A CORRELATION BETWEEN NATURALLY OCCURRING INFRASONICS AND SELECTED HUMAN BEHAVIOR

BY

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THESIS

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I. INTRODUCTION

Considerable interest has developed in the subject of infrasonics, i. e., air-borne sound waves in the frequency range between 10 Hz and 0. 01 Hz, within the last decade. As a consequence of recent technological developments, the acoustic environments in which humans must perform demanding tasks are more severe in the low frequency range than any previously encountered and there is reason to believe that future developments will increase appreciably this severity. It has been estimated that the very large super space-craft boosters of the future, viz., Nova class, will produce their maximum noise energy in the infrasonic range (Joint Air Force National Aeronautics and Space Administration Hazards Analysis Board, 1961). Acoustic energy generated by large propellers and turbojet aircraft engines is often most intense in frequency range from 5 Hz to 100 Hz (Cole et al, 1962; Wiener, 1962; Guild, 1965). Infrasounds of somewhat lesser intensities are generated by diesel engines, industrial ventilating systems, and, more generally, by large machines operating at a slow rhythm (Gavreau et al, 1966). Infrasonic waves of substantial intensity are also generated by tornadoes, winds, volcanoes, magnetic storms, earthquakes, seaquakes, and certain types of ocean waves (Cook, 1962; Wood, 1967; Daniels, 1962).

The physiological and psychological effects of intense infrasonic environments on humans were first observed during the two World Wars.

Surgeons serving on German submarines observed middle ear changes in diesel room personnel which were attributed to the infrasounds produced by the suction strokes of the diesel cylinders. World War II "snorkels" superimposed rhythmic pressure changes of about 1 Hz which appeared to add to the frequency and severity of middle ear pathology. Subjective observations indicated that engine room personnel appeared to tire faster and were of a poorer disposition than other submarine crew members (Tonndorf, 1950; Gavreau et al, 1966). Studies in which the ear alone was subjected to infrasounds have been concerned primarily with the investigation of the lower limits of auditory periodicity analysis; however, the physiological and psychological effects, if any, were not recorded (Guttman and Julesz, 1963; von Bekesy, 1960; Wever and Bray, 1936).

This thesis represents an initial attempt to determine the importance of the infrasonic environment produced by naturally occurring phenomena, viz., strong winds and tornadoes, on human behavior. Automobile accident rate and rate of absenteeism were selected as indicators of the human behavior to be examined since these quantities can be computed from well defined, recorded events which, it was felt, would most likely be influenced by the type of symptoms previously observed for individuals in intense man-made infrasonic environments (Mohr et al, 1965; Gavreau et al, 1966).

The thesis is divided into the following sections. Part II is a brief discussion of the previous major infrasonic studies, including discussions of the effects of low frequency and infrasonic noise on man and the propagation characteristics of low frequency sound through the atmosphere. Previous observations relating human behavior and weather phenomena are described in Part III. Here the hypotheses that the mechanisms responsible for the observed relationship of human behavior and certain weather phenomena are infrasonic waves generated by such phenomena are discussed. To examine these hypotheses further, the present study was undertaken in a fashion which differed from all previous investigations in that the weather fronts or, as they are considered in this thesis, sources of infrasonic waves, were not required to be spatially or temporally coincident with the observation area. In this way it is possible to eliminate various local storm phenomena, e. g., low atmospheric pressure, wind, rain, increased ozone concentration, as causes for the observed effect upon human behavior. The manner in which this study examined the earlier hypotheses and the manner in which infrasonic activity in the observation area was to be determined is also described in Part III. Part IV contains discussions of the methods used to obtain data concerning the selected human behavior, of the analyses of the data, and of the correlation with chosen weather phenomena. Part IV also contains a discussion of uncertainties in the methods and a discussion on subjects for further study.

The Bibliography is comprehensive and felt to be the first of such completeness on the subject of infrasonics.

The Appendix contains the raw data used in this study, a record of the local weather conditions of the study area during the study period, and sample pages of the weather bureau data used to determine the time of arrival and duration of infrasonic waves in the study area.

II. PREVIOUS INFRASONIC STUDIES

The subject of infrasonics can be divided into two major categories. The first is concerned with the study of man-made low frequency sounds while the second is concerned with infrasounds produced by natural phenomena. The former category includes infrasounds deliberately generated, as is the case for "pure" infrasonic studies, or those generated as a by-product of man-made devices such as the slowly rotating submarine engines mentioned earlier in this paper.

Man-made infrasonics

In the United States, infrasonic studies, for the most part, have been directed toward understanding the by-product type of infrasonics and the effect these infrasounds have upon men working within an infrasonic environment. Such studies are being carried out at the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, with the Apollo Space Program providing the motivation (Wiener, 1962; von Gierke, 1959; Cole et al, 1962; Guild, 1965) since it has been estimated that large rocket boosters will generate intense infrasonic noise (NASA Hazards Analysis Board, 1961; WADC Tech Report, 1957). One such study (Mohr et al, 1965) investigated human tolerance to the type of infrasonic environment expected to be present in space capsules during lift-off with the large (Nova) class boosters. Here four male and one female noise-experienced Air Force officers, i. e., individuals having worked in intense sound environments, were exposed to various low frequency sounds produced by large propellers, turbojets, rocket engines, and an infrasonic siren, the latter being the only source generating pure infrasonic waves while other sources had broad frequency spectra similar to that expected to be present in the crew compartments of a Saturn-boosted vehicle. The objective portions of the test were geared to the space program requirements of astronauts' responses during lift-off and revealed that the expected infrasonic environment would create decrement in visual acuity and interfering modulation of speech sounds. As part of the subjective portion of the study, the subjects were to report the occurrence of pain, body vibration, respiratory changes, vertigo, flushing, tingling, nausea, anxiety, fatigue, and other miscellaneous complaints. "In the very low sonic frequency range, chest wall vibration, gag sensations, and respiratory rhythm changes were regularly observed. . . . Responses including headaches, choking, coughing, visual blurring and fatigue were sufficiently alarming to preclude undergoing higher level exposures without more precise control of the noise environment and definition of the physiologic effects elicited." (Mohr et al, 1965)

In France, infrasonic studies have been directed toward understanding the problems involved with the generation and detection of pure infrasonics and the effects of these infrasounds on humans. These studies are being conducted at the Centre National de la Recherche Scientifique, France, (Lysanov, 1962). Gavreau et al (1966) reported on a detailed study of the development of generators of low frequency sounds in which various resonant pipe, loud speakers, organ pipe, pistonphone and whistle type generators were constructed and tested, with the lowest frequency achieved being 3.5 Hz produced by a 1/4 wavelength closed infrasonic pipe organ. This study was also concerned with infrasonic detectors with the most practical detector being the multiple capsule barometer, developed after the hand of a normal barometer was observed to oscillate during the presence of infrasounds. The subjective portion of the study has shown that the presence of 7 Hz sound seemed to hinder intellectual activity, e. g., simple additions could not be performed correctly, and the authors suggest that since the alpha-wave of an electroencephalogram has a frequency of about 7 Hz, the infrasounds may be interfering with the normal brain functioning. It is interesting to note a technique used in the theatre (Burris, 1959) to induce an emotional climax in the patron by introducing a slowly beating drum and increasing the frequency of the drum beat, which causes the patron's pulse rate to increase since the pulse has a tendency to synchronize with the drum beat. Although it is pure speculation at this time, it may be that the brain functions which produce the alpha-wave patterns attempt to synchronize with the low frequency sounds and cannot do this without interfering with normal brain functions. Further, it has been established that man is particularly affected by 7 Hz stimuli (von Gierke, 1965; Harris et al, 1964; Parks et al, 1961; Burris, 1959).

It has been observed that many of the psychological effects caused by infrasonics can be greatly reduced, and in some cases eliminated entirely, by introducing masking or overriding sounds of audible frequencies (Gavreau, 1968).

Infrasound of natural origin

Cook (1962) published a detailed account of naturally occurring infrasonics, now called "geo-acoustics," which are produced by distant tornadoes, high winds, volcanoes, earthquakes, magnetic storms; and some, such as the microbarom, are of unknown origin.

