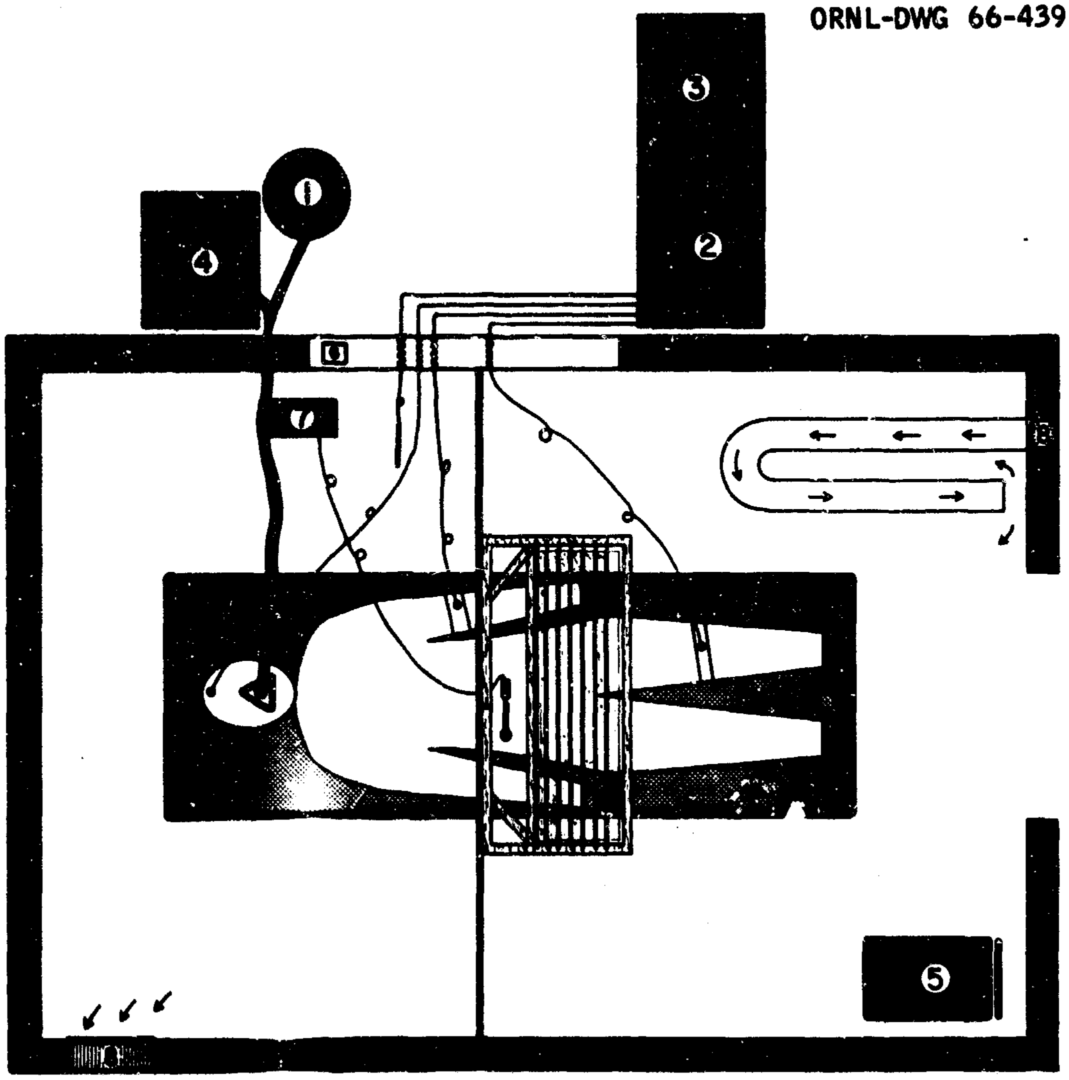

1. Spirometer
2. Brown Recorder
3. Resistance Hygrometer
4. Oxygen Analyzer
5. Weighing Scale
6. Hygrometer
7. Anemometer
8. Air Duct

Fig. 3.1. Schematic Drawing of the Experimental Setup.

During the first hour of each of these tests, the subject did not pull the fan (punkah) and the air velocity was less than 5 fpm. During the second, third, and fourth hour, air velocities recorded were 25, 50, and 75 fpm, respectively.

For control comparisons, additional data on physiological responses were also obtained under each of the first four experimental conditions when the punkah was not pulled for the entire four-hour period.

B. Second phase--designed further to elucidate the interrelationships between the physiological responses and the above-mentioned climatic variables, but with all experiments carried out at effective temperature of 85.0°F (DB 96°F, RH 50%).

Six four-hour experiments were conducted with each subject. These experiments involved alternating an hour of still-air conditions with an hour during which the air velocities were either 25, 50, or 75 fpm. Also included were various combinations of the punkah being operated by the experimenter or by the subject.

3.3 RESULTS AND CONCLUSIONS

A. From the standpoint of civil defense researchers attempting to satisfy at minimum cost the survival needs of people in shelters cooled only by outside air, even under summer heat conditions, the most significant result of this study is additional evidence that man's heat-adaptive mechanisms are remarkably efficient. Provided that essential minimum requirements for sufficient and well-distributed air and for drinking water are met (see C, below) and also provided that effective temperatures do not rise much above ET 85°F, persons can adjust to heat. In the words of the experimenters, Drs. Banerjee and Bullard: "We have been impressed by the versatile thermoregulatory system of the human body. This system from the evidence presented herein can adjust its function to meet the demands. Sweating or evaporative cooling is controlled perhaps by changing the surface area wetted with sweat so that thermal regulation is not greatly altered with marked changes in air velocity and temperature." Figure 3.2, one of 13 pages of graphs in the complete report, illustrates the small influence which widely differing air velocities have on mean body temperature with the shelter air at

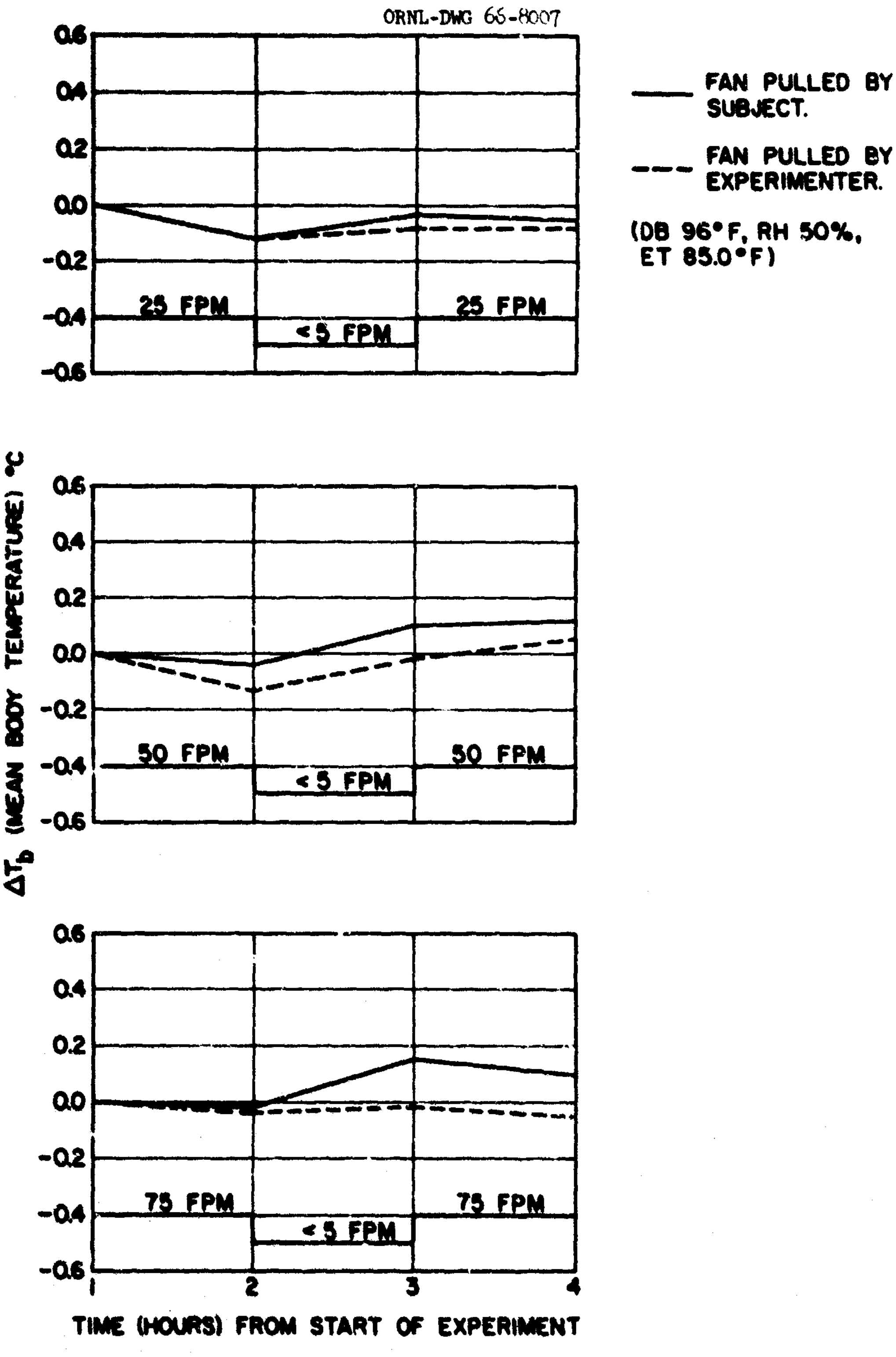

Fig. 3.2. Effect of Intermittent Use of the Punkah on Mean Body Temperature Changes During the Second Phase.

ET 85°F. This statement does not negate at ET 85°F the favorable influence of increased air velocities for improving comfort, for decreasing the percentage of body area wetted by sweat, and for increasing the efficiency of the evaporative process.

As a result of this fortunate adaptability of man, the present evidence indicates that fanning a person in a shelter is of secondary importance to providing him with sufficient well-circulated air so that he remains in an environment not much higher than ET 85°F.

B. The punkah was found to be an effective means of reducing (with air velocities at 25 and 50 fpm) or eliminating (at 75 fpm) temperature stratification of 3.6°F within the test room (measured at two points 40 in. apart vertically) when the air flow through this small room was 30 cfm. "The present investigation was conducted with only one subject at a time in the hot room, who was lying on a bed 10-1/2 in. above the floor. With the pulling of the fan, the hot air of upper layers was brought down to the subject. Thus, punkah utilization would change the location of individuals within a shelter. Occupants of upper bunks could be provided with major protection from heat stress by reducing stratification." In other words, by reducing the temperature layering in the shelter, the temperature stresses on individuals in upper bunks would be reduced to a significant degree.

C. At ET 85°F, it was found that evaporative water consumption per person was at a rate of about four quarts per 24 hours without fanning, as compared to approximately six quarts per day with fanning at 75 fpm. It follows that in a shelter in which (1) all persons are on the floor, (2) the ET is high, and (3) water is in short supply, the ventilating air should be well distributed but should not be fanned so as to force down to the floor hotter stratified air from above--even though such fanning would lower body temperatures slightly and improve comfort as long as people were not partially dehydrated.

D. Another condition of these tests which caused the operation of the punkah fan to appear less advantageous than might be the case in many real shelter situations was that during the hours when a test subject was not pulling the punkah, he tended to go to sleep. In the words of the experimenters: "With sudden exposure to hot and humid atmosphere of the experiments the subjects showed a strong tendency to go to sleep when they were not pulling the fan. They had to wake up to pull the fan, an activity not preferred by our subjects. In a few experiments where the sweat loss of the subjects was continuously recorded from local skin areas by the resistance hygrometry method, the fall and rise in sweating rate were directly associated with sleep and wakefulness. Minute volume* was lower when the subjects awakened for the respiratory gas collections. Average values of energy metabolism of a 70-kg nude man with a 1.85 m^2 surface area as given by Hertig and Belding are 63 Kcal/hr (260 Btu/hr) during sleep and 101 Kcal/hr (400 Btu/hr) while sitting quietly.

E. "Only in Experiment No. 1 with an ET of 85.0°F was the beneficial effect of the use of punkah obvious. There was a progressive decrease in body temperature and heat storage with time as the air velocity increased."

"The body surface temperature was always above the air temperature so that both evaporative and convective losses were taking place." ... "However, except for Experiment No. 4 (ET 96°F) body temperatures were lower under experimental conditions when the fan was pulled as compared to those of control conditions..."

In contrast, in Experiment No. 4, with 104°F dry bulb temperature and RH 70% (ET 96°F), the higher the air velocities were raised by fanning, the worse became the disadvantages caused by the resultant increased convective heat gains being greater than the increased evaporative heat losses produced by the higher air velocities.

Drs. Banerjee's and Bullard's largely problem-defining experiments did not involve any effective temperatures in the very important range between ET 85.0°F and ET 89.5°F. Nor did their experimentation include test subjects taking off and putting on summer clothing--as Americans in hot wartime shelters no doubt would do--so as better to meet the different

*Minute volume is the liters of oxygen consumed per minute--a measure of metabolism.

stresses of hot-dry and hot-humid air. Even within the same shelter such differences may exist, due to the evaporation of sweat lowering the dry bulb air temperature while raising the relative humidity and effective temperature of the air as it moves through the shelter. Nor did these Indiana University experiments involve other than young healthy men as subjects. (The shelter environment requirements of the old, the young, and the handicapped are being investigated by a number of projects supported by the Office of Civil Defense.)

Additional research is desirable to find and test minimum-cost solutions to these and other environmental problems of all types of shelters from improvised basement shelters to complex blast shelters. For example, occupants of the tunnel-grid system (as at present designed) would experience air movement too slow to be perceptible in one end of an air-circulation section, whereas in the other end of this same section the occupants would live in air moving at abnormally high velocities of about 100 fpm.

3.4 APPENDIX A. EVAPORATIVE COOLING OF CYLINDERS

John S. Newman and Conrad V. Chester

The purpose of this appendix is to illustrate how well-founded principles of heat and mass transfer can be used to estimate the cooling characteristics of wet cylinders and thereby provide a basis for the study of the cooling of people as this problem might be related to the ventilation requirements of blast shelters. This work is thus related to that on the physiological response of people and to that on the heat capacity of shelter walls.

This section shows the importance of the wet bulb temperature of the ambient air in the case of forced convection. Account should possibly also be taken of the heat transfer by radiation from people to the shelter walls. The commonly used "effective temperature" could probably be elucidated by consideration of the total heat transfer by radiation and natural convection for a given skin temperature.

3.4.1 Forced Convection

Consider a cylinder of diameter D and length L oriented perpendicular to a uniform stream of air having a speed v_∞ far from the cylinder. The air is further characterized by its dry bulb temperature T_∞ and its wet bulb temperature T_W. The surface of the cylinder is assumed to be wet with water at the temperature T_0. As a consequence of these conditions, there will be a convective heat transfer rate Q_1 from the cylinder to the air due to the temperature difference $T_0 - T_\infty$, and a rate of evaporation W due to the fact that the concentration of water vapor in the air very near the cylinder is higher than that in the approaching air. These processes will require a heat transfer rate Q_s from the interior of the cylinder to the surface:

$$Q_s = Q_1 + \lambda W , \qquad \text{(A-1)}$$

where λ is the heat of vaporization. It is the heat Q_s which represents the energy dissipation of a man.

The quantities Q_1 and W can be related to the driving forces for heat and mass transfer and to the velocity v_∞ (see, for example, Bird, Stewart, and Lightfoot, Transport Phenomena, 1960, pp 408 and 646). By inserting numerical values for the Prandtl number of air, the Schmidt number for an air-water mixture, the latent heat of vaporization of water, and the heat capacity of air and by making use of vapor pressure data for water, one obtains

$$Q_2 = B\rho DLv_\infty \hat{C}_p(T_o - T_w)(\nu/Dv_\infty)^{0.452} \quad , \qquad \text{(A-2)}$$

where

ρ = the density of air,

$\hat{C}_p$ = the heat capacity of air per unit mass,

ν = the kinematic viscosity of air,

B = a dimensionless coefficient which depends on $T_o - T_w$ as follows:

$T_o - T_w$ (°F)	B
-5	10.95
0	10.25
10	9.17
20	8.30
30	7.51

In calculating the mole fraction of water vapor from the vapor pressures, it was assumed that the atmospheric pressure was 760 mm Hg.

Figure A-1 expresses the results of formula (A-2) for the following conditions:

$\rho = 0.0712$ lb/ft^3 $\qquad \hat{C}_p = 0.241$ Btu/lb-°F

D = 1.2 ft $\qquad \nu = 0.17$ cm^2/sec

L = 5 ft

The horizontal lines indicate the approximate rate of heat loss by natural convection alone (see below). Figure A-2 facilitates the conversion of relative humidities to wet bulb temperatures.

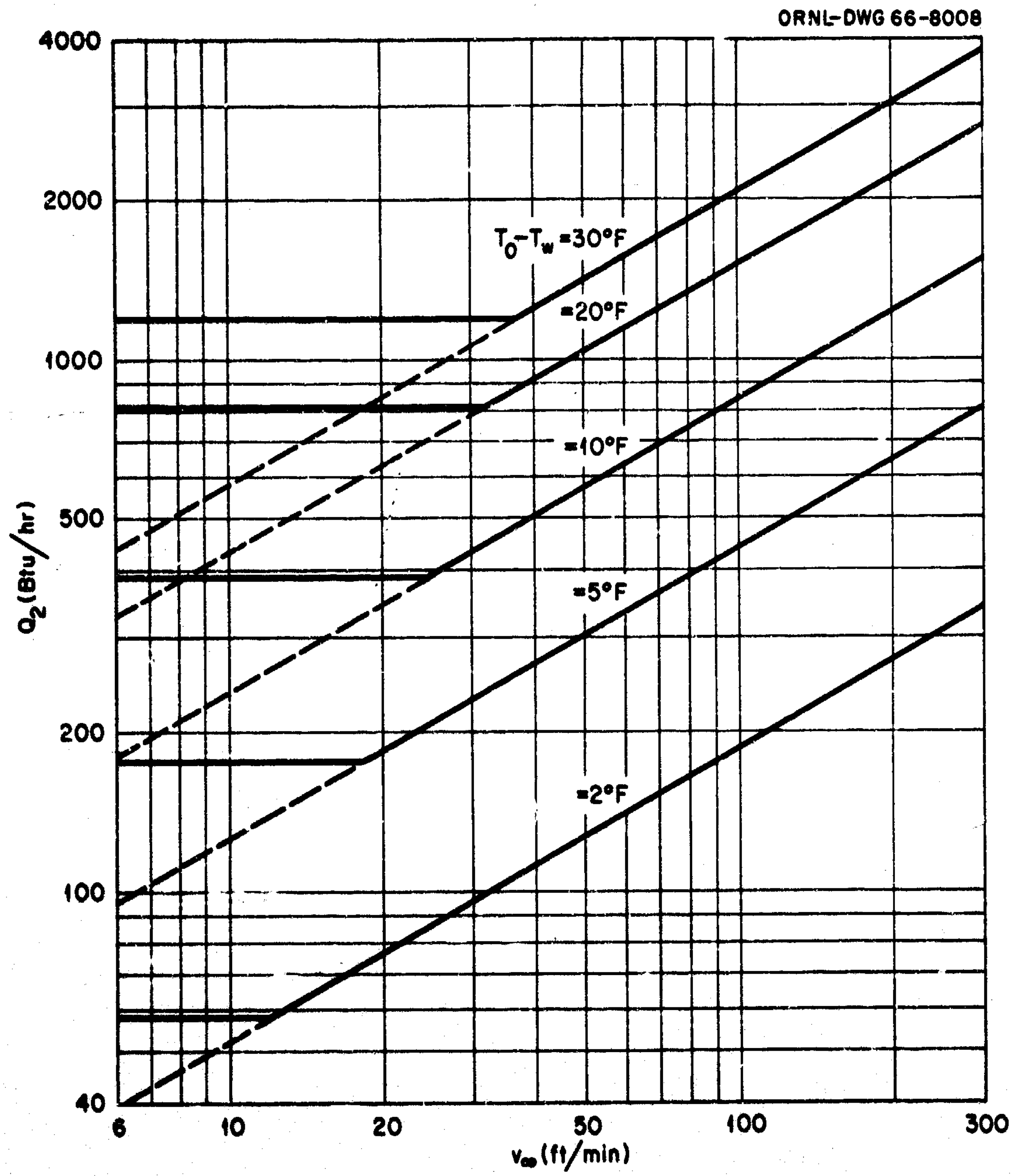

Fig. A-1. Heat Loss from a Cylinder by Evaporation and Convection (Cylinder 5 ft long by 1.2 ft diam).

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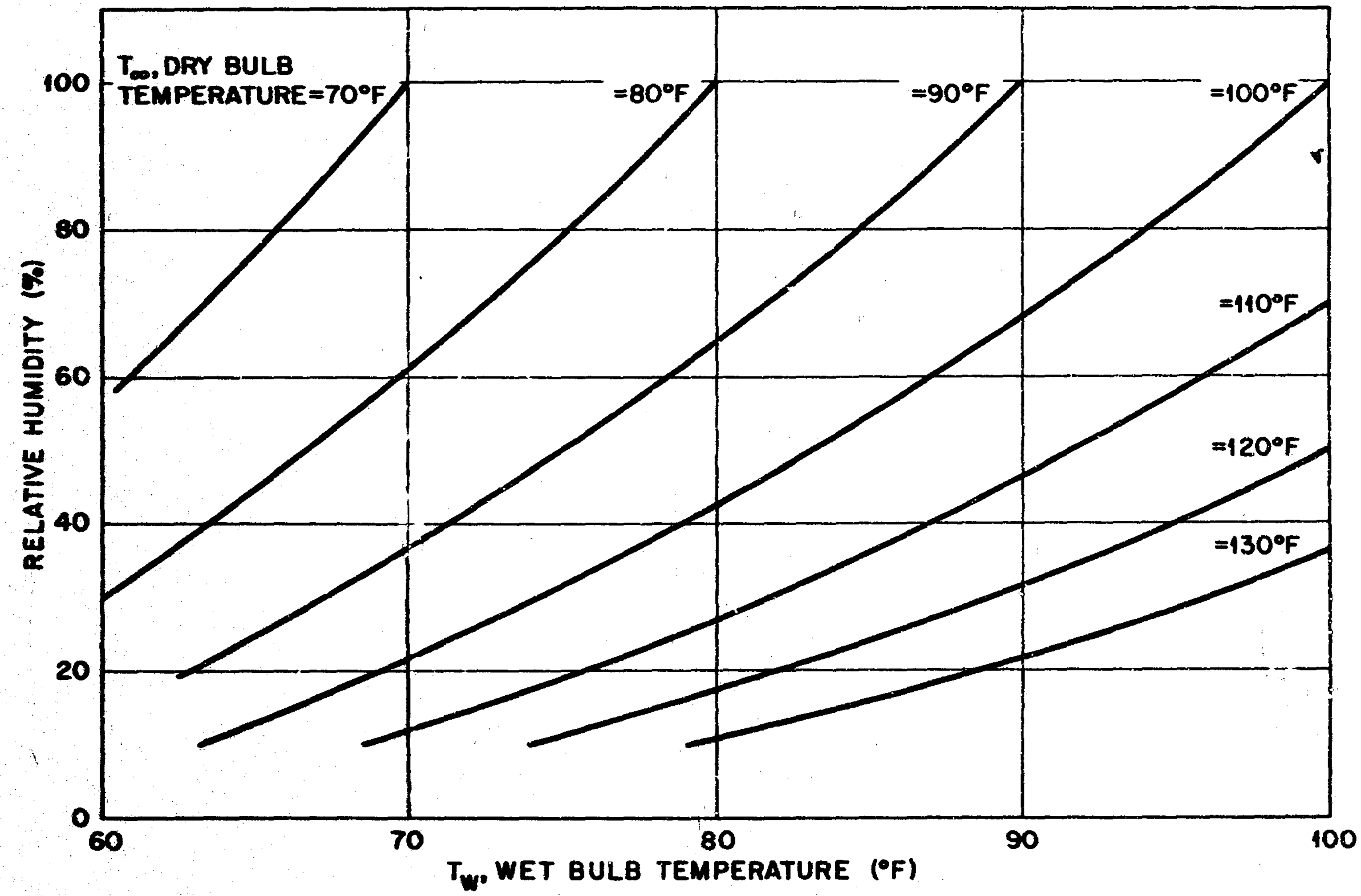

Fig. A-2. Conversion Chart for Humidity.

3.4.2 Velocity Distribution Near a Cylinder

The question of the velocity distribution near a man's skin arises when talking about cooling people by forced convection. If we approximate a man by a series of cylindrical sections of diameters equal to those of arms, legs, and torso, and assume that the skin is smooth and free of hair, hydrodynamic theory can provide a description of the velocity profiles near the skin.

If the free stream velocity at some distance from a cylinder is v_∞, the velocity just outside the boundary layer is given by

$$U(x) = 2v_\infty \sin \frac{x}{R} ,$$

where x is the distance parallel to the wind direction, and R is the radius of the cylinder.

The boundary layer is a film of air close to the skin retarded by viscous friction with the skin. It is usually less than 1/10 of an inch thick for velocities of interest around human-sized objects. The velocity distribution in this layer is shown in Fig. A-3. It can be seen that at distances of the order of twice the radius divided by the square root of the Reynolds number, the velocity is very close to the potential flow velocity.

For this reason, it is recommended that flow measurements in the boundary layer not be attempted, and that all data be correlated with the free stream velocity measured two or three radii from the cylindrical portion of interest of the test subject. The potential velocity can be measured just outside the boundary layer, and the corresponding free stream velocity can be calculated for use in the correlations.

3.4.3 Free Convection

For free convection the driving force for air motion is the difference in density between the air near the cylinder and the ambient air. This density difference is due to the combined effect of a temperature difference and a difference in the amount of water vapor in the air. For free convection to horizontal cylinders, one obtains (see, for example, Bird, Stewart, and Lightfoot, p 413)

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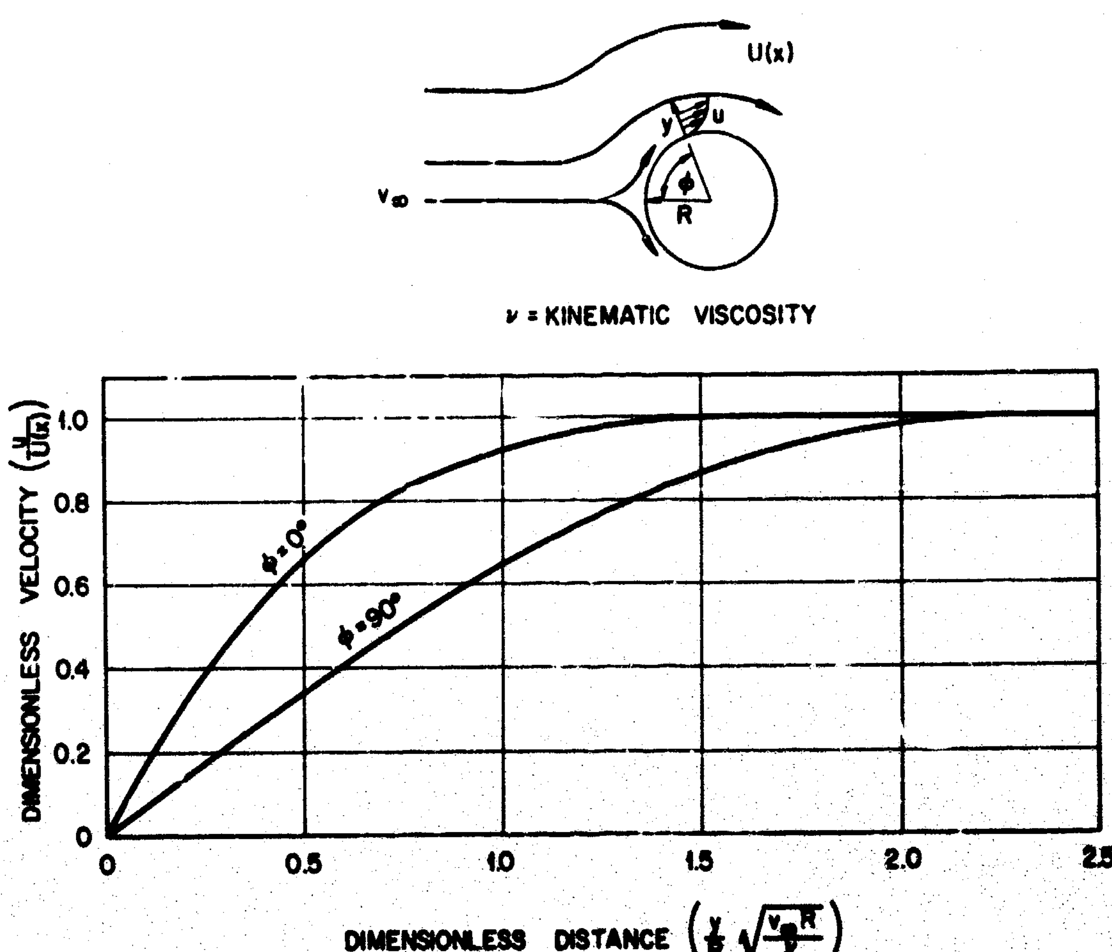

Fig. A-3. Velocity Distribution Around a Cylinder.

$$Q_s = 0.0887\ BLk\ (T_o - T_w)\left(\frac{D^3 g}{\nu^2}\right)^{1/4} \left[B\ (T_o - T_w) + 19.8\ (T_o - T_\infty)\right]^{1/4}, \tag{A-3}$$

where k is the thermal conductivity of air, and g is the gravitational acceleration.

In Fig. A-4, Q_s is plotted against $T_o - T_w$ with $T_o - T_\infty$ as a parameter. For this graph $k = 0.0154$ Btu/hr-ft-°F, $g = 980$ cm/sec^2, and the other parameters have their previous values. The dip in the curve for $T_o - T_\infty = -5$°F corresponds to the point at which the density of the air near the cylinder is equal to the density of the ambient air.

3.4.4 Evaporation Rate

The evaporation rate is

$$W = (Q_s - Q_1)/\lambda \ .$$

For forced convection

$$W = \frac{Q_s}{\lambda} - \frac{1.625}{\lambda}\ \rho D L v_\infty\ \hat{C}_p\ (T_o - T_\infty)(\nu / D v_\infty)^{0.452} \ .$$

If $Q_s = 400$ Btu/hr and $v_\infty = 50$ ft/min, then $T_o - T_w = 7$°F according to Fig. A-1. If $T_o - T_\infty = 5$°F, then $Q_1 = 51$ Btu/hr, and evaporation accounts for 349 Btu/hr. If, on the other hand, $T_o - T_\infty = -5$°F, then $Q_1 = -51$ Btu/hr, and evaporation needs to account for 451 Btu/hr.

An evaporation rate of $\lambda W = 400$ Btu/hr corresponds to $W = 4.4$ qt/day.

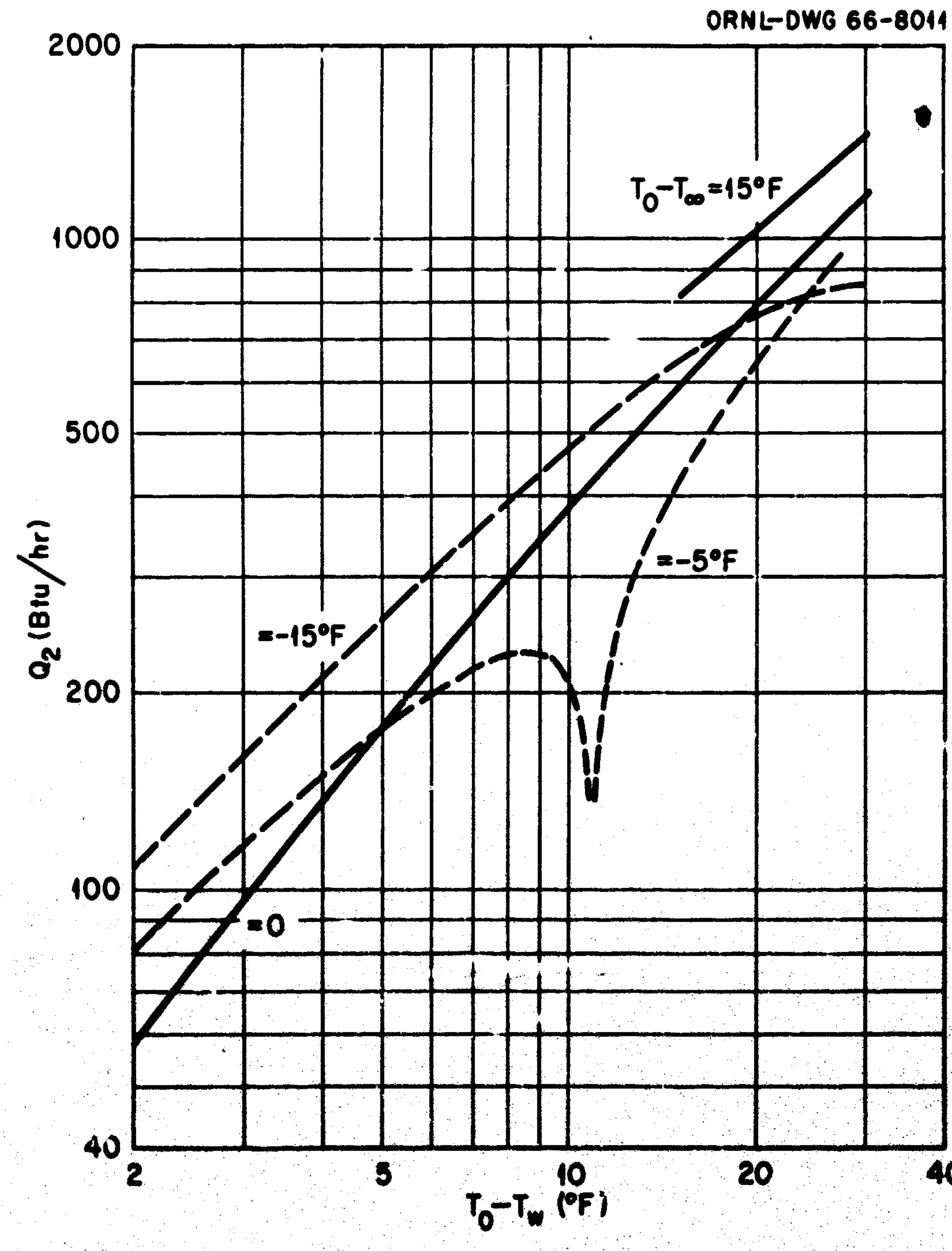

Fig. A-4. Evaporative Heat Loss by Free Convection for a Horizontal Cylinder 5 ft Long by 1.2 ft Diam.

