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TECHNICAL OPERATIONS Incorporated

FALLOUT PROTECTION FOR AM TRANSMITTER OPERATORS
A STUDY OF THE SELECTION OF STATIONS
TO BE PROTECTED

By

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ABSTRACT

This report presents the initial results of a study (since redirected) of the selection of AM radio transmitters for fallout protection. Although an actual selection is not made, those factors which should be considered in a selection and their interactions are examined.

Visits were made to seven transmitter sites and the existing shelter factors at each of these sites were calculated. The possibilities of upgrading the existing shelter factors are discussed. In addition, the probabilities of blast destruction of each of 22 transmitters are calculated using a previously published Technical Operations, Inc., listing of probable aiming points within the continental United States.

It is concluded that the dissemination of Civil Defense information via AM broadcasting transmitters is quite feasible, but for a complete treatment of the problem, alternatives other than those contained within the scope of this report should be considered.

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CHAPTER 1

INTRODUCTION

The worth of existing AM broadcasting facilities as a means for the general dissemination of Civil Defense information has long been recognized. Since AM transmitters and their operators are vulnerable to the blast and radiation effects of a nuclear attack, it is most appropriate that The Office of Civil Defense consider providing protection for selected AM transmitter sites. Use of the maximum broadcast power of selected AM stations could enable OCD to insure extensive population coverage through a relatively small expenditure for protection. In the development of a system based on selected high-power AM transmitters, the adequacy of the care taken in station selection is obviously important to the cost effectiveness of the final system.

In this report we describe approaches which were made by Technical Operations, Inc., to the problem of station selection and to the development of a plan for an information-dissemination system using the selected stations. Although our effort has now been redirected, it is believed that statements of our method of approach and of the preliminary results based on our initial investigations may be of some value to The Office of Civil Defense.

ELEMENTS OF THE STUDY

As it was originally envisioned, this study was to consist of consideration of station coverage data, a radiation shelter survey, and cost estimates, each of which is covered below.

1. Station Coverage Data — The maximum day-time population coverage of each radio station may be derived from signal-intensity contours available from either the individual stations or the FCC. An unofficial compilation of coverage data is also available in the "Broadcast Allocation Map Book" of the Cleveland Institute of Electronics, Cleveland, Ohio.[1] The 1960 Census of Population provides the needed population distribution data.[2]

2. Radiation Shelter Survey — We intended to make estimates of the radiation shelter afforded by existing transmitter buildings and various alternatives for providing additional protection. These alternatives would be:

   1. Building alterations—closing in certain windows and providing additional wall and ceiling mass

   2. Building additions—providing a standard shelter near the transmitter

   3. Alternate facilities—providing an alternate transmitter site, complete but in a "safe" location.

3. Cost Estimates — Once an estimate of the desired amount of radiation protection was settled upon, cost estimates would have been generated for each acceptable alternative for station protection. The cost estimates would have to include the cost of providing auxiliary power in those cases where sufficient alternative power is not now available. An estimate of the cost of providing survivable communications to the appropriate CD headquarters would also be included.

Selection of Stations

The selection criterion to be used was to be settled upon early in the study. It was to be closely related to the number of people who might be able to receive CD reports as a result of the funds expended on sheltering and equipment.

Next, a selection procedure which would maximize the selection criterion while selecting a set of stations would be developed. This procedure would take into account the following factors:

1. Probability of transmitter blast destruction

2. Station-coverage pattern

3. Station-coverage overlap with the coverage areas of other stations

4. Probability of blast destruction of the other stations

5. Required fallout-radiation attenuation factor

6. Costs of the sheltering alternatives.

Output

The primary result of this study was to be a graph showing the value of the maximized selection criterion as a function of the amount of funds spent on protection. Also given would be the lists of stations selected for the various points shown on the maximized curve and a complete description of the selection procedure. It was intended that the costs of providing communication between the transmitters and Civil Defense headquarters would be included in protection costs.