Reports in the late nineteenth and early twentieth centuries discuss audible sounds due to natural causes, e. g., volcanoes and meteor impact, which were recorded several thousand kilometers from their sources (Cook, 1962). Although electro-acoustic instrumentation was not available at that time, the inaudible sound waves were recorded because the waves from these catastropic events were so intense that observable deflections were produced on barographs (recording barometers) throughout the world. Surprisingly, some of the sounds were observed several times, and at such time intervals, by the same instrument, implying that the infrasonic wave had completely circled the earth and retained sufficient energy to affect the barographs. This latter observation can be understood in terms of the propagation characteristics of infrasound through the atmosphere. Infrasonic waves have the same speed of propagation through air as audible sound, viz., about 344 m/sec at 20° C, and therefore infrasounds in the frequency range of 10 Hz to 0.1 Hz have wavelengths of 34.4 m to 3.4 km. The classical absorption coeffient, α, due to viscosity and heat conductivity of the air, is given by the following relation between sound pressure amplitude and propagation distance as

$$P(x) = P_o \exp(-\alpha x).$$

Experimentally, α is found to be about $1.6 \times 10^{-4}/T^2 B$ db/m, where T is the period of the sound wave in seconds and B is the barometric pressure in d/cm^2. For a plane wave in the lower atmosphere (B is approximately $10^6 d/cm^2$) with T = 10 sec, the absorption coefficient would be less than 2×10^{-9} db/km. If allowances are made for losses due to water vapor in the atmosphere, α becomes approximately 5×10^{-8} db/km, for the same values for T and B. Estimated losses due to relaxation of thermal energy stored in the vibrational state of the diatomic molecules of the atmosphere are 10^2 to 10^3 times greater than those due to classical absorption processes at infrasonic frequencies. With these processes taken into account, α is approximately 10^{-6} db/km and the loss occurring in one propagation over the earth's surface is insignificant (Cook, 1962). Observed pressure amplitudes of infrasonic waves of natural origin are often in the range 0.15 d/cm^2 to 40 d/cm^2. A sound wave propagating from a point source can be approximated by a plane wave at large distances from the source.

For the detection of natural infrasonic waves, Cook used six standard electro-static condenser type microphones placed in an array (Ady, 1962) which covered approximately 7 km, thus overcoming the problem associated with the low signal level and the stronger signals from winds. A study of natural infrasonics was carried out using this detector and the results show clearly that earthquakes, magnetic storms, high winds, and tornadic storms generate infrasounds, the latter generating frequencies predominantly with periods between 12 and 50 seconds. Fehr introduced portable infrasonic detectors, called variometers, that are being used aboard research aircraft in a study of high altitude infrasonics (Wood, 1967). It is expected that the portable variometers will be used to give advance warnings of impending natural catastrophes, viz., tidal waves (Daniels, 1962), volcanic eruptions, and strong winds, and possibly to locate schools of fish which appear to generate infrasonic waves (Walker, 1963).

III. STATEMENT OF THE PROBLEM AND DESIGN OF THE STUDY

Early observation of a relationship between human behavior and certain weather phenomena

The literature contains numerous references to a possible relationship between human responses similar to those observed in the infrasonic tests (Mohr et al, 1965 and Gavreau et al, 1966) and weather phenomena that are known to produce infrasonic waves. For the most part, these references are found as folklore (Aubert de La Rue, 1955) of regions where perennial winds, e. g., the khamsin or foehn, are found (Hoff, 1968). The following description of the effect of stormy weather on human beings is typical of the observations that have been made.

"Just before a storm, . . . people are irritable, restless and more likely to have headaches, nightmares and fainting spells. There are more attempts at suicide, the rates of industrial accidents go up, and rules are broken more frequently in schools and prisons. Lost and found officers say that during the pre-storm period more packages are left on busses and more gloves and scarfs lost in theaters." (Ellis, 1961).

Detailed studies recently completed have shown a definite relation between occurrence of automobile accidents and the pre-arrival hours of the foehn winds in Switzerland (Moos, 1964). The foehn is caused by damp air ascending the windward side of a mountain, losing moisture and heat as it ascends, after which the resulting dry air "tumbles" down the lee side of the mountain, rising in temperature as it progresses (Hoff, 1968). Foehn weather is notable for its dryness, extremely good visibility, and almost clear sky. Thus, the problem of isolating the other contributory factors, e. g., wet streets, fog, damaging wind and hail, for increased accident rates, is treated more easily than in the case of similar studies using other types of weather fronts (Reiter, 1951). The study concludes that there is a statistically significant higher accident rate during the time interval four hours prior to the arrival of the foehn wind; however, no attempt is made to determine the possible mechanism responsible for this finding.

A hypothesis regarding the pre-storm observations

It is hypothesized that the mechanism responsible for the pre-storm human behavior observed in this study is the presence of infrasonic waves generated by the foehn wind center some distance away. It is known that foehn type winds do produce significant infrasonic waves (Wood, 1967; Hoff, 1968). Further, the arrival of the infrasonic waves would be expected to precede the arrival of the generating winds at an observation point by t hours, where t is given by

$$t = \frac{d(v_s - v_w)}{v_s v_w}$$

where v_s is the speed of sound in km/hour, v_w the forward speed of the wind in km/hour, and d the distance between the observation point in km and the point where the winds had attained sufficient strength to produce the infrasonic waves. Using nominal values for v_s and v_w, viz., 1.24 x 10^6 m/hr and 9 x 10^4 m/km, respectively, it is seen that d need be only 100 km to cause a one hour delay between the onset of the infrasonic waves and the arrival of the generating winds at an observation point. Thus the change in human behavior caused by the presence of the infrasonic waves would be expected to occur some time before the arrival of the winds, as was observed. The observed return of the accident rate to normal during the presence of the winds may be explained by the masking effect of the audible sounds created by the winds (Gavreau, 1968). Finally, the responses observed in the infrasonic tests, viz., visual blurring, fatigue, and inability to perform intellectual tasks, could easily impair a driver's ability and consequently cause an increase in accident rate.

To examine further the hypothesis that naturally produced infrasonics may influence human behavior, the following study was devised, viz., to select an observation area, determine when infrasonic waves produced by naturally occurring phenomena at distant points would be present in the observation area, to select suitable human activities that would most likely be affected by the presence of infrasonic waves, and to observe whether statistically significant correlations ensue. Chicago, Illinois, was chosen as the observation site for this study for the following reasons: a) tornadoes and strong windstorms, which were considered as the generators of infrasonic waves, normally originate sufficiently far removed from the Chicago area such that the problem of separating infrasonic effects from other storm-related effects was minimal; b) the high population density of this city allowed a larger number of observations of human behavior to be made in a small geographical area, thereby minimizing the need for corrections due to variations of the infrasonic environment in the observation area at a given time, while permitting a significant data sample to be taken; c) the author, being originally from the Chicago area, found less difficulty in acquiring the necessary data on human behavior for this region than for any other. Weather conditions in Chicago during the period of the study, May 1-28, 1967, were excellent (see Table A-1), and as a result minimal corrections were required for local weather conditions.

Determination of the time of arrival and duration of infrasonic waves in the Chicago area were accomplished by two methods. The first method consisted of ascertaining the time intervals that tornadoes or high winds were present in specific localities in the United States and by accounting for time zone differences and propagation time from the storm center to the area under study. The weather information, obtained from the U. S. Department of Commerce publication "Storm Data," did not present the data on storm intensity in quantitative terms (see Figure A-1 for sample page), and consequently no attempt was made to estimate the amplitude of the infrasonic waves. It was estimated from the "Storm Data" information that the Chicago area would experience the presence of infrasonic waves, generated by storms up to 1500 miles away, for thirteen of the twenty-eight days included in the study. As a second method of determining the time of arrival and duration of infrasonic waves in the area of study, the U. S. Department of Commerce publications, "12-Hour Barogram Chicago, Illinois, O'Hare Arpt.," covering the twenty-eight days of the study period were obtained and examined for indications that infrasonic waves were present. It was expected that a barograph indicator would oscillate, as the arm of an ordinary barometer had been observed to do, in the presence of infrasonic waves (Gavreau et al, 1966), and that the normally narrow trace of the barograph would have low frequency disturbances superimposed upon it when infrasounds were present. The barograph records obtained revealed that the recorded trace did have the predicted perturbations (see Figure A-2) on twelve of the thirteen days estimated by the first method that infrasonic waves would be present as well as one additional day, viz., May 6, 1967. Reexamination of the "Storm Data" information for May 6, 1967, revealed that weather conditions were typical of conditions normally found just prior to tornado activity, viz., hail and strong winds (Hoff, 1968), and it is possible that tornadoes were generated but not sighted. The "Storm Data" information predicted that infrasonic waves would be present on May 20, 1967, in the Chicago area while the barograph trace did not contain any significant perturbation on that date. Re-examination of the "Storm Data" information for May 20, 1967, revealed that the storm activity on that date was weak and spasmodic and consequently the storm center may not have had sufficient energy to generate the infrasonic wave amplitudes to affect barometer recordings. Because of their greater objectivity, it was decided to use the barograph perturbations as indicators of probable infrasonic wave activity for the purpose of this study. Perturbations occurred on the following dates during the study period: May 1, 5, 6, 8, 11, 12, 13, 15, 18, 19, 23, 25, 28, 1967, with the underlined dates indicating large perturbation patterns which would imply that stronger infrasonic disturbances were present.