3.5 APPENDIX B. TEMPERATURE RISE IN SHELTERS

John S. Newman

The accompanying psychrometric chart (Fig. B-1) shows the relationship between the temperatures of the air entering and leaving a shelter. In order to distinguish these lines, their end points are recorded as follows:

Line Designation	Inlet Temperatures		Outlet Temperatures	
	Wet Bulb	Dry Bulb	Wet Bulb	Dry Bulb
A	31.9	49.1	65	65
B	39	61.2	85	85
C	50.2	84.3	85	90
D	57.6	102.8	85	95
E	63	117.1	85	100
F	73	149	90	100

Notice that for lines D, E, and F the air is cooled by the evaporation of water from the inhabitants. Under these conditions, heat flows both from the air and from within the shelterees to the water film.

The inlet and outlet air conditions for a shelter should lie along one of these lines. The distance between these points along such a line is determined by the heat load. If this is expressed as $Q_s/\rho V$, where Q_s is the total metabolic heat load, ρ is the density of air, and V is the volume flow rate of air, then one can use the enthalpy lines already on the psychrometric chart. If, for example,

$$Q_s = 400 \text{ Btu/hr-person},$$
$$\rho = 0.0712 \text{ lb/ft}^3,$$
$$V = 15 \text{ ft}^3\text{/min-person},$$

then the heat added to the air is

$$\frac{Q_s}{\rho V} = \frac{400}{0.0712 \times 15} \frac{1}{60} = 6.25 \text{ Btu/lb} .$$

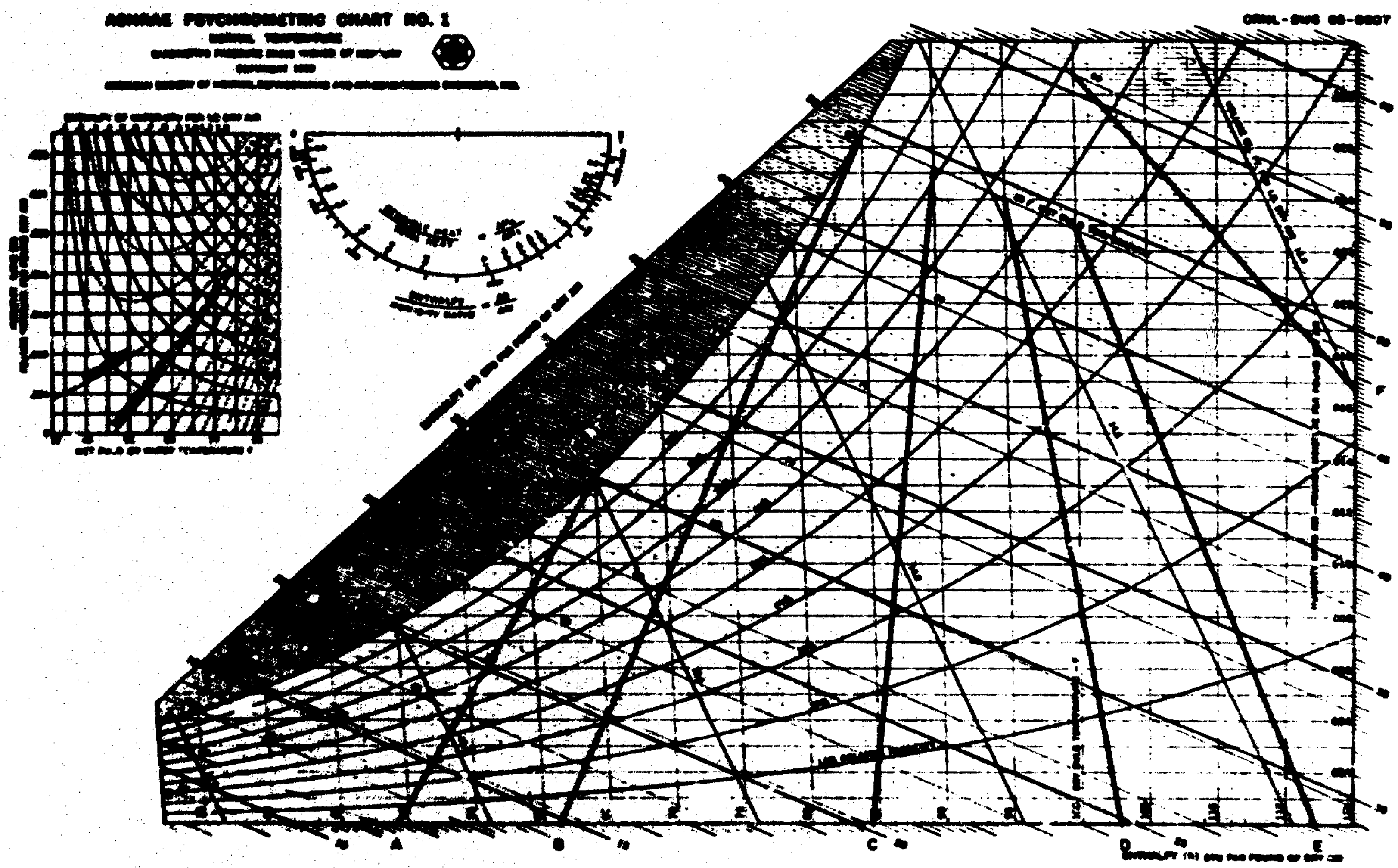

Fig. B-1. Change of Temperature and Moisture Content of Air As It Passes Through a Personnel Shelter. If the inlet air lies on one of the lines A, B, C, D, E, or F, then the outlet air should also lie on the same line at a distance which depends on the heat load released by the people divided by the air flow rate.

If the inlet conditions for this shelter were 80°F dry bulb and 60% relative humidity, one would estimate the outlet conditions to be 82.8°F dry bulb and 76% relative humidity.

The lines on the chart are based on the following assumptions:

1. No heat is transferred to the wall of the shelter,

2. The distribution of the heat load between evaporative cooling and convective heat transfer is the same as that for wet cylinders under conditions of forced convection (see Appendix A),

3. The outlet conditions prevail throughout the shelter,

4. The skin temperature is 92°F.

The second assumption, that the people are wet, should be in error at low temperatures where the physiological response reduces the perspiration rate. The slope of the lines should then be less.

4. STATUS OF PUNKAH-PUMP TESTS AT FORT BELVOIR

C. H. Kearny

4.1 INTRODUCTION

As part of the continuing studies of shelter habitability of the Office of Civil Defense and the U. S. Army Corps of Engineers, during 1965 tests of punkah-pumps[1] were conducted at the Protective Structures Development Center (PSDC), Fort Belvoir, Virginia. Most models of the PSDC punkah-pump tested were made at ORNL. The performance figures from some of these Belvoir tests illustrate the operating characteristics of punkah-pumps used as the primary means of supplying air to a shelter. This chapter contains a summary of preliminary data on several significant test results (reproduced here through the courtesy of J. O. Buchanan, Office of Civil Defense); final results, which may alter the preliminary data described here, will be contained in the summary document being prepared by PSDC. A comprehensive OCD report[2] shows the operating characteristics of punkah-pumps used as an efficient means for distributing air within a shelter.

4.2 SUMMARY OF THE FORT BELVOIR TESTS

These PSDC tests had two objectives: (1) to measure the characteristics of a 6-ft punkah-pump used as the prime air-moving device for a shelter, moving outside air through the shelter; and (2) to test other punkah-pumps (mainly 3-ft models) as means of distributing the air throughout a shelter and reducing longitudinal temperature gradients, especially in siderooms which have only one opening.

4.2.1 The Punkah-Pump As a Prime Air Mover

A 72-x-29-in. wooden-frame punkah-pump was swung so as to operate as an exhaust pump in one of the two doorways of a basement shelter within the 1000-space shelter at PSDC. The pump was powered by a mechanical drive, which closely approximated the timing and amplitude of efficient manual operation. It was pulled at 25 cpm with a maximum angle of swing from the vertical of approximately 45°.

Pressure Drop Flow Rate Tests

At very low pressure, it was found that the punkah-pump functioned like a positive displacement pump, delivering approximately 4400 cfm (when used with baffles on both sides) over the pressure drop range of 0 to 0.2 in. of water (1 in. water gauge = 0.036 psi). The flow rate dropped rapidly for larger pressure drops and reached zero at about 0.06 in. w.g. (see Fig. 4.1).

A characteristic of most shelters in buildings is the large cross-sectional areas (with resultant very low resistances to large air flows) of the available openings such as doorways, stairwells, elevator shafts, and windows. As an example, a 30-x-72-in. passageway, 100 ft long, offers a resistance of less than 0.01 in. of water to a flow of 5000 cfm. A punkah-pump is designed to take advantage of these large available openings. In contrast, the designs of conventional fans and blowers cause these devices to force air through much smaller openings. An illustration of the magnitude of this advantage of punkah-pumps is the fact (calculated in ORNL-TM-1154)[3] that the power required to pump a given volume of air with a 100% efficient six-ft punkah-pump is only 4% of the power required to pump the same volume of air with a 100% efficient fan two ft in diameter.

To test the effect of several different resistances to air flow through the shelter at PSDC, the available opening provided in the air-inlet doorway was varied. As illustrated by Fig. 4.2, these tests showed that even when this air-inlet doorway was only one-third open (about 6.7 sq.ft. of opening), some 3000 cfm was forced through the shelter by the punkah-pump, with ΔP being 0.03 in. w.g.

Prior tests[4] of this six-ft punkah-pump--when used as an <u>intake</u> pump to ventilate the entire 5000-sq-ft. basement shelter at PSDC--showed that it can pump 3400 cfm through 25.4 sq.ft. of 1-in. fiberglass filter. This filter had a rated resistance of about 0.02 in. of water to a flow of 3400 cfm.

<u>The Utility of Baffles</u>

The pump was tested with and without vertical plywood side baffles (or "wings") fixed close to the lateral sides of the swinging punkah-

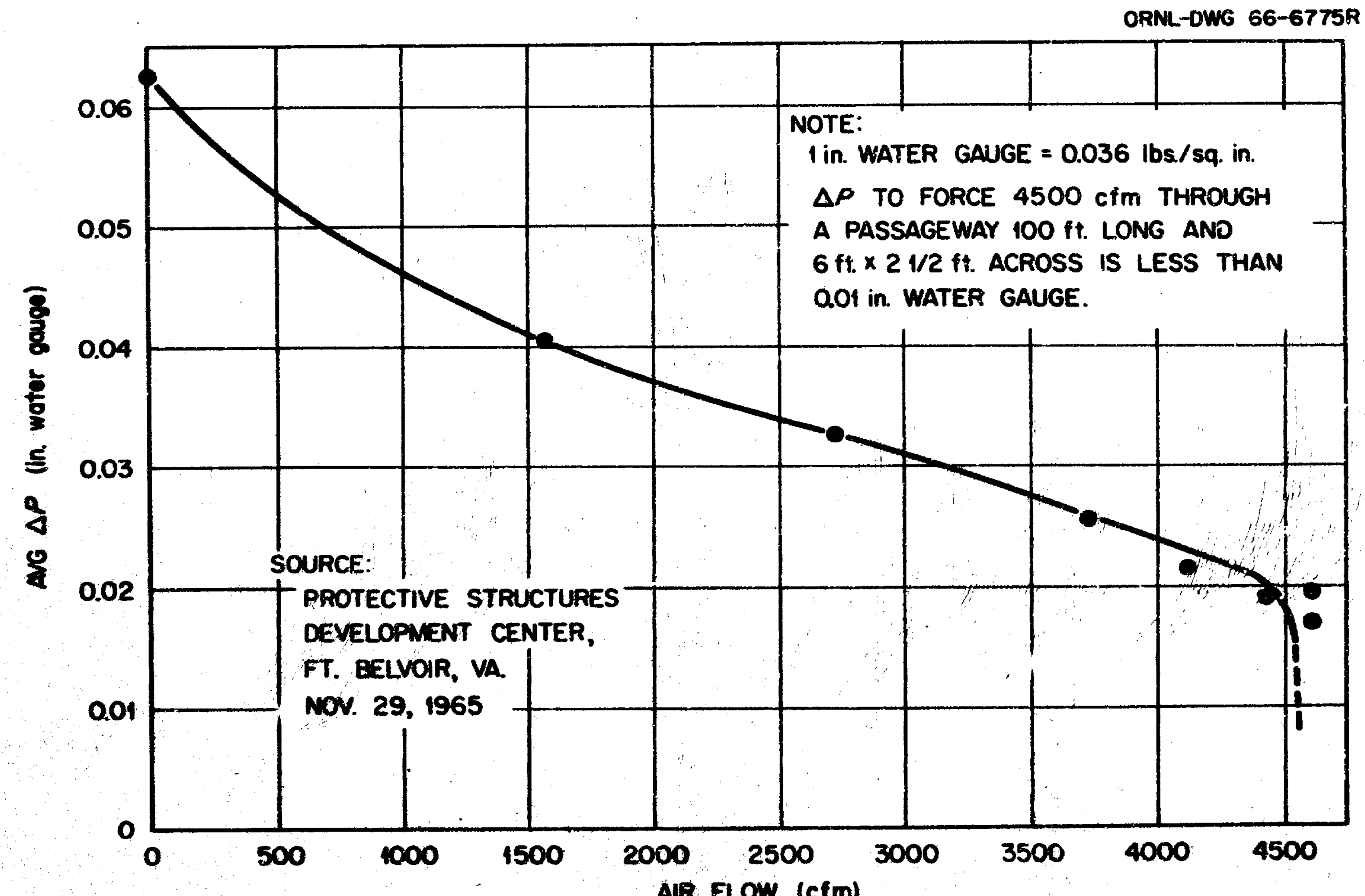

Fig. 4.1. Flow Characteristics for Variable Resistance and Constant Pumping Speed. A six-foot punkah-pump used as an exhaust pump with side baffles on both its inlet and outlet sides.

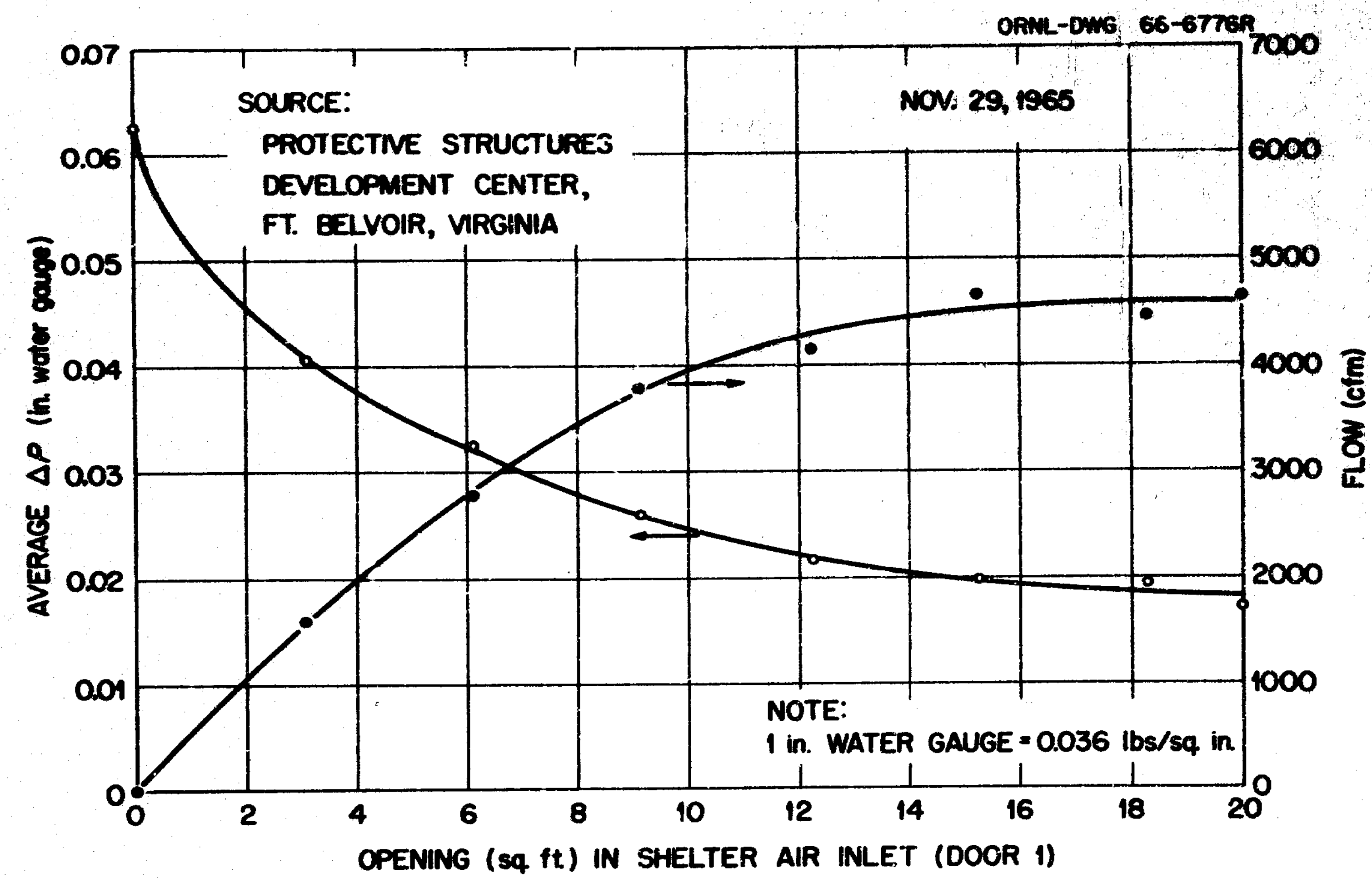

Fig. 4.2. Flow Characteristics for a Six-Foot Punkah-Pump. Used as an exhaust pump at a constant pumping speed, with side baffles on both its inlet and outlet sides. Pressure differences developed across the pump and resultant air flows shown as functions of different size openings in the remote air-inlet doorway.

pump frame and parallel to them. Side baffles on the outlet side of the pump are shown in Fig. 4.3. Such side baffles increased the pump's delivery capability but are not essential for many smaller shelters. The following flow rate data indicate the effectiveness of side baffles.

	Pressure Drop Across Pump		
	0.01-in. w.g.	0.02-in.w.g.	0.04-in. w.g.
1. cfm without any baffles	3800	3000	0
2. cfm with baffles only on inlet side	4000	3400	1200
3. cfm with baffles on both inlet and outlet sides	4400	4400	1600

Baffles become quite important in the pressure drop range of 0.02 to 0.04 in. of water. However, for many shelters in buildings adequate ventilation can be provided without baffles.

Horsepower Requirements

With side baffles on both inlet and exhaust sides, through the use of a special electronic load-sensing device developed at PSDC, it was determined that slightly less than 0.05 hp was required to pump about 4400 cfm. This is but a small fraction of the horsepower that would be required to pump an equal volume of air through this shelter using any type of conventional manual fan or blower.

Although the mechanical efficiency of a punkah-pump is of very secondary importance in evaluating its relative effectiveness for ventilating typical shelters in buildings, nevertheless it is interesting to note from the following calculation that the mechanical efficiency of the wooden-framed model tested is adequate.

$$\text{theoretical horsepower} = 0.02 \text{ in. } H_2O \times \frac{5.2 \text{ lb/sq.ft.}}{\text{in. } H_2O} \times 4400 \frac{\text{cu.ft.}}{\text{min}}$$

$$\times \frac{1 \text{ hp}}{33{,}000 \text{ ft lb/min}} = 0.014 \text{ hp}$$

$$\text{actual mechanical efficiency of pump} = \frac{0.014}{0.05} \times 100 \cong 30\% .$$

PHOTO 68489A

Fig. 4.3. A Six-Foot Punkah-Pump Undergoing a Successful 1000-hr Mechanical Durability Test,[4] Showing the Flap-Valves Open During the Return Swing.

The Effect of Natural Air Flow on Punkah-Pump Utilization

If a low-pressure pump were inflexibly installed, changes in natural air flow directions such as those caused by a change in outside wind direction or a chimney effect could decrease pump effectiveness. Two possible solutions exist for such problems. If the pump were used to move air into a shelter, it could be disconnected and reconnected to an exhaust opening if a wind direction change made the exhaust point a preferable supply point. More practically, the pump could be reversed at its original site and used to move the ventilation air in the opposite direction. A special problem may be encountered in such a change. If the operator must remain in the original position (for example, if air were to be exhausted to an elevator shaft), the original pull-cord would have to be replaced by a light push-pole or stick. A strap and cord lashing similar to that used on sleds seems to be the most promising improvised connection. With such a push-pole, the pump can easily be operated by pushing on the power stroke and pulling on the return stroke, with the operator's hands holding the free end of the stick.

4.3 CONCLUSIONS AND RECOMMENDATIONS

1. These recent PSDC performance tests of a punkah-pump used as the primary pump to supply air to a shelter show that one man operating this simple device can force several times as much air through a typical basement shelter as can one man using any conventional manually powered ventilating pump.

2. It appears very likely that a production model punkah-pump would cost much less than any conventional manually powered ventilating pump capable of delivering as much air.

3. Therefore, it appears desirable to conduct practical tests of production model punkah-pumps designed to be operated by push-poles as well as by pull-cords. Such tests advantageously could involve average citizens using punkah-pumps to ventilate typical basement shelters, while during the same tests they also would use other promising shelter-ventilating devices capable of being employed either as intake or as exhaust pumps.

4.4 BIBLIOGRAPHY

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III. SOCIOLOGICAL ASPECTS OF CIVIL DEFENSE

6. STRATEGIC INTERACTION

Davis B. Bobrow

6.1 INTRODUCTION

The project deals with the use of political and psychological variables to estimate the differences in the strategic impact of alternative American continental defense postures. The members of a working group drawn from a number of behavioral science specialties have applied their knowledge to arrive at conclusions based on current knowledge, to isolate information gaps, and to assign priorities to future research possibilities.

6.2 PROBLEM HISTORY

This project derives from a number of observations about the evaluation, selection,and presentation of American weapons systems. The first was that these steps in the weapons adoption process are not made solely on the basis of technological performance and dollar cost expectations. They also involve expectations about the responses of foreign elites and the American public--anticipations often derived from implicit, private models of the nature of foreign elite and American public perceptions and interpretations of American elite actions and words. The second observation was that the cost-effectiveness analyses currently central to weapons system evaluation are extremely sensitive to the political and psychological assumptions involved in many of their parameters. It follows that many of the analyses provide useful information only to the extent that these parameters approximate reality. The third observation was that different foreign elites and elements of the American public do not perceive or process the stimuli of U.S. weapons decisions identically. For example, they differ in the extent to which they view our actions as helpful or hostile and in the historical experience on which they draw to clarify present phenomena.

These differences involve political and psychological factors, even if to no greater extent than assigning utilities to different levels of technological performance and currency cost.

The fourth observation was that currently available information on the political and psychological factors germane to weapons system evaluation, selection, and presentation tends to be expressed with sufficient looseness to make its analytic manipulation difficult and, given the absence of testable models, predictions, and solid data, tends to be treated as if lacking in credibility. That is, political and psychological inputs to the weapons system decision process tend to be viewed as matters of "judgment" or "experience" in which one seasoned man's word is no better than that of another. Our fifth and final observation was that there is no clear agreement in the behavioral sciences on what is the most useful theory, method, or data to use in evaluating the political and psychological factors germane for decisions on U. S. defense postures.

These observations led to a series of assumptions about policy research requirements. The first and second observations led us to conclude that research was seriously needed to begin constructing explicit and systematic public models of the nature of major foreign governments, the American public, the American defense community, and international relations. The important policy implication of such models is to confront public and private models and to make explicit the political and psychological assumptions involved in the parameters of cost-effectiveness analyses. This does not mean that the behavioral sciences must or can now generate algorithms to improve the weapons acquisition process. It does mean that they should and can now work toward more explicit and fruitful heuristics for this process.

The third observation led us to conclude that research was needed on the attributes of the different important audiences for U. S. weapons systems decisions. By important, we mean audiences whose responses significantly affect the costs and gains of particular weapons systems decisions. Since the time futures involved in modern weapons systems are long, it was clear that research would have to be in terms of audience attributes germane throughout the period from adoption decision to deployment. The fourth observation led us to conclude that inputs about political and psychological factors would have policy utility to the extent that they were more than matters of opinion, i.e., could be tested and confirmed or disconfirmed. This conclusion does not confine the realm of useful work to quantified analyses; it also includes psychologic paradigms which can be tested.

We can summarize the policy research needs stated thus far as an answer to one of the four questions which Alain Enthoven places in the province of the defense analyst. His question is: "What does the decision-maker need to know?" Our answer is that he needs, among others, to understand his own political and psychological processes and those of his different audiences which are germane to the evaluation, selection, and presentation of weapons systems. The second part of this answer is that he needs to know about these factors in forms subject to manipulation and confirmation.

Our fifth observation led us to two conclusions. First, initially the research would have to involve alternative theories, methods, and data. Second, for the utility of these alternative approaches to be evaluated and for their findings to satisfy the requirement derived from the fourth observation, they would have to be conducted according to a common set of criteria. We selected the criteria of: (1) explicit relevance to the weapons system evaluation, selection, and presentation issues under consideration; (2) testability of findings; and (3) foreclosure of the largest possible number of specific inquiries. The sense of the latter criterion is similar to the concept of "strong inference" stated by John Platt.[1]

Three attributes of active/passive defense hardware implied research directions supplementary to those above. First, on purely technological dimensions, members of this hardware class differ from major current deterrence systems in that they operate to prevent damage to self rather than to inflict damage on others. Second, passive defense is unique among nuclear war systems in the extent to which it impinges on the public. Third, the military need for these systems depends on the extent to which punishment systems are or are not anticipated to deter nuclear attack, in a series of situations through time. These attributes implied research requirements, but ones more specific than implied by the first set of observations.

Although excellent work (e.g., Project Michelson) has been done on the political and psychological characteristics of deterrence by means of punishment systems, the first attribute of active/passive defense systems implied that we could not automatically apply this work to damage-limiting systems. The extent and nature of symmetry between the two hardware classes is unknown and a critical inquiry area. The second attribute implied that the American public response significantly affects the credibility of any U. S. passive defense hardware to American and foreign elites. Thus, the American public cannot be treated as a relatively minor actor in the evaluation, selection, and presentation of passive defense systems even if these comprise a relatively small part of our total continental defense inventory. The third attribute implied that active/passive defense systems cannot be evaluated independently of determining the extent to which foreign governments are adequately deterred by U. S. offensive weapons.

6.3 PROBLEM PROGRESS

The working group has consisted of individuals whose disciplinary affiliations include anthropology, political science, psychiatry and social psychology, and whose technical skills include content analysis, simulation, survey interview analysis, area studies and non-directive interviewing. It was assumed that: (1) each group member would use his particular theoretical, methodological, and/or regional skills to prepare a paper; (2) the project resources would confine the authors to reanalysis of available data and theory or to spin-offs from work in which they were already engaged; (3) the group would work within the perspective summarized in the preceding section of this report; and (4) to the extent possible, the members would try to compare the political and psychological implications of four hypothetical active/passive defense postures at two points in time--adoption announcement and operational deployment. The postures, summarized in the Appendix, were basically those of: unilateral public freeze and arms reduction proposals (I); de facto freeze (II); moderate

ABM increments without civilian involvement in passive defense (III); and massive active and passive defense buildup, including extensive civilian involvement (IV).

The rest of this report states examples of research conclusions and implications, organized in analytic rather than individual paper units.* As this organization suggests, the following examples derive from the papers but are not direct statements of individual authors or statements submitted for group approval. To a degree which specific papers make explicit, the policy implications represent inferences which have yet to be tested. The following examples are organized in terms of: (1) rules, which are not country, weapons system, or situation-specific, about the effects of basic variable positions on policy responses; (2) reviews of analogous historical and artificial universes; (3) work on establishing the political and psychological parameters of important strategic actor responses to alternative postures; and (4) lists of research priorities and research design ideas.

6.3.1 General Rules

6.3.1.1 The extent to which an increase in defensive weapons will be perceived and responded to as different from an increase in offensive (i.e., punishing) weapons by American and foreign elites is a function of differences in context, time, source, and cued response.

This rule states that foreign and American governments will perceive U. S. continental protection decisions as distinct from strategic offensive and limited-war forces to the extent that they are (a) adopted and deployed in situations different from those in which we have tended to acquire the latter two types of military capability; (b) distinct in time from acquiring and using offensive military capabilities; (c) distinct in organizational location from organizations which control offensive defense systems, especially attack missiles; and (d) distinct in responses cued by the American government for foreign governments from those frequently cued for offensive increments. An example of this last point is: to the extent that the American government tends to suggest responses for foreign governments

*The individual papers and a compendium of major conclusions and policy implications will be publicly available in the near future.

other than compensatory force increases or accepting increased military inferiority, the foreign government will tend to perceive a continental protection increment as distinct in meaning from an offensive increment. Obviously, all of the above distinctions operate only to the extent that they are perceived by the foreign audience.

6.3.1.2 A decrease or freeze in defensive capabilities will be responded to or interpreted as indicative of positive, or neutral, intent to the extent that it is reinforced sufficiently to counteract established beliefs about hostile intent.

The implications of rule 6.3.1.1 refer to continental protection postures III and IV; those of rule 6.3.1.2, to postures I and II. If an active/passive defense cutback or freeze is to have tension-reducing or stabilizing consequences, this rule implies that it should occur in a context of: (a) a set of salient policies which indicate friendly or neutral intent to specific governments; (b) authoritative communications that indicate that the freeze or cutback involves continental defense systems of real value; and (c) decisions to maintain the posture for a period of time sufficient to imply commitment to it.

These three types of behaviors, as positive reinforcements for the initial stimulus, are essential if the stimulus is to be received by usually suspicious foreign governments as genuinely friendly or neutral in intent.

6.3.2 Analogous Universes

6.3.2.1 The adverse effects which were predicted for active/passive defense increments in the first forty years of this century were not realized and resemble those effects predicted for currently envisioned increments.

Several implications of this statement are too complicated to develop properly in a report of this length. The obvious one which can be easily stated is that current predictions about effects (adverse or positive) of continental protection systems may not be a function of attributes of the hardware or contemporary strategic situation. During this historical period, different attitudes about active/passive defense seemed to correlate with different general attitudes about war and peace, which suggests that the source of anticipated consequences of continental protection may bear little relation to continental protection *per se*.

6.3.2.2 Since city-walls were almost universally present in civilized, but preindustrial, societies, this indicator of passive defense is not appropriate for determining historical relationships between level of passive defense and domestic or external attributes and events.

Presence of passive defense hardware (primarily city-walls for this historical universe) does not explain variation in either domestic attributes, e.g., information flows, or external events, e.g., aggression against hostile powers. The orientation of the political unit's national security posture (relative emphasis on defense or offense) seems to be a more promising avenue for clarifying variations of these kinds. This tentative result does not demonstrate that currently proposed active/passive defense hardware would not observably affect our domestic climate and international success. However, it does suggest that evaluations of these weapons system effects which abstract them from possible policy environments artifically magnify their consequences for our domestic and international affairs.

6.3.2.3 Inter-nation simulations suggest that: (a) gradual increments in defensive systems do not increase the incidence of war; (b) rapid increments are correlated with increased number of wars in 50% of the cases and not correlated in 50%; and (c) the level of active/passive defense is positively correlated with escalation of wars that do occur.

These conclusions are particularly germane to postures III and IV. The variance in result (b) could not be explained. Since it relates to an important question, it would be fruitful to pursue the problem. Conclusions (a) and (c) imply: since gradual defense increments do not in themselves increase the probabilities of war, any adoption and deployment programs should be staged over considerable time periods; and rapid increments in continental protection should be associated with controls to damp escalation.

6.3.3 Current Actors

6.3.3.1 Soviet leaders are unwilling to bargain for or participate in a cutback or freeze on active/passive homeland defense. They do not seem to regard passive defense or a few-city deployment of active defense as threatening, and they perceive U. S. continental defense increments as significantly less threatening than increments in offensive systems.

The first sentence is germane to postures I and II; the second sentence, to postures III and IV. The implications of these conclusions for these postures are (a) postures I and II will probably not be reciprocated by the Soviets; (b) posture III probably will not affect Soviet military policy significantly; and (c) the Soviets may view even posture IV positively if the funds for it are diverted from offensive systems. These implications assume that any of the continental protection postures are not announced or deployed in a tense international period.

6.3.3.2 Chinese Communist leaders perceive U. S. continental protection alternatives as essentially irrelevant to their strategy of "people's wars of liberation" and to the uses to which they plan to put their nuclear capability in the next decade.

Thus, American officials should not evaluate continental defense postures in terms of altering "the challenge" which Communist China will pose or of intersecting military actions which the Chinese will tend to take. Active/passive defense of our territory cannot effectively counter the Chinese support of sub-limited and mobile warfare by proxies and the use of CPR nuclear weapons for regional leverage.

6.3.3.3 French elite attitudes indicate that American defensive increments would not basically affect French support for an Atlantic alliance or commitments to nuclear autonomy.