INVESTIGATIONS

The body of this report describes the investigations and observations made as we began to carry out the study and analysis. Chapter 2 deals with the shelter survey and our visits to transmitter sites. Chapter 3 deals with our procedure for estimating blast-destruction probabilities. In Chapter 4 the selection criterion which was to be used is described. Next the selection algorithm based on the selection criterion is described. Chapter 5 presents a brief summary and certain tentative conclusions regarding the protection of AM radio transmitters against fallout radiation.

CHAPTER 2

SHELTER SURVEY AND VISITS

The decision was made to begin the work on two elements of the study simultaneously; one being station selection, the other the calculation of currently available radiation shelter factors. Because of their proximity to large segments of the population, it was decided to survey the three Boston 50-kw stations and the eight in the New York area initially. This procedure, we felt, would yield a large amount of information to aid in structuring the remainder of the study.

DISCUSSION OF THE METHOD

Because of the redirection of effort, only seven of the eleven chief engineers for the Boston and New York areas were contacted. Each was given a brief description of the problem and asked for three items—a coverage contour map, building plans for the transmitter site, and permission to visit the transmitter site. Complete cooperation was given in all cases. In some cases, building plans were not available for release. In those cases all the necessary shielding information was copied from building plans during our visits and additional data resulting from visual inspection were recorded. In other cases, no building plans could be located. The appropriate dimensions of these sites were measured, and all other necessary information was obtained from inspection or from the broadcast engineer or site superintendent on duty.

The following list indicates the kinds of information which were collected:

1. General description
2. Dimensions of basement below and above ground
3. Dimensions of first floor
4. Dimensions and locations of doors and windows
5. Heights of floors, ceilings, windows, openings, roof, and so forth
6. Materials contained in roof, ceilings, floors, walls
7. Location of any nearby buildings
8. Equipment descriptions and capabilities.

Portions of this information were coded for the Technical Operations, Inc., "Shielding Analysis Computer Program." The output of the program is a value of the protection factor at a chosen location within the building.

TRANSMITTER DESCRIPTIONS AND SHELTER FACTORS

Descriptions of the buildings and facilities of those transmitters which were visited are presented on the following pages. Table I summarizes the results of our shelter factor calculations and certain additional data gathered during our visits to the transmitters. The column in Table I entitled, "Feasibility of Augmenting Existing Shelter Characteristics," is the result of a purely qualitative estimate which took into account building construction and layout, such as size and availability of a basement, and local terrain features, such as water table level.

TABLE I

STATION PROPERTIES

Call Letters	Estimated Existing Shelter Factor	Feasibility of Augmenting Existing Shelter Characteristics	Auxiliary Power To Run Transmitter of Listed Power
WBZ	7	Moderate	30 kw
WNAC	113	Very easy	5 kw
WOR	50	Very easy	10 kw
WNEW	50	Easy	10 kw
WMGM	45	Moderate	50 kw
WINS	10	Difficult	10 kw
WABC	15	Easy	10 kw

WNAC Transmitter

The WNAC transmitter is located in Burlington, Massachusetts, about 3 miles from the USAF facility at Bedford Airport (L. G. Hanscom Field) and about 6 miles from the Boston population concentration. The transmitter is housed in a one-story concrete block and brick building which has a well compartmented basement. The basement is divided by more than three concrete block walls of considerable mass. The main floor consists of one eight-inch reinforced concrete slab and the roof is also of concrete varying in thickness from two to four inches. The shelter factor of the basement is estimated to be 113.

The station has three towers, none of which is guyed. The resulting directional pattern is pointed approximately north and south from the transmitter and covers the Boston area with a strong signal.

The transmitter itself is water-cooled and, therefore, a supply of replacement distilled water is kept on hand. A well and pump provide drinking water. A stand-by generator of sufficient capacity to power the separate 5-kw Conelrad transmitter is available within the transmitter building.