Three types of human activities were selected for correlation with the determined periods of infrasonic disturbances, viz., automobile accidents, absenteeism among school children, and absenteeism among unskilled factory workers. It was felt that these activities, all of which are well defined events, would most likely be affected by the presence of infrasonic waves. As discussed previously in this section, infrasonic effects may produce an increase in accident rate. Similarly, the gag sensations, fatigue, and other infrasonic effects could induce individuals to remain at home rather than going to school or work. To emphasize any infrasonic effects, absenteeism among primary school children and unskilled factory workers was chosen over absenteeism among secondary school students or professional occupation workers since it was felt that the latter groups would be less inclined to absent themselves because of minor symptoms. Automobile accident data were obtained from insurance company records rather than police or state records, thereby allowing the minor accidents, i. e., less than $100 damage, to be included in the study; the State of Illinois does not normally require the filing of a report on accidents involving less than $100 damage. The inclusion of minor accident data was considered essential since they would be more indicative of minor disturbing effects. Absenteeism data for the primary school children were available only as monthly summaries; consequently the daily absentee data were obtainable only by reviewing individual instructors' record books. During the compilation of this data, individual absences of three or more consecutive days, Friday and Monday being considered consecutive, were ignored to eliminate from the data cases of serious illness and thereby emphasizing the mild, short-term absences expected to be caused by minor disturbing effects. Absentee data for factory workers were obtained from payroll department records and compiled by a company employee, and as a result the elimination of long-term absences was not made.

IV. RESULTS AND CONCLUSIONS

Since daily statistics concerning the human behavior of interest to this study are not published, the author was required to seek this information at the source level, viz., individual accident claims, individual instructor record books, and individual employee time cards. To obtain the automobile accident data, approximately 3,000 accident claims were reviewed at the Bloomington, Illinois, office of the State Farm Insurance Company. Of these claims, over 2,000 were not used in this study for one or more of the following reasons: a) the claim involved a date not included in this study period; b) the claim concerned a loss due to theft or vandalism; c) the claim concerned a loss due to natural causes, i. e., falling tree, flood, etc; d) the claimant was unable to state the date the damage was incurred because the automobile had been unattended for several days. It is felt that the accident data included for study represent an accurate cross section of all pertinent automobile accidents in the Chicago area during the study period.

Data concerning absenteeism among school children were obtained from individual instructor record books located at the office of the Superintendent of School District 111, Oaklawn, Illinois. The record books of two schools, viz., Burbank and Maddock Elementary Schools, were examined. The combined enrollment of approximately 1500 students for these two schools was considered a sufficient sample space. Data concerning absenteeism among factory workers were the most difficult to obtain. Most companies were reluctant to reveal payroll information of any kind, particularly detailed daily statistics. The factory worker absenteeism data obtained from the Haggard and Marcusson Company, Chicago, payroll records were the only such data available to the author, and though they were included in this study, the sample space, viz., 142 employees, was much smaller than desired.

Results

	Days of infrasonic disturbances	Days of intense infrasonic disturbances
Automobile accident rate	0.37	0.49
Absence rate among school children	0.33	0.50
Absence rate among factory workers	0.26	0.32

Table 1. Correlation coefficients of selected human behavior and periods of infrasonic disturbances

The correlation coefficients (Lindgren, 1960) relating the selected human behavior with the days on which infrasonic disturbances were present in the study area were computed and are presented in Table 1.

The correlation coefficients relating the selected human behavior with the four days of strongest infrasonic disturbances are also presented in Table 1. A correlation coefficient of ± 1 indicates that a linear relationship exists with probability P = 1 between the two variables considered. A correlation coefficient of 0 would imply that a linear relationship does not exist between the two variables, although some type of non-linear relation may exist.

Table 2 presents the data in a form that displays the shifting effect an infrasonic environment has on each type of selected human behavior. The days of the study are divided into two halves: those days having a behavior rate above the median and those having a behavior rate below the median. These halves are further divided into two parts: those days which contain infrasonic disturbances and those days which do not. The greater effect the infrasonic disturbances have on the behavior, the greater the variance of the ratios of the columns of each row will be expected to have. This same presentation is also made comparing days of strongest infrasonic disturbances with all other days in the study period for each selected human behavior.

Figure 1 also displays the shifting effect as well as the spreading effect, i. e., increased deviation from norm, infrasonic waves may have on human behavior. The days of infrasonic disturbances are represented as vertical dashes above the horizontal line and the days without

	Number of days having automobile accident rate:	
	Above median	Below median
Days with infrasonic disturbances	8	5
Days without infrasonic disturbances	6	9

Days with intense infrasonic disturbances	4	0
All other days	10	14

Daily Automobile Accident Rate

	Number of days having a daily absence rate for school children:	
	Above median	Below median
Days with infrasonic disturbances	6	4
Days without infrasonic disturbances	4	6

Days with intense infrasonic disturbances	3	1
All other days	7	9

Daily Absence Rate for School Children

Table 2. Contingency tables for test of homogeneity

	Number of days having a daily absence rate for factory workers: Above median	Below median
Days with infrasonic disturbances	4	6
Days without infrasonic disturbances	6	4
Days with intense infrasonic disturbances	2	2
All other days	8	8

Daily Absence Rate for Factory Workers

Table 2 continued

significant disturbances are represented as vertical dashes below the line. The horizontal displacement to the right of the origin represents the number of occurrences of the specific behavior. Days of intense infrasonic disturbances are represented by larger dashes.

Figures 2, 3, and 4 display graphically the daily deviation of the selected human behavior rate from the average rate observed during the study period. The dates of strong infrasonic disturbances are noted on these graphs.

Discussion of error

Determination of the presence and duration of infrasonic disturbances was accomplished by two independent methods, viz., noting perturbations on barograph recordings and computations based on "Storm