This conclusion suggests that the relationship of American continental vulnerability to the "credibility" of the American nuclear umbrella is a paper issue, that our continental defense posture will not directly affect our relations with France, and that the costs and gains of alternative postures should thus be determined exclusive of France.

6.3.4 Future Research

6.3.4.1 Research priorities. The following list of priorities does not specify the more promising methodologies:

(a) more refined analyses of Soviet and Chinese responses in situations of different international tension levels and sets of actors;

(b) analyses of the responses of major friendly European (particularly British and German) and Asian (particularly Indian and Japanese) governments to:

  (i) unilateral increments in U.S. continental defense;

  (ii) military assistance in the form of defensive systems;

(c) developing replicable quantitative procedures to monitor changes in foreign elite perceptions of U. S. continental protection decisions between the time of announcing the decision and operational deployment;

(d) exploring the intersections between the probable damage-limiting effects of different active/passive defense postures and the utility of conflict curves employed by American officials; and

(e) analyses which clarify the relationships between American public criticism of alternative continental protection postures and the sources and costs of these alternatives.

6.3.4.2 Example of ideas for future projects, suggested by individual authors. The following brief example is an idea for researching the last (e) research priority. The study would be concerned with selected groups of influentials and opinion leaders to determine:

(a) the extent to which they respond to source rather than content of communications about continental defense;

(b) how and the extent to which differences in attitudes toward and information about personal, national, and international affairs affect their responses to these communications; and

(c) their tendencies to respond to communications with a variety of public behaviors.

Such a study should begin to clarify: the extent to which the nongovernmental response is a function of the identity of authorities who support and oppose the policies; the nature and influence of other attitudes and information which affect reactions to policies; and the probable pattern of nongovernmental actions, which obviously affect the credibility of the policy to foreign governments and its costs and gains for American officials.

6.4 FORTHCOMING PAPERS

The following papers will become available in the next few months. The first paper states the policy implications of the others.

1. D. B. Bobrow - Consequences of Alternative Active/Passive Defense Postures: First-Order Conclusions

General Rules

2. P. Ratoosh - Defense Decision-Making: Cost-Effectiveness Models and Rationality

3. R. North - A Partial Theory and Hypotheses Concerning Active and Passive Defense Systems and the Types of Response They Seem Likely to Evoke

Analagous Universes

4. G. Quester - Historical Analogies to the Problem of Active and Passive Defense

5. R. Naroll - A Possible Cross-Historical Survey of Active and Passive Defense

6. J. Raser - Studying Effects of Continental Defense Through Simulation

Major Current Actors

7. E. Hartley - Prediction of American Public Response to a Damage-Limiting Program

8. M. Gorden - A Cost/Benefit Analysis of French Elite Attitudinal Response To American Active and Passive Defense Systems

9. D. Bobrow - Chinese Communist Response to Alternative U. S. Active and Passive Defense Postures

10. J. Thomas - Soviet Perspectives on Active and Passive Defense

11. R. White - The Genuineness of Soviet Elite Fear of American Aggression

12. B. Wedge - Estimation of Soviet Response to Alternative U. S. Defense Postures

6.5 APPENDIX

6.5.1 Hypothetical Alternative Active and Passive Defense Postures

The following postures are in order of increasing technological capability and dollar cost.

6.5.1.1 Arms Reduction Toward Complete Vulnerability

The U. S. government undertakes to freeze its active and passive defense but to continue research on such systems. We offer to participate in a staged reduction of existing active defense (the SAGE system, airplane interceptors, radar warning networks and antisubmarine patrols) and passive defense (remove shelter signs, stockpiles, warning sirens, etc.). The freeze is unilateral; the reduction, multilateral. Inspection is a condition for reduction. This posture tends to decrease expenditures on active and passive defense.

6.5.1.2 Status Quo

Without formal announcement, the U.S. government in effect stands pat and maintains the present system of defense against bomber and submarine delivered attack with no significant antimissile capability. Passive defense continues along present lines which means, in effect, fallout shelters concentrated at the center of major cities (countervalue targets). Rural areas have few shelters as do areas near counterforce targets which are also countervalue targets. The population does not engage in passive defense drills nor do the shelters contain more than austere two-week supply kits. Expenditures are on the order of $2 billion per year.

6.5.1.2 Build Up for "Light" Attacks

Both active and passive defense are expanded with the bulk of increased expenditure going into an area defense system of antimissile missiles. The missiles would primarily be of a high-altitude character. The fallout shelter system would be expanded to conform to national population distributions, largely through additions of small shelters with low radiation protection factors in suburbs and rural areas. The population does not engage in passive defense drills nor do the shelters contain more than austere two-week supply kits. Expenditures would be on the order of $25 billion over a five-year period.

6.5.1.3 Build Up for Maximum Protection

Extensive and expensive changes are scheduled in both active and passive defense hardware. In the former, existing air defense is upgraded through improvements in command and control; area defense anti-missile missiles are accompanied by Nike-X protection for fifty of our most important cities (i.e., high-altitude and low-altitude missiles), antisubmarine detection systems are strengthened and accompanied by a continuous air surveillance of nearby waters and a capability to deal with low trajectory submarine-launched missiles. The full-fallout-shelter program mentioned in the previous posture is accompanied by a connected system of blast shelters in fifty of our most important cities. The population becomes familiar with these blast shelters through peacetime use and occasional drills. The shelters are stocked for 30-day occupancy and with some supplies for immediate recovery activities. Expenditures would be on the order of $50 billion over a five-year period.

6.6 BIBLIOGRAPHY

1. John Platt, "On Strong Inference," Science, vol. 146, No. 3642, Oct. 16, 1964, pp. 347-353.

7. DYNAMICS OF AMERICAN NATIONAL SECURITY ATTITUDES*

Davis B. Bobrow

7.1 INTRODUCTION

This project investigates the dynamics of American national security attitudes by means of secondary analysis of over one hundred national surveys conducted since the use of atomic weapons against Japan. This report deals with the reasons for the project and the tasks completed in transforming the old surveys into a working data base. The analysis we plan for the future will implement and test the reasoning presented in the problem history section of this report.**

7.2 PROBLEM HISTORY

The fruitfulness of this project depends on the assumptions that: (1) American national security attitudes are relevant to U.S. defense policy; (2) certain types of analyses of U.S. national security attitudes are particularly powerful for evaluating, selecting, and implementing defense policies; and (3) previous public opinion surveys are appropriate data sources for these analyses. Each assumption is discussed in more detail in the following sections.

American national security attitudes are relevant to U.S. defense policy. In this project "American" attitudes refer to those of the general public, not to those of government officials or influentials outside the national government. We assume that general public attitudes are germane to defense policy in those situations when:

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*For a more extensive discussion of the points made in this report and a bibliography of especially relevant technical literature, see my "International Interactions, Surveys and Computers," presented at the Computers and the Policy-Making Community Institute, Lawrence Radiation Laboratory, Livermore, April 4-15, 1966.

**The work reported here was done by the following in addition to the author: Douglas Bwy, Allen and Pamela Wilcox, and Eric Nordheim during the summer or 1965; Sue Berryman Bobrow and Patricia Defenderfer during the whole period covered by this report.

1. The defense policy under discussion cannot be implemented without public cooperation;
2. Public attitudes significantly affect the domestic political costs and rewards of alternative defense policies and defense announcement policies;
3. Public attitudes significantly affect international costs and rewards of alternative defense policies and defense announcement policies, in cases when foreign governments evaluate U. S. intentions and capabilities partly on the basis of U.S public responses to U.S. defense policy; and
4. Public attitudes are used as indicators of how and the extent to which physical measures to preserve the nation affect the quality of the society which they are designed to defend.

Certain types of analyses of attitudes are particularly powerful for evaluating, selecting, and implementing defense policies. Even if we assume that public national security attitudes are relevant to defense policy in the above situations, we still have to make another set of assumptions (decisions) about what we need to know about these attitudes to realize their explanatory power.

The first assumption is that interviewees respond to specific national security questions partly in terms of primitive (in the sense of fundamental) beliefs and feelings about the world and the actors in it. This assumption derives from two logically previous assumptions:

1. The concept of national security involves possibilities of deprivation and loss of control, and thinking about it thus tends to produce more emotion in the individual than some other types of national policy; and
2. National security involves actions which are quite unrelated to the personal experience, substantive knowledge, and daily concerns of many members of the public.

These two assumptions seem particularly tenable for the post-World War II decades, characterized as they are by immensely destructive possibilities, complex and rapidly changing military technologies, and world-wide American security involvements. They imply that specific questions, which seek specific opinions and are useful for researching voting and some forms of consumer behaviors, may not necessarily elicit for national security issues what casual inspection of the responses would indicate they are eliciting. When an interviewee responds to questions about issues which tend to be relatively emotion-arousing, about which he has little information, and to which he does not pay prolonged attention, it seems reasonable to suggest that his responses are less in terms of the specific question and more in terms of his primitive beliefs and feelings about the world, e.g., feelings of personal security/insecurity; efficacy/lack of efficacy. Locating the germane basic belief-emotion structures requires a generic kind of analysis, known as latent structure analysis, for which tools such as factor analysis are appropriate.

The second assumption is that interviewees respond to specific national security questions partly in terms of opinions about other specific questions not obviously germane to national security questions. For example, a 68-year-old, male respondent is asked whether he thinks his city should be ringed with anti-ballistic missiles. He responds "No, I sure don't." He may respond thus <u>not</u> because he feels that all individuals are without efficacy (i.e., can do nothing to control their fate--a primitive belief), or because he feels that missiles are technically not worth the cost (a situation-specific belief), but because he thinks that enough money is going into defense and more should go into Medicare (a belief about a specific question not automatically included in the national security domain). In this case, then, the specific national security question elicited a response, not in terms of primitive beliefs or knowledge about the specific situation involved in the question, but in terms of opinions about how the federal government should spend its money. To determine the meaning of responses of this type requires analysis of clusters, or syndromes, of specific opinions in which national security opinions might be imbedded, i.e., with which they correlate highly. Techniques appropriate to this kind of analysis are correlational in nature.

The third assumption is that many of the important relationships of public national security attitudes to the evaluation, selection, and implementation of defense policies involve questions about the stability and change of attitudes, i.e., questions about if and how different national security policies make a difference in public attitudes. Questions of this nature require two types of analyses: trend analysis of public attitudes at different points in time and sensitivity analysis of public attitudes in different contexts of international and domestic events.

The fourth assumption is that all groups of the American public, and thus their attitudes, are not equally relevant to all national security problems and policies. For example, the success of a specific national security policy may depend partly on the contribution of certain skill or sex/age groups in the population. Thus, it is the attitudes of these, and not other, groups which are germane to the policy. We need an extremely large and varied pool of respondents if we are to isolate groups of respondents according to a variety of criteria without losing statistical significance.

Previous public opinion surveys are appropriate data sources for these analyses. Essentially, this assumption involves assumptions about the fruitfulness of survey data and of data from large numbers of old surveys conducted over a significant period of time.

Fruitfulness of survey data:

1. If we are interested in the national security attitudes of the general American public, national cross-section surveys (i.e., surveys whose sampling enables their results to be extrapolated to the American population as a whole) represent the least interpreted and statistically least distorted source of public attitudes.

2. National cross-section surveys ask questions about a large variety of topics presumed relevant to the American public and thus have data appropriate for elucidating the primitive belief and opinion syndrome response sets.

Data fruitfulness of large numbers of old surveys, conducted over time and comparable in sampling frame and types of questions:

1. Although distorting artifacts of the survey method cannot be completely controlled in any single survey, these artifacts are reasonably constant across a series of surveys. Differences revealed by analyses of the series are thus probably less a function of survey artifacts than of genuine difference;

2. More complex and varied latent structure and syndrome frameworks can be constructed because of the greater range of questions and larger respondent pool provided by a series of surveys;

3. Analysis of attitude trends and of the sensitivity of attitudes to different contiguous domestic and foreign events can be conducted on a series of surveys;

4. A large range of statistically significant groups can be located in the large respondent pool of a survey series;

5. Predictions and models derived from part of the survey series can be tested on other parts; and

6. Re-analysis of a series of old surveys costs considerably less than a new national cross-section survey.

Obviously, a more sophisticated description of American national security attitude dynamics does not in itself provide more help to proponents than to opponents of a specific policy, to public officials than to private citizens. It is also obvious that analyses of old surveys are not sufficient to construct and validate predictive models of U.S. national security attitudes. However, we suggest that these analyses will represent significant progress in constructing such models and will locate those questions which have to be answered by other means, including those of new surveys using innovative techniques.

7.3 PROBLEM PROGRESS

During the period covered by this report, we assembled the survey material (questionnaires, code books, and response data) and designed and implemented a system to manage it. During the Spring of 1965, we contacted the following survey data repositories: the Research Office of Sociology of the University of Pittsburgh, the Roper Public Opinion Research Center, and the Survey Research Center of the University of Michigan. The surveys which we obtained are listed in chronological order in Appendix A.

We designed the data management system according to the following criteria:

1. Accuracy (unedited representation of survey content);

2. Routinized input and output (standard, economical, and rapid setup of survey data for the system);

3. Manipulation (input and output formats which the analyst can use easily);

4. Flexibility (multiple use of the data); and

5. Efficiency of search and retrieval (ready location and extraction of all and only relevant material).

Labelled system RAPID, our system is in the same tradition as work underway at the Inter-University Consortium for Political Research and M.I.T. We do believe that the retention of the complete question text and response categories and the survey volumes and indexes give RAPID advantages over other systems on criteria 1, 3, 4, and 5 (above). Since the field of survey data management is changing rapidly, these advantages may well be temporary.

The application of RAPID involved five tasks which are now complete. To have some idea of the effort required to complete these tasks, the reader should realize that these operations were performed on 113 surveys, which contained over 7,000 question-answer units administered to well over 100,000 respondents.

1. The question package. The question package consists of:

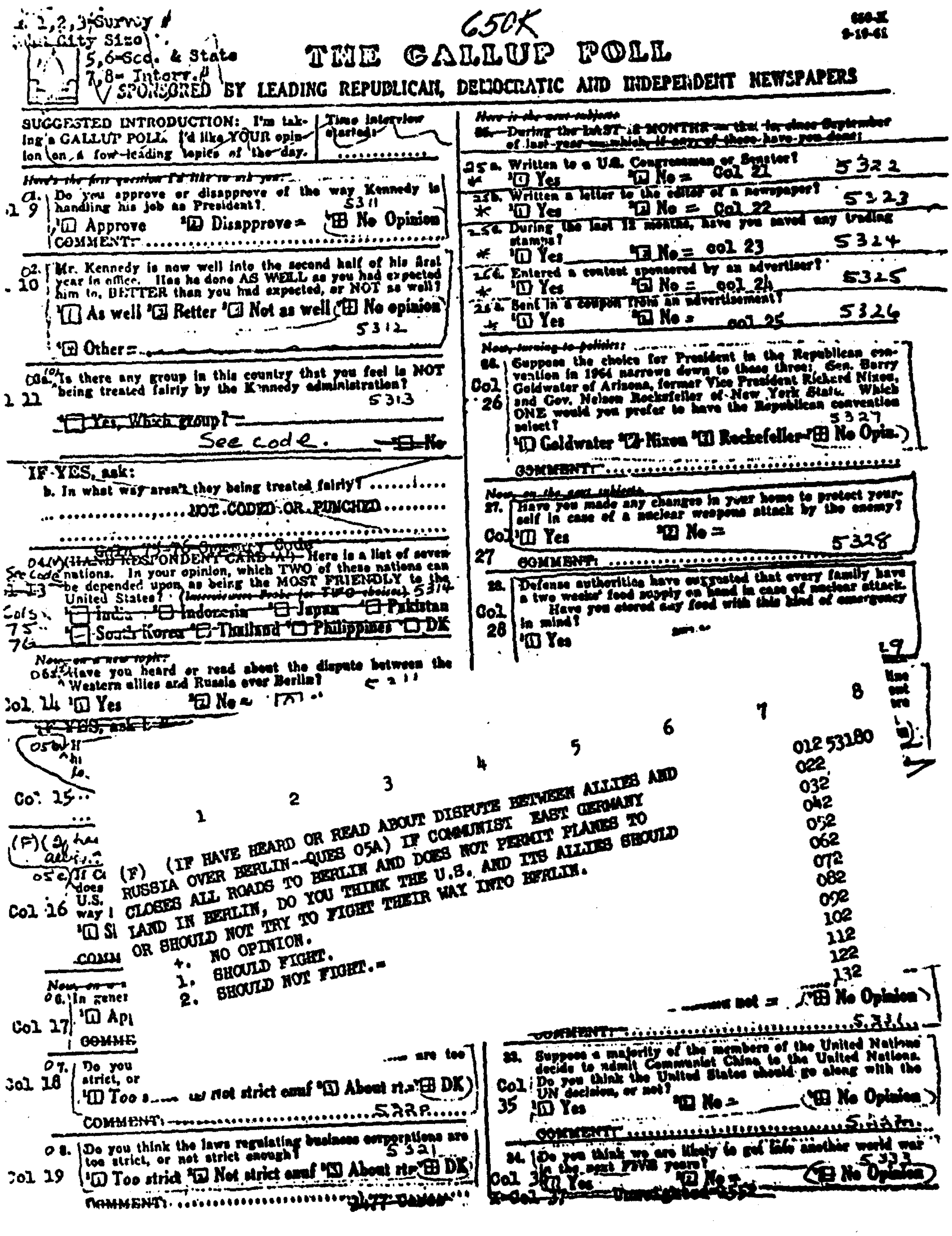
   a. Descriptive information about the question (techniques of eliciting the response and dependence of the question on other questions), and

   b. Literal text of the question and its response category code.

To produce the package, we had, first, to prepare the over 7,000 questions and response codes for typists and keypunchers and, second, place the key-punched material in our data base. In Fig. 7.1, the background is a typical survey schedule page. The insert indicates how we have integrated and clarified the material from the schedule and the accompanying code book as input for keypunching.

2. The data package. The data package consists of:

   a. Responses given by interviewees,



650K

650-K
9-19-61

1,2,3-Survey #
4-City Size
5,6-Gcd. & State
7,8- Intorr.#

THE GALLUP POLL

SPONSORED BY LEADING REPUBLICAN, DEMOCRATIC AND INDEPENDENT NEWSPAPERS

SUGGESTED INTRODUCTION: I'm taking a GALLUP POLL. I'd like YOUR opinion on a few leading topics of the day.

Time interview started: ....

~~Here's the first question I'd like to ask you:~~

01. 9 Do you approve or disapprove of the way Kennedy is handling his job as President? 5311
1 Approve 2 Disapprove = + No Opinion
COMMENT: ....

02. 10 Mr. Kennedy is now well into the second half of his first year in office. Has he done AS WELL as you had expected him to, BETTER than you had expected, or NOT as well?
1 As well 2 Better 3 Not as well + No opinion 5312
4 Other = ...

03a. 11 Is there any group in this country that you feel is NOT being treated fairly by the Kennedy administration? 5313
~~1 Yes, Which group?~~
See code. ~~+ No~~

IF YES, ask:
b. In what way aren't they being treated fairly? ....
.... NOT CODED OR PUNCHED ....

04. ~~(HAND RESPONDENT CARD A)~~ Here is a list of seven nations. In your opinion, which TWO of these nations can be depended upon as being the MOST FRIENDLY to the United States? ~~(Interviewer: Probe for TWO choices)~~ 5314
See code
Cols 75 76
India ~~Indonesia~~ ~~Japan~~ Pakistan
South Korea ~~Thailand~~ Philippines DK

~~Now on a new topic:~~
05a. Have you heard or read about the dispute between the Western allies and Russia over Berlin?
Col. 14 1 Yes 2 No =

Col. 15
Col 16
Col 17 1 Ap
COMMENT

07. Do you think ... strict, or ...
Col 18 1 Too s... not strict enuf 3 About rt. + DK 5320
COMMENT: ....

08. Do you think the laws regulating business corporations are too strict, or not strict enough? 5321
Col 19 1 Too strict 2 Not strict enuf 3 About rt. + DK
COMMENT: ....

~~Here is the next subject:~~
~~25. During the LAST 12 MONTHS — that is since September of last year — which, if any of these have you done?~~

25a. Written to a U.S. Congressman or Senator? 5322
1 Yes 2 No = Col 21

25b. Written a letter to the editor of a newspaper? 5323
1 Yes 2 No = Col 22

25c. During the last 12 months, have you saved any trading stamps? 5324
1 Yes 2 No = col 23

25d. Entered a contest sponsored by an advertiser? 5325
1 Yes 2 No = col 24

25e. Sent in a coupon from an advertisement? 5326
1 Yes 2 No = col 25

~~Now turning to politics:~~
26. Suppose the choice for President in the Republican convention in 1964 narrows down to these three: Gen. Barry Goldwater of Arizona, former Vice President Richard Nixon, and Gov. Nelson Rockefeller of New York State. Which ONE would you prefer to have the Republican convention select? 5327
Col 26
1 Goldwater 2 Nixon 3 Rockefeller + No Opin.
COMMENT: ....

~~Now on the next subject:~~
27. Have you made any changes in your home to protect yourself in case of a nuclear weapons attack by the enemy?
Col 27 1 Yes 2 No = 5328
COMMENT: ....

28. Defense authorities have suggested that every family have a two weeks' food supply on hand in case of nuclear attack. Have you stored any food with this kind of emergency in mind?
Col 28 1 Yes

1 2 3 4 5 6 7 8

(F) (IF HAVE HEARD OR READ ABOUT DISPUTE BETWEEN ALLIES AND RUSSIA OVER BERLIN--QUES 05A) IF COMMUNIST EAST GERMANY CLOSES ALL ROADS TO BERLIN AND DOES NOT PERMIT PLANES TO LAND IN BERLIN, DO YOU THINK THE U.S. AND ITS ALLIES SHOULD OR SHOULD NOT TRY TO FIGHT THEIR WAY INTO BERLIN.
+. NO OPINION.
1. SHOULD FIGHT.
2. SHOULD NOT FIGHT.=

012 53180
022
032
042
052
062
072
082
092
102
112
122
132

... not = + No Opinion 5331
COMMENT: ....

33. Suppose a majority of the members of the United Nations decide to admit Communist China to the United Nations. Do you think the United States should go along with the UN decision, or not?
Col 35 1 Yes 2 No = + No Opinion 5332
COMMENT: ....

34. Do you think we are likely to get into another world war in the next FIVE years? 5333
Col 36 1 Yes 2 No = + No Opinion

Fig. 7.1. Example of a Question Package.

b. Response frequencies for different answers to a particular question, and

c. A set of statistical measures of the distribution and significance of the responses.

To produce the package, new nominal statistics were developed and programs prepared to apply existing statistics for ordinal and interval data. Designed to measure the distribution of response frequencies, the nominal statistics are applicable to response codes unsuitable for scaling. Figure 7.2 presents an example of such a question and the nominal statistics package beneath the data table. Figure 7.3 presents an ordinal question, and the ordinal statistics package appears below the data table. Because most of the surveys were not prepared for computer manipulation, the pattern in which the data were punched posed a large variety of difficult problems. Instead of the one-punch-per-card column of modern data processing mores, we confronted instances where several answers to a question were punched in a particular column, where a column was divided between two questions, where a question occupied more than one but less than two columns. These all imposed significant programming problems which had to be overcome.

3. The support package. The support package consists of the following information for each question-data universe:

a. Date of the survey,

b. Name of survey organization,

c. Survey identification number,

d. Scope of the sample, (e.g., National)

e. Number of the question, and

f. Card and column location of data for the question.

Procedures were developed and applied for machine preparation of most of this package.

4. Integrating question, data and support packages. The purpose of this step was to merge the question, data and support packages for a particular question-answer unit. Obviously,

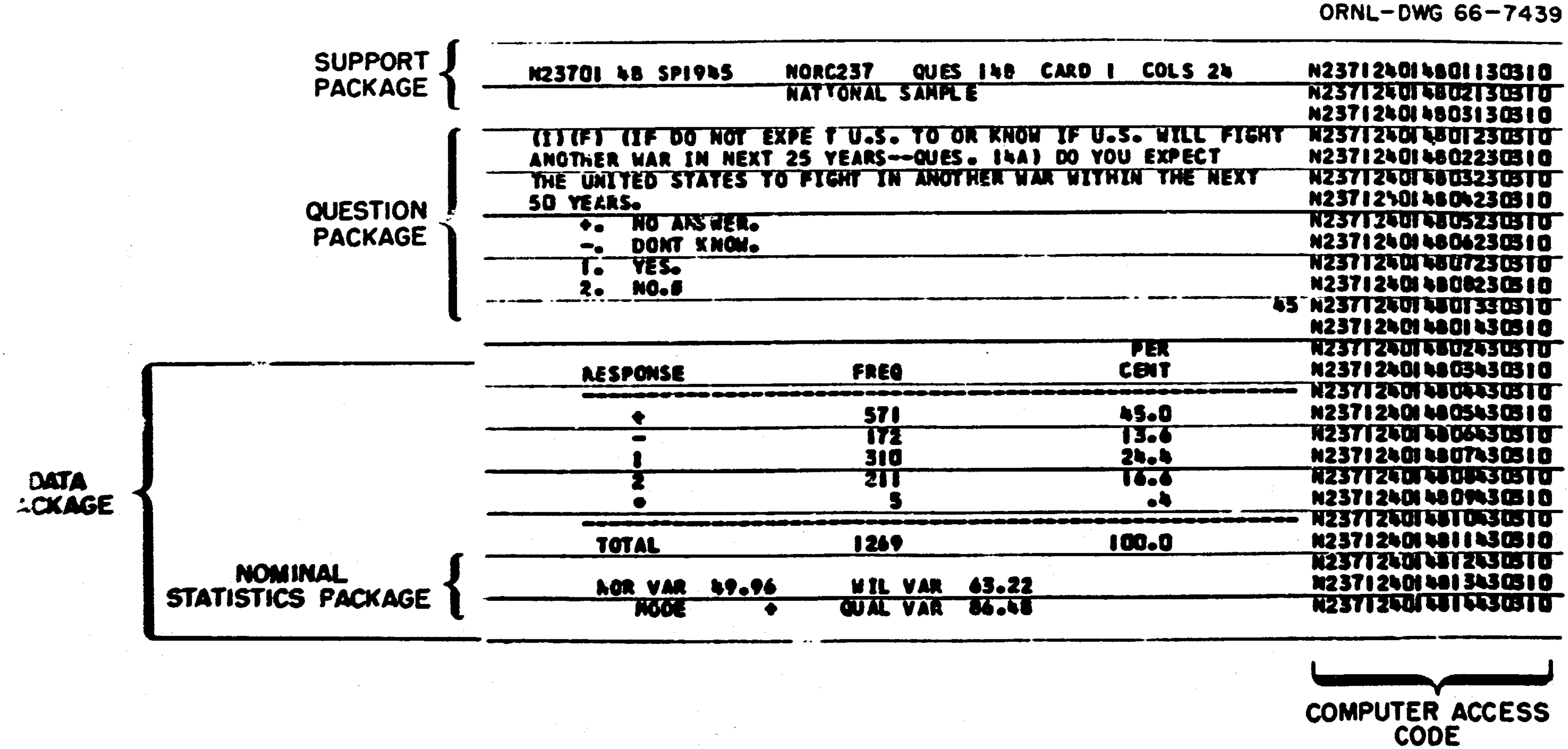


Fig. 7.2. A Nominal Data Book Entry.

ORNL-DWG 66-7438

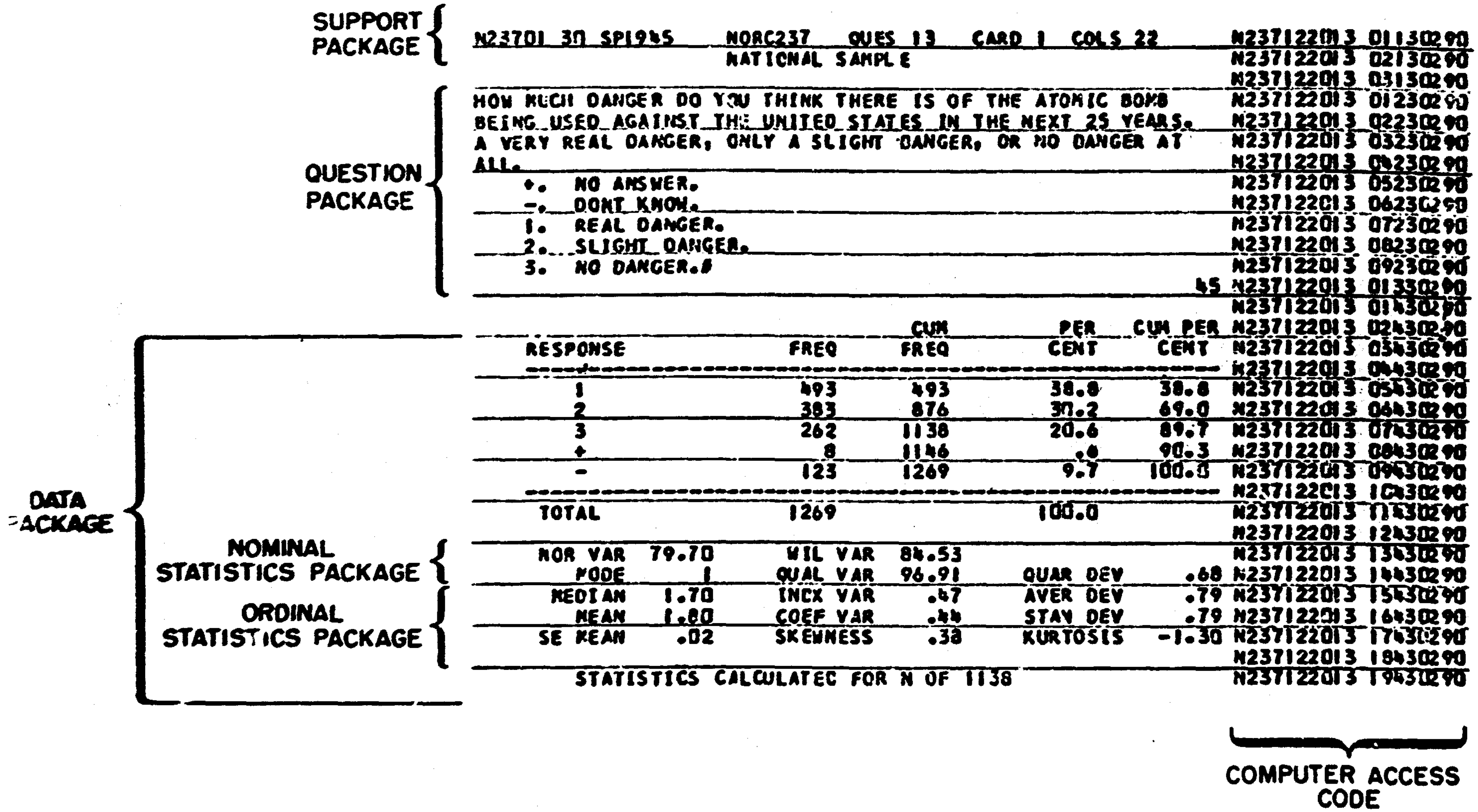


Fig. 7.3. An Ordinal Data Book Entry.

a number of control and checking devices had to be developed and applied to insure that the correct three packages were merged.

5. Master output. The master output consists of:

   a. Survey data books which present the merged material for each question-answer unit in the survey. Figures 7.2 and 7.3 illustrate data book pages. With these data-books, the researcher can immediately plot the co-occurrence of response frequencies within a survey and trends across survey for the total set of respondents.

   b. Key-Word-In-Context indexes of the question and answer text. Illustrated in Fig. 7.4, the KWIC indexes provide a flexible and efficient search and retrieval tool.

7.4 EVENT CHRONOLOGY

To enable us to study attitude sensitivity to different domestic and international contexts, we developed a computer manipulable events chronology for the period covered by the survey data (1945-1964). The chronology contains all the events listed in the World Almanac volume for that year abstracted and placed in one of the following categories:

a. Technology - U.S.
b. Technology - foreign.
c. Military - U.S.
d. Military - foreign.
e. Treaties, pacts, bans, foreign aid - U.S. involved.
f. Treaties, pacts, bans, foreign aid - U.S. not involved.
g. Visits - U.S. to foreign.
h. Visits - foreign to U.S.
i. Visits - foreign to foreign.
j. Subversion - everywhere.
k. Scandals - U.S.
l. Race - U.S.
m. Labor and economic - U.S.