The transmitter operator can disconnect any of the three towers from the transmitter from within the building. It may be noted that at one time one tower was blown down and that transmission was continued from the remaining two towers through the use of the disconnecting arrangment.

WBZ Transmitter

The WBZ transmitter, located in the town of Hull, Massachusetts, achieves a very good coverage of the population of Boston and the New England coastal area.

The transmitter stands on a very low peninsula approximately 8 nautical miles from the Boston Harbor docking facilities and approximately 5 miles from the shipyards at Quincy. The transmitter station has two towers, both of which are guyed.

It appears that a tidal wave could destroy the towers if they were to survive the blast effects resulting from an attack on either Boston or Quincy. Surrounding the transmitter building are a number of small houses of light construction. They are not substantial enough to provide much, if any, protection to the transmitter buildings.

The transmitter building has the appearance of a large private home of bungalow style. It has one and one-half stories but has no basement, probably because of a high water table. It is of cement block construction, but has an exterior surface of clapboard. The second floor is a two-inch slab of poured concrete supported on light steel beams and the building has a heavy slate roof. Detailed analysis indicates that the building would afford a shelter factor of about 7 to an operator in the entrance to the control room, one of the best locations within the building.

In should also be noted that the transmitter is cooled by air taken in at the roof of the building and blown through the heat-generating transmitter components. Some radioactivity could be drawn in by this cooling system.

The WBZ transmitter is equipped with an auxiliary power source arranged for automatic operation. This equipment is located in a separate structure behind the transmitter building. The generator is sufficient to power the 50-kw transmitter since it has a rated capacity of 125 kva.

WOR Transmitter Site

The WOR transmitter is located in Carteret, New Jersey, about 15 miles from the center of Manhattan. WOR has two unguyed towers with a caternary wire supporting a third vertical wire antenna midway between them. The two towers have withstood every storm since they were erected in the 1930's. A third small guyed tower has been located nearby for future use with a 10-kw transmitter. The transmitter building is an old, but very sturdy, structure having a deep full basement with some existing compartmentation. There is adequate room within the basement for the construction of a sizable shelter-control room. The floor over the basement is now a 7-1/2 inch reinforced concrete slab. This basement is estimated to have a radiation shelter factor of about 50.

Stand-by power currently available is only sufficient to run the 10-kw auxiliary transmitter at somewhat less than its rated output. Plans have been made for the purchase of an auxiliary power unit of slightly greater power rating.

The 50-kw transmitter achieves a good coverage of the area since it is in a good position to benefit from the sea conductivity and the general concavity of the shoreline.

WABC Transmitter Site

WABC, an omnidirectional clear-channel station, has its transmitter located near Hackensack, New Jersey, at a point only about 8.5 miles from the Empire State Building. A single tall guyed tower is used with the WABC 50-kw transmitter and a smaller guyed tower is available for use with an auxiliary transmitter of about 10 kw. A very good coverage of New York City and the surrounding population concentrations is achieved by this transmitter. Stand-by power is available but sufficient to run only a 10-kw transmitter.

The transmitter building is a low solidly built structure with only one story and no basement. The radiation protection provided by the building is therefore slight. However, there are two concrete-lined pits within the building. They are about 6 feet deep and so they provide the best attenuation factor available anywhere within the building. The largest of the two pits has a floor area of about 5 by 10 feet and is estimated to provide a shelter factor of about 15. The addition of a concrete slab pit cover about 10 inches thick could increase the shelter factor to as much as 100.

WNEW Transmitter Site

WNEW achieves directional coverage of the New York City area with two unguyed antennas. A smaller separate antenna is available for use with a 10-kw transmitter. Only enough stand-by power is available at WNEW to run the 10-kw transmitter. The transmitter is located in a low land area nearly at sea level and is less than 6 miles away from the Empire State Building.