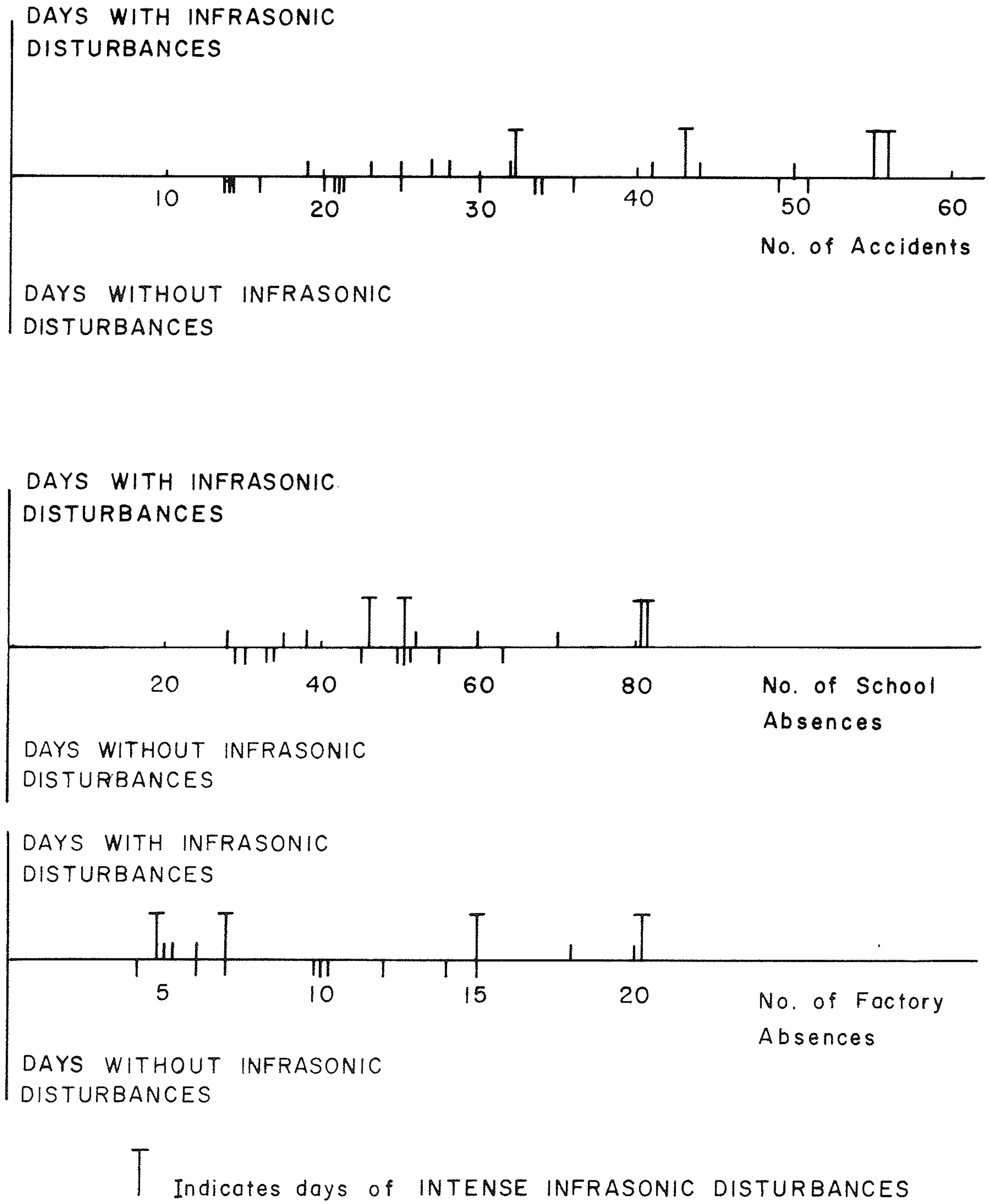

Figure 1. Data display for observation of the shifting and spreading effects of infrasonic disturbances