ORNL-DWG 66-7440

(KEY WORD)

```
SSIONALT NOT ENOUGH MONEY.  6.  CHARLES WILSON, DEFENSE DEPARTMENT.  7.  INTER-SERVICE RIVALRY.  8. P   6592117C09C  3017C
EE AT THIS TIME ABOUT THE REORGANIZATION OF OUR DEFENSE DEPARTMENT.  IF IT COMES TO A SHOWDOWN ON THIS   6598113C05   50040
IN ILL WILL, CAPITALISTS WOULD MAKE MONEY, GIVE DEFENSE HEADS MORE MONEY, DEFENSE WORK.  4.  STOP COMM   6531118CC7   15300
HAT IS, THEY HAVE AGREED TO COME TO EACH OTHERS DEFENSE IF ANY ONE OF THEM IS ATTACKED.  DO YOU FAVOR   6400122C078  10890
ALLIANCE--THAT IS, AGREE TO COME TO EACH OTHERS DEFENSE IMMEDIATELY IF THE OTHER IS ATTACKED.  DO YOU   6367125CC9   06210
Y.# WHAT IS YOUR FEELING ABOUT THE WAY CIVILIAN DEFENSE IS BEING HANDLED IN THIS LOCAL AREA - DO YOU T   6644127025   50970
HE CASE OF INDUSTRIES MAKING MISSILES AND OTHER DEFENSE MATERIALS--WOULD YOU FAVOR OR OPPOSE JAIL SENT   6644134C318  51040
 AM INTERESTED IN HOW YOUR ATTITUDE ABOUT CIVIL DEFENSE MAY HAVE CHANGED AS A RESULT OF THE CUBAN CRIS   N110348C45   03430
ARSHALL.  3.  LIKE STRONG POLICY TOWARD RUSSIA, DEFENSE OF AMERICAN INTERESTS.  4.  LIKE EFFORTS TOWAR   N155127C160  2368C
STED THAT THE NATIONAL GUARD TAKE CHARGE OF THE DEFENSE OF CIVILIANS INSTEAD OF A SEPARATE CIVIL DEFEN   6644129C27   5099C
7.  HELPING WITH THE FIGHT--SERVING MY COUNTRY, DEFENSE OF MY COUNTRY WAS WONDERFUL TO DO, SATISFACTIO   6514144019C  11020
TION WITH IT, GET IN TOUCH WITH THE LOCAL CIVIL DEFENSE OFFICE TO GET INFORMATION OR ADVICE.  1.  YES.   N110344C41   03390
ES, LIKELY.  2.  NO.  3.  NO OPINION.# CIVILIAN DEFENSE OFFICIALS SAY IT WOULD COST ABOUT $200 FOR A F   6517125011   12180
THESE MONEY MATTERS BE MADE BY THE SECRETARY OF DEFENSE OR BY CONGRESS.  4.  NO OPINION.  1.  SECRETAR   6598112C04   50030
PEAN COUNTRIES, ARE JOINED TOGETHER BY A MUTUAL DEFENSE PACT--THAT IS, THEY HAVE AGREED TO COME TO EAC   6400122C078  1089C
 MAGAZINES.  03.  3 OR MORE.  04.  1 OR 2 CIVIL DEFENSE PAMPHLETS.  05.  3 OR MORE.  88.  DONT KNOW.     N1104140048A 03580
TO YEARS SPENT IN ARMY TO WHAT I WOULD GET IN A DEFENSE PLANT.# (P) (O) (IF MALE WORLD WAR II VETERAN-   6375151C24E  04950
NESS HAS HAD TOO MUCH TO SAY ABOUT THE COUNTRYS DEFENSE PROGRAM AND THAT LABOR HAS NOT HAD ENOUGH TO S   6472130C150  09080
YOU THINK THE UNITED STATES SHOULD CONTINUE OUR DEFENSE PROGRAM AS PLANNED, OR DO YOU THINK THE DEFENS   6477126C1C   10340
TEMENT ON THIS CARD DESCRIBES THE PRESENT CIVIL DEFENSE PROGRAM IN YOUR COMMUNITY (NEIGHBORHOOD).  C1.   N110424052   03480
99.  NO ANSWER.# (P) (IF YOU ARE AWARE OF CIVIL DEFENSE PROGRAM IN COMMUNITY --QUESTION 52) DO YOU HAP   N110425053   0349C
DEFENSE PROGRAM AS PLANNED, OR DO YOU THINK THE DEFENSE PROGRAM SHOULD BE REDUCED.  1.  CONTINUE AS PL   6477126C1C   10340
S YOU, YOURSELF, DOING ANY WORK IN THE CIVILIAN DEFENSE PROGRAM--SUCH AS AIR RAID WARNING, FIRST AID,    6517123C1GA  12160
THINK-- SHOULD LABOR HAVE MORE TO SAY ABOUT OUR DEFENSE PROGRAM, OR NOT.  1.  SHOULD.  2.  SHOULD NOT.   6472130C15C  09080
 YEARLY FOR EACH MAN, WOMAN AND CHILD FOR CIVIL DEFENSE PROGRAMS.  LESS THAN A DOLLAR A YEAR.  LESS TH   N11C336C33   03310
LD SPEND FOR EACH MAN,WOMAN AND CHILD FOR CIVIL DEFENSE PROGRAMS.  LESS THAN A DOLLAR A YEAR.  LESS TH   N110337034   03320
MONY, KEEPING THE COUNTRY PROSPEROUS, ETC.  7.  DEFENSE PROGRAMS, GOOD MISSILE PROGRAM, DOING ALL WE C   6652111C02   54390
 YOU, YOURSELF, THINK THIS ADDITIONAL MONEY FOR DEFENSE SHOULD BE RAISED--MOSTLY BY AN INCREASE IN PER   6471136C10C  0047C
.  1.  FAVOR.  2.  OPPOSE.  3.  NO OPINION.# IF DEFENSE SPENDING CAN SAFELY BE CUT, WOULD YOU FAVOR OR   6514132C128  11720
EFENSE OF CIVILIANS INSTEAD OF A SEPARATE CIVIL DEFENSE UNIT AS AT PRESENT.  DO YOU THINK THIS WOULD B   6644129027   50990
N, BACK YARD.  7.  FOLLOW INSTRUCTIONS OF CIVIL DEFENSE WARDENS.  8.  REPORT FOR DUTY TO CIVIL DEFENSE   6531123011   15350
 HOW YOU FEEL ABOUT THE WAY OF SETTING UP CIVIL DEFENSE WORK DESCRIBED ON THIS CARD--MOSTLY VOLUNTEERS   N110266C19A  0301C
 HOW YOU FEEL ABOUT THE WAY OF SETTING UP CIVIL DEFENSE WORK DESCRIBED ON THIS CARD--MOSTLY LOCAL, STA   N110267019B  03020
 HOW YOU FEEL ABOUT THE WAY OF SETTING UP CIVIL DEFENSE WORK DESCRIBED ON THIS CARD--NEAR-MILITARY ORG   N110268019C  03030
 HOW YOU FEEL ABOUT THE WAY OF SETTING UP CIVIL DEFENSE WORK DESCRIBED ON THIS CARD--UNDER ARMY.  GIVE   N110269019D  03040
 HOW YOU FEEL ABOUT THE WAY OF SETTING UP CIVIL DEFENSE WORK DESCRIBED ON THIS CARD--NEW SERVICE.  GIV   N11027CC19E  03C50
OULD MAKE MONEY, GIVE DEFENSE HEADS MORE MONEY, DEFENSE WORK.  4.  STOP COMMUNISM FROM SPREADING, KEEP   6531118C07   15300
T NUMBER AVAILABLE.# (P) (O) (IF DOING CIVILIAN DEFENSE WORK--CUES 10A) WHAT ARE YOU DOING.  4.  YES O   6517124C1CB  12170
S, MONEY IN CIRCULATION.  02.  PUBLIC WORKS AND DEFENSE 03.  KEEP EMPLOYMENT UP--CREATE JOBS 04.  HIGH   6517144C208  1231C
ING YEAR TO HELP PAY FOR THE INCREASED COSTS OF DEFENSE.  AND AGAIN, TAKE A FAMILY OF FOUR WITH A TOTA   6471140C19D  00510
 INTO ONE DEPARTMENT HEADED BY THE SECRETARY OF DEFENSE.  DO YOU APPROVE OR DISAPPROVE OF THIS.  4.  N   6598111003A  50020
MORE THAN WAS SPENT THIS LAST YEAR FOR NATIONAL DEFENSE.  HOW DO YOU, YOURSELF, THINK THIS ADDITIONAL    6471134010C  0047C
ING YEAR TO HELP PAY FOR THE INCREASED COSTS OF DEFENSE.  LETS TAKE A TYPICAL FAMILY OF FOUR--A HUSBAN   6471137C19A  0048C
ING YEAR TO HELP PAY FOR THE INCREASED COSTS OF DEFENSE.  NOW, TAKING A FAMILY OF FOUR WITH A TOTAL IN   6471139C19C  0050C
ING YEAR TO HELP PAY FOR THE INCREASED COSTS OF DEFENSE.  SUPPOSE A FAMILY OF FOUR HAD A TOTAL INCOME    6471138019B  00490
OF COUNTRY - GENERAL, FOR THE PEOPLE.  14.  FOR DEFENSE.  THE ARMED FORCES.  15.  FOR MISSILES, ROCKET   6612132C25A  52020
F COUNTRY - GENERAL.  FOR THE PEOPLE.  14.  FOR DEFENSE.  THE ARMED FORCES.  15.  FOR MISSILES, ROCKET   6612134C25B  5203C
ANYONE IN YOUR FAMILY EVER BEEN ACTIVE IN CIVIL DEFENSE.  01.  YES.  02.  NO.  88.  DONT KNOW.  99.  N   N110421C51   03450
U RECALL WHERE THESE APPEARED.  01.  YES, CIVIL DEFENSE.  02.  YES, OTHER GOVERNMENT AGENCIES.  03.  Y   N1104160049A 03600
ANY OTHERS YOU RECALL READING.  01.  YES, CIVIL DEFENSE.  02.  YES, OTHER GOVERNMENT AGENCIES.  03.  Y   N110417049B  0361C
.  14.  SPEND MORE MONEY TO STRENGTHEN NATIONAL DEFENSE.  05.  RAISE MINIMUM WAGES TO $1.25 PER HOUR.    6639119C05   1960C
CIVIL DEFENSE--PROTECTING OUR COUNTRY, NATIONAL DEFENSE.  09.  DRAFT PROBLEMS--UMT, AGE LIMITS FOR DRA   6517111C02A  1203C
CIVIL DEFENSE--PROTECTING OUR COUNTRY, NATIONAL DEFENSE.  09.  DRAFT PROBLEMS--UMT, AGE LIMITS FOR DRA   6517113C02B  12040
T FOR DEFENSE, OR IS TOO LITTLE BEING SPENT FOR DEFENSE.  1.  TOO MUCH.  2.  TOO LITTLE.  3.  ABOUT RI   6519116C07   12370
OR BY CONGRESS.  4.  NO OPINION.  1.  SECRETARY DEFENSE.  2.  CONGRESS.# EACH YEAR DECISIONS MUST BE M   6598112C04   50030
NER, LEFT BLANK.  1.  STRENGTHENED OUR NATIONAL DEFENSE.  2.  INCREASED OUR SPACE PROGRAM.  3.  LOWERE   6639113002   41100
2.  PREPAREDNESS, DRAFT, ARMY, NAVY, AIR FORCE, DEFENSE.  3.  RELIGIOUS PROBLEMS, NEED CHURCHES.  4.     6640110001   10700
W DO YOU FEEL U.S. CONGRESS (FEELS ABOUT CIVIL DEFENSE)) GIVEN SCALE NUMBERED FROM -3 TO +3.  01.  -3,   N110311C20A  03040
(HOW DO YOU THINK) DEMOCRATS (FEEL ABOUT CIVIL DEFENSE)).  GIVEN SCALE NUMBERED FROM -3 TO +3.  01.  -   N110312C20B  0307C
HOW DO YOU THINK) REPUBLICANS (FEEL ABOUT CIVIL DEFENSE)).  GIVEN SCALE NUMBERED FROM -3 TO +3.  01.  -  N110313020C  03080
```

Fig. 7.4. A Key-Word-in-Context Page.

n. Elections - U.S.

o. Elections - foreign.

p. Major speeches, congressional hearings and debates, announcements of policy, bills, executive orders, etc. - U.S.

q. Major speeches, policy announcements, etc. - foreign.

r. Verbal and political exchanges - between U.S. and foreign.

s. Verbal and political exchanges - between foreign and foreign.

t. Violence, wars, coups, incidents - South American

u. Violence, wars, coups, incidents - elsewhere.

v. Meetings - United Nations, big 2 (3,4), disarmament, and test ban.

w. Meetings - NATO, OAS, SEATO, and other "alliance."

x. Meetings - Soviet bloc.

y. Meetings - other where U.S. not involved.

z. Other - everywhere.

To check on the inclusion of major events, the categorized chronology was compared with the summary section of the New York Times "Year in Review." Figure 7.5 presents a page of events chronology computer output.

ORNL-DWG 88-8006

	COMPUTER ACCESS CODE
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P07461002103580
U.S.	P07461003103580
JULY, 1946	P07461001203580
FOOD PEOPLE CHARGE NO FREE ACCESS TO U.S.S.R. ZONE IN	P07461001403580
AUSTRIA.#	P07461002403580
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460101104150
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460102104150
U.S.	P08460103104150
AUGUST, 1946	P08460101204150
ATOMIC ENERGY ACT TO ESTABLISH AEC PASSED.#	P08460101404150
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460201104160
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460202104160
U.S.	P08460203104160
AUGUST, 1946	P08460201204160
A-BOMB EVALUATING COMMITTEE TELLS OF NECESSITY FOR	P08460201404160
ELIMINATION OF WAR IN BOMB AGE.#	P08460202404160
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460301104170
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460302104170
U.S.	P08460303104170
AUGUST, 1946	P08460301204170
DULLES SAYS NEW TENSIONS NOT TO BE FRIGHTENING.#	P08460301404170
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460401104180
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460402104180
U.S.	P08460403104180
AUGUST, 1946	P08460401204180
MARSHALL TELLS OF DIFFICULTY OF REACHING PEACEFUL	P08460401404180
SETTLEMENT IN CHINA.#	P08460402404180
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460501104190
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460502104190
U.S.	P08460503104190
AUGUST, 1946	P08460501204190
NAVY ANNOUNCES PLANS FOR PILOTLESS PLANES TO CARRY BOMBS.#	P08460501404190
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460601104200
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460602104200
U.S.	P08460603104200
AUGUST, 1946	P08460601204200
NAVY GUY TELLS OF SUCCESS OF BIKINI TESTS.#	P08460601404200
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460701104210
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460702104210
U.S.	P08460703104210
AUGUST, 1946	P08460701204210
HERBERT HOOVER TELLS OF MENACE OF COMMUNIST 5TH COLUMN.#	P08460701404210
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460801104220
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460802104220
U.S.	P08460803104220
AUGUST, 1946	P08460801204220
ARMY ANNOUNCES GUIDED MISSILE PLANS.#	P08460801404220
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08460901104230
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08460902104230
U.S.	P08460903104230
AUGUST, 1946	P08460901204230
VANDENBERG ASKS FOR UNDERSTANDING OF U.S.S.R. LEGITIMATE	P08460901404230
AIMS.#	P08460902404230
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08461001104240
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08461002104240
U.S.	P08461003104240
AUGUST, 1946	P08461001204240
U.S. IN BITTER CRITICISM OF YUGOSLAVIA FOR PLANE INCIDENTS.#	P08461001404240
P. MAJOR SPEECHES, CONGRESSIONAL HEARINGS AND DEBATES,	P08461101104250
ANNOUNCEMENTS OF POLICY, BILLS, EXECUTIVE ORDERS, ETC. -	P08461102104250

Fig. 7.5. Events Chronology Page.

7.5 APPENDIX A

7.5.1 Surveys in the Data Base

Key:

NORC --- National Opinion Research Center (University of Chicago)

SRC --- Survey Research Center (University of Michigan)

Gallup --- American Institute of Public Opinion

Roper --- Elmo Roper, Inc.

SURVEY ORGANIZATION	MONTH	YEAR
NORC 133	August	1945
NORC 237	September	1945
Gallup 367	March	1946
NORC 140	March	1946
ROPER 53	April	1946
ROPER 24	May	1946
NORC 143	June	1946
Gallup 375	July	1946
Gallup 378	September	1946
Gallup 379	September	1946
NORC 144	September	1946
NORC 146	November	1946
NORC 149	April	1947
NORC 150	April	1947
ROPER 60	May	1947
NORC 151	June	1947
NORC 152	October	1947
ROPER 59	November	1947
NORC 155	February	1948
NORC 156	March	1948
ROPER 64	March	1948
NORC 089	May	1948
NORC 158	June	1948
NORC 160	July	1948
ROPER 67	July	1948

SURVEY ORGANIZATION	MONTH	YEAR
NORC 161	October	1948
ROPER 71	October	1948
NORC 162	November	1948
NORC 163	January	1949
NORC 166	January	1949
NORC 164	March	1949
NORC 165	April	1949
NORC 167	June	1949
NORC 169	September	1949
NORC 170	October	1949
NORC 273	January	1950
NORC 276	March	1950
NORC 282	June	1950
NORC 287	July	1950
Gallup 460	August	1950
NORC 288	September	1950
NORC 291	October	1950
SRC 089	October	1950
Gallup 467	November	1950
NORC 292	November	1950
NORC 294	November	1950
Gallup 469	December	1950
NORC 295	December	1950
Gallup 470	January	1951
NORC 298	January	1951
Gallup 471	February	1951
Gallup 472	March	1951
NORC 300	March	1951
NORC 302	April	1951
NORC 307	May	1951
NORC 303	June	1951
Gallup 477	July	1951
SRC 102	August	1951

SURVEY ORGANIZATION	MONTH	YEAR
Gallup 480	September	1951
NORC 314	November	1951
NORC 315	December	1951
NORC 317	February	1952
NORC 320	March	1952
SRC 136	March	1952
NORC 323	April	1952
NORC 325	May	1952
NORC 327	June	1952
NORC 332	October	1952
NORC 333	November	1952
Gallup 514	April	1953
NORC 339	April	1953
NORC 341	June	1953
Gallup 517	August	1953
Gallup 519	August	1953
NORC 347	August	1953
NORC 348	September	1953
Gallup 521	October	1953
NORC 349	November	1953
SRC 408	March	1954
Gallup 529	April	1954
NORC 355	April	1954
Gallup 531	May	1954
NORC 363	September	1954
NORC 365	November	1954
NORC 366	January	1955
Gallup 544	March	1955
NORC 370	March	1955
NORC 372	June	1955
Gallup 552	August	1955
NORC 374	August	1955
NORC 376	September	1955

SURVEY ORGANIZATION	MONTH	YEAR
NORC 378	October	1955
NORC 379	November	1955
NORC 382	January	1956
NORC 386	April	1956
SRC 418	May	1956
Gallup 566	June	1956
Gallup 622	December	1956
Gallup 576	December	1956
NORC 401	December	1956
Gallup 582	April	1957
NORC 404	April	1957
Gallup 592	November	1957
Gallup 598	April	1958
Gallup 612	March	1959
Gallup 617	August	1959
Gallup 639	December	1960
Gallup 644	May	1961
Gallup 647	June	1961
Gallup 648	July	1961
Gallup 649	August	1961
Gallup 650	September	1961
Gallup 651	October	1961
SRC 444	October	1961
Gallup 652	November	1961
Gallup 662	August	1962
Gallup 666	December	1962
NORC 110	June	1963
NORC 330	December	1963
NORC 640	June	1964

8. DETERMINANTS OF INFLUENTIALS' RESPONSES TO COMMUNICATIONS ABOUT A NEGATIVE CONTINGENCY*

Sue Berryman Bobrow

8.1 PROBLEM HISTORY

The project originated in observations of discrepancies between a certain kind of negative contingency and the nature of action in relation to it. We are using the idea of discrepancy as it is used in psychology: for those cases where an objective observer looks at behaviors and cannot see how they make "sense," in terms of any cultural criteria of intelligibility.

The discrepancy of concern to us is that between the negative contingency of deterrence failure and our continental protection (active and passive defense) actions.** This particular discrepancy implies the following question: if certain individuals in a society anticipate that a bad thing might happen (i.e., deterrence failure), why are members of the society not taking coping actions commensurate with the nature of the bad thing (e.g., arms reduction actions, developing and implementing

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*Represents contributions by Drs. Davis Bobrow (political sociology, Director's Division, Oak Ridge National Laboratory), Keith Davis (social psychology, Institute of Behavioral Sciences, University of Colorado) and Lewis Dexter (sociology, Political Science Department, Massachusetts Institute of Technology) and Sue Berryman Bobrow (psychological anthropology, Director's Division, Oak Ridge National Laboratory).

**The idea of discrepancy which seems to exist between the possibilities of deterrence failure and our continental defense actions is appropriate to other national and regional problems: for example, natural disasters, air pollution, social disorganization. This is relevant because it has been assumed in this project that: (1) the specific discrepancy of concern to us cannot be explained only by properties of the individual case; (2) properties of the class to which the case belongs may provide reasons for the specific discrepancy which properties of the case cannot provide; and (3) it is thus necessary to look at analogous instances of discrepancy to locate the class and class properties of which these discrepancies are examples.

active and/or passive defense options)? We assume that all human beings have reasons* for types of action and inaction. The problem then becomes to determine those reasons for action versus inaction and for one type of action/inaction rather than another. It is not assumed that the discrepancy should necessarily be corrected. Even when the reasons for the discrepancy are satisfyingly explained, it may be agreed that there are more good reasons to continue the discrepancy than to correct it. However, it is assumed that the reasons for the discrepancy should be understood.

For social science readers the project may be seen as a study of decision-making in a certain class of situations, i.e., negative contingency situations. Negative contingencies (bad things that might happen in the future) may be seen as conceptually related to crises (bad things that will almost inevitably happen) and to disasters (bad things that have happened), and thus the study of the first type as related to studies of the second and third types. This project is particularly in the tradition of recent studies of decision-making in crises, such as the Stanford Studies on Conflict and Integration, 1960-1966, and some inter-nation simulations such as C. Hermann, 1965.

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*Classifying reasons as either "rational" or "irrational" is not helpful in any objective analysis of human behavior. From one perspective behavior may be irrational, but from another it is completely rational. Given his motives, what he knows, and what he knows how to do, an individual always has reason enough to do what he is doing. For example, an individual may be unable to participate in social practices (means of coping) which are associated with being guilty, anxious, or ashamed, either because: (1) he is a member of a culture which has never developed these coping means, or (2) he was never taught these. If he is exposed to the affect of guilt, anxiety, or shame, if the affect is powerful, and if he has no means of coping with the affect, a very sensible and reasonable course is to defend against the affect by using ego defense mechanisms. All of this says nothing about the possibility that, for the health of the individual or group, it would be wise for him to do something other than what he is now doing.

8.2 PROBLEM STATUS

8.2.1 Introduction

Pieces of heuristics or analytic systems,* not necessarily fruitful, exist in the social science literature for handling questions about the determinants of influentials' responses to crises (bad things that will almost inevitably happen) and to disasters (bad things that have happened). None, fruitful or otherwise, exists for handling questions about the determinants of influentials' responses to negative contingencies (bad things that might happen in the future), although the literature includes investigations of several single variables probably relevant to the questions.

Thus, this report is primarily concerned with progress toward an analytic system or heuristic, in terms of which data may be economically and fruitfully gathered and analyzed. The need for developing such a system should be self-evident: the question to which we are addressing ourselves is not unmanageable, but it is large, and an analytic system is essentially a means by which to limit search for solutions in large problem spaces (Levy, 1956; Davis, 1965; Feigenbaum and Feldman, 1963).** For those familiar with the distinction between a heuristic and algorithm in computer programming, mathematics, or logic, the costs and gains of a heuristic approach are known: the important advantage is greatly reduced search, and thus economy of effort. The possible, not necessary, disadvantage is that the best, and sometimes any or all, solutions may be overlooked. The means by which the advantages are maximized, disadvantages minimized, are frequently intuitive in nature and the least explicit steps in the whole investigation process.

The events admissible for study in this project are restricted to that class called "negative contingencies," although the one of overwhelming concern to us is nuclear attack on the homeland. An event

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*Levy (1956, p. 13) notes that a system of analysis may be defined as a generalized description of germane phenomena which states the component parts of the phenomena and some of the relationships among those parts considered particularly relevant for the treatment to be attempted. It is thus equivalent to a "model" or "paradigm" but not to a theory.

**Refer to Bibliography for complete references.

represents an instance of the negative contingency class when it manifests the following attributes:

1. the probability of the event's occurring is less than one (less than certainty) but greater than zero.. (This attribute excludes events not seen as genuine possibilities--e.g., the Martians' conquest of the U.S.--or are seen as inevitable--e.g., the physical death of the human being.)
2. if the event occurs, it is anticipated to advance through stages recognized as instances of crisis and disaster/catastrophe, the former stage implying imminent, significant deprivation of valued experiences; the latter, that the deprivation has occurred. (This excludes events seen, if they occur, as problems or nuisances, i.e., as not involving significant deprivation, such as a stevedore strike at East Coast ports.)
3. if the event occurs, it is possible to anticipate that it will occur sufficiently in the future to allow influentials to select responses that take time, e.g., the development and execution of complicated plans. (This excludes events which, if they occur, are anticipated to occur shortly, thus making long-term responses inappropriate.)
4. if coping action is taken with regard to the event, it is seen to require collective or group, as well as personal, action.

If an event falls in the negative contingency class isolated above, three initial conceptual tasks have to be managed before we can begin to talk about the nature of responses to the event and reasons for them. These tasks involve elaborating the nature of the: (1) independent variable, i.e., how the contingency is communicated to the decision-maker; (2) intervening variables, i.e., why he responds the way he does; and (3) dependent variable or outcome, i.e., what response(s) he makes. The status of these tasks is described below in order of independent, dependent, and intervening variables.

8.2.2 Independent Variable

When an influential (message receiver) is exposed to a communication about a negative contingency, whether a verbal statement or newspaper headline, he is in fact exposed not to a single stimulus, but to several types of stimuli. The purpose of the following stimulus typology is simply to specify types of stimuli which can be present in such a communication and thus to specify the initial set of stimuli to which an influential can be responding at time zero (T_0). At least two empirical questions have to be answered when this typology is used in collecting data: (1) what stimuli, out of the set listed below, are actually present in the particular communication to the particular individual or group; and (2) can the individual's or group's response or responses be explained as responses to some or all of the below stimulus types, or are they better explained as responses to stimuli cued by the stimulus types present at T_0, e.g., to emotions such as anxiety or to objects associated with one or more of the initial inputs?

An analysis of a sample of assertions (communications) about a negative contingency (e.g., "Said Hortense to Cellini: 'Y'know, those Mongols may declare war on Brooklyn--would you look at all those missiles they've got--and that'll be the end of your corner delicatessen unless you cover it up with a geodesic dome.'") suggests that assertions about a negative contingency can be categorized in terms of the following types of stimuli:

1. Threat verbalizer (Hortense). This is an optional stimulus component since the threat verbalizer is in some cases the same as the threat agent.
2. Threat agent (Mongols).
3. Threatening event (declare war on Brooklyn).
4. Threat indicator (missiles).
5. Deprivation (loss of corner delicatessen).
6. Suggested solution (cover with geodesic dome).

This typology should make explicit what should be, but frequently is not, the obvious point that even a simple statement about a bad thing that might happen in the future involves stimuli other than the bad thing itself (declare war on Brooklyn). Implicitly we accept this, as, for example, in children's fairy tales where the messenger who brings bad news to the king loses his head for his act. (An historical example is Stalin's treatment of analogous messengers immediately before the German invasion of Russia.) Even children understand that the messenger lost his head not because he caused the bad thing, but because he verbalized it. Why the king chose to respond overtly to the threat verbalizer instead of to the threat itself is an interesting question and of interest to us, but to bring intelligence ~~to the king's~~ act it is essential to include the threat verbaliser in the set of stimuli to which the king could be responding.

8.2.3 Dependent Variable

The following typology of "responses" represents a list of the important different kinds of responses which influentials can be observed to select when they are presented with some communication about a negative contingency. This list, then, represents the types of behaviors we are trying to explain. Why do some influentials essentially ignore the existence of the negative contingency? Why do others spend little energy in actually trying to cope with the contingency, but a great deal in getting others to agree with them that it can be handled? Why do still others take actions which are presumed to contribute to coping with the contingency, but in fact are analogous to bailing out a sinking ship with a Dixie cup? Obviously, members of a group or an individual at different points in time can manifest more than one type of response. Individuals or groups which select the same response may also be selecting it for very different reasons.

The reader must remember that none of the following responses is either necessarily sensible or foolish. Assessing the response in these terms requires determining the circumstances under which the response was chosen. Initially, we thought of our problem as why influentials plan or don't plan for a negative contingency. Aside from the fact that the dichotomous plan-don't plan blurred important differences in response, the original orientation of the problem was biased in favor of "planning." Planning, which for us is closest to response 12 below, is not necessarily the optimal response to a negative contingency, even though relative to other cultures Americans place a high value on ideas such as "plans" and "planning." For example, not enough may be known about the properties of the contingency to make sensible plans, or the properties may be known, but the group may not possess the abilities to frame sensible plans.

As previously indicated, the following response typology lists what seem to be the important different kinds of responses, not all those logically possible. It can obviously be restructured at different levels of generalization: for example, the 12 outcome types can be divided into an action class and non-action class, if action is defined as allocation of resources.

Response Typology

1. A (A = actor = individual or group) is not aware of S_n (S = Stimulus, n = type of S) for physical reasons.
2. A is not aware of S_n for perceptual reasons.
3. A is aware of S_n, but acts as though he is not (does not admit S_n).
   a. denial (cognitive and affective ignoring).
   b. isolation of affect and belief (affective ignoring).
4. A is aware of and admits S_n affectively and cognitively, but considers himself adequately "programmed" (March and Simon, 1958) to handle S_n.
5. A is aware of and admits S_n, but has little or no feeling of his or O's (O = other = person, group, thing, or idea without specific object referent) efficacy in relation to it.
6. A is aware of and admits S_n and has little or no feeling of his efficacy or appropriateness with regard to S_n, but believes that perhaps O does/should have efficacy.
7. A is aware of and admits S_n and has little or no feeling of his efficacy or appropriateness with regard to S_n, but believes that perhaps O does/should have efficacy, and seeks discriminant or indiscriminant validation for his belief.
8. A is aware of and admits S_n, but decides that in relation to other S's, S_n does not require resource allocations at the time ("priority" concept--S_n may be negative, but not that negative, and/or S_n may be possible, but not that possible).

9. A is aware of and admits S_n and allocates minimal resources to S_n in order to maintain response flexibility (concept of "muddling through," e.g., Lindblom, 1959, a response frequently resorted to when individuals feel that the situation is not sufficiently clear and certain on any of several dimensions to warrant responses that seem to involve more commitment).
10. A is aware of and admits S_n, allocates resources to cope with S_n, but the resources allocated are manifestly disparate with the S_n <u>as A publicly defines it</u>, and A acts as though he is unaware of the discrepancy.
11. A is aware of and admits S_n and allocates adequate resources to remove (eliminate, demolish) it. A does this without regard for the effect of this act for other goals, as he would define these if he were in another state (usually unemotional).
12. A is aware of and admits S_n and allocates resources to reduce S_n systematically, with regard for the consequences of this response for other goals.

Figure 8.1, below, is a type of flow-chart which diagrams outcomes in terms of psychological requisites, i.e., it locates those branches which have to be taken for subsequent outcomes to be possible. For example, if a person wants another individual to come out at any of the responses 4-12, rather than 1, he has to ascertain not only that the other person is physically aware of the stimulus but also that he is perceptually and emotionally aware of it. The figure also begins to clarify what kinds of concepts are relevant for understanding the reasons for one rather than another outcome. For example, to understand individuals who chose response 4 (routine already exists for handling problem), the figure tells us we would not need to use concepts germane to differentiating types of resources allocation responses.

8.2.4 Intervening Variables

The task here has been to postulate those intervening variables which most satisfyingly explain why influentials respond to one rather than another stimulus and choose one rather than another response to

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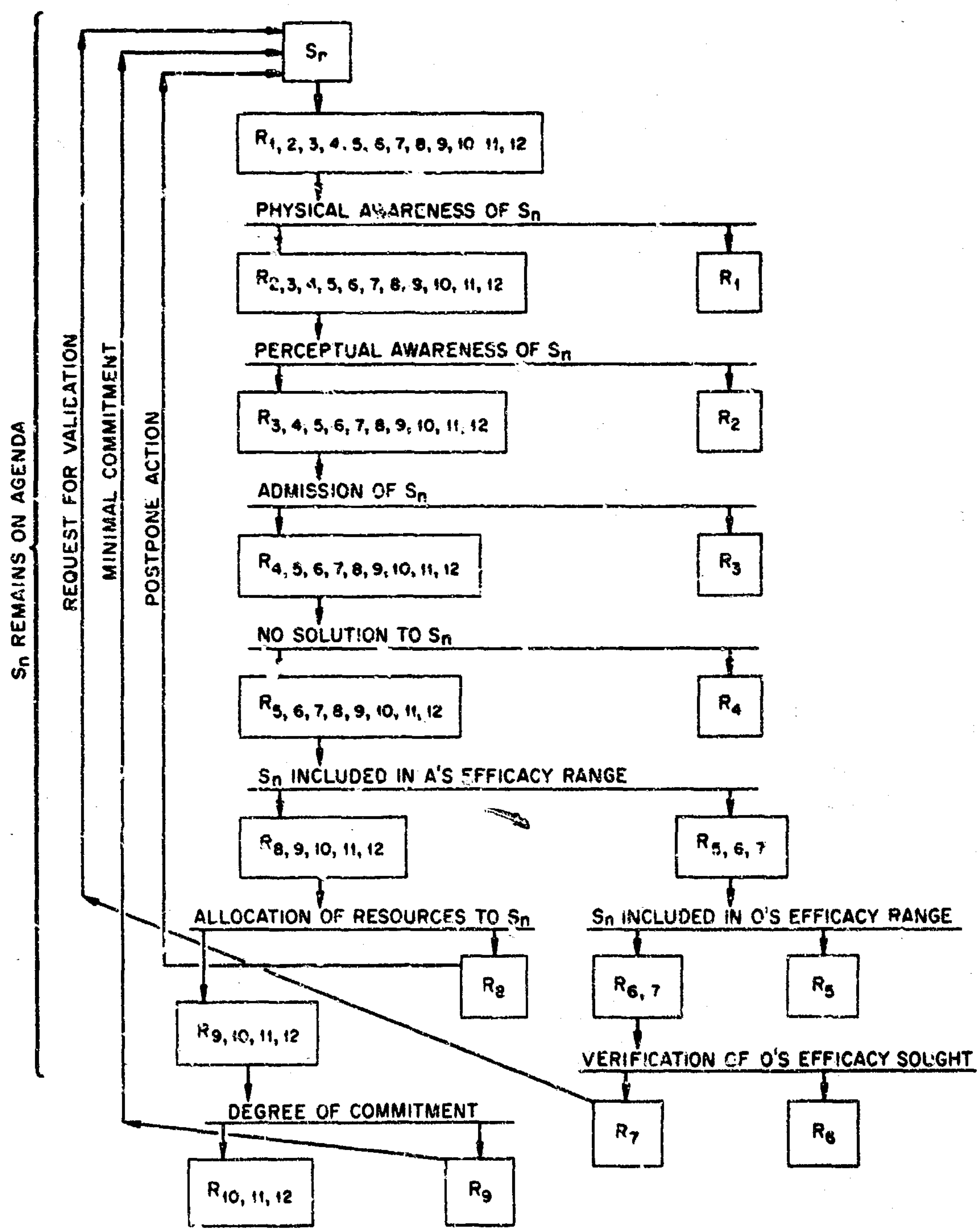

S_n = STIMULUS OF n TYPE
R = RESPONSE
1 thru 12 = TYPES OF RESPONSE (SEE ABOVE)

A = ACTOR (PERSON OR GROUP)
O = OTHER (PERSON, GROUP, THING, IDEA)

8.1 Logical Structure of Response Typology the contingency of nuclear attack (see Bibliography for the literature search involved in this task). Some variables are anticipated to be specific to the nuclear attack case, such as the value an individual places on courage and the acts which he thinks manifest courage or cowardice. Other variables are anticipated to relate to the class of negative contingencies, as defined earlier in this report, as well as to the particular case. An example here is how comfortable an individual is with fairly unstructured, uncertain situations, such as events that might happen sometime in the future seem to be. This second set of variables is emerging as very important for explaining the discrepancy in the specific case simply because some of the reasons individuals seem to choose one response rather than another have nothing to do with nuclear war on the homeland but a great deal to do with those properties of the case which are common to the class of negative contingencies.