The transmitter building is a well built brick and reinforced concrete structure. It has a shallow but usable basement. The reinforced concrete main floor above the basement and thick side walls give the basement an estimated shelter factor of 50. Since most of the basement protrudes above grade, a considerable improvement could be realized from providing fill around the outside of the building.

WMGM Transmitter Site

WMGM achieves 50-kw directional coverage of the New York City area and has, in addition to its regular antenna array, one short unguyed tower for use with a 10-kw auxiliary transmitter. Auxiliary power is currently available at WMGM to run the 50-kw transmitter at full power.

WMGM is located in lowlands less than 5 miles from the Empire State Building. A 5-foot basement beneath the transmitter building gives the best available radiation protection. It is estimated that a shelter factor of 45 is about the best available at WMGM. Since most of this basement is above grade, additional fill around its outside would increase the shelter factor. However, the low basement overhead clearance and small available shelter factor indicate that a separate external shelter might provide the most desirable radiation protection at WMGM.

WINS Transmitter Site

WINS broadcasts on an array of four unguyed towers located in a tidal marsh near Weehawken, New Jersey, about 6 miles from the Empire State Building. An auxiliary power source capable of powering only an auxiliary 10-kw transmitter is installed behind the transmitter building. Only one antenna array is available. Below the transmitter building only a 3-foot crawl space is available. The construction of a basement fallout shelter seems infeasible. The building above provides an estimated shelter factor of only 10. The best shelter alternative for this station appears to be an external below-grade shelter of a standard design. The tidal nature of the area makes even this alternative somewhat doubtful.

CHAPTER 3

PROBABILITY OF ANTENNA DESTRUCTION

One of the factors that should be considered in the determination of a selection criterion is the probability of a transmitter being unavailable for the dissemination of information following a nuclear attack. There are many reasons for unavailability, such as blast damage to the antenna, tidal wave effects, unreliable equipment, blackout due to ionization, and so forth.

It was assumed that the major cause of cessation of a station's transmission would be blast damage to the antenna. In order to calculate the probability of antenna destruction, it is first necessary to establish criteria by which an antenna may be assumed to have been destroyed.

EXPLANATION OF PROCEDURE

References 3 and 4 were examined with regard to the effect of nuclear weapons upon both guyed and unguyed radio transmission towers. The towers considered by the two references were of dissimilar physical characteristics and only several conditions of destruction were considered. The results for the several conditions were evaluated and it was decided that 3 psi would be taken to be the limit of endurance of all radio transmission towers considered in this study. This blast effect occurs at a distance of 9 miles from the point of explosion of a 5-MT bomb and the distance increases with the cube root of the bomb yield.

A factor which should be considered in a study of this nature is the circular probable error (C. P. E.) of the point of explosion of a bomb. It was estimated that 1.75 miles would be a reasonable figure.

Although Reference 5 considered only 5-MT bombs, it was decided that in cases where targets were to receive a number of 5-MT bombs, the total yield would be considered to be contained in one bomb. It was determined for several specific cases, and it is felt that it is generally true, that this reasoning does not generate any appreciable error. Also, in the case of small-area military targets, this method of analysis provides a very realistic worst-case approach.

The tables contained in Reference 6 were used to provide a probability of antenna destruction. These tables present probabilities (normalized to a unit standard deviation) of a warhead aimed at a certain point falling within the radius of destruction of another point.

Using Local Aeronautical Charts published by the U. S. Coast and Geodetic Survey, the distance between each transmitted tower and the center of each aim area was measured. These distances were then normalized by dividing the distance by the standard deviation (0.8493 C. P. E.). The radii of destruction were also normalized. The radius of destruction (R) for the particular warhead was subtracted from the distance (r) between each tower and each aim point. The probability of destruction was then read directly from the tables as a function of R and (r - R).

Although factors such as the lethal radius, C. P. E., assigned weaponage, and targeting may be disputed to a certain extent, the ranking of the stations as to their ability to survive a nuclear attack is the object of the study and this relationship would generally remain unchanged.