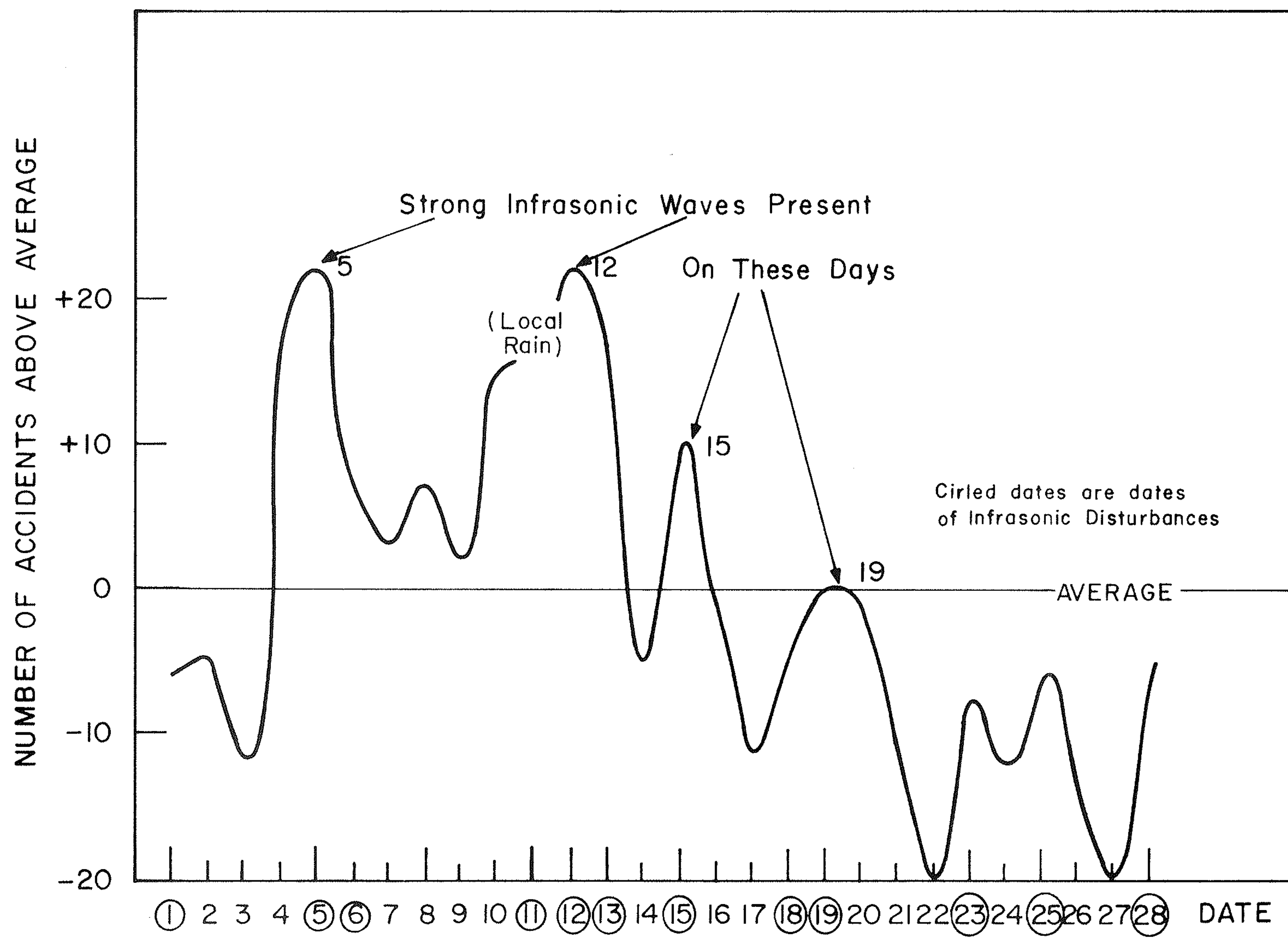

Figure 2. Deviation of daily accident rate at Chicago, May, 1967

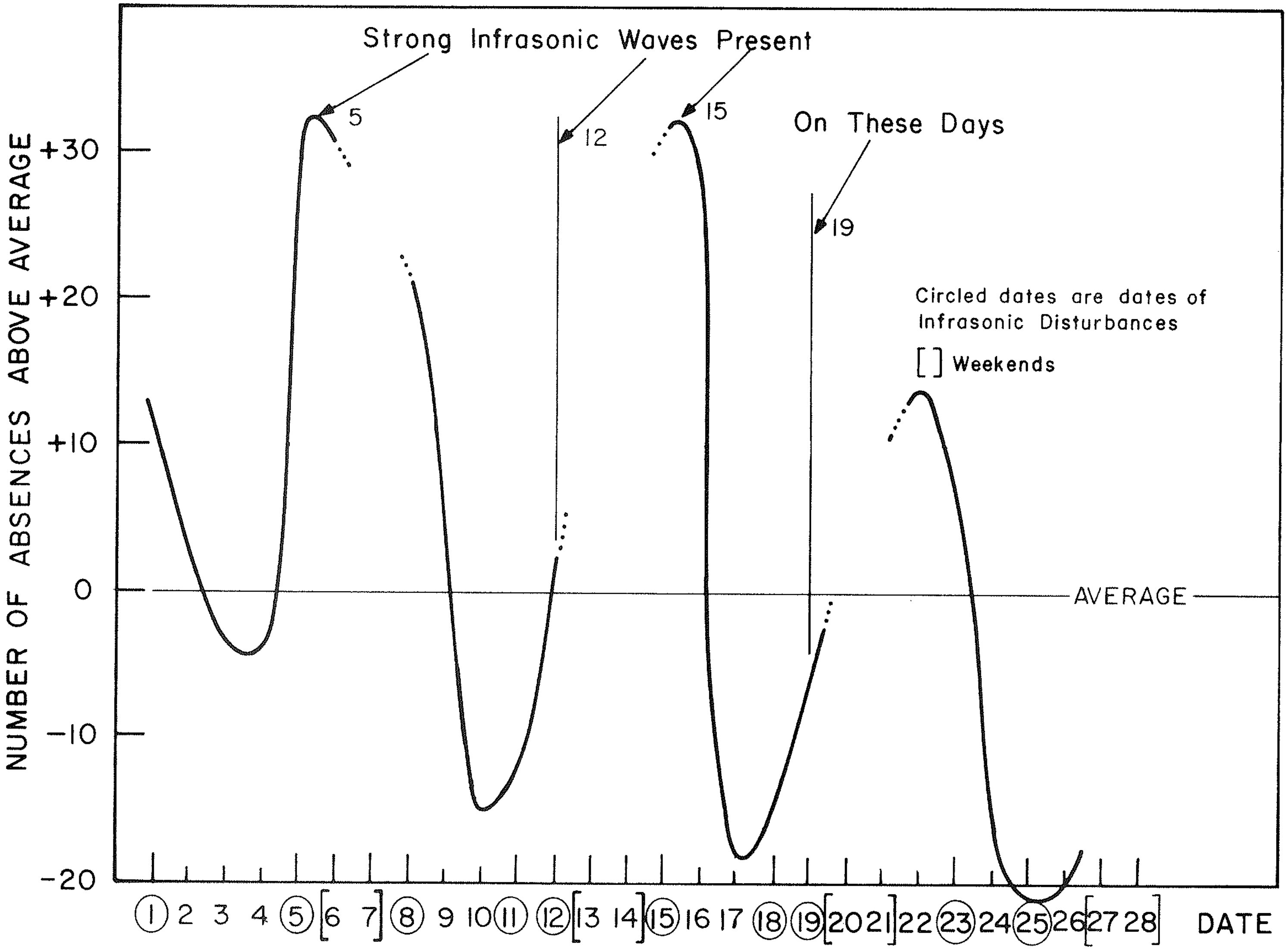

Figure 3. Deviation of daily absence rate for two schools in the Chicago area, May, 1967

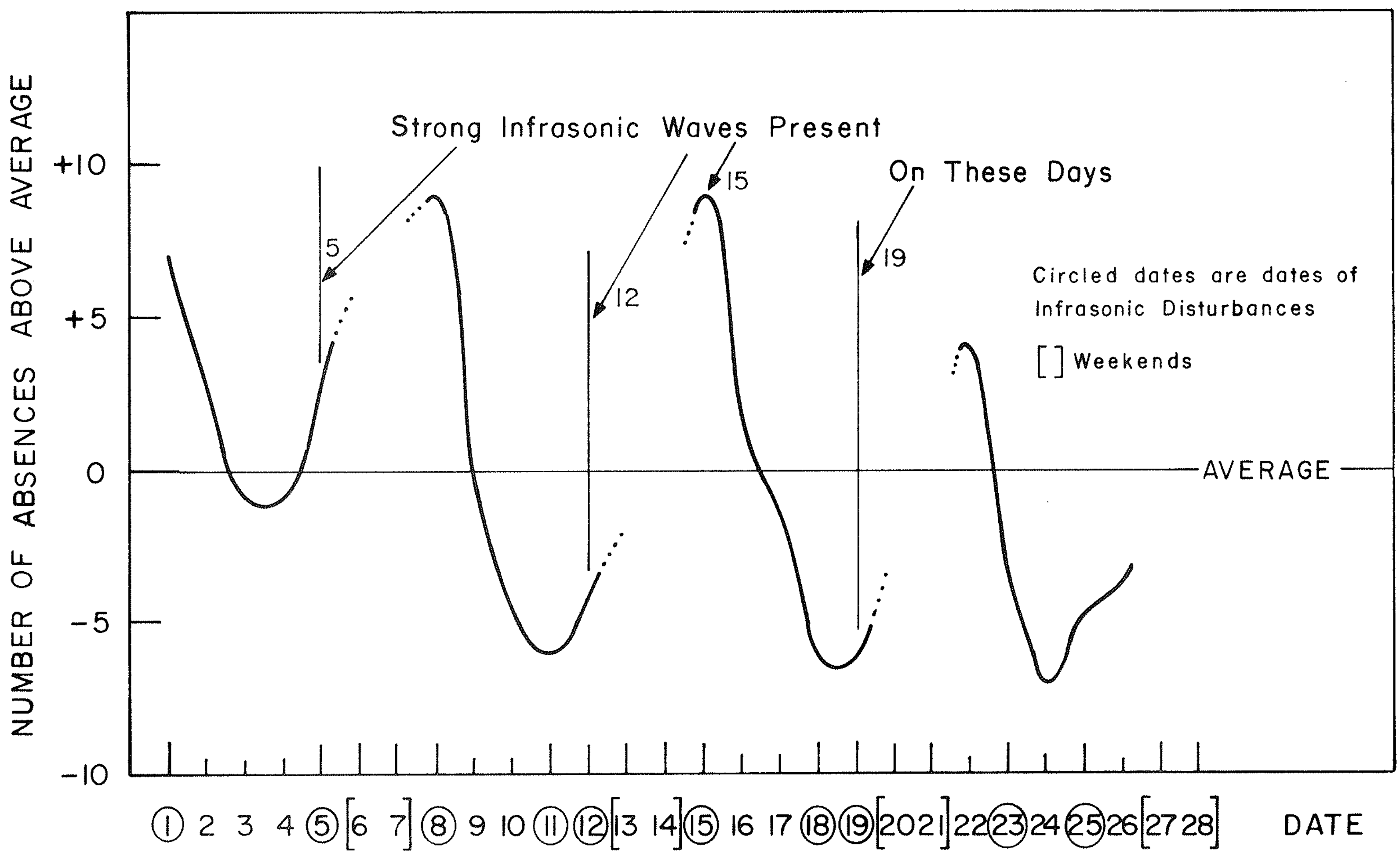

Figure 4. Deviation of daily absence rate for a Chicago factory, May, 1967

Data" reports. For the most part these two methods yielded identical results. While it is known that infrasonic waves cause barometer indicator arms to oscillate, it cannot be assumed that this is the only phenomenon causing these oscillations. It may be that wind directions were such that, on the days of significant perturbations, the aircraft arriving and departing the airport, at which the barograph recordings were taken, passed over the instrument causing the observed oscillations. It is doubtful that the dates of infrasonic activity determined by the barograph method would correspond as closely with those determined by the "Storm Data" method if this were the only cause of the barograph perturbations. However, this possibility cannot be discounted completely without further study.

The weather conditions in the Chicago area during the study period were such that minimal error was introduced by neglecting local conditions. Statistics reported by the State of Illinois Traffic Safety Division indicate that a light rain, such as that which occurred on four days of the study period, does not significantly increase the accident rate (anon. 1967d). The effect of light precipitation on absenteeism among school children and factory workers is not known. Judging from the observations made in this study, the effect appears to be insignificant.

It is considered that during the period studied, there were no major road hazards or traffic pattern changes that would have a significant effect on the automobile accident rate. Accident statistics (anon. 1967d) indicate that there exists a significant difference in the urban automobile accident rate on weekdays as compared with that during the weekend. Since the ratio of weekend days with infrasonic disturbances to weekdays with infrasonic disturbances was approximately the same ratio as all weekends to all weekdays, viz., 3/10 compared to 2/7, it was not necessary to distinguish the days of the week during the study of automobile accident rates.

The absence rate among school children appears to depend on the particular day of the week. From Figure 3 it is seen that there is an increased absence rate on Mondays and Fridays and a low absence rate on Wednesdays and Thursdays. It is difficult to determine if this is a normal pattern or if the observed pattern is due to the presence of infrasonic waves, which have an almost identical distribution pattern for this study period, since statistics concerning daily absence rates among school children are not compiled for the study area.

It was learned during an interview with a Haggard and Marcusson Company payroll clerk that the normal absence pattern for this factory is a high rate on Monday decreasing throughout the week to a low rate on Friday, which is the employees' payday. This strong absence pattern and the relatively small sample space are felt to obscure whatever infrasonic effects may be present. There were no known conditions that would cause a significant change in the absence pattern of these workers in existence during the study period.