The conceptual problems involved in the intervening variables are enormous relative to those of the independent and dependent variables. Thus, most of our effort has gone into the intervening variables and our progress here has been slowest. The following list represents examples of variables which we think identify powerful explanatory phenomena. Although we are still in the process of defining the logic of these variables, their referents stated below identify them roughly. Most of these variables derive from the psychological literature, which simply means that so far we have spent more time on that rather than the social science literature.

1. future time perspective: nature of orientation toward the future, as measured by the location of individuals on the following dimensions:
   a. extension: the length of future time span conceptualized.
   b. coherence: the degree of organization of events in that future time span (concept of synthesis ability). Statistically, this variable is highly related to a dimension labelled "inclination to explore and organize future possibilities when the immediate situation is minimally structured" (Kastenbaum, 1961).

c. density: number of distinct events and experiences which the individual or group populates the future.

d. directionality: temporal realm (past, present, future) in which the individual or group is most confortable.

e. movement: degree of sense of moving forward in time.

2. desire to achieve success: a motive imputed to an individual who is observed on a series of occasions to possess a capacity for taking pride in accomplishment when a performance is successful.

3. desire to avoid failure: a motive imputed to an individual who is observed on a series of occasions to have a capacity for reacting with shame and embarrassment when a performance fails.

4. intolerance for ambiguity: a trait imputed to an individual who is observed on a series of occasions to desire visual or concrete feedback from the environment which allows him and others to evaluate his performance.

5. inability to delay gratification (inability to control the self): a trait attributed to an individual on a series of occasions when he is known to desire long-term rewards and is unable to sustain whatever effort may be needed to attain them. It is assumed that he would be able to secure the reward if he were able to control the self.

6. dispositional self-confidence: a trait attributed to an individual who is observed in a series of <u>different kinds</u> of situations to anticipate success as a result of his own actions.

7. situational self-confidence: a trait attributed to an individual who is observed in a series of the same type of situation to anticipate success as a result of his own actions.

8. ego-defensiveness: a trait attributed to an individual who is observed on a series of occasions to try to maintain an image of a personally desirable nature.

A brief example, using some of these variables, should give a feeling for, if not an understanding of, how we are working with these and other variables not listed above. Presume that an influential interprets a communication about the possibility of nuclear attack as a challenge to cope with a potentially threatening situation. One of the considerations that may very possibly affect his decision (response) to try to solve it, to try to get others to solve it, or not to try to solve it, is: what are his or others' chances of succeeding or failing to cope with it. A success assessment is not unimportant, particularly in this culture where many of the rewards are distributed on the basis of the individual's ability to do, to achieve. It is not difficult to record comments by influentials such as "I like to work on problems I can solve." Nor is it difficult to observe the sensitivity of influentials, particularly vulnerable public figures, to failure.

McClelland et al. (1953), Atkinson (1964), and others have developed separate models of the tendencies of individuals to seek success and to avoid failure. Individuals who register strong tendencies to approach success on the measures of the model have been observed to enjoy coping with problems and tend to select those associated with intermediate risk of failure. Individuals who register strong tendencies to avoid failure on measures of the model have been observed to dislike coping with problems, to avoid acting, or if they are constrained to act, to select problems associated with either very high or very low risks of failure. The very low risk situation has low probabilities of failure, while the high risk situation absolves them of blame if they fail. Several factors seem involved in determining an individual's tendency to seek success or to avoid failure. These and their relationships can be stated in crude, but initially useful, function statements for the tendency to seek success:

$$T_s = M_s \times P_s \times I_s$$

where T_s = tendency to try to succeed.

M_s = dispositional motive to try to succeed (same variable as our desire to achieve success. Our variable of dispositional self-confidence is conceptually related to, but not the same as, the desire to achieve. Dispositional self confidence seems to involve generalized beliefs that I can do. The desire to achieve seems to involve generalized beliefs that I want to do.)

P_s = probability of success, or anticipation that engaging in this activity will result in success (same variable as our situational self-confidence).

I_s = incentive of success, or attractiveness of success at this activity. It is assumed in the model that $I_s = 1 - P_s$. Thus this variable does not involve external incentives to perform the action, such as McNamara asking the Secretary of the Army to do something. The model assumes that external incentive is held constant, although this would have to be measured in real-life predictions.

Atkinson (1964, p. 242) assumes two different values for the motive to achieve and demonstrates how these differences affect an individual's tendency to seek success in five tasks with different probabilities of success.

Table 8.1

Tendency to achieve success (T_s) as a joint function of Motive to achieve (M_s), Expectancy of success (P_s), and Incentive value of success (I_s) for individuals in whom $M_s = 8$. It is assumed that $I_s = 1 - P_s$.

			($T_s = M_s \times P_s \times I_s$)	
Task	P_s	I_s	When $M_s = 1$	When $M_s = 8$
A	.90	.10	.09	.72
B	.70	.30	.21	1.68
C	.50	.50	.25	2.00
D	.30	.70	.21	1.68
E	.10	.90	.09	.72

The obvious implication of the table is that the individual with the higher dispositional motive to achieve will tend to approach tasks in order to achieve success and will tend to select that task of intermediate risk. If all other variables are held constant (e.g., external grants of prestige), and if it is assumed that the problem of civil defense tends to be perceived generally as an exceedingly difficult one (i.e., one with relatively low probability of success), the implication is: those individuals who are most disposed to act, to work on problems with the intention of succeeding with them, will not tend to spend their personal and group resources on a problem such as civil defense.

The model of the tendency to avoid failure is similar, the major implications being that the tendency to avoid failure, i.e., not to perform the task, is greatest when the dispositional motive to avoid failure is high and the risks are intermediate. Since it is usually assumed that individuals are motivated both to approach success and to avoid failure, both tendencies have to be calculated and added to determine (within the assumptions of the models) an individual's tendency to approach success or avoid failure in a particular situation.

8.2.5 Data Collection Strategy

Although data collected in terms of our analytic system will be collected primarily in the field, not in the laboratory, we have not yet selected or designed specific interview schedules, innovative "games" and scales.

Those readers with training in the behavioral sciences may be interested in our philosophical assumptions about what constitutes adequate knowledge. Ossorio and Davis (1967) specify these assumptions for social psychology, and these are basically the same as those used by anthropologists known as the "new" ethnographers, such as Goodenough, Frake, D'Andrade, Conklin, Hymes. This strategy assumes that complete description of individual and group behaviors involves answering two basic questions:

1. what act was that, or what did he (they) do?
2. what place does that action have in that individual's life or that group's history?

In answering the first question it is assumed that the behavior, individual or collective, is intentional and that descriptions of action can be carried out in terms of structural concepts involved in the concept of intentionality. These structural concepts are: want, know of, know how, and overt attempt. When an action (behavior) is analyzed in terms of each of these structural concepts, i.e., when content is furnished for each concept, then we have a complete description of what act that was, i.e., we have answered the first question. In other words, we know what motivated the individual (group) to attempt the action, we know what the individual (group) had to know to act thus, we know what skills or abilities he (they) had to possess to act thus, and we know what action he is (they are) doing or seems to be accomplishing (neutral behavior description).

Answering the second question involves redescriptions of intentional action which allow us to ask and answer new and different questions. X and Y may perform exactly the same action, i.e., descriptions of what acts they performed may be identical. However, the place of that action in the life of X can be very different than in the life of Y. Let us assume that both X and Y are observed to hit a child. For X this aggressive act may be simply one in a series of such acts that lead us to conceive of him as an aggressive person--we attribute a trait which we call aggressiveness to X. For Y this act may simply have been an unusual outburst--we attribute a state which we call, for example, tiredness to Y, thus indicating a lapse in normal performance. As suggested above, answers to the second question are carried out in terms of structural concepts such as abilities, states, traits, values, etc.

The basic questions which must be asked to explain what we have described are these:

1. why did he (they) perform that act?
2. how did he (they) get to that particular place in his life (in their history)?

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9. EMERGENCY PLANNING AND URBAN PROBLEMS

Claire Nader

9.1 SUMMARY

The focus of this discussion is the relation between emergency planning and urban problems in a particular city. The main point which emerges is that civil defense, or emergency planning, constitutes but one strand in a complex network of urban problems competing for the attention of government officials and leading citizens. Moreover, it does not have a high priority in this network.

The specific conditions described draw on the situation in an urban community actually engaged in emergency planning with the federal government. A city of some 400,000 persons was selected and a number of its officials and influential citizens interviewed. Suffering from the effects of serious disorganizing forces, this city faces a substantial loss of its collective and recuperative powers. Thus, the prime concern of its leaders is to restore some equilibrium in the city's general health.

In this context, several realities affecting the establishment of an effective civil defense program became apparent: (1) social and economic disorder makes it difficult to undertake any program not directly related to the fundamental objective of ameliorating situations of urban stress, strain, or runaway social disorganization; (2) when the main responsibility for a program is regarded primarily as a federal rather than a local one, local problems take precedence; (3) deficiencies in emergency planning tend to be further aggravated by the absence of a long-range national civil defense commitment, particularly when the quality of the existing federal program is questioned by responsible officers.

The critical dilemma, however, is provided by destabilizing social conditions which critically determine the city's order of priorities. The selection of these priorities is affected by what needs the city recognizes, by the resources at its disposal to meet these needs, and by what it defines as primary responsibilities, that is, "local" problems. Even local problems are sometimes more than the city can handle.

Although based largely on interviews in a particular city (hereafter to be referred to simply as "the City"), the observations to be made are not unique to it. Recent discussions in another city and examination of cases where cities have terminated emergency planning arrangements suggest that other urban areas may well share some of the same problems. This report will discuss the kinds of urban problems that City officials face, which ones they give priority to, and what factors guide their choices.

9.2 URBAN PROBLEMS: HOW URGENCY DETERMINES PRIORITY

The kinds of situations which concern the officials in the City are similar to those in other so-called central cities. Severe economic and social problems which cause critical deprivations and tensions occupy the forefront. These pose a further threat to urban stability if not adequately met in time. Thus, problems of unemployment resulting from obsolescent training, lack of jobs, problems of juvenile delinquency, and problems accompanying the presence of a large and growing minority group are not only important, but urgent. These difficulties are compounded by the loss of the purchasing power of a middle class, the deterioration of the downtown shopping area, departing industry and lagging industrial development, inadequate housing and educational resources and other facilities. Further problems are those created by urban renewal and rehabilitation, urban sprawl, and the severe dearth of leadership elements, the latter being a key part of the general trained manpower problem.

City officials appreciate the dynamic character of these primary social and economic problems as well as their interrelationship. They know that the unfortunate conditions responsible for these problems are not new; but experience has outlined the dire consequences to the City's survival capacity if the fullest resources of government and other public organizations are not applied to meeting them. Still generally positive in outlook as to what can be accomplished but knowing well the hazards of lagging efforts, these government officials and other leaders are focusing serious, sustained, and concentrated attention on the impending dangers of continued social disturbances and disequilibrium. They seek cooperative means to reduce the resulting tensions and have both used existing organizational resources and developed new responses when necessary. A case in point is a municipal department to develop human resources, a notable hallmark of innovation, emphasizing the importance of the human as well as the material resource.

Yet, despite such demonstrated resourcefulness the framework of severe limitations within which City officials must act is painfully evident. The expenditure of time, money, and skills in one hardship area subtracts from the total store of energies available to another. The necessity of choice immediately becomes apparent. Ranking first in importance among municipal concerns are the primary urban needs mentioned above and commonly referred to as "people problems." Because of their number, size, and character, they demand the immediate attention of the local authorities. The incentive to act here is, of course, rooted in the City's responsibility to insure the public safety and health of its citizens. Since City officials cannot cover every contingency or need, priority is given to a situation that constitutes a clear threat in the present as opposed to some vague threat in the future. This future threat is hard put to compete for attention with existing serious problems, especially in the face of constant reminders of imminent crises such as the Watts racial riots in Los Angeles and the Rochester disturbances.

Thus, problems which raise basic questions of civilized survival itself of necessity take precedence over all others, even those of air and water pollution in a region where there are pressing difficulties. A leading citizen, when asked about the City's role in clean air, granted the seriousness of the hazards of environmental pollution. Indeed, he said, they are likely to match in impact the major local issues--the Negro and the whole related complex of concern, the marked shortage of leaders, and the question (on which there is disagreement) of what constitutes a viable region and how to pull together its various communities on common problems. And yet, he argued, if these social issues are not resolved, the ability of the City to serve its people will decline even more and the disorganizing forces ultimately infect the entire region as if by chain reaction. Such an adverse contingency, he pointed out, must have priority even over environmental danger. Although he recognized the seriousness and immediacy of pollutions problems, in his view the more fundamental concern of the moment was the development of the urban economy and its resources. An extension of his line of reasoning could include federally designated potential emergencies in the same class as environmental hazards. In short, the problems that catch the official eye are largely those that threaten to undermine the City itself if overlooked.

Under such circumstances, it is not easy for a City administrator to assume direct policy responsibility in a program described by the federal government unless local needs are embraced by the program. This difficulty applies to civil defense. But, should civil defense come to rank in importance and urgency with the current issues in the minds of officials, the question of responsibility would become, in the final analysis, accountable to and dependent on the people, their resources and their order of priorities.

In the event of an attack on substantially heightened or sustained international tension, the City will attempt to respond to this problem without federal prodding. For example, in the Cuban missile crisis special measures to strengthen the local civil defense arrangements were instituted by the Chief of Police who was the responsible operations officer, reporting ultimately to the Mayor of the City.

The central point of this extended discussion is that the City will not plan ahead for the nuclear attack contingency due to present, locally rooted emergency needs which draw heavily on resources. The result is that civil defense protective measures receive inadequate attention and plans remain minimal. The City is not able to cope with this problem area. Such a situation could logically lead to the regional approach in emergency planning since the precedent is set. Metropolitan regional districts exist to deal with air and water pollution control flood control, rapid transit, municipal utilities and sewage disposal. Yet, no similar district exists for civil defense. In sum, then, recognized immediate needs help establish urban priorities.

9.3 URBAN PROBLEMS: HOW RESOURCES DETERMINE PRIORITY

Lack of resources constitutes a further limitation on what problems get attended to. Urban leaders, well aware of the threat to community well-being, are highly cognizant of the insufficiency of resources at hand with which to counter it. Meanwhile these resources, scarce in themselves, are actually diminishing as attraction of new industry fails to keep pace with the departure of established industry and as leaders and potential leaders leave the City for the suburbs. Such a drain on the financial and leadership resources would be hard for a flourishing city to sustain; it leaves a declining one in severe straits.

Effective action is limited not only by an insufficiency of resources but also by the kinds of resources available. Competition for the same resource is keen; choice is further complicated because usually one has to choose between equally desirable objectives. In other words, resources as well as needs determine urban priorities.

The kind of human and material resources available to a city or a region can contract responses and shape expectations. It can limit the areas of substantive action. Among these restraints are: (1) lack of financial resources, (2) inadequate specialized skills and leadership elements, and (3) organizational limitations. Administrative vision is bounded, as Geoffrey Vickers has noted,[1] by the spatial area and time span over which an organization can plan, by its own past experience which affects how it will respond to its new problems, and by its present activities. Attention itself then must be considered a scarce resource, because a focus of attention on any one activity restricts attention to other activities.

While the drain of citizens to the suburbs has been mentioned, the citizenship of the commuter deserves attention, particularly since it was pointed up by numerous individuals. In the words of a leading official, "a commuter population in the power structure" creates a vacuum in civic leadership and results in a "desperate situation." That group which could contribute critically to the improvement of urban health lives mostly in the pleasant surrounding suburbs which attempt to insulate themselves from the City's problems. The absence of large elements of this leadership group contributes significantly to the disintegration of the urban center.

9.4 CIVIL DEFENSE: A PROBLEM REQUIRING LOCAL, STATE, AND FEDERAL COOPERATION

Current urban problems absorb the time and energy of local government, heavily taxing its creativity and its political organization and limiting its focus largely to the present and the possible. In the context of this environment, civil defense is not an important issue. Defense planning, of which civil defense is a component, is perceived as a national problem and therefore beyond the perimeter of mere urban concern. While it is recognized that the cooperation of urban leadership is required in emergency planning, the basic responsibility for protecting the nation against attack belongs to the federal government. This perception of local leaders raises fundamental and recurring questions of intergovernmental relations, especially for problems which by their substance, impact, and consequence affect the whole society. Many serious problems besides civil defense require the close cooperation of federal, state, and local governments for resolution. The volume of these problems and their importance to the common welfare suggest and mandate a major role for agencies of government. How will government organize to handle them?

It has never been easy to arrive at a proper division of labor in the American federal system for lack of consensus on guiding principles and their specific application. The administrative and political problems associated with allocating functions have by no means been resolved. Moreover, the rate and nature of changes in human society further discourage any idea of fixed or satisfactory answers on this question. A facile division of functions neatly between local, state, and national governments is neither practical nor likely; complex problems require collaborative governmental action on the basis of shared functions. Although the mix of responsibilities will vary according to the prevailing conditions in society and the requirements of specific problems, the combined energies of the three levels of government are joined in increasing instances. These circumstances led Morton Grodzins[2] to observe that the marble cake more appropriately symbolizes the American system of government than the layer cake, denoting a clean separation of functions. This is an apt analogy for the City's view of civil defense preparations. Although the City officials would allocate to the federal government the responsibility for primary policy and comprehensive planning for civil defense, they are prepared to participate cooperatively in carefully defined programs funded basically from nonmunicipal sources. National leadership must not only provide funds but also some evidence of a realistic plan of protection against the impact and subsequent effects of a nuclear attack.

Thus far, in their view, the nation's civil defense program has had inadequate authority and guidance at the highest levels. Historically, they point out, policy guide lines have often been ambivalent and unclear, and programs unimpressive. This situation has not served to give the program in the City much credence in official and nonofficial circles. One former City official, who had performed high management functions in two cities, summed up his twenty-year experience with civil defense. He noted deficiencies in: (1) national and state leadership, (2) effective federal and state legislation, (3) appropriations, and (4) county and City council interest. Also, he mentioned the advice of the local taxpayers association to abolish the existing program on grounds of inadequacy. He concluded that without definitive Department of Defense leadership in civil defense, the City cannot be expected to respond significantly. It can ill-afford to plan or finance any large-scale shelter construction program. This overall viewpoint is shared by several other local government officials who are still on the job.

A leading participant in community affairs made the following related point: he observed that there are simply too many immediate and proximate community problems which occupy his attention. Moreover, these are problems that he can affect way beyond any of those of modern warfare. For an effective protection policy against nuclear war, he will depend on federal leadership.

In general, urban leaders look for serious expressions of an enduring national commitment to civil defense. Without sustained Presidential and/or Congressional support, they do not believe progress can be made on the problem. Such a commitment must be reflected in policy, in a comprehensive plan, and in adequate funding. That the various functions for making any plan operative will have to be shared is appreciated. Officials who would be involved in implementation express the belief that local personnel will have to shoulder a major responsibility if a viable civil defense program is to be carried out. They recognize that an efficient system depends on continuing attention to interactive technical, administrative, and socio-political factors. Such a civil defense system, they maintained, requires strong local leadership, as does the orderly use of state and federal aid. Nonetheless, these officials remain pragmatic. In their view, a viable national plan supported at the highest levels of government is an absolute prerequisite for realistic action by the City.

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IV. CIVIL DEFENSE PROTECTIVE SYSTEMS

10. BLAST AND SHOCK WAVES

Lawrence Dresner

10.1 INTRODUCTION

This chapter summarizes theoretical work on blast and shock waves carried out between May 1965 and March 1966. Part of the work deals with propagation of plane, cylindrical, and spherical blast waves in homogeneous, isotropic media (Sect. 10.2). Two practical applications have been made of the theory developed, one to the decay of blast waves in tunnels, and the other to the decay of blast waves from underground nuclear explosions in alluvium. The rest of the work deals with the distribution of reflected pressure on the ground following an air burst (Sect. 10.3) and the action of blast doors (Sect. 10.4).

10.2 BLAST WAVES IN HOMOGENEOUS, ISOTROPIC MEDIA

To understand the blast effects of nuclear explosions one needs to know the pressure, density, and material velocity as functions of time and position. Brode's detailed numerical calculations[1] supply this information for spherical blast waves in air, but for other geometries and for other materials (e.g., solids) no comparable calculations exist. In these latter cases, we can resort to the older method of piecing together a solution from the analytic solutions known to apply very near and very far from the explosion.

Very near an explosion in a polytropic gas, the variation of pressure, density, and material velocity is described by the well-known similarity solution of Taylor, von Neumann, and Sedov.[2] This solution also applies to point explosions in solids in the region where the solid is vaporized. What is of more practical value is that the similarity solution sometimes also applies in the high-pressure region just beyond the boundary of the vaporized region. This is the case with the alluvium found at the Nevada Test Site, as briefly indicated below.

Holzer[3] has reported a series of experimentally determined points on the Hugoniot curve of alluvium in the pressure range 25-500 kilobars. These points are well fitted by the curve $p = 30\ v^2$ (p in kilobars, v in mm μsec^{-1}), where p is the pressure just behind the shock front and v is the corresponding material velocity. Now according to the Rankine-Hugoniot equations for strong shocks, $\rho_0/\rho = 1 - \rho_0 v^2/p$, where ρ and ρ_0 are the respective densities of the shocked and undisturbed matter; thus in the pressure range 25-500 kilobars, ρ/ρ_0 is constant (and equals 2.1). If we define a constant γ such that $\rho/\rho_0 = (\gamma + 1)/(\gamma - 1)$, the Rankine-Hugoniot equations for strong shocks imply that the internal energy e per unit mass of the shocked solid is $e = p/(\gamma - 1)\rho$. If this expression describes the matter behind the shock front, the adiabatic equation of state of this matter is $p\rho^{-\gamma}$ = constant. Formally, therefore, we should be able to describe shock waves from an explosion in alluvium in the 25-500 kilobar range as though the explosion occurred in a polytropic gas with an adiabatic exponent γ (= 2.8).

We can test this idea by comparing the results on the similarity theory with experimental data reported by Holzer[3] on the time of arrival of the shock front at various positions. For a self-similar shock wave, the time of arrival t of the shock at a given radius R is

$$R = \left(\frac{Y}{\alpha\ \rho_0}\right)^{1/5} t^{2/5} , \qquad (1)$$

where Y is the yield of the explosion and α is a number related to γ. For alluvium, $\alpha = 0.15$.[4] The agreement between Eq. (1) and the experimental results is good.

The similarity solution loses its validity far from the explosion. But far from the explosion, we can use the fact that the shock wave is weak to obtain the law of its propagation. To see how this is done, let us begin by considering a <u>weak</u> plane disturbance propagating in the positive x-direction.

Let the air behind the disturbance have the same pressure and density as the undisturbed air. The tail of the disturbance then travels with the sound velocity c_0 of the undisturbed air. The head of the disturbance travels faster with a velocity U given in terms of the peak overpressure P behind the shock front by the Rankine-Hugoniot equations:

$$U = c_0 \left(1 + \frac{\gamma + 1}{2\gamma} \frac{P}{p_0}\right)^{1/2} \approx c_0 + \frac{\gamma + 1}{4\gamma} c_0 \frac{P}{p_0} . \tag{2}$$

The length l of the disturbance increases at a rate given by

$$\frac{dl}{dt} = U - c_0 = \frac{\gamma + 1}{4\gamma} c_0 \frac{P}{p_0} . \tag{3}$$

We can eliminate l on the left-hand side of Eq. (3) in favor of P by using the condition of conservation of energy. For a weak disturbance,

$$E = \int_0^\infty \frac{P'}{\gamma - 1} dx = \frac{Pl}{2(\gamma - 1)} , \tag{4}$$

where P' is the overpressure at any point at a fixed time. The second equality has been obtained by using the fact that the pressure profile asymptotically becomes linear. If we now use Eq. (4) to eliminate l on the left-hand side of Eq. (3), we obtain the differential equation

$$-\frac{1}{P^3} \frac{dP}{dt} = \frac{\gamma + 1}{2\gamma(\gamma - 1)} \frac{c_0}{Ep_0} . \tag{5}$$

The solution of this differential equation gives the asymptotic behavior of the overpressure for long times:

$$\frac{P}{p_0} = \left(\frac{4\gamma(\gamma - 1)}{\gamma + 1} \frac{E}{p_0 X}\right)^{1/2} , \tag{6}$$

where X has now replaced $c_0 t$. This result was first obtained by Bethe,[5] Chandrasekhar,[6] and Landau.[7]

Similar results may be obtained for the asymptotic decay of spherical shock waves, but they are not as easily normalized by use of the law of conservation of energy as in the case of plane waves. Weak spherical shock waves decay according to the law

$$\frac{P}{p_o} \sim \frac{1}{R\left[\ln(R/R_o)\right]^{1/2}} , \qquad (7)$$

where R_o is an undetermined constant.

In the introduction, two applications of the theory outlined above were mentioned. The first was to the attenuation of blast waves in tunnels. Blast waves are attenuated in tunnels because there is a rarefaction behind the shock front and because a boundary layer builds up at the wall. The effects of the rarefaction behind the blast front can be accounted for using the theory already described. Let us consider a plane blast wave created by the instantaneous liberation at time $t = 0$ of an energy $2E$ per unit area in the plane $x = 0$. At any later time t, shock fronts reach the planes $|x| = X$. When the overpressure P is large compared to the pressure p_o of the undisturbed air, it is given by the similarity solution in plane geometry[8] as

$$\frac{P}{p_o} = 0.69 \frac{E}{p_o X} . \qquad (8)$$

When $P \ll p_o$, Eq. (6) describes the variation of overpressure with distance. Shown in Fig. 10.1 are Eqs. (6) and (8) along with a curve that joins them smoothly.

The effect of boundary-layer buildup at the wall has been studied experimentally. Emrich and Wheeler[9] conclude that owing to wall friction shock waves in a tube are attenuated exponentially with distance, falling by a factor of e (2.718...) in about 400 diameters (D). Thus, the overall attenuation of shock waves in tubes might be described by the equation

$$\frac{P}{p_o} = f\left(\frac{p_o X}{E}\right) \exp\left(- \frac{X}{400D}\right), \qquad (9)$$

where $f(p_o X/E)$ is the curve shown in Fig. 10.1.

The second application mentioned in the introduction of the theory is to the decay of blast waves from underground nuclear explosions in alluvium. Figure 10.2 shows experimental points[3] on the pressure-distance curve of alluvium. It also shows as the high-pressure asymptote the following equation of the similarity theory:

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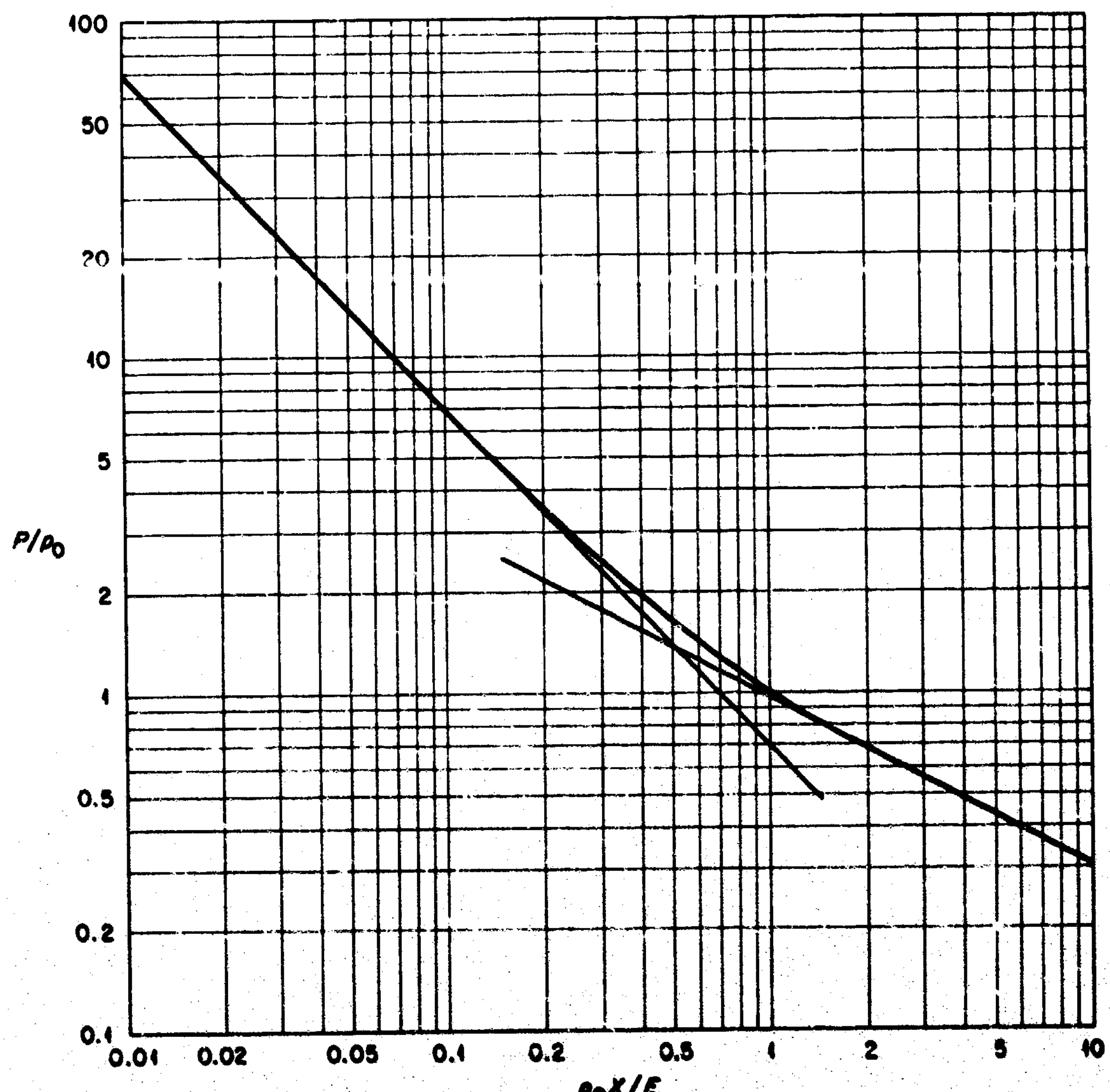

Fig. 10.1. Dimensionless Representation of the Variation of Peak Overpressure with Distance for Plane Blast Waves.