PRELIMINARY RESULTS

The probabilities of destruction of those stations which could be considered during the limited time available for this study are presented in Table II.

Although distance from probable target areas was the only criterion used in determining the probability of destruction of the antennas, other factors should also be considered in attempting to determine which of the antennas in a general area would be most likely to survive a nuclear attack. These factors are: protection by terrain, possibility of destruction by tidal waves, and so forth.

TABLE II

PROBABILITY OF ANTENNA DESTRUCTION

Area	Station	Type of Attack		
		Military	Industrial	Combined
Boston	WHDH	0.00	0.99	0.99
	WBZ	0.44	0.99	0.99
	WNAC	1.00	1.00	1.00
New York	WNBC	0.00	1.00	1.00
	WCBS	0.00	1.00	1.00
	WOR	0.00	1.00	1.00
	WABC	0.00	1.00	1.00
	WINS	0.19	1.00	1.00
	WMGM	0.81	1.00	1.00
	WNEW	0.66	1.00	1.00
	WQXR	1.00	1.00	1.00
Chicago	WLS	0.00	1.00	1.00
	WCFL	0.01	1.00	1.00
	WMAQ	0.36	1.00	1.00
	WGN	0.90	1.00	1.00
	WBBM	0.96	1.00	1.00
	WJJD	*		
Central Florida	WGTO	0.02	0.00	0.02
	WINQ	*		
Miami	WGBS	0.00	0.25	0.25
	WINZ	*		
Nashville	WLAC	0.00	0.18	0.18
	WSM	[illegible]	0.20	0.20
Sacramento	KRAK	0.00	0.00	0.00
	KFBK	0.17	0.00	0.17

*Antenna could not be located on available maps.

CHAPTER 4

SELECTION CRITERION AND ALGORITHM

STATION SELECTION

The selection of a set of stations to be protected from radiation was to be an important segment of this study. The rationale of selection warranted serious thought and rigorous development, not only because of the large amounts of funds likely to be involved in protecting AM radio transmitters, but also because of the large number of operating organizations and operators who would be affected by allocation decisions and the many individuals who might be affected by the resultant AM transmission capability.

The definition of the station-selection criterion must be in agreement with the real purpose which AM transmission is intended to fulfill for the Office of Civil Defense. We believe that purpose to be fourfold:

1. The rapid dissemination of attack warning to as large a part of the total population as is possible
2. The prompt and selective dissemination of accurate information describing the post-attack radiation and damage environments
3. The selective dissemination of information for the control of the survival and recovery operations of the general public
4. The general dissemination of statements originating from the ranking federal governmental authority.

In addition to the purpose stated above, the following factors are of importance in the development of a selection criterion:

1. Because of their locations, some radio transmitters are more likely to be destroyed by direct attack on military and/or population targets than others.
2. All radio transmitters have unique areas of daytime coverage, i.e., each station has a different set of population groups within listening range.

3. The coverage areas of many stations overlap certain other coverage areas to some extent.

4. The costs of protecting transmitters will vary because of: a) the availability of stand-by power at some transmitters but not at others, and, b) the availability of basements for the installation of inexpensive, but otherwise adequate, fallout shelters at some transmitters but not at others.

5. The ever-present need to get the most "defense" per dollar.

The selection criterion which was chosen is the expected number of persons who could receive communications from the Civil Defense AM radio station under consideration per dollar expended on that station. Specifically, the criterion is the product of the three following factors:

1. The adjusted number of people who reside within day-time listening range of the station under consideration

2. The estimated probability of continued transmitter operation

3. The reciprocal of the estimated cost of providing the necessary fallout protection for the personnel who must operate the transmitter.

To clarify the first factor, it should be recognized that the selection procedure should allow overlapping station coverage only to the extent warranted by the uncertainty of continued transmitter operation and the costs involved. The population coverage of any station must, therefore, be adjusted to account for the expected coverage of stations which were previously selected for protection and use.