Conclusions

It is seen from Table 1 that automobile accidents and absenteeism among school children appear to have a significant degree of correlation with the presence of infrasonic waves. Further, it is seen from Table 1 that these human behaviors have a high degree of correlation with the presence of strong infrasonic waves, although as discussed above, the high correlation coefficient relating absenteeism among school children and infrasonic disturbances may be due to the coincidence of the infrasonic disturbance distribution with the normal absence distribution. Table 2 shows that a very significant degree of shifting of the median occurs in the automobile accident rate and absence rates among school children during the presence of strong infrasonic disturbances. No noticeable shifting can be observed in the case of absenteeism among factory workers. Figure 1 indicates that infrasounds do not cause significant spreading, i. e., larger deviations from the norm, in the automobile accident rate or absence rate among school children. There is some indication that the presence of infrasonic waves have a spreading effect on the absence rate of the factory workers considered in this study, viz., three of the four days with the highest absence rate had infrasonic waves present and three of the four days with the lowest absence rate had infrasonic waves present. Figures 2 and 3 indicate that relative maxima occur on dates of intense infrasonic waves for the deviation of daily accident rate and absence rate among school children. Deviation of the daily absence rate among factory workers, Figure 3, does not indicate this peaking to the extent observed in the previous two behaviors.

It appears that a significant relationship exists between the presence of strong infrasonic waves, generated by natural phenomena, and the frequency of automobile accidents. It further appears that a similar relationship exists between the presence of infrasonic waves and the absence rate of students in elementary schools; however, the significance of this relationship cannot be determined without further investigation of the normal daily absence pattern of these students. Because of the small sample space involved and the strong pattern of normal absenteeism among the factory workers studied, the results of this portion of the study are considered inconclusive.

Considerations for further study

The infrasonics area of the science of sound is an important yet still little explored field. The need for a detailed systematic study of the relationship the parameters frequency, intensity, and duration have on the biological effects of infrasound is apparent. Much work also remains to be done in the area of instrumentation for future infrasonic studies.

There are indications that a similar study dealing with the relationship between suicides and other types of deaths and the presence of infrasonic waves would also have a significant correlation (Mills, 1934; Aubert de La Rue, 1955; Ellis and Allen, 1961; Moos, 1963).

Little is known of means of protecting man from infrasonic waves. The acoustic insulating effectiveness of a structure is a function of the thickness of the walls, the materials of construction, and the frequency of the sound. The low frequency of infrasounds requires an impractical thickness of materials for effective insulation (Gavreau et al, 1966). It is not known if ear-protecting devices would protect an individual from suffering the effects caused by an infrasonic environment. There is some indication that audible sounds effectively mask infrasonic effects, but only cursory observations have been made in this area (Gavreau et al, 1966).

The detection of the presence of infrasonic waves may serve as a warning of an expected change in human behavior. Officials, e. g., police or traffic controllers, thus forewarned could initiate action which would minimize or counteract the infrasonic effects. Actions such as decreasing the speed limit of electronically controlled thoroughfares, e. g., the New Jersey Turnpike, and instructing all police vehicles to display blinking emergency lights could possibly create the desired counter-effect.

The character of infrasonics is such that the efforts of many individuals from many fields will be required to answer the numerous outstanding questions raised by these first studies.

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APPENDIX

Daily Precipitation (in inches)

Date	5/1	5/2	5/3	5/4	5/5	5/6	5/7
	0.04	---	T	0.09	T	---	0.08
Date	5/8	5/9	5/10	5/11	5/12	5/13	5/14
	0.06	---	0.67	0.23	---	---	T
Date	5/15	5/16	5/17	5/18	5/19	5/20	5/21
	T	---	----	0.15	----	----	----
Date	5/22	5/23	5/24	5/25	5/26	5/27	5/28
	----	0.03	T	----	----	----	.26

Snow on Ground: T on 4th

(T = trace: less than 0.01 in.)

Daily Temperatures: High / Low

Date	5/1	5/2	5/3	5/4	5/5	5/6	5/7
	76	49	50	43	52	53	63
	48	36	31	33	32	35	37
Date	5/8	5/9	5/10	5/11	5/12	5/13	5/14
	57	63	63	55	52	60	62
	43	36	41	41	38	40	47
Date	5/15	5/16	5/17	5/18	5/19	5/20	5/21
	56	66	74	85	70	61	68
	42	40	44	55	50	40	43
Date	5/22	5/23	5/24	5/25	5/26	5/27	5/28
	57	72	70	84	92	75	62
	40	40	52	49	61	52	51

Data obtained from: "Illinois Climatological Data," U. S. Dept. of Commerce, Environmental Data Service, Vol. 72, No. 5.

Table A-1 Weather data for Chicago area, May, 1967

Date		12 M - 2 AM	2 - 4 AM	4 - 6 AM	6 - 8 AM	8 -10 AM	10 AM - 12 N	12 N - 2 PM	2 - 4 PM	4 - 6 PM	6 - 8 PM	8 - 10 PM	10 PM - 12 M	Totals
Mon May	1	0	0	2	3	4	2	3	3	6	3	1	1	28
Tues	2	0	0	0	4	7	1	1	2	4	6	1	4	30
Wed	3	0	1	0	1	4	0	1	2	1	3	2	1	16
Thurs	4	2	1	2	13	7	2	7	3	5	6	3	0	51
Fri	5	1	0	0	2	2	3	2	9	10	8	12	6	55
Sat	6	0	3	1	0	0	4	6	2	6	6	1	3	32
Sun	7	2	2	0	1	2	0	4	8	6	2	5	2	34
Mon	8	1	2	0	3	1	3	3	9	12	4	2	1	41
Tues	9	2	0	0	4	6	1	2	3	12	5	1	0	36
Wed	10	2	1	0	2	5	4	4	8	5	8	8	2	49
Thurs	11	1	0	0	10	9	1	6	5	10	1	4	3	50
Fri	12	1	1	1	5	3	4	8	10	5	9	5	4	56
Sat	13	1	1	0	2	6	2	5	6	5	6	6	3	43
Sun	14	1	1	0	0	2	3	2	3	1	4	3	0	20
Mon	15	0	0	0	7	9	8	2	4	7	4	2	0	43
Tues	16	0	0	0	2	3	5	5	5	7	4	2	2	35
Wed	17	1	0	0	3	3	3	2	1	2	1	4	1	21
Thurs	18	2	0	0	0	0	2	2	2	7	3	4	5	27
Fri	19	1	0	1	1	4	3	4	3	5	5	3	2	32
Sat	20	0	0	0	1	2	4	8	2	1	3	1	3	25
Sun	21	0	0	1	0	0	1	2	2	4	1	2	1	14
Mon	22	0	0	0	2	1	0	0	1	4	3	3	0	14
Tues	23	0	0	0	4	0	3	1	2	7	3	4	1	25
Wed	24	1	0	1	0	4	2	2	2	3	1	2	3	21
Thurs	25	0	1	0	1	0	3	2	3	6	1	3	3	23
Fri	26	0	1	0	2	2	2	2	1	3	5	1	2	21
Sat	27	0	0	0	0	2	2	3	2	4	1	1	0	15
Sun	28	0	0	1	0	1	0	6	6	4	0	1	0	19

Table A-2 Automobile accident data covering May 1 to 28, 1967, in the city of Chicago, Illinois, by two-hour periods

	Mon	Tues	Wed	Thurs	Fri
Date	5/1/67	5/2/67	5/3/67	5/4/67	5/5/67
Number of Students Absent	$\frac{30}{30}$	$\frac{26}{25}$	$\frac{15}{30}$	$\frac{28}{27}$	$\frac{36}{45}$
Date	5/8/67	5/9/67	5/10/67	5/11/67	5/12/67
	$\frac{29}{41}$	$\frac{28}{23}$	$\frac{15}{19}$	$\frac{12}{26}$	$\frac{17}{34}$
Date	5/15/67	5/16/67	5/17/67	5/18/67	5/19/67
	$\frac{34}{47}$	$\frac{18}{31}$	$\frac{16}{15}$	$\frac{13}{23}$	$\frac{21}{25}$
Date	5/22/67	5/23/67	5/24/67	5/25/67	5/26/67
	$\frac{23}{40}$	$\frac{18}{34}$	$\frac{13}{20}$	$\frac{13}{15}$	$\frac{6}{23}$

Note:

Data are of the form:

Date

Burbank Data

Maddock Data

(Burbank Data over Maddock Data)

Burbank and Maddock are elementary schools in Oak Lawn, Illinois, with a combined enrollment of approximately 1500 students.