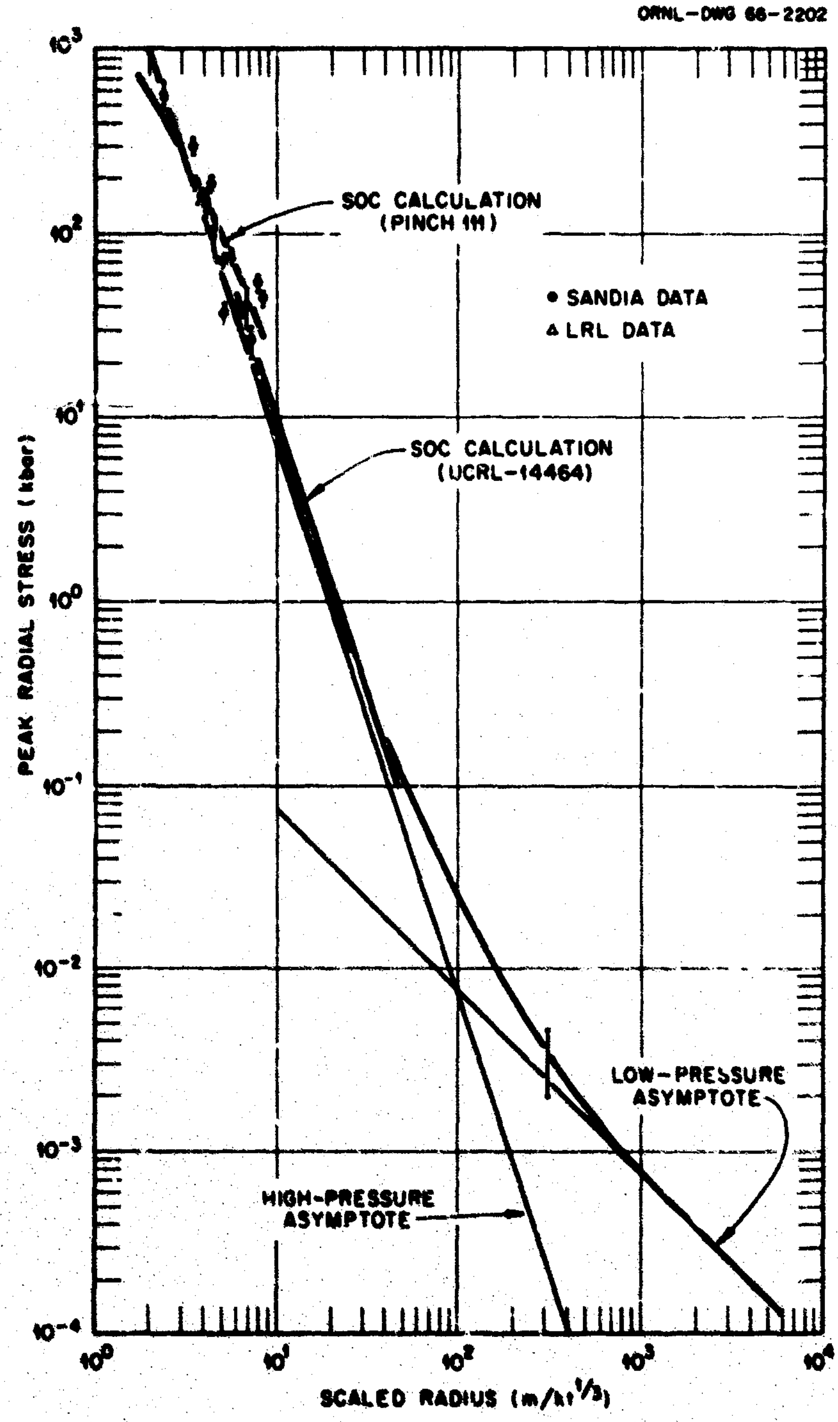

Fig. 10.2. Variation of the Peak Radial Stress with Distance from an Explosion in Alluvium.

$$PR^3 = \frac{8Y}{25(\gamma + 1)\alpha} , \tag{10}$$

where α has the same value as it does in Eq. (1). Equation (7) (with the logarithmic factor on the right-hand side henceforth assumed constant) gives the low-pressure asymptote except for normalization. It has been normalized using some data reported by Sauer et al.[10] on the ground motion induced by an underground nuclear explosion. Shown also is a curve smoothly joining these asymptotes. It passes through the string of experimental points and also agrees well with the results of a much more detailed numerical calculation.[11]

10.3 DISTRIBUTION OF REFLECTED PRESSURE ON THE GROUND FOLLOWING AN AIR BLAST

The chart given in "The Effects of Nuclear Weapons"[12] for calculating peak reflected pressure on the ground following an air burst extends to overpressures up to 200 psi. The accompanying figure (Fig. 10.3) gives this distribution in the ultra-high pressure region above 200 psi.

Plotted vertically is the reflected pressure in psi. Plotted horizontally is the distance from surface zero in units of the burst height. The numbers labeling the various solid curves are the free-field (incident) pressures at surface zero.

The calculations are based on the following assumptions:

1. The atmosphere is homogeneous and composed of a polytropic gas with a ratio of specific heats of 1.4.
2. The pressure behind a spherical blast front falls off with radius in the manner calculated by Brode.[1] Close to the explosion, the pressure falls off with the third power of the radius, as expected from the similarity solution.
3. Only weak regular reflection and weak direct Mach reflection occur. When both Mach and regular reflection are possible, Mach reflection is assumed to occur.[13]

For the upper five curves (incident pressures at surface zero of 100, 150, 200, 300, and 500 psi), the loci representing regular and Mach reflection intersect on the weak branch of the regular reflections. The change

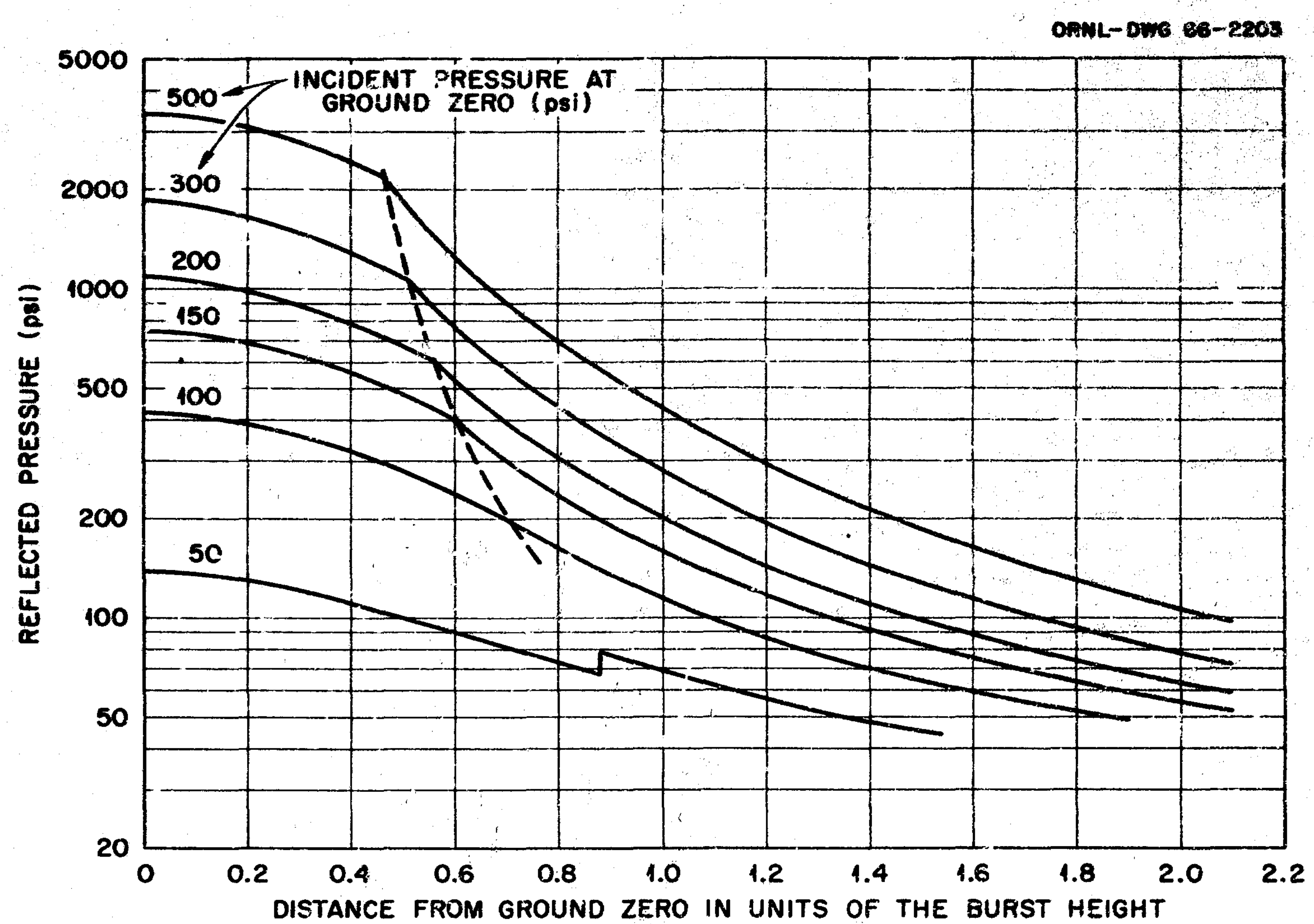

Fig. 10.3. The Distribution of Reflected Pressure on the Ground Following an Air Burst.

from regular to Mach reflection therefore produces at most a discontinuity in slope in the curve of reflected pressure vs distance from surface zero. The coarse dotted curve is the locus of these discontinuities and separates the region of regular reflection from the region of Mach reflection. In the lowest curve (incident pressure at surface zero of 50 psi), the loci representing regular and Mach reflection intersect on the strong branch of the regular reflections. Therefore, the change from regular to Mach reflection is marked by a discontinuity in value in the curve of reflected pressure vs distance from surface zero. This discontinuity is shown in the figure as a fine dotted line.

The calculations were done with the aid of published graphs[14] of the so-called "magnification factor" as a function of angle of incidence for various strengths of the incident shock wave. Since the information in these published graphs was scanty, they were supplemented with additional graphs.

10.4 BLAST DOORS

The work to be reported here on the action of blast doors is purely exploratory in nature. Its purpose is to study in an "order-of-magnitude" way some of the obvious questions regarding the operation of blast doors.

The first question that one thinks of in connection with any blast door is, "How strong is it?" When an elastic-plastic solid, such as steel, fails, the strain it has undergone has largely occurred in the plastic range of behavior. In the plastic range, stress is roughly constant and independent of strain, allowing us to approximate steel blast doors as elastic membranes of constant surface tension. (This approximation is of course valid only for monotonically increasing strain; should the strain decrease, the stress would drop sharply to zero, and a large residual strain would remain.)

Let us imagine a membrane of constant surface tension sealing the end of a right circular cylinder of radius R_o. Let the cylinder contain a gas at pressure p. The membrane accommodates itself to the pressure of the gas by ballooning out in the shape of spherical cap. The radius R of the cap is related to the pressure and surface tension by the equation

$$p = \frac{2\Lambda}{R}. \tag{11}$$

The strain η in the membrane can be calculated from the change in its surface area:

$$\eta = \left(\frac{R}{R_o}\right)^2 \left[1 - \sqrt{1 - \left(\frac{R_o}{R}\right)^2}\right] - \frac{1}{2} \approx \frac{1}{8}\left(\frac{R_o}{R}\right)^2 . \tag{12}$$

If T is the thickness of the steel blast door and σ is the constant stress it sustains in the plastic range, the surface tension Λ equals σT. Let us now consider, for example, a blast door two in thick and eight ft in diameter made of T-1 steel* (such as might be appropriate to the tunnel-grid system under consideration at ORNL). The constant stress in the plastic range is about 1.1×10^5 psi and the strain at failure is about 10%. From Eqs. (11) and (12) we see that this door can support a static stress of about 6900 psi.

The maximum strain produced by a load suddenly applied to a door is larger than the strain produced by an equal load applied slowly. When the strain is small, the motion of the membrane is governed by the wave equation

$$\mu \frac{\partial^2 Y}{\partial t^2} = p + \Lambda\left(\frac{\partial^2 Y}{\partial r^2} + \frac{1}{r}\frac{\partial Y}{\partial r}\right), \tag{13}$$

where μ is the mass per unit area of the membrane, Y is the displacement of a point on the membrane out of its original plane, r is the radius measured from the center of the membrane, and t is the time after the sudden application of the pressure p. The relevant boundary and initial conditions are

$$Y(r,0) = 0, \quad \frac{\partial Y(r,0)}{\partial t} = 0, \quad Y(R_o,t) = 0 . \tag{14}$$

*United States Steel T-1 steel.

The solution determined by these conditions is

$$Y(r,t) = \frac{pR_o^2}{4\Lambda}\left[\left(1 - \frac{r^2}{R_o^2}\right) - 8\sum_{k=1}^{\infty}\frac{J_o(\alpha_k\, r/R_o)(\alpha_k t/aR_o)}{\alpha_k^3 J_1(\alpha_k)}\right], \qquad (15)$$

where $a^2 = \mu/\Lambda$, J_o and J_1 are the Bessel functions of order zero and one, respectively, and α_k is the k^{th} root of J_o. This solution is only applicable to describing the motion of the blast door during its first outward passage. The door does not, of course, move in again. The first term on the right-hand side is the static solution.

The center of the membrane reaches its first maximum displacement when $t = 1.18\ aR_o$ (about 4.7 msec for the door made of T-1 steel); the displacement at this time is $2.21\ pR_o^2/4\Lambda$, i.e., 2.21 times the static displacement. If the strain at failure is small, the blast door can support a suddenly applied pressure 2.21 times smaller than the static pressure it can support. The door made of T-1 steel can support a suddenly applied pressure of about 6900/2.21 = 3100 psi; a 3100-psi pressure results from the normal reflection of a 450-psi incident shock wave. Its energy absorption capacity, based on an energy absorption of T-1 steel of 9400 in.-lb/in.^{3}, is about 7.8 lb-TNT. For comparison, the linear energy density of a 450-psi shock wave in an 8-ft tunnel is about 10 lb-TNT/ft. Since a shock wave with a 450-psi peak overpressure and a duration of several tenths of a second is of the order of 1000 ft long, it is clear that energy absorption by doors that fail will probably not attenuate a long-duration blast wave from a megaton weapon by more than a fraction of a percent.

Some of the theory developed in the preceding sections may be applied to analyzing the operation of blast-activated blast doors. A blast-activated blast door is a door that is closed by the reflected pressure of an incident blast wave. Because of its inertia, a blast-activated door requires a finite amount of time to close; during this time, a portion of the highly compressed air behind it may leak past it and create a shock wave on the protected side of the door.

What is the pressure behind this secondary shock front? We can find the answer to this question by noting that the situation is not unlike that in a shock tube. The reflection of the incident shock wave produces a region of highly compressed, stationary air in front of the reflecting surface. The expansion of this compressed "driver" air around the door produces a shock front that advances into the stationary air beyond the door.

The pressure p behind the shock front in a shock tube is related to the pressure p" of the driver gas by the so-called Taub equation.[15] This equation takes the following form when the driver gas and the driven gas are the same:

$$p = p''\left[1 - \frac{\gamma - 1}{c''} \cdot \frac{p - 1}{\sqrt{2\gamma\left[(\gamma + 1)\, p - (\gamma - 1)\right]}}\right]^{2\gamma/(\gamma-1)} . \qquad (16)$$

Here both p and p" are expressed in units of the pressure of the ambient air; c" is the sound velocity of the compressed driver gas expressed in units of the sound velocity of the ambient air; and γ is the ratio of the specific heats of air (1.4).

By hypothesis, p" and c" characterize air that has been compressed by reflection of a shock the pressure behind which is p' in units of the pressure of the ambient air; p" and c" are related to p' as indicated below $\left[\mu^2 = (\gamma - 1)/(\gamma + 1) = 1/6\right]$:

$$p'' = p' \cdot \frac{(2\mu^2 + 1)p' - \mu^2}{\mu^2 p' + 1} , \qquad (17)$$

$$c'' = \sqrt{p'' \cdot \frac{1 + \mu^2 p'}{p' + \mu^2} \cdot \frac{p' + \mu^2 p''}{p'' + \mu^2 p'}} . \qquad (18)$$

Once a value of p' has been chosen, p" and c" may be readily calculated from Eqs. (17) and (18). Equation (16) may then be solved for p by iteration. A good initial trial value for p is p'. The trial value is inserted in the right-hand side of Eq. (16) and a first iterate obtained. The method converges rapidly when the average of the trial value and the first iterate is chosen for the next trial value. Given below is a short table of p vs p'.

p'	1.50	3.00	6.00	12.00	24.00	>> 1
p	1.50	3.00	6.007	12.10	24.39	1.0306 p'

Thus for all practical purposes, the secondary shock wave has the same characteristics as the incident shock wave. For this reason, it is probably an adequate approximation to assume that the shock wave leaking past a blast-activated blast door is simply the truncated head of the incident shock wave.

The length of time it takes a blast door to close determines its effectiveness. Although this time depends on the design of the door, its order of magnitude may be estimated as follows. The door must be strong enough to withstand the reflected pressure p" of the shock wave after it has closed. Thus, given the material of which the door is made, its mass per unit area μ is determined by its strength. The quotient of the reflected pressure of the shock wave and the mass per unit area determined by it equals the acceleration a of the door. The acceleration and the stroke s through which the door travels determine the time t it takes to close. Quantitatively,

$$t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2\mu s}{p''}} .$$

By allowing the door to fail plastically, μ can be made small. In the plastic range, the mass per unit area necessary to withstand a given pressure p" varies directly with p", as is evident from the preceding discussion of plastic failure. Thus, we expect the minimum ratio μ/p'' to be independent of p", i.e., that the maximum attainable acceleration will be the same for all doors no matter what overpressure they are designed to withstand. It takes about 8.2 mm of T-1 steel to withstand a suddenly applied pressure of 500 psi. Thus $\mu = 0.82 \text{ cm} \times 7.75 \text{ g cm}^{-3} = 6.35 \text{ g cm}^{-2}$, and $a = p''/\mu = 5.25 \times 10^{6} \text{ cm sec}^{-2} = 5360$ g, where g is the acceleration of gravity. If the stroke s of the door is one meter, which is surely a lower bound, the time t it takes the door to close is 6.15 msec.

In this paper, it is assumed that all blast doors close in 10 msec when activated by the maximum pressure p" they are designed to withstand. Naturally, they close more slowly when they are activated by a lower pressure.

Let us now consider a blast-activated blast door designed to protect inhabitants of an 8-ft-diam shelter tunnel up to but not beyond 100 psi. At the 100-psi radius, the blast door will close in 10 msec. The shock speed of a 100-psi shock wave is $U = 2910$ ft sec^{-1}. In 10 msec, a segment of the shock 29.1 ft long will leak past the blast door. The overpressure p in this segment is 100 psi; the dynamic pressure q is 125 psi. The energy density of this moving compressed air $p/(\gamma - 1) + q = 375$ psi $= 2.5 \times 10^7$ ergs cm^{-3}. The energy density per unit area E of the compressed moving air is 2.18×10^{10} ergs cm^{-2}, and its total energy is 9.85×10^{14} ergs = 23.5 kg TNT. Since the total energy of the initial shock wave was 750 kg TNT, this truncation process can be considered as an energy "filter." If the 23.5 kg of TNT were spread uniformly over the inside of the blast door and exploded there, the overpressure of the resulting blast wave would reach 5 psi 1900 ft from the blast door, according to Eq. (9).

The foregoing considerations can be applied to analyzing the performance of a tunnel shelter containing periodically spaced blast doors. Shown below in the table are the overpressures at the first few blast doors that do not fail. The doors are spaced every 1000 ft in the tunnel, which is 8 ft in diameter.

Peak Overpressure at the First Few Blast Doors
That Do Not Fail
(Doors spaced every 1000 ft in 8-ft tunnel)

	Maximum Incident Overpressure That Can Be Withstood		
Door	1000	300	100
First	1000	300	100
Second	200	31	9
Third	41	7	--
Fourth	12	--	--

As an example of the use of these figures, let us consider the case of a 1-MT surface burst. The radii of the 1000-, 300-, 100-, and 30-psi circles are 1300, 2100, 3400, and 5800 ft, respectively. If 1000-psi blast doors are installed, the 10-psi radius extends to slightly more than 4300 ft. For 300-psi doors, it extends to slightly less than 4100 ft, while for 100-psi doors, it extends to slightly less than 4400 ft. For 30-psi doors, it extends beyond 5800 ft. It appears, then, from this example that there is little advantage in using blast-activated blast doors designed to withstand very high pressures.

Of course, the foregoing analysis is based on the assumption that the truncated head of the incident shock wave continues to propagate down the tunnel. Designs have been suggested that avoid this feature of simple blast-activated blast doors. In a sense, the foregoing analysis discloses the advantage obtained for the additional cost of these more complex doors.

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11. THE THERMAL THREAT TO SHELTERED POPULATIONS

J. W. Strohecker

11.1 NUCLEAR WEAPONS EFFECTS

The thermal threat to sheltered populations comes entirely from the secondary fire effects of nuclear weapons. (Shelters here are defined as spaces shielded, up to design competence, from the direct effects of nuclear weapons.) The effect of direct thermal radiation from the fireball on the unshielded population will not be discussed here. The primary ignitions caused by thermal radiation and the secondary ignitions caused by blast effects will combine to cause fires in rural and urban areas. Under certain circumstances the magnitude of these conflagrations can be very large. It is these fires which pose the major threat to the surviving sheltered population.

The main threats of fire are heat, toxic gases, an excess of carbon dioxide, and the absence of oxygen. To a sheltered population, these threats may take the following forms:

1. Direct heat transmission into the shelter
2. Air too hot to allow proper ventilation of the shelter
3. Air inimical to life because of the presence of dangerous gases or the absence of necessary gases
4. Air too hot to provide a suitable mechanism for the removal of heat from the shelter

It should be noted that air brought into a shelter to operate an internal combustion engine for auxiliary power might first have to be cooled (to the boiling point of water for example), but air samples taken near the ground in mass fires indicate that engine operation would probably be feasible with only decreased efficiency as oxygen is depleted.

To a deeply buried blast shelter or other underground shelter, the direct transmission of heat into the shelter should present no serious problem, but fallout shelters located in basements or upper floors of buildings may be much more vulnerable. Air which is too hot or otherwise unfit for ventilation will affect both types of shelters, while the absence of air suitable for heat removal will primarily affect blast shelters in areas without useful ground water supplies.

11.2 IGNITIONS VERSUS BLAST EFFECTS

Considerable field, laboratory, and theoretical work has been done on the ignition thresholds of materials, the thermal radiation of nuclear weapons, and models for the expected number of ignitions (both primary and secondary) from the weapons. Figure 11.1 gives approximate slant ranges for ignition of several typical kindling fuels for various weapons yields.[1] While atmospheric conditions may decrease the ranges shown, preparatory efforts at cleanup or removal of ignition sources can do little more than decrease the number of fires that will be started. While these efforts may be significant in reducing the overall damage to an urban area, the shelters in fire areas that are affected by fire still face the same problems listed earlier. Surveys of urban areas have shown the frequency of possible external ignition points to be from 3 to 30 per acre,[2] with internal ignition points somewhat higher.[3] On the basis of data from Hiroshima and Nagasaki, secondary ignitions have been estimated to be about 0.006 per 1000 square feet of floor area in the areas of major blast damage.[4] Although such secondary ignition points are less than the possible primary ignition points, they can add significantly to the possible number of fires, particularly in multistory buildings.

11.3 FIRE SPREAD, FIRE STORMS, AND CONFLAGRATIONS

Although considerable effort has been expended on models for the prediction of fire spread, casualties, and damage assessment, the knowledge in the field is uncertain and highly qualitative. At best, the present models can give a general picture only of overall damage and casualties; the specific local situations remain difficult to predict. Some of the

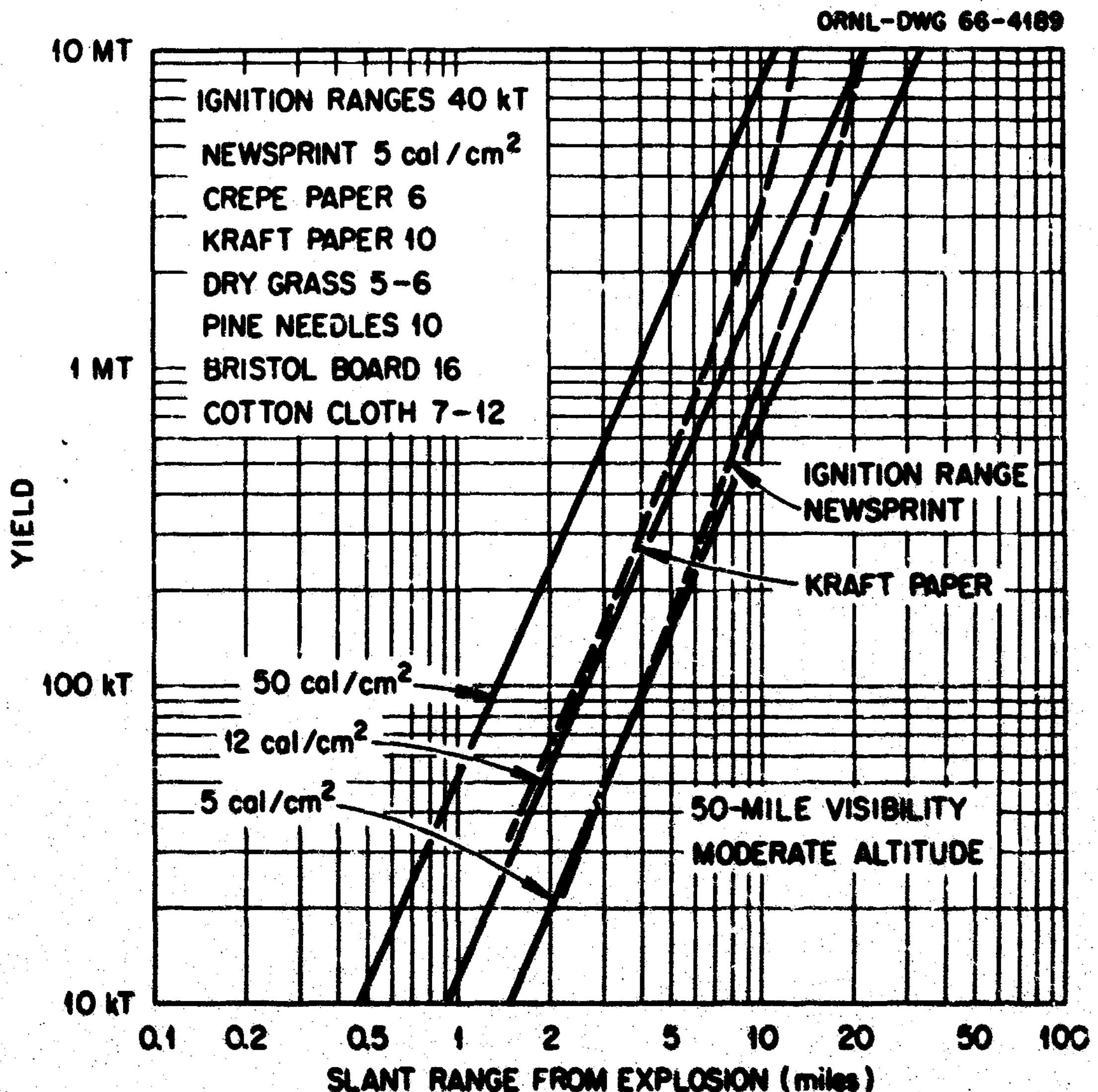


Fig. 11.1. Ignition Range--Kindling Fuels.

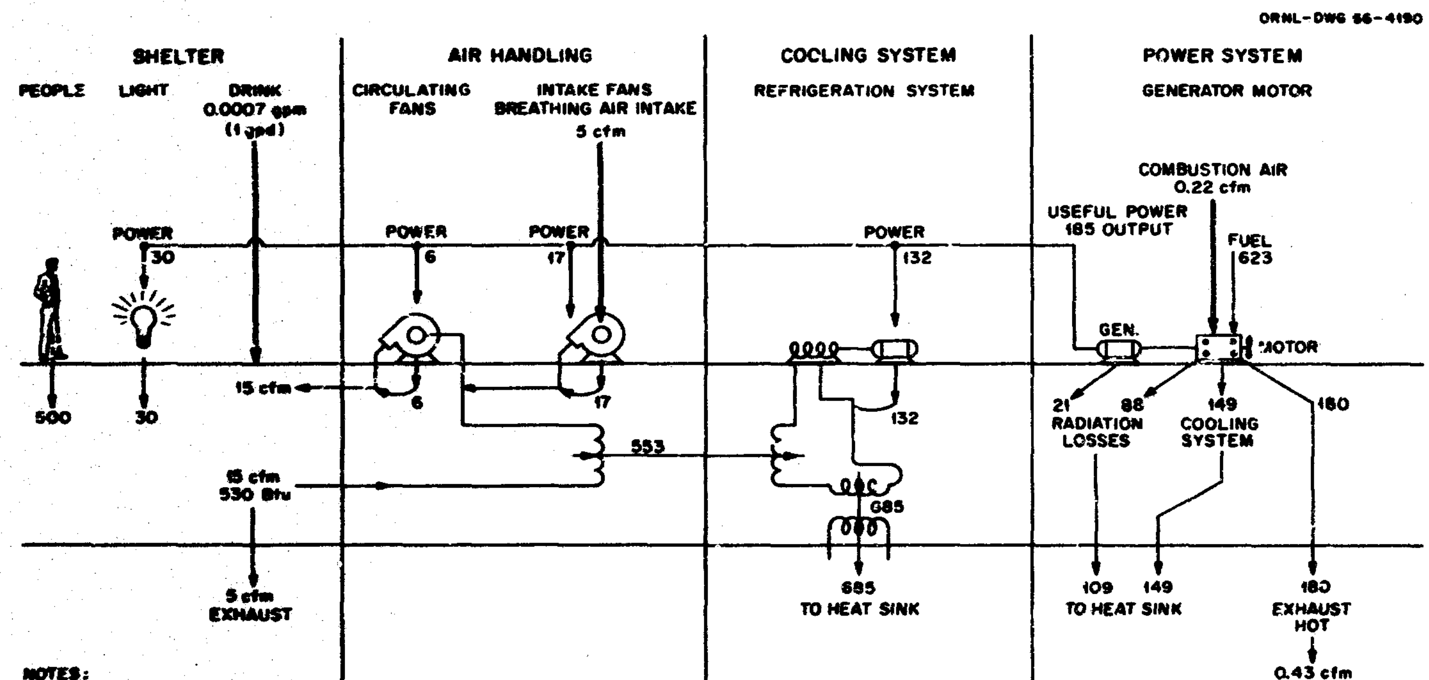
problems involved are determining the probability of ignition, the number of ignitions that will develop sustaining fires, the probability of spread and merging of these fires, and the possibility of the development of a fire storm or major conflagration. Prediction of the occurrence of a fire storm, such as those in Hiroshima and Hamburg, is even more difficult than the prediction of the damage which would be caused by it. These unknowns make the specific situation at any given shelter extremely hard to assess, especially in the major blast damage zone (in the pressure regions above 5 psi).

11.4 BLAST SHELTERS

Most blast shelters for the civilian population would quite naturally be built in areas with a strong probability of heavy damage or complete destruction by blast. Consequently, it is in these areas where a fire storm or conflagration is likely to occur, since most of the normal or inherent fire-resistant features of the buildings will be destroyed. Most blast shelters would also be built underground to simplify design and to find room in crowded urban areas. As was mentioned earlier, putting the structure underground will essentially remove the threat of direct heat transmission through the earth into the shelter.

The condition of the air above ground would constitute a threat to the sheltered population from three major standpoints. Air must generally be available for breathing, heat removal, and combustion (operation of power generation equipment). The heat balance shown in Figure 11.2 (a typical design for average conditions) gives approximate heat transfer requirements, neglecting transfer through the shelter walls. These requirements are operative only under normal circumstances. In an emergency, conditions could be changed, especially by an increase in the human metabolism rate due to stress.

The normal breathing requirement of 5 cfm of outside air per person will result in a carbon dioxide level in the shelter of about 0.3%. If this makeup rate were cut to 0.5 cfm, the carbon dioxide concentration would rise to 2.7%, which is acceptable under emergency conditions. Since



NOTES:

HEAT BALANCE

INPUT

PEOPLE	500
FUEL	623
TOTAL	1123 Btu/hr/PERSON

REMOVAL

MOTOR EXHAUST	180
MOTOR COOLING	149
MOTOR-GEN. SET RADIATION	109
REFRIGERATION SYSTEM	685
TOTAL	1123 Btu/hr/PERSON

* UNLESS OTHERWISE NOTED ALL NUMBERS ARE Btu/hr/PERSON

ALTERNATE HEAT SINKS	cfm	gpm
A-AIR CONDENSER AT 12°F ΔT	54	
AT 20°F ΔT	32	
B-EVAPORATIVE CONDENSER	~12	0.001
C-WATER AT 10°F ΔT		0.135
AT 20°F ΔT		0.060
AT 30°F ΔT		0.045
D-STEAM		?

ALTERNATE HEAT SINKS	cfm	gpm
A-AIR AT 20°F ΔT	12	
AT 30°F ΔT	8	
B-AIR + WATER 20-30°F ΔT, 50°F ΔT	3-5	0.006
C-AIR + STEAM 20-30°F ΔT	3-5	0.00027
D-STEAM ?		0.0005

Fig. 11.2. Shelter Heat Balance.

the heat content of air is small, the simple expedient of turning off the lights (see Fig.11.2) would allow the entry of 0.5 cfm per person at 150°F without adding to the normal heat load of the shelter.

If the air is completely shut off, the normal shelter volume of 50 to 100 cubic ft per person will be adequate for 3 to 6 hours before the carbon dioxide rises to 5%. Adding equipment for the addition of oxygen and the removal of carbon dioxide would make it possible to survive indefinitely with no outside air. However, the expense of this equipment is not the only consideration. The normal systems for carbon dioxide removal and the supply of oxygen would add approximately 200 Btu per person per hour to the heat load, necessitating an increase in the capacity of the refrigeration and power systems.

The combustion air requirement for the power generation equipment will be about 0.22 cfm per person. A decrease in the oxygen and an increase in the temperature of the inlet air will reduce the efficiency of the motor but will not necessarily prevent operation; nor will toxic gases such as carbon monoxide appreciably affect the operation of the motor. If cost were no object, a standard motor could be operated on a "closed cycle" by the addition of bottled oxygen and the recycle and purging of exhaust gases. For most power uses, an air supply must be maintained to the motor.

The heat removal from the refrigeration equipment and the power generation equipment is the greatest problem for blast shelter operation in a burning city. As shown in Fig. 11.2, if normal air cooling is used it could require as much as 66 cfm per person. In general, air cooling is quite expensive in most blast shelters because large ducts are costly and difficult to make blast-proof. When large quantities of water are available, air cooling may be eliminated and the problem disappears. In many urban areas, however, sufficient water is not available and some compromise is required. The best method commercially available for the power generation equipment would be the combination of 3 cfm per person of cooling air for the radiation losses from the motor to the surroundings and 2.7×10^{-4} gpm per person of water discharged as steam from the cooling system of the motor. A possible further step--insulating the motor and operating the equipment room at about 150°F--might make possible the removal of all of the waste heat as steam from this system with 5.0×10^{-4} gpm of water per person. The steam could be exhausted into almost any external environment. Such power equipment is not available commercially, and an experimental study is planned to test the concept.

For the refrigeration system, the use of an evaporative-type condenser may cut the air requirement by a factor of 3 to 5 with the addition of 1×10^{-3} gpm per person of water. This carrier air would have, of course, no oxygen or toxic gas requirements. A possible compound refrigeration system using water as the refrigerant in the second stage appears feasible. This system could allow rejection of heat to boiling water and could be of use in eliminating the carrier air stream in areas of limited water supply. Combined with the water-cooled power equipment, a single steam heat-rejection stream would be possible. Again the concept will need experimental verification and an economic analysis.