Also, the availability of radio receivers is not accounted for explicitly in this criterion. This position is defensible since receivers are likely to be distributed fairly regularly with respect to population.

The estimated distribution of population fatalities and population injury have similarly not been accounted for explicitly. Although it would be possible to make estimates of the fatality and injury distributions, it was considered inappropriate to do so for this study for the following reasons:

1. Making such estimates would get us into the nebulous area of estimating where Civil Defense information is most needed and most useful.

2. The urgent need to communicate to the survivors in damaged areas would tend to counterbalance the reduction in the need for communication due to fatalities.

3. The time and expense required by such an analysis would be considerable.

SELECTION ALGORITHM

Next we must consider the need for a selection procedure or algorithm which maximizes this selection criterion while selecting a set of stations large enough to require the expenditure of a specified amount of funds. Such an algorithm would be capable of generating a curve showing the maximum number of people who might be expected to benefit directly from the expenditure of funds for the protection of AM radio transmitter stations.

The use of this type of curve in planning the extent of the AM transmitter-protection program and in considering the worth of alternatives to the currently envisioned program is likely to be of great value—both in terms of system cost and its effectiveness. In particular, the relative effectiveness of money spent on existing stations and money spent for a well located new station, perhaps of very high power, could be easily examined.

An algorithm for the selection of sets of stations is available and ready for use. It is simple and concise enough to be manageable manually when the choice of a moderately small total number of stations (about 100) is being made. Also, it could easily be programmed for use with an electronic computer, if an automatic computation were desirable.

However, this algorithm cannot, in general, guarantee that the single best set of stations for any specified amount of funds will be selected. Nevertheless, under certain conditions it can produce optimally selected sets of stations. For the problem at hand, it is likely to develop entirely adequate solutions and it has the important advantage of being usable without recourse to an electronic computer.

The algorithm would operate as follows:

The population coverage (at 0.5 mv/m) of each transmitter would be listed for each of the Standard Metropolitan Statistical Areas as defined in Reference 2. The sum of these numbers for each of the transmitters, multiplied by the probability of survival of the antenna, would be the maximum number of those people originally resident in the area who might be expected to be able to receive transmission from a particular station after an attack. This number, divided by the sum of the cost of protecting a radio transmission site against a certain radiation level, and the cost of providing communications between the transmitter and the local or regional Civil Defense headquarters, would be the value of the selection criterion.

This value would be calculated for each of the transmitters. The transmitter with the highest value of the selection criterion would be selected and its expected population coverage would be subtracted from the population distribution contained in a list of Standard Metropolitan Statistical Areas The remaining transmitters would be re-analyzed on the basis of a smaller possible population coverage whenever coverage overlap with a previously selected station had occurred. Again the transmitter with the highest value would be selected and the population distribution reduced accordingly. This selection would continue until all the stations were listed in the order of their selection or until the maximum possible expenditure had been reached.

It was our intention to expend a small amount of additional effort on a search for a more powerful selection algorithm.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Since it was necessary to conclude this study in a much shorter time than was anticipated, it is not possible to furnish a list of those stations which should be provided with radiation protection. It is hoped, however, that the procedures we have described and the examples that we have demonstrated will be of assistance to those responsible for the selection of the stations.

We conclude that it is possible to make an intelligent selection of 50-kw radio transmission sites to maximize population coverage. It is also concluded that radio transmission sites can be protected against fallout dangers at reasonable cost.

Some additional areas which were not within the scope of this study, but which should be considered prior to a final selection are: the effect of changes in targeting philosophy, the feasibility of building new high-power stations in remote areas, and a search for low-power stations located in areas considered to be free of targets.

In view of the extremely high probabilities of destruction for many of the transmitters near large cities, consideration might be given to providing increased wartime power for selected stations in target-free areas.

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