Table A-3 Absence data for two schools in the Chicago area for May, 1967

	Mon	Tues	Wed	Thurs	Fri
Date	5/1/67	5/2/67	5/3/67	5/4/67	5/5/67
Number of Workers Absent	18	14	10	10	15
Date	5/8/67	5/9/67	5/10/67	5/11/67	5/12/67
	20	10	6	5	7
Date	5/15/67	5/16/67	5/17/67	5/18/67	5/19/67
	20	12	10	5	5
Date	5/22/67	5/23/67	5/24/67	5/25/67	5/26/67
	15	7	4	6	7

Average Number of Employees During This Period:

Male	123
Female	19
Total	142

Table A-4 Absence data for Haggard and Marcusson, a factory in the Chicago area, for May, 1967

STORM DATA AND UNUSUAL WEATHER PHENOMENA

MAY 1967

PLACE	DATE	TIME - LOCAL STANDARD	LENGTH OF PATH (MILES)	WIDTH OF PATH (YARDS)	NO. OF PERSONS: KILLED	NO. OF PERSONS: INJURED	ESTIMATED† DAMAGE: PROPERTY	ESTIMATED† DAMAGE: CROPS	CHARACTER OF STORM
GEORGIA									
Bowdon	6	8:15 p	2	150	0	0	4	0	Tornado
	Storm blew out one wall of high school auditorium while play was in progress. Numerous small buildings demolished and several residences damaged. Large number of trees uprooted or twisted off along storm path. Storm moved NNE.								
Marietta, near	6	8:45 p							Funnel Cloud
	Reported by State Highway Officer to be moving toward NE.								
Early County	7	9:00 a	4	Narrow	0	0	3	0	Tornado
	Small tornado damaged several farm houses and uprooted numerous trees.								
Colquitt County	7	10:30 a	Short	Narrow	0	0	3	0	Tornado
	Storm damaged a rural church while service was in progress. Several cars on grounds damaged by falling trees.								
Macon	7	?			0	2	0	0	Lightning
	Two young brothers injured when hit by a power line knocked down by lightning.								
Augusta Area	8	p.m.			0	0	4	0	Wind and Lightning
	Many buildings damaged and numerous trees uprooted in Augusta, Richmond County and surrounding counties. Wind speeds of 60 mph recorded at Augusta WBAS. One house was destroyed by lightning.								
Tift County	8	9:00 p	?	?	0	0	3	3	Tornado and Hail
	Tornado reported near Eldorado, a few miles south of Tifton with damage limited to blown down lines. Additional damage to lines at Brookfield about 8 miles to the NE. Hail caused scattered damage to crops in adjoining Colquitt County a little earlier.								
Chickamauga, near	12	9:15 a	?	?	0	0	2	0	Tornado
	Trees blown down but no other significant damage.								
Cobb, DeKalb and Gwinnett Counties	12	8:15 p			0	1	4	0	Windstorm
	Winds wrecked a large boat dock on Lake Allatoona and caused damage to houses and trees in the three county area. Heaviest damage was in the Ackworth area of north Cobb County where several houses were damaged by falling trees and large branches. Winds of 75 mph were reported at Peachtree-DeKalb airport. A woman was slightly hurt at the demolished boat dock.								
Santee Community, White County	15	1:30 p	Short	Narrow	0	0	4	0	Tornado and Wind
	Several trees were uprooted or twisted off and one large oak tree heavily damaged a house. A number of other buildings were damaged in the area of the tornado and scattered wind damage was reported from other parts of the County.								
Augusta Area	21	6:00 p			0	0	?	?	Hail
	Golf ball size hail reported.								
Manchester, 5 miles north	22	11:40 a							Funnel Cloud
	Reported by Department of Public Safety.								
Tifton, 10 miles northeast	22	10:00 a	Short	Narrow	0	0	4	0	Tornado
	One residence demolished, other buildings damaged and trees uprooted.								
Valdosta	22	12:30 p	½	500	0	0	4	0	Tornado
	Storm hit south side of town causing heavy damage to Farmers Market, Livestock sale barn, three tobacco warehouses, a tire company and several residences. Many trees uprooted. Storm moved eastward.								
Southern	29	p.m.			0	0	5	5	Wind, Hail and Lightning
	Heavy thunderstorms, with damaging winds and hail, hit several sections of south Georgia during the afternoon. A club house was demolished at Byron, just south of Macon, and several motels suffered roof damage. A house burned after being struck by lightning. Several trees were blown down in Dalsahne(?) and a number of houses suffered minor wind damage. Lightning heavily damaged one house. Marble size hail fell in the Albany area and numerous trees were blown over, many falling on utility lines and causing an interruption of service. Hail and wind caused major crop damage in parts of Colquitt, Atkinson, Brooks, Lowndes, Tift and possibly other counties. Tobacco was the hardest hit, with several fields considered a total loss.								
HAWAII									
Northeastern Kauai	21-22	Afternoon, 21st to Morning, 22nd			0	0	*4	C	Thunderstorm, Rain
	Near cloudburst struck northeastern Kauai near midday. Rainfall well over 10 inches in mountains, 6 to 8 inches coastal areas. Two cars swept from Kuhio Highway near Hanalei and two from Kauaala(?) Road near Kapaa during height of storm. $7,000.00 damage to equipment and tools on ground floor of two dwellings on Kauaala(?) Road. Taro fields flooded by Hanalei River.								
IDAHO									
Boise	11	11:15 a. / 5:00 p.							Funnel Clouds
	The first funnel was sighted by Weather Bureau observer southwest of Boise Air Terminal, moving southeast. It dissipated in less than 10 minutes. The second, around 5:00 p.m., was reported northwest of Boise by a pilot and confirmed by observer on the ground. Both funnels remained aloft and no damage was reported.								
ILLINOIS									
Central	1	4:20-5p							Funnel clouds
	Several funnel cloud sightings in area south and east of Springfield to Indiana line.								
Knox County	7	[illegible]	3	150	0	[illegible]	5	0	Tornado
	Tornado moved southeast from Galesburg Airport to southeast part of city in 100 to 250 yard wide path. [illegible] Several homes, outbuildings, automobiles and truck trailers badly damaged. Only minor injuries. WBAS, Peoria.								
North Central	7	6p-7:30p							Funnel Clouds
	Several funnel clouds reported in north central, especially in Peoria and Rockford areas.								
Pulaski County	11	[illegible]			0	0	3	4	Hail, wind
	Extensive damage to [illegible] area by hail and some wind [illegible] Cairo.								
Effingham County	15	1:45p	5	30	0	[illegible]	3	0	Tornado
	Funnel cloud observed [illegible] and damage [illegible] roof of industrial building. Debris from roof [illegible] in departing funnel. WBAS, St. Louis.								
Madison County	16	4:30p	5	[illegible]	[illegible]	0	3	0	Tornado
	[illegible]								
Northern	18	5-10p			0	[illegible]	4	0	Wind, lightning, hail, funnels
	Severe thunderstorms with high winds [illegible] damaged trees, utility lines, windows and roofs. [illegible] 75 mph. Numerous funnel clouds reported [illegible] moved across northern part of state. One funnel was reported to have touched down in open field [illegible] with no damage.								
INDIANA		E.S.T.							
Indianapolis, 4125 E. 16th Street	1	4:40 p.							Funnel
Marion County	8	10:00 a. (about)	?	?	0	0	0	3	Hail
	Hail reported in most sections of County. At 23rd & Arlington in Indianapolis size ranged from pea to walnut; marble size reported at 71st & Post Road.								
Hamilton County, between Noblesville and Fishers	11	3:10 a.							Funnel
Indianapolis, 15 miles NE	28	2:30 p.	?	?	0	0	4	0	Wind
	Near Geist Reservoir power and telephone lines blown down. Twenty or more trees felled, barn roof lifted, cement block building damaged and a 250 gallon tank blown into lake.								
Economy, Webster, and Jacksonburg (Wayne County)	28	3:30 - 3:40 p.	½	35	0	0	4	3	Tornado, hail, rain
	Damage was reported in areas of Wayne County near Economy, Webster, and Jacksonburg. Sheriff verified that a tornado briefly touched down between Jacksonburg and Road I-70. Some huge trees were levelled and the tower of a high voltage power line was twisted to the ground. Traffic on I-70 was closed while high voltage lines were being removed. Area had a severe thunderstorm and much hail from ¼ to 3/8 inch in size. Wind, falling trees and limbs damaged several houses. One mobile home was a total loss.								
Ft. Branch, 17 miles north of Evansville	28	7:20 - 7:25 p.							Funnel
	Funnel moved eastward according to State Police.								
Goldsmith, Tipton Co.	28	7:49 p.							Funnel
Coatsville, Hendricks County	28	7:49 p.	?	?	0	0	0	0	Tornado
	State Police reported funnel cloud touched down ½ mile south and 2 miles west of Coatsville on the western edge of Hendricks County.								
IOWA									
Northwood-Kensett area	7	3:00 p							Windstorm
	The re-building in April 30 tornado zone damaged and destroyed.								
5NW Marengo	7	3:17 p							Funnel cloud
	Moved SE, 35-40 mph.								
E of Evansdale, Black Hawk County	7	3:30 p							Funnel cloud
6S Durant	7	4:34 p	12						Tornado
	Sighted 3S of Stockton, moving SE, and in Scott County.								
5½SE Northwood	7	4:40 p							Tornado
	Tornado touched down 5½ SE Northwood.								
5SE Northwood	7	4:40 p							Funnel cloud
Buffalo, Scott County	7	5:15 p							Funnel cloud
	Moved SE.								