Another possibility would be to shut down completely the power and refrigeration systems and allow the shelter to be heated by human metabolism. The time limit for survival under this condition would then depend on heat removal through the walls of the shelter and could be extremely short. It is possible that from 1 to 3 hours would be available for complete shutdown, depending on initial wall temperatures, before conditions became intolerable. If the walls were thick concrete and were warm (>80°F) before shutdown, less than an hour would be available.

In summary, it is possible that a complete blast shelter ventilation system could be shut down for periods up to 1 to 3 hours in extreme emergencies with no air from outside. Longer periods could result in many casualties. Two approaches to the problem of providing an air supply in a hostile fire environment seem promising. The first would be to supply air regeneration equipment and sufficient water stocks for heat removal for an extended (many hours) button-up period. The high costs of this method mean reduced shelter spaces per available dollar. The second approach would be to provide multiple air intakes to increase the probability that an air supply would remain adequate in spite of a hostile fire environment. The first of these approaches is technically feasible now and merely requires space, time, and money to accomplish. The second approach is probably feasible, but there does not yet exist sufficient information to give a high degree of reliability for designs in crowded urban areas. Some experimental verification of the multiple inlet concept is needed.

11.5 FALLOUT SHELTERS

Fallout shelters face many of the same fire problems as blast shelters. Direct convective and radiation heat transmission from nearby fires poses a severe threat to fallout shelters located in basements and upper floors. To assess effects from large yield weapons, fallout shelters may be divided into three areas according to their distance from the blast: first, the area beyond major structural damage from the blast where there are thermal ignitions but the major active and passive fire protection systems remain intact and there are very few shelter casualties; second, the area of minor structural blast damage where fire protection systems are largely destroyed and there are moderate casualties; and third, the area of major structural damage to frame buildings where casualties are high but there are still fallout shelter survivors.

An example of the areas involved in the three regions is given below for a one-megaton weapon exploded at optimum height for each level of damage.

Table 11.1. Annular Areas of Destruction from 1 MT*

	Radius, Miles	Area, Sq. Mi.	Percent of Total
Region One--thermal ignitions, minor casualties	10-6	200	64
Region Two--minor to major damage, major casualties	6-2.5	95	30
Region Three--major to total damage, major to 100% casualties	2.5-1.2	15	4.8

*NOTE: Casualties based on fallout protection in reinforced concrete structures.

The first of these areas has comparatively minor problems and will not be considered further. The second and third areas pose more extreme problems and seem to require the approaches mentioned for blast shelters--making provisions for survival in spite of a hostile fire environment. The air problem is similar to that of the blast shelters. Yet the direct transmission of heat through shelter walls, which does not affect underground blast shelters, does affect fallout shelters. It is difficult to visualize many basement fallout shelters surviving heat transmission from a major fire on the first floor. The only design approach would seem to be to eliminate the probability of a fire of major proportions in an area adjacent to the walls, roof, or floor of a fallout shelter. A practical method in time of crisis may be the removal of sufficient combustibles from the adjacent areas to prevent a major fire close to the shelter.

11.6 ADEQUATE AIR SUPPLIES IN A MAJOR FIRE AREA

Are adequate air supplies available in a major fire area? On first glance, the answer to this question is no. Typical quotes from the literature say:

1. "Such an area would very likely be uninhabitable because of oxygen deficiency and toxic gases."[5]
2. "There was no escape for shelter occupants in the firestorm area."[6]
3. "Shelters offered no protection in the conflagration in Tokyo."[7]
4. "A shelter would be an expensive crematorium."[8]

Evidence can be gathered to show that these statements have been or could be true. However, there is also evidence that many people survived in firestorms and other major conflagrations. Somewhere in a mass fire an air supply adequate for survival existed. The optimum location for this air supply needs to be determined for the adequate design and construction of shelters, but there is already some indication where the good air may be found.

Surveys of bunkers in Germany including the ones located in the fire storm area of Hamburg revealed that "From the standpoint of protection during large city fires, no evidence was found of a single death in a bunker during these fires."[9]

These bunkers, mostly above ground, were heavy concrete structures provided with mechanical ventilation systems. Witnesses have stated that in many cases the quality of air was almost unbearable--sometimes hot and often clouded with dust and smoke[9]--but still adequate for survival. None of these bunkers were under combustible buildings, but Earp[10] describes one in Hamburg in a narrow courtyard that required a water curtain to enable people to evacuate after a raid.

In the Brunswick raid of October 15, 1944,[11] a medium strength fire storm was created. About two and one-half hours after the raid, during the height of the fire storm, a "water-alley" was established into the center of the fire storm area to rescue over 20,000 people trapped in bunkers. These people, all alive when reached four and one-half hours after the raid, were led out through the "water alley." Along with the firemen manning the "water-alley," they survived in the fire storm area for hours without casualty.

Descriptions of the Dresden fire storm,[11] one of the largest known, indicate that there were a number of survivors in the center of the fire storm who were not rescued until several days after the attack. Unfortunately, the circumstances which made survival possible are not described in most cases. However, one survivor in the boiler room of the railroad station did manage to describe how a small hole in the ceiling prevented suffocation for a few, when thousands in adjacent areas of the basement were killed.

Hiroshima surveys collected by members of the USSBS,[12] indicate that eyewitnesses were in several buildings well within the fire storm area at least two and one-half hours after the explosion and survived.

Stories of survivors from some of the large forest fires in the United States[13] indicate that survival was possible in fields, streams, and other open spaces. In many of these instances, protection from direct radiation made the difference between survival and death. In one case several people survived for hours under a wetted blanket while another person without this protection died in minutes at the same place.

The few cases cited above together with many similar ones in the literature seem to lead directly to the conclusion that, even in the midst of the most severe fires, there exists air that is adequate for survival for long periods of time. The high fatality rates in the larger conflagrations and fire storms have also proved that conditions exist in many places which do not allow survival. The challenge remains for the engineer to design and place shelter ventilation systems in such a way as to increase the probability of survival in spite of fire.

For people in the open in fires, the major problem is apparently radiation from nearby flames, blasts of flame, and blasts of hot gases driven by the high winds rather than the oxygen content of the air. For people in basement or underground shelters, however, direct heat transmission from a fire directly above, toxic gases, and oxygen deficiency constitute the main threats.

Yet there are rays of hope in the midst of a difficult picture. Most blast shelters will be immune to the direct effects of the fires and will be dependent only on an adequate air supply. Most present fallout shelters, located in buildings of fire-resistant construction, will be considerably more effective against internal fire problems than the basement shelters in the Hamburg and Dresden fires. The location of these German shelters under buildings of combustible interior construction allowed collapse and burning to take place directly over the shelter space.

11.7 WHAT DO WE NEED TO KNOW?

Can we pinpoint more accurately the places at which an adequate air supply for blast and fallout shelters will be most likely to occur in a mass fire? Can we determine why one basement fills with smoke and fumes while another maintains a livable atmosphere in the midst of a fire?

Considerable experimental work by Pacific Southwest Forest and Range Experiment Station[14] has thrown some light on the first question. Further experimental work with large fires is needed before accurate design information is available. The second question has almost no answers in the literature. The tendency in most reporting is to describe the conditions which led to fatalities rather than the conditions conducive to survival. Such knowledge is vital and may be obtainable from the experience of fire-fighters.

11.8 AREAS FOR FUTURE EXPERIMENTATION AND STUDY

Recommendations for future research include the following:

1. Continuation and expansion of experimental mass fires to provide design information for ventilation systems.
2. Re-evaluation of data from past conflagrations and fire storms with emphasis on data about conditions of survival rather than death.
3. Evaluation of experience in burning buildings in the United States with emphasis on survival conditions under the fire. Continued collection of data in major cities may well increase our knowledge in this area.
4. Investigation of the feasibility of using motor-generator sets to reject heat to boiling water and refrigeration systems to reduce the dependence of shelters on large air supplies.

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12. PROTECTED CITY STUDIES

George A. Cristy and Clifford J. Williams

12.1 INTRODUCTION

The "protected city" concept has been expanded to include several types of protective systems applied to a number of specific cities. The single-purpose shelter approach (the so-called "tunnel-grid" system), based upon the present-day design of a 25-square-mile section in Detroit, Michigan, was studied and developed in considerable detail. The dual-purpose approach has been applied to the island of Manhattan, and studies of its application have been started in Washington, D. C., and Dallas, Texas.

12.2 SINGLE-PURPOSE SYSTEM

12.2.1 Detroit Tunnel Grid

The tunnel-grid concept uses a single-purpose network of reinforced concrete pipe installed under city streets. This concept was first proposed by Professor Howard Harrenstien of the University of Arizona.[1] Professor Harrenstien first conceived of the pipes as merely transportation corridors for the protected evacuation of shelterees from very badly contaminated areas following an attack. However, the capacity of the pipes was so great that the need for additional shelter areas shrank to zero by the time adequate transportation routes had been provided.

The selection of the criterion for hardness of the shelter system was based upon information summarized in Fig. 12.1. The solid lines indicate the range, and the dashed lines indicate the area over which pressures in excess of the labeled values extend from nuclear weapons in the megaton range. As an example, the ten-megaton yield curve shows that ten-psi-or-greater blast waves extend six miles and cover more than 100 square miles. On the other hand, the 100-psi blast waves cover only seven square miles. This decrease in affected area of a factor of sixteen looks attractive from a cost effectiveness standpoint since providing the additional protection will probably involve less than a factor of ten in cost.

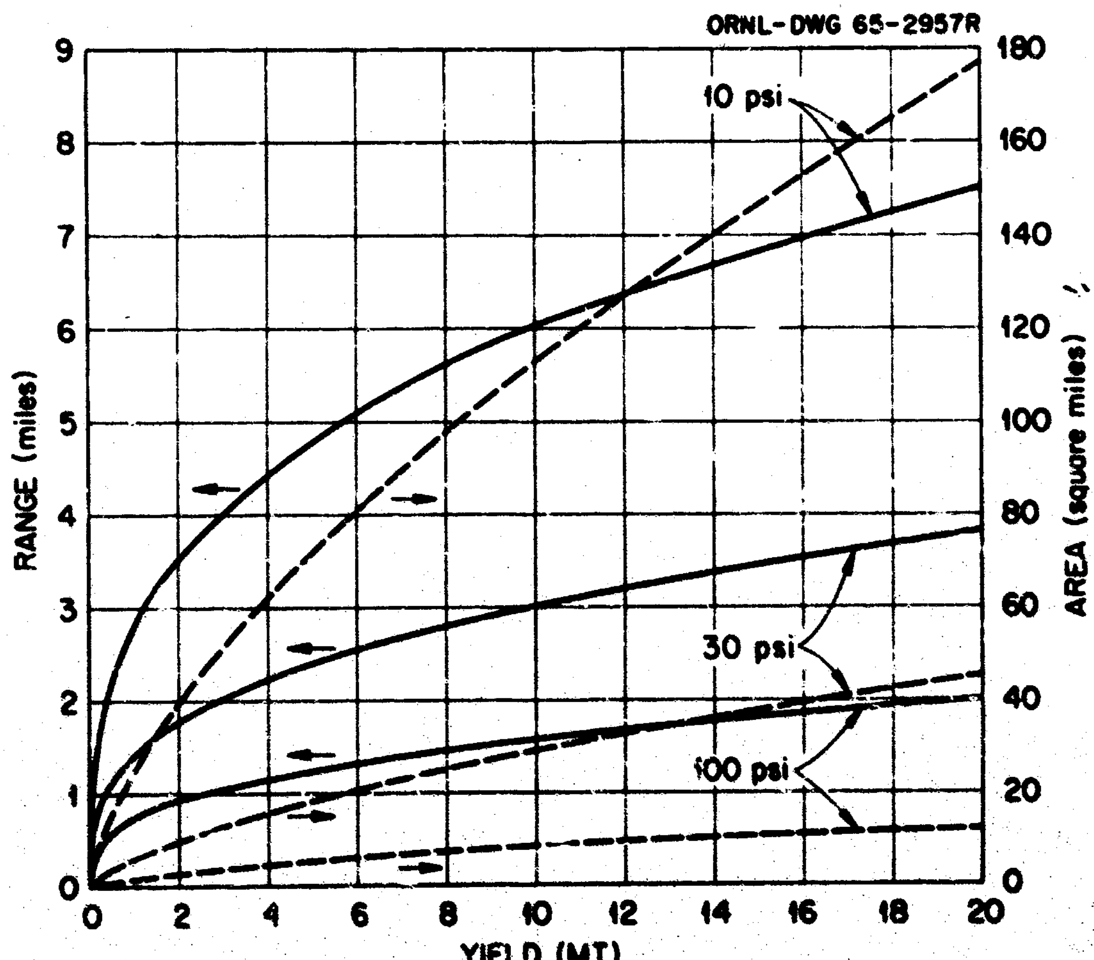

Fig. 12.1 Optimum Blast Effects.

The possible advantages of a tunnel-grid shelter concept are listed below.

1. Cylindrical structure is very resistant to blast damage. This general property of cylinders helps to minimize the cost of the shelter.

2. The entire urban shelter system is interconnected

a. Members of a family in various parts of the city can enter the shelter at the nearest point and then be reunited in safety by walking to a predesignated location.

b. Critical personnel and facilities can be made accessible to the entire population.

c. Localized overcrowding can be rapidly and safely reduced. Thus, the shelter is less sensitive to rapid population density shifts (i.e., daytime vs nighttime) than are isolated shelters. Further, population vulnerability to blast effects can continuously be reduced even after shelter entry.

3. Supporting facilities can be easily duplicated. Such modular installations provide rapid emergency availability of all services. Loss of any one unit does not jeopardize the inhabitants of the shelter to the extent that it would in an isolated shelter. As an example, external air supply points can be shifted to avoid fire or rubble problems.

4. Protected city evacuation becomes possible, using multiple exit routes which are insensitive to local damage or contamination. Evacuation can be accomplished in any direction that the situation requires.

5. Interconnected tunnels have potential dual use (i.e., use during peacetime).

The tunnel-grid shelter system does have some disadvantages which must be considered. These include:

1. Possible higher cost in some pressure ranges;

2. Possible greater vulnerability to contagious biological agents;

3. Greater vulnerability to blast damage once the system is breached.

Possible solutions to the biological agent vulnerability are discussed in Part II (Secret).

Studies of methods of reducing the vulnerability to blast damage when part of the system is breached are continuing. These methods include segmentation of the grid using air locks, installation of blast doors at frequent intervals, or installation of blast attenuation devices throughout the system (see Chapter 10).

The Detroit study provides a conceptual design and cost estimate of a complete network of tunnels with all necessary life support services to shelter the population within the selected test area--a 25-square-mile section of Detroit lying on either side of Grand River Avenue in the northwestern section of the city. The location and the layout of the grid are shown in Fig. 12.2. The identified streets are on one-mile centers. Thus, no point in the test area is more than 1/2 mile or about 10 minutes walk from the tunnel. Entrances are located approximately every 1000 ft depending on the maximum local population density. The exact locations would be dependent upon certain presently unresolved factors, i.e., warning system effectiveness, initial reaction of residents, and stress-induced inefficiencies. Studies of these factors are continuing.

The conceptual design provides for bunks on the wall to increase the capacity and livability of the tubes. Although the bunks limit the width of the passageway, they still allow rapid foot movement throughout the system (Fig. 12.3).

The design includes use of an airlock system for the entryways. The airlock concept provides continuous (actually batch-continuous) access to the shelter and continuous protection against blast waves for those who have already entered the shelter. Although Fig. 12.4 shows a two-cell airlock, a three-cell airlock is often desirable to assure adequate entry provisions for completely continuous loading.

The insert in Fig. 12.2 also shows other modular appendages off the main tunnel. Two examples of important life support systems are shown in Fig. 12.5. These equipment modules provide the ventilation, refrigeration, and power generation units as well as fuel and water tanks. The entire shelter system is provided with air conditioning and a self-contained power supply. Other modules provide supplies, rest rooms, and medical facilities.

The grid system was located under the streets in order to preclude the necessity for and the cost of private land acquisition. The depth

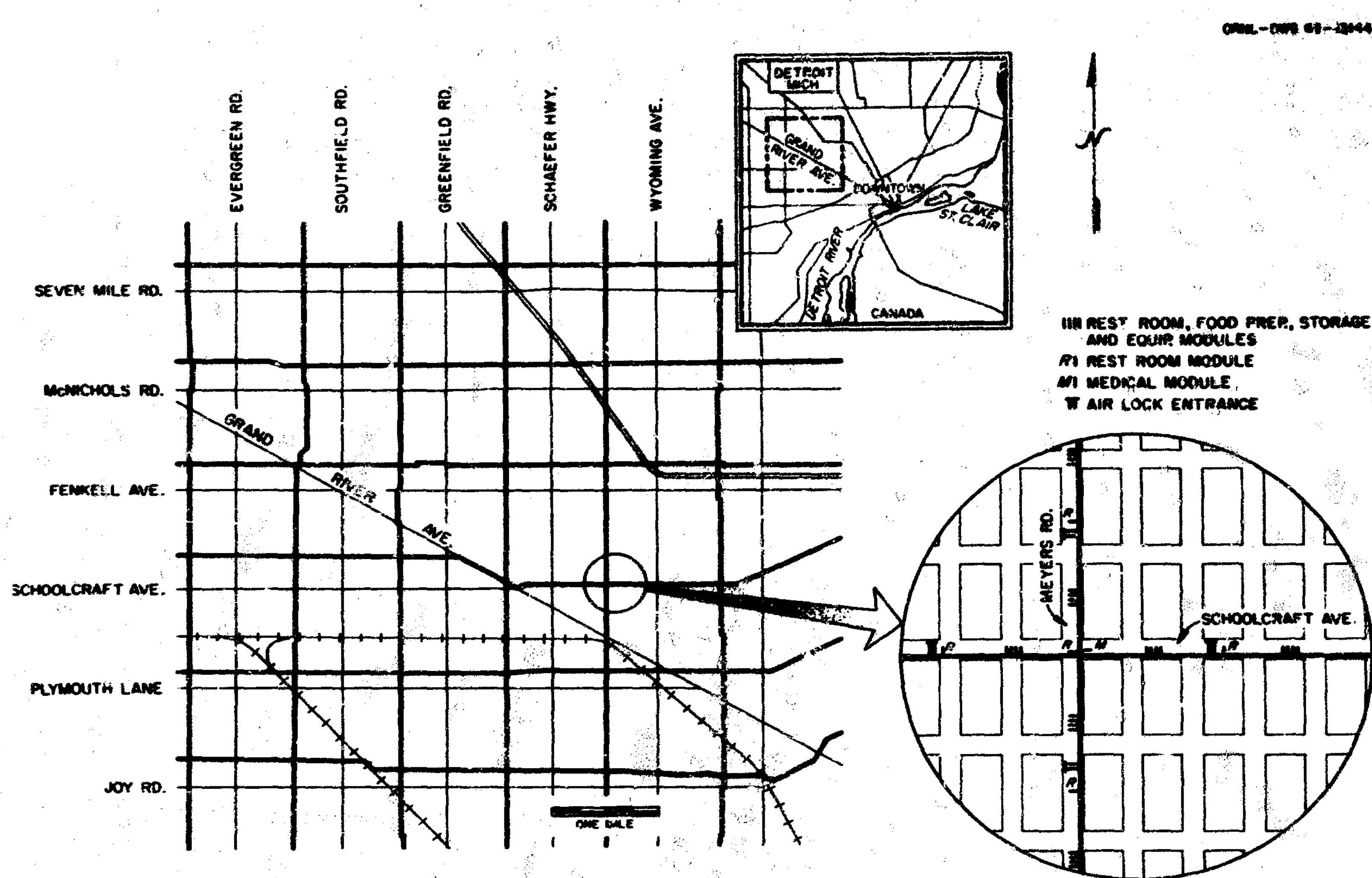

Fig. 12.2. Location of Tunnel-Grid Blast Shelter.

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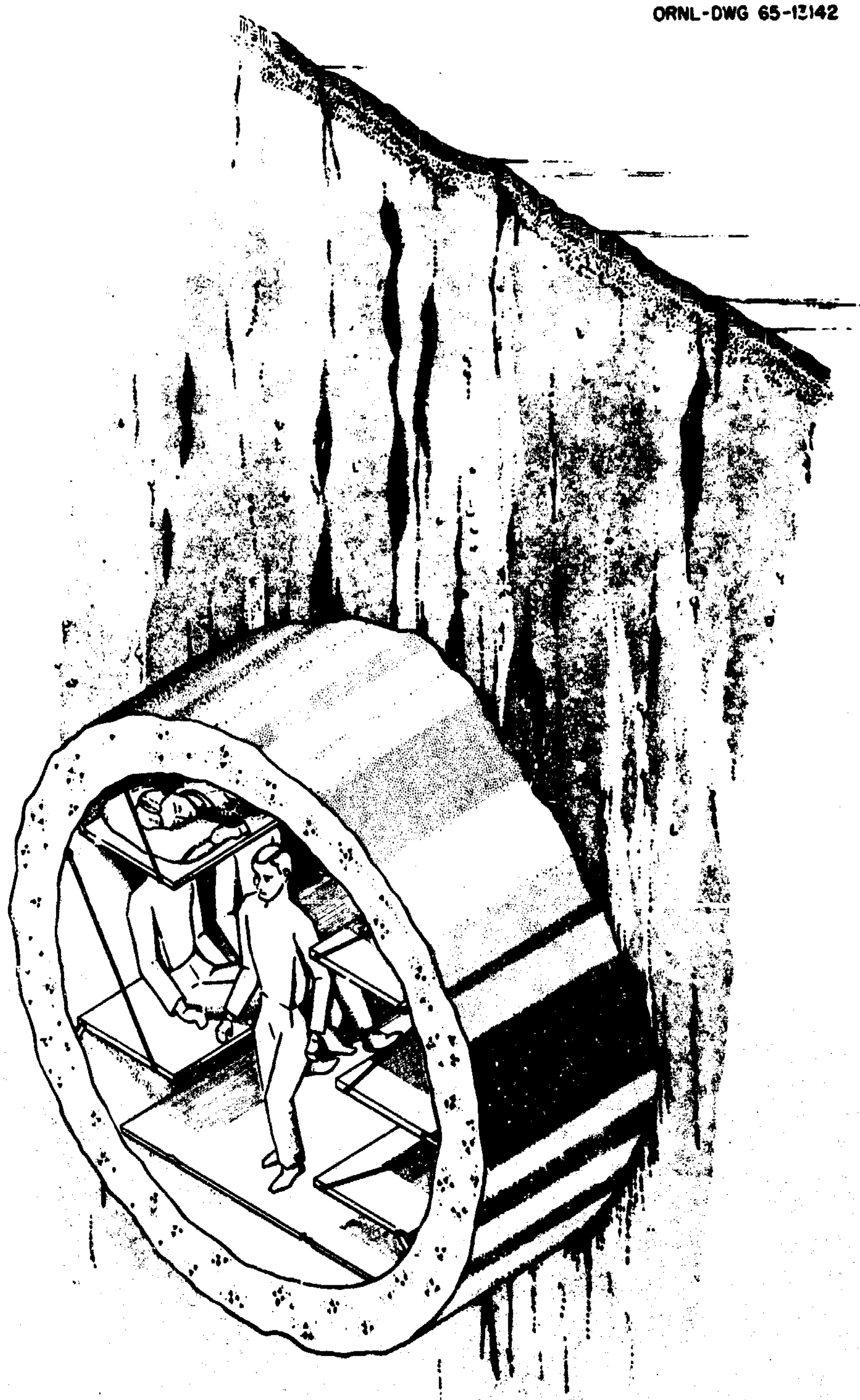

Fig. 12.3. Section of Tunnel-Grid Shelter.

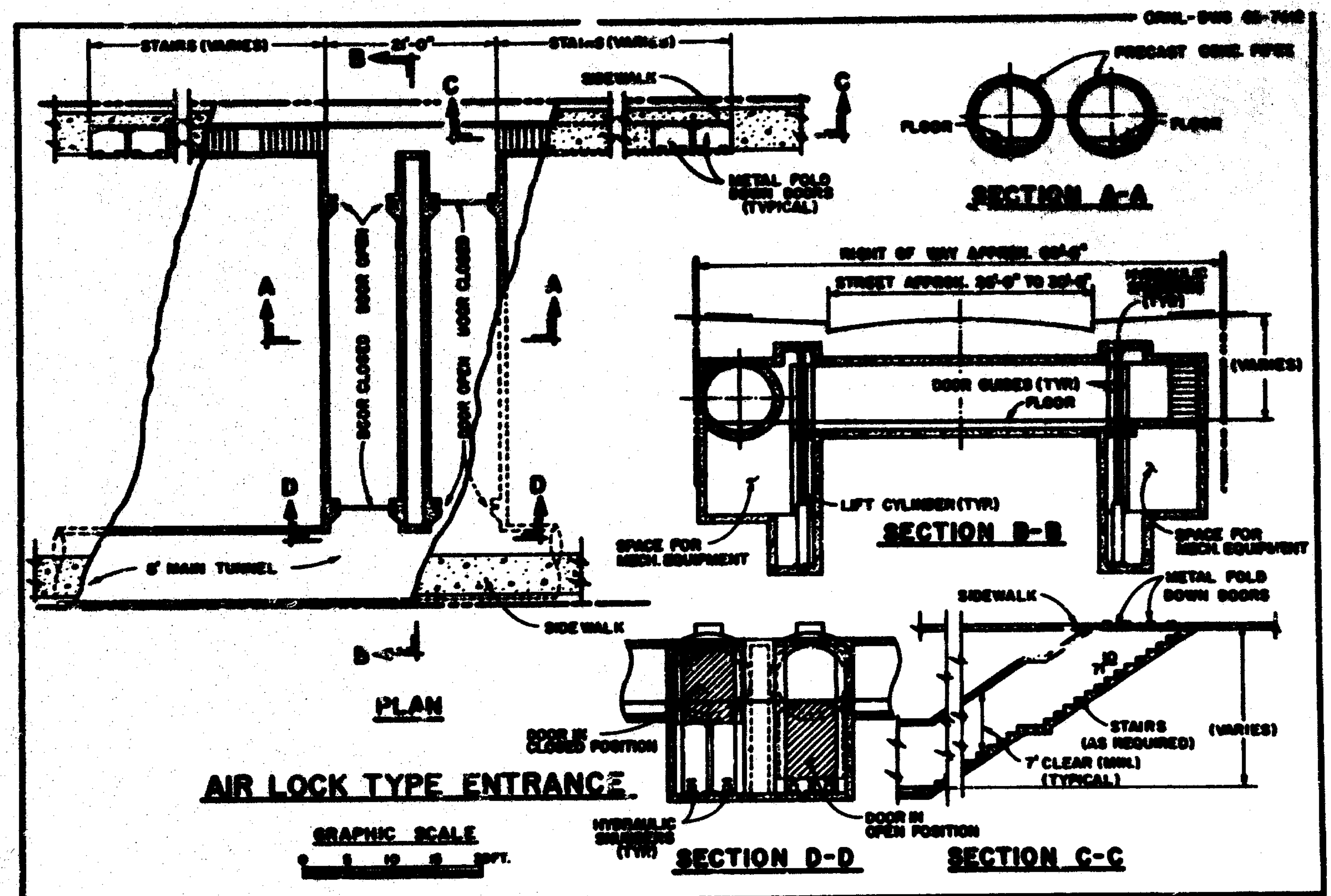

Fig. 12.4. Airlock Type Entrance.

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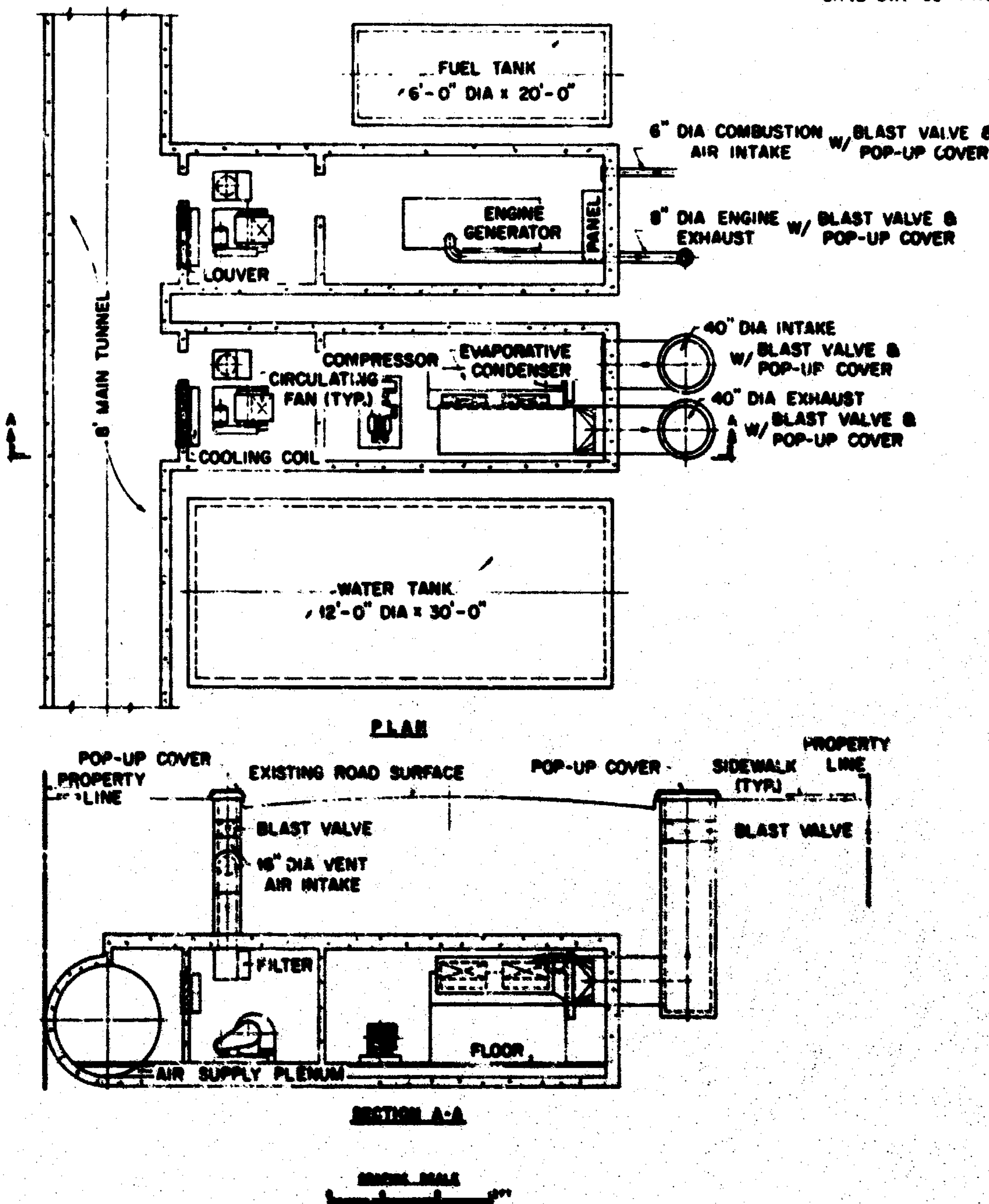

Fig. 12.5. Equipment Room Module.

of burial, which varied from five ft on the north-south tunnels to 30 ft on the east-west tunnels, was based on the location of existing utilities under the Detroit streets.

The construction cost of the system was estimated to be between $400 and $500 per person in 1965 dollars, depending on the tunneling method.[2]

12.3 DUAL-USE SYSTEMS

European countries have developed many dual-purpose systems for civil defense shelters. Sweden, Germany, and Switzerland in particular have pioneered in this area. Civil defense shelter capability has been incorporated in the design and construction of public garages, transportation systems, and public buildings at a fraction of the cost of shelters designed only for defense.

About three years ago, George Hoffman of the RAND Corporation presented the plot shown in Fig. 12.6 and suggested that the time was approaching in many areas of the country when urban tunnels and surface highways would cost approximately the same. Tunneling costs are being reduced by increased mechanization, while surface highway costs are soaring due to land acquisition costs, including the loss of revenue accompanying conversion of tax-paying property to highway right-of-way.

An opposite conclusion regarding tunneling cost trends came from an MIT study[3] as part of the High Speed Ground Transport Project. In his report, Hirschfeld points out that variations in geology can play such an important cost-determining role that time trends may be completely swamped. He presents data for additional tunnels through the same formations, which show an increase in tunneling costs with time from 1934 to 1964. The data are presented on the following page.

Hirschfeld agrees with Hoffman that the greatest potential for tunnel cost reduction lies in the use of tunneling machines or moles in hard rock or under adverse geological conditions. He outlines a development program in tunneling machine technology and stresses the importance of standardization of tunnel sizes so that the high capital cost of machines can be written off over more than one project. His report cites an atmosphere of optimism that machine tunneling will become more attractive in the near future.

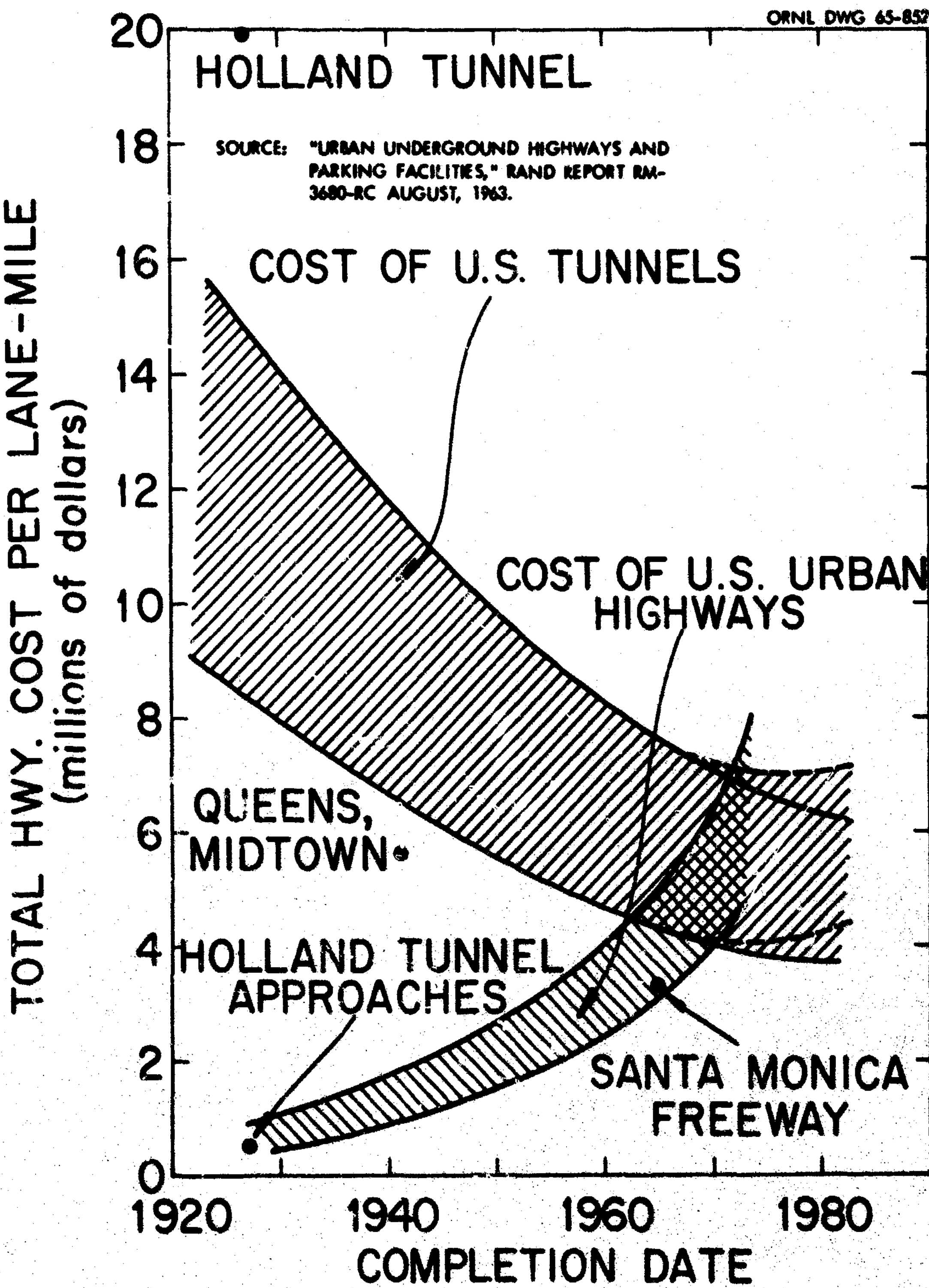

Fig. 12.6. Cost of Aboveground and Underground U. S. Highways.

The optimism is borne out by an article in the Engineering News-Record[4] which describes the last four contracts awarded by the Metropolitan Sanitary District of Greater Chicago for sewer tunnels in the 8-to-22-ft-diam size range. The contractors all use mechanical tunneling machines and were "far and away the lowest bidders."

		Completion Date	Cost per Lane-Mile ($million)
I.	Lincoln Tunnel, N. Y.		
	First Tube	1937	16.3
	Second Tube	1940	12.7
	Third Tube	1957	32.8
II.	Sumner and Callahan Tunnels, Boston		
	Sumner	1934	12.2
	Callahan	1960	14.0
III.	Broadway Tunnel, Oakland		
	First and Second Bores	1953	4.2
	Third Bore	1964	8.0

12.3.1 Manhattan Parking Garage[5]

Hoffman's suggestion stimulated an investigation of a dual-use highway and parking garage deep under the streets of midtown Manhattan, shown in Figs. 12.7 and 12.8.

The economic incentive for such a project arises from a number of closely related problems. The midtown area of the island of Manhattan has the greatest daytime population density in the world. During the daytime, Manhattan Island has approximately 1.7 million persons and a peak density greater than 400,000 persons per square mile (compared with a residential population density of 10,000 for Detroit and 6000 for Los Angeles). The daily influx presents many transportation problems, particularly since all of the incoming traffic must cross one of the rivers. Further, there is a serious shortage of parking spaces available within the city for the daytime storage of passenger vehicles which New Yorkers now use in addition to the public transportation services (subway, bus, and commuter train). New York City planners have long recognized a need for an improved grade separated-link between the Lincoln and Queens

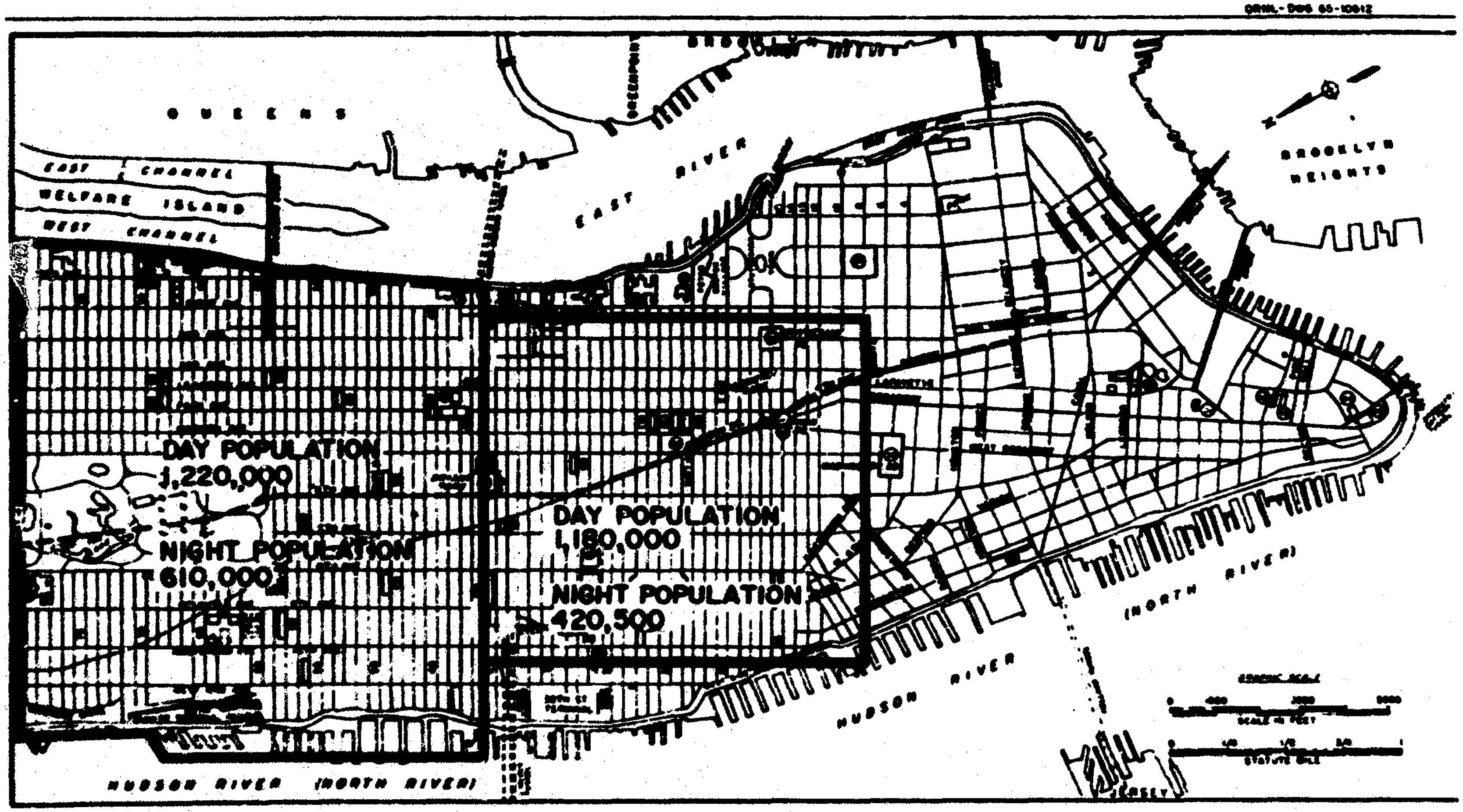

Fig. 12.7. Manhattan Population.

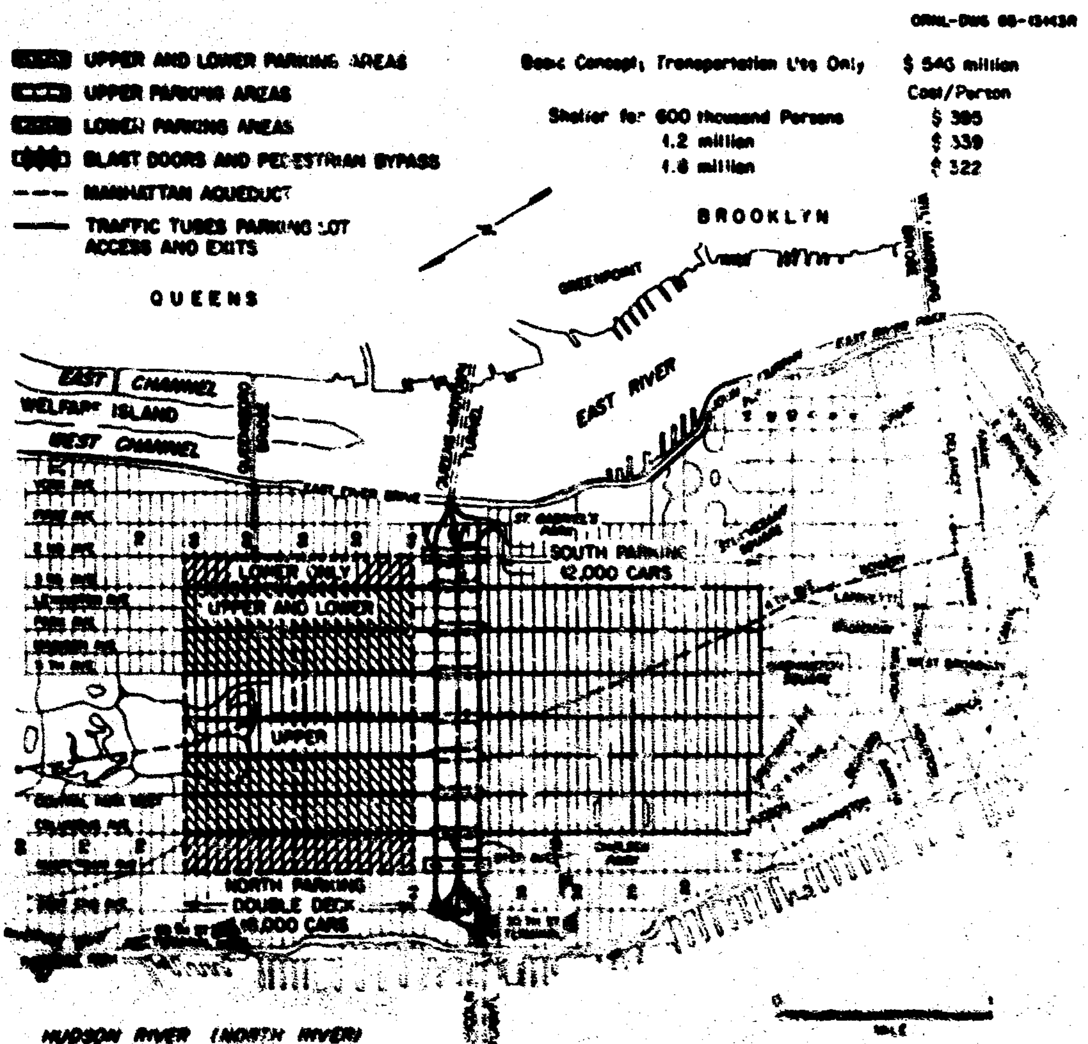

Fig. 12.8. Proposed Dual-Use Shelters for Manhattan. (Interconnecting Traffic Tubes and Underground Parking Areas) (From "Engineering Study of Underground Highway and Parking Garage and Blast Shelter for Manhattan Island," ORNL-TM-1381)

Midtown Tunnels. A six-lane tunnel linking the two under-river tunnels was used as the basic element in the study. The proposed garage provides 30,000 parking spaces lying under crosstown streets between 63rd and 13th Streets, connected to the crosstown tunnel by access tunnels under the nine north-south avenues. The study yielded transportation-related costs separately and incremental costs of sheltering 0.6 million, 1.2 million, and 1.8 million per ons in spaces capable of withstanding an overpressure up to 100 psi.

The cost estimate indicates that the basic transportation system would cost about 1/2 billion dollars (1965 construction costs). Incremental shelter costs range between $300 and $400 per person. These figures are encouraging since they show that the same quality space as was provided in Detroit can be provided in midtown Manhattan at about $100 less per person through dual-use design with cost sharing.

One of the most important cost items involved was the escalator and airlock entrances shown in Fig. 12.9. Enough additional stairway entrances were added to the basic transportation requirements to provide a 15-minute filling time for the shelter.

12.3.2 Washington, D. C., Subway

After ten years of study and development by various government agencies, the Washington Rapid Transit System was approved by Congress in August 1965. The enabling legislation provides for a 25-mile system shown in Fig. 12.10. Half of the system (nearly 13 miles) is underground, including 20 subway stations. The Van Ness Sation at the end of the Connecticut Avenue line is shown in Fig. 12.11. The present plans call for pedestrian tunnels connecting the station with the parking area across the street. Similar tunnels will probably be provided between subway stations and adjacent or nearby government and public buildings along most of the trace of the subway.

A study has been initiated to explore the feasibility and costs of using the subway as a dual-purpose shelter, providing various levels of protection in the tubes and in the stations. This study will seek to determine incremental costs for a complete shelter system as well as those minimum investments at the time of construction which would facilitate conversion of the subway to a dual-use system at some future date.

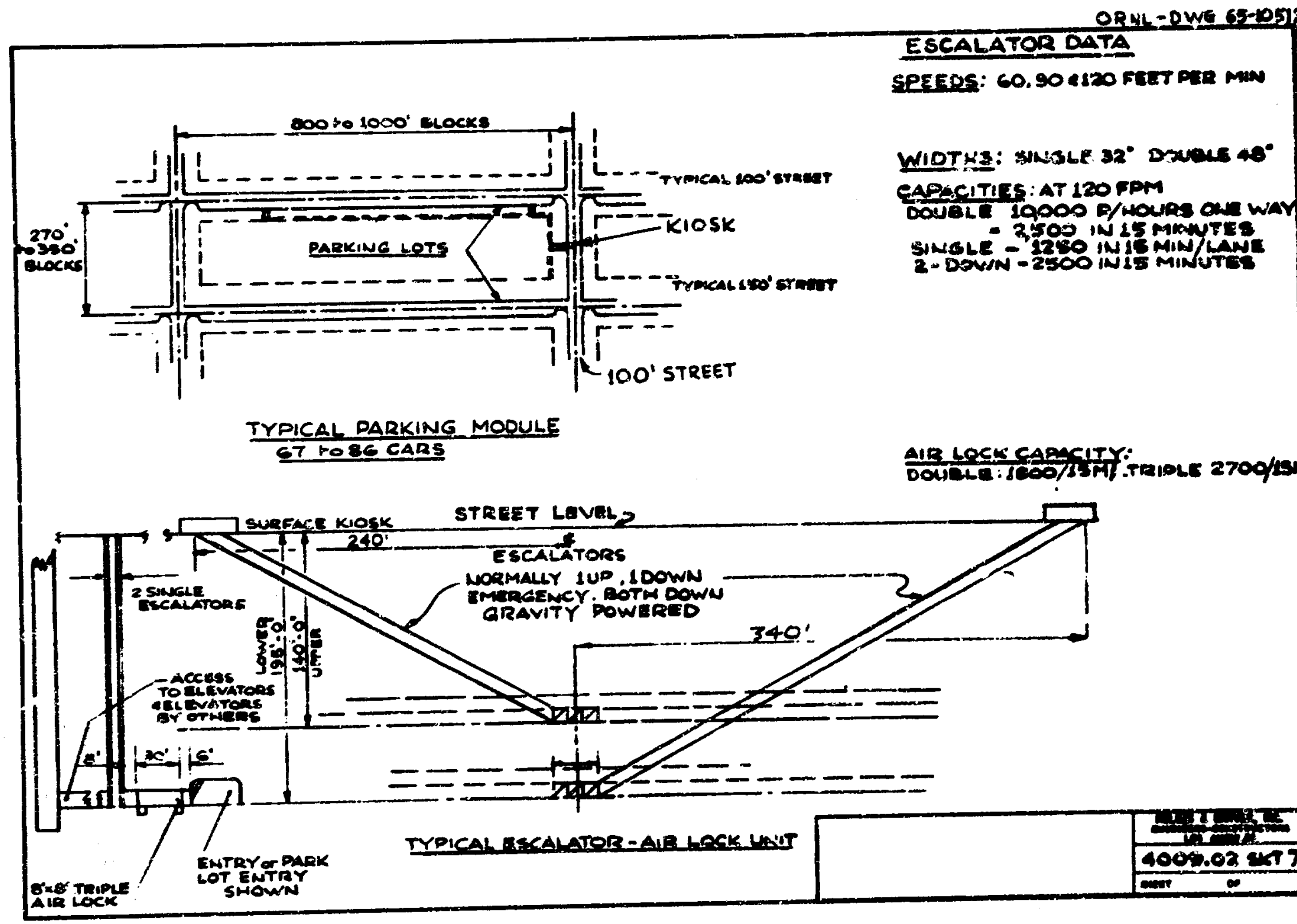

Fig. 12.9. Manhattan Blast Shelter Proposed Escalator-Airlock Installation.

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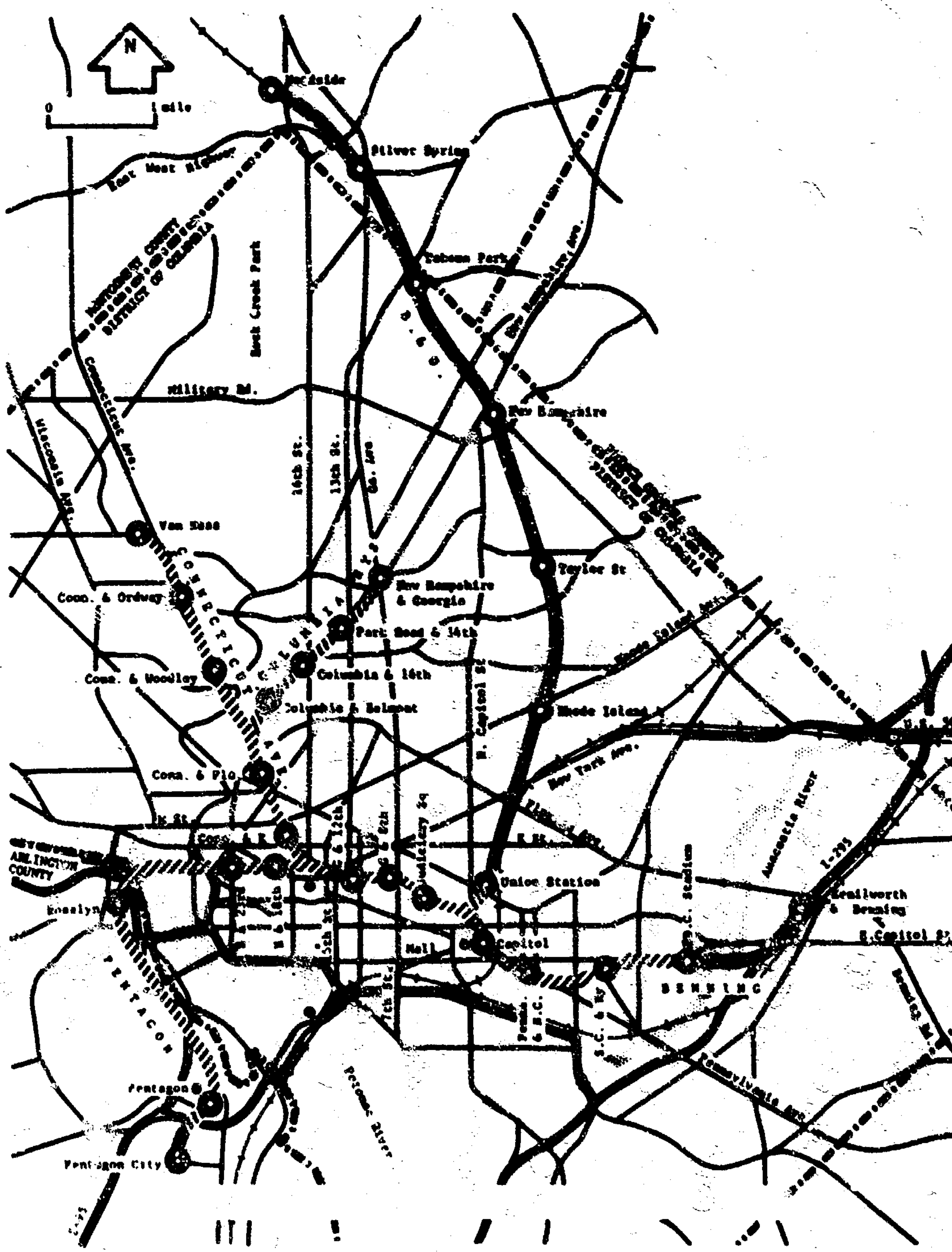

Fig. 12.10. Recommended Rail Rapid Transit System.

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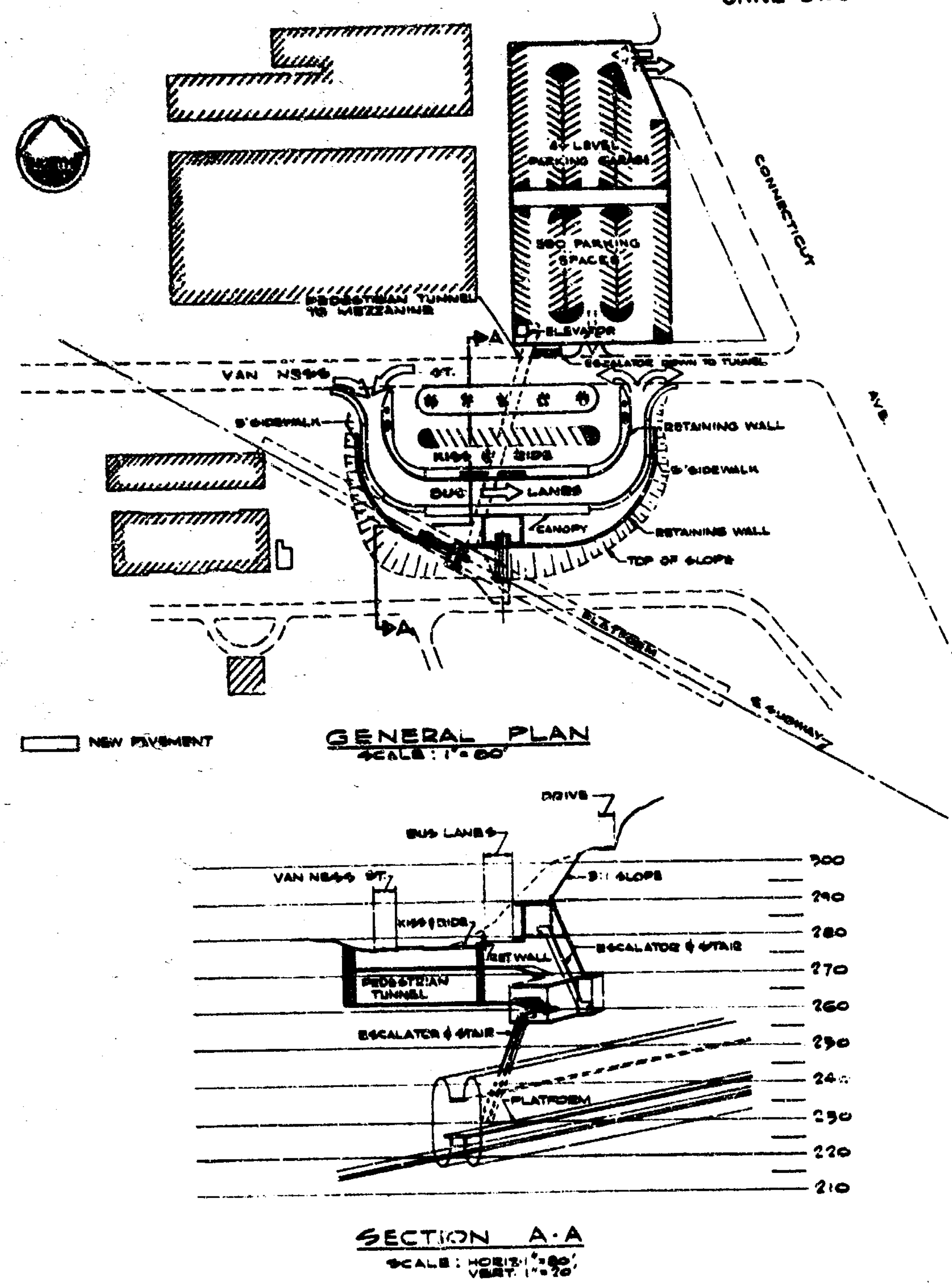

Fig. 12.11. Connecticut Avenue Route Van Ness Station.

12.3.3 Dallas Central Business District Study

The city of Dallas, Texas, has a problem in its Central Business District (CBD) which is by no means unique. The CBD has many main streets but it has no alleys or service ways from which trucks can unload their merchandise to the commercial buildings. For this reason, the main arteries are sometimes clogged with large trucks which are in the process of unloading. To determine the possibility of alleviating this undesirable condition, a conceptual study[6] has been completed for Dallas which investigates the feasibility of having truck unloading tunnels below the CBD (see Figs. 12 and 13).

A study has been initiated at ORNL to investigate the possibility of a civil defense protection plan for the CBD interconnecting underground passageways using (a) the proposed network of truck tunnels; (b) a proposed and existing network of pedestrian underpasses interconnecting building basements; and (c) a possible rearrangement of building basements.

This study will determine and compare the costs of this system for fallout protection and also for blast protection levels between 30 psi and 100 psi.

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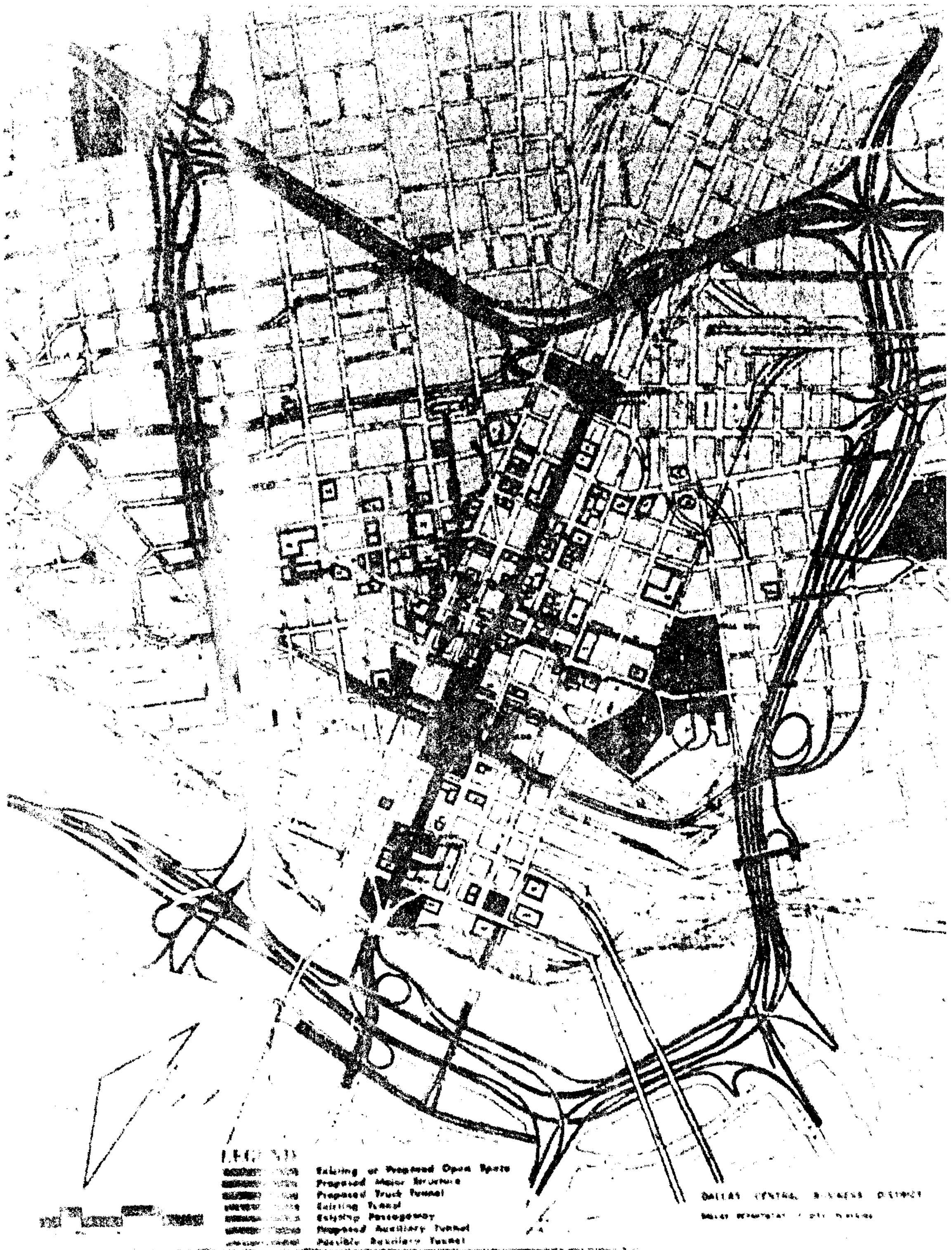

Fig. K.2. Dallas Central Business District.

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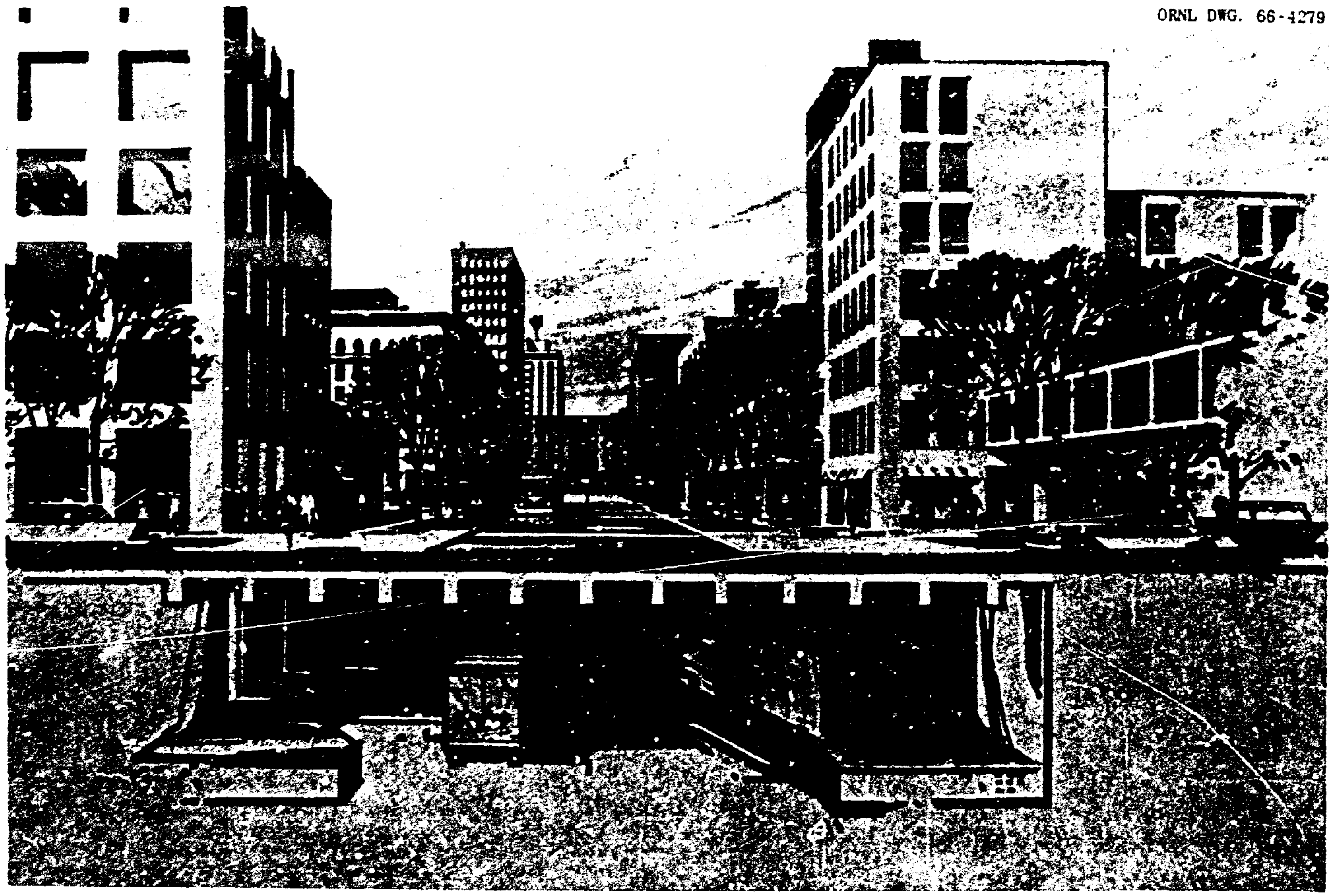

LONG-RANGE TRANSPORTATION PLAN
for the
CENTRAL BUSINESS DISTRICT
DALLAS, TEXAS
DE LEUW, CATHER & COMPANY, CONSULTING ENGINEERS, CHICAGO
JULY 1965

Fig. 12.15. Proposed Main Street Improvements, Dallas.

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