See reference notes at end of table.

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MAY 1967

PLACE	DATE	TIME - LOCAL STANDARD	LENGTH OF PATH (MILES)	WIDTH OF PATH (YARDS)	NO. OF PERSONS: KILLED	NO. OF PERSONS: INJURED	ESTIMATED† DAMAGE: PROPERTY	ESTIMATED† DAMAGE: CROPS	CHARACTER OF STORM
WISCONSIN (Cont'd.)									
Gays Mills	15	1:55 p	1/4	100	0	0	3	0	Tornado
	Small tornado moving southeastward did minor damage to farm between Gays Mills and Mount Sterling.								
Oshkosh 10SW	15	5:20 p			0	0	0	0	Funnel cloud
Dodgeville	15	6:05 p	1/4	100	0	0	0	0	Tornado
	Small tornado dipped down briefly, moved southeastward.								
Oconomowoc	15	7:20 p	5	100	0	0	4	0	Tornado
	Small tornado moving southeastward did minor damage southeast of Oconomowoc.								
Kenosha	15	5:45 p			0	0	0	0	Funnel cloud.
Beloit 4E	15	Evening	1/4	50	0	0	4	0	Tornado
	Several buildings destroyed or damaged on the Vander Kooi farm. Tornado moved southeastward.								
WYOMING									
Northeastern Wyoming	1	All day			0	0	*6	C	Severe Snowstorm
	A heavy snowstorm started the evening of the 30th of April and continued to late on the 1st of May accompanied by strong winds. Damage was done to communication lines, electric lines, transportation was halted, and several thousand sheep and cattle were killed.								
Southern Wyoming	12, 13	Eve of 12 to eve of 13			0	0	*5	C	Heavy snow and ice storm
	Snow and freezing rains through the period caused extensive damage to electric and communication lines as well as temporarily halting or interrupting transportation.								
Carpenter	20	Evening			0	0	*5	C	Heavy rains
	Heavy rain storms accompanied by hail and strong gusting winds did damage over a three-mile width path from Carpenter and vicinity fifteen miles eastward.								

* Includes crop damage.
C Crop damage.
• Miles instead of yards.
•• Yards instead of miles.
† Storm damages are placed in categories varying from 1 to 9 as follows:
1 Less than $50
2 $50 to $500
3 $500 to $5,000
4 $5,000 to $50,000
5 $50,000 to $500,000
6 $500,000 to $5,000,000
7 $5,000,000 to $50,000,000
8 $50,000,000 to $500,000,000
9 $500,000,000 to $5,000,000,000.

Note: This publication contains our best information on storms but, due to the difficulties inherent in collection of this type of data, it is not all-inclusive. Delayed data and corrections will be carried in the June and December issues of this publication.

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Figure A-1 Sample page of "Storm Data"

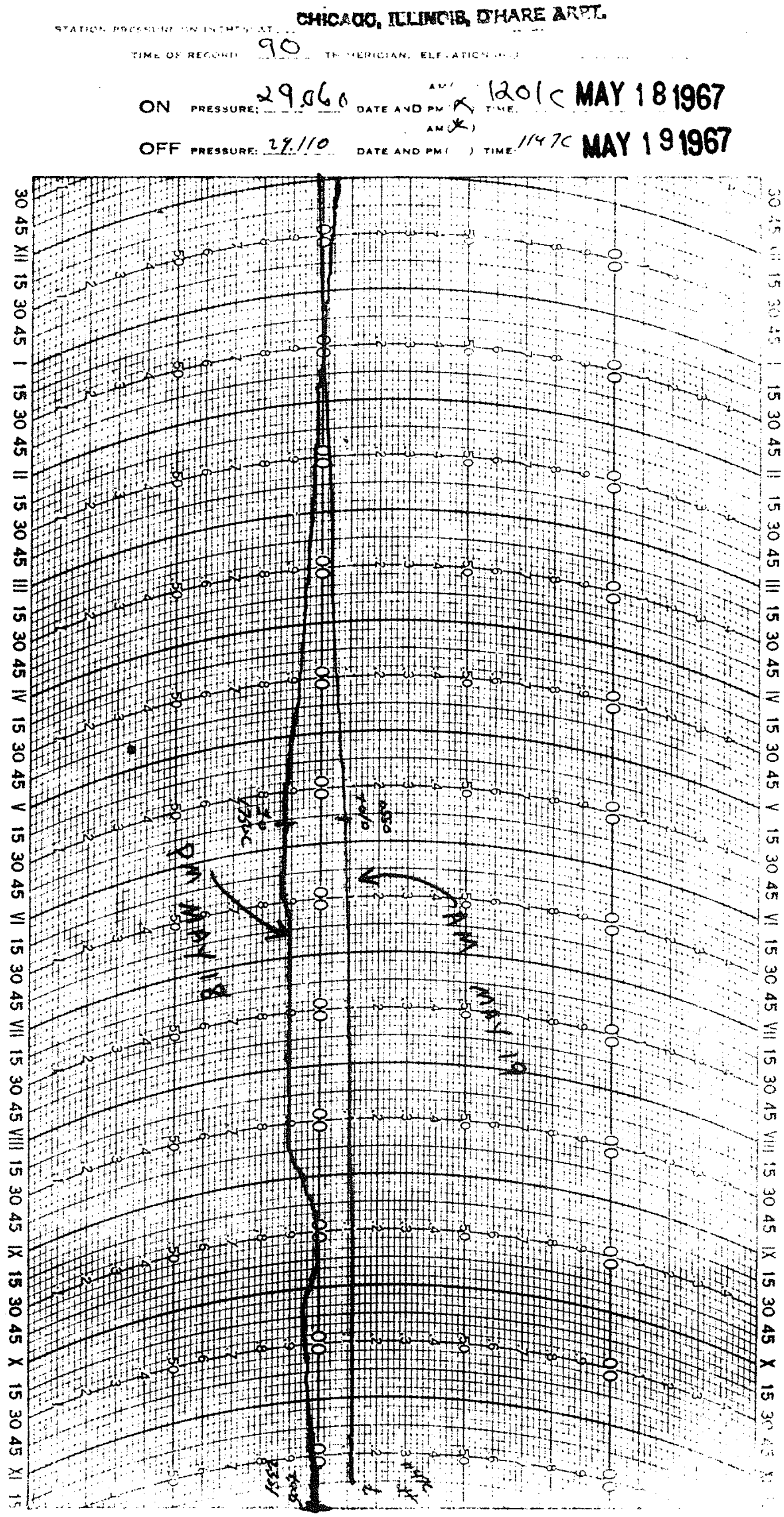

Figure A-2 Typical 12-hour barogram showing perturbations believed caused by infrasonic waves