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OPERATION REDWING—PROJECT 1.10

Blast Over Vegetated and Cleared Areas

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Albuquerque, NM

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NOTICE:

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Measurements were made to determine the difference in blast effects over a surface covered with low shrubs and grass and over a cleared sandy surface in the precursor region, and an attempt was made to correlate this difference with measurements of preshock sound speed over the surface. Overpressure was measured with ground-baffle gages and with pivot-static gages at 3-foot elevations. Dynamic pressures were measured at the 3-foot elevation with the same gages. Measurements were made at the same ground ranges for vegetated surface as for the sandy surface. The vegetation reduced the severity of the precursor, showing later arrival times and smaller dynamic pressures than over the cleared area. The overpressures over the vegetation were the same at the ground and 3-foot levels. No measurements of sound speed after zero time were obtained, so a correlation is not possible.

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FOREWORD

Classified material has been removed in order to make the information available on an unclassified, open publication basis, to any interested parties. The effort to declassify this report has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

The material which has been deleted is either currently classified as Restricted Data or Formerly Restricted Data under the provisions of the Atomic Energy Act of 1954 (as amended), or is National Security Information, or has been determined to be critical military information which could reveal system or equipment vulnerabilities and is, therefore, not appropriate for open publication.

The Defense Nuclear Agency (DNA) believes that though all classified material has been deleted, the report accurately portrays the contents of the original. DNA also believes that the deleted material is of little or no significance to studies into the amounts, or types, of radiation received by any individuals during the atmospheric nuclear test program.

FOREWORD

This report presents the results of one of the projects participating in the military-effect programs of Operation Redwing. Overall information about this and the other military-effect projects can be obtained from WT-1344, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, type, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussions of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

ABSTRACT

Measurements were made to determine the difference in blast effects over a surface covered with low shrubs and grass and over a cleared sandy surface in the precursor region, and an attempt was made to correlate this difference with measurements of preshock sound speed over the surface. Overpressure was measured with ground-baffle gages and with pitot-static gages at 3-foot elevation. Dynamic pressures were measured at the 3-foot elevation with the pitot-static gages. Measurements were made at the same ground ranges for vegetated surface as for the sandy surface. The vegetation reduced the severity of the precursor, showing later arrival times and smaller dynamic pressures than over the cleared area. The overpressures over the vegetation were the same at the ground and 3-foot levels. No measurements of sound speed after zero time were obtained, so a correlation is not possible.

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Chapter 1

INTRODUCTION

1.1 OBJECTIVE

The objective of this project was to determine the difference in the blast effects over a vegetated and over a sandy surface in the precursor region and, if possible, to correlate this difference with a difference in preshock sound speed.

1.2 HISTORY

Blast measurements have been made during most nuclear tests. The so-called precursor, a pressure wave that races ahead of the regular shock wave giving distorted pressure-time records, has been observed in many cases. Lowered overpressures and increased dynamic pressures characterize the precursor (References 1, 2, and 3). It generally occurs on shots with fairly low scaled burst heights—from less than 50 to about 600 feet. Since Operation Tumbler, it has generally been believed that precursor formation is due to a gaseous surface layer with a sound speed well above ambient. It is also generally accepted that this layer is caused by thermal radiation from the explosion.

Three methods by which the sound speed can be increased have been suggested: (1) the explosive liberation of water of hydration (the so-called popcorn effect) throws dust particles into the air, where they absorb thermal radiation and transfer it rapidly, because of the small size of the particles, to the air; (2) heat is transferred to the air by turbulent convective flow of the air; and (3) heating of the surface materials releases high sonic velocity gases, such as hydrogen. The relative importance of these three methods probably varies with device yield, ground range, and type of surface; but the method of formation of the thermal layer is not at all understood (References 4, 5, 6, 7, and 8). Temperature measurements have indicated, in general, large temperature rises (up to 2,000 C) that return to nearly ambient before shock arrival. Sound-speed measurements have generally shown much lower increases in the sound speed or apparent temperature (only 100 C in many cases). During Operation Teapot, each type of measurement (References 7 and 8) gave about the same results over all of the surfaces (desert, asphalt, concrete, and vegetation), but the various types of measurements were in decided disagreement with each other. The low values of sound speed and temperature at precursor arrival were also in disagreement with the high temperatures inferred from the precursor velocities.

1.3 DEVELOPMENT OF EXPERIMENTAL PLANS

The need for a study of the effect of various surfaces on precursor formation was recognized several years ago. Plans were made to measure overpressure, dynamic pressure, and air temperature during Operation Castle on Site Pearl for Shot Echo, over a vegetated surface and over a sandy, cleared area. The shot was cancelled, however, so the study could not be carried out. Extensive studies were made in the precursor region over desert, asphalt, and water surfaces during Operation Teapot. Construction of a large vegetated area in the Nevada desert was not attempted, but small plots of various surfaces, including fir boughs and ivy, were instrumented for temperature and sound speed.

At the inception of Operation Redwing, a tower shot (Mohawk) was scheduled at the old Castle Echo site; therefore, a project similar to the Castle plans was proposed. Subsequently, Shot Inca was added to the Redwing schedule, and because of the small range in expected yield, Inca provided a much better shot on which to make these measurements. Therefore, Project 1.10 actually participated on Inca, rather than Mohawk.

Chapter 2

PROCEDURE and INSTRUMENTATION

2.1 INSTRUMENTS

Wiancko pressure gages mounted in ground baffles (Reference 9) and pitot-static gages mounted on 3-foot towers were used to measure the overpressure and dynamic pressure. The pitot-static gages were of the design used during Teapot (Reference 10), and utilized the same sensing head originally developed by Sandia Corporation (References 11 and 12) in a different supporting configuration.

Sound-speed gages were completely revised versions of the whistle gage tested during Operation Upshot-Knothole (Reference 12) and used during Teapot (Reference 13), but the principle of operation remained the same. In these gages air was drawn through an open-ended cavity in a manner that excited the natural acoustic frequency of the cavity. Since this frequency depended on the sound speed of the air, a record of frequency versus time could be easily converted to sound speed versus time. The cavity was made of barium titanate and acted as its own transducer. The frequency output of the cavity was amplified by a transistorized amplifier mounted at the gage, and the signal was fed directly to the magnetic-tape recording head.

2.2 RECORDING SYSTEM

The recording system was the same as that used on Project 1.2 for Shot Lacrosse. The pressure gages formed one arm of four-arm inductance bridges driven at 3 kc. Consolidated Type D System oscillator power supplies and amplifier-demodulators were used along with Ampex Model S-3439 magnetic tape recorders. Backup for the system was provided by the recording of each gage on two separate recorders.

2.3 GAGE CODE

Gages were given code designations for easy reference following the usual scheme, which employed: (1) a number taken from that of the station; (2) an abbreviation for the type of gage; (3) a number giving the height above ground for gages mounted in towers; and (4) a C or V to indicate whether the gage was in the cleared area or in the vegetation. Abbreviations used were GB for ground baffle; q and P for the dynamic pressure and the overpressure elements of the pitot-static gage; and S for the sound-speed gage.

2.4 LAYOUT

The layout on Site Pearl is shown in Figure 2.1. The pertinent details of the instrumentation, along with the predicted values of the blast parameters, are shown in Table 2.1.

The project was planned as a minimum effort experiment; thus, no complete coverage versus distance was attempted, but it was felt that at least two stations over each surface were necessary to give sufficient reliance to the results in order that they be useful.

Exact positions of the gages were chosen by ground and air reconnaissance at the site to give continuous ground cover toward ground zero and still not have high bushes immediately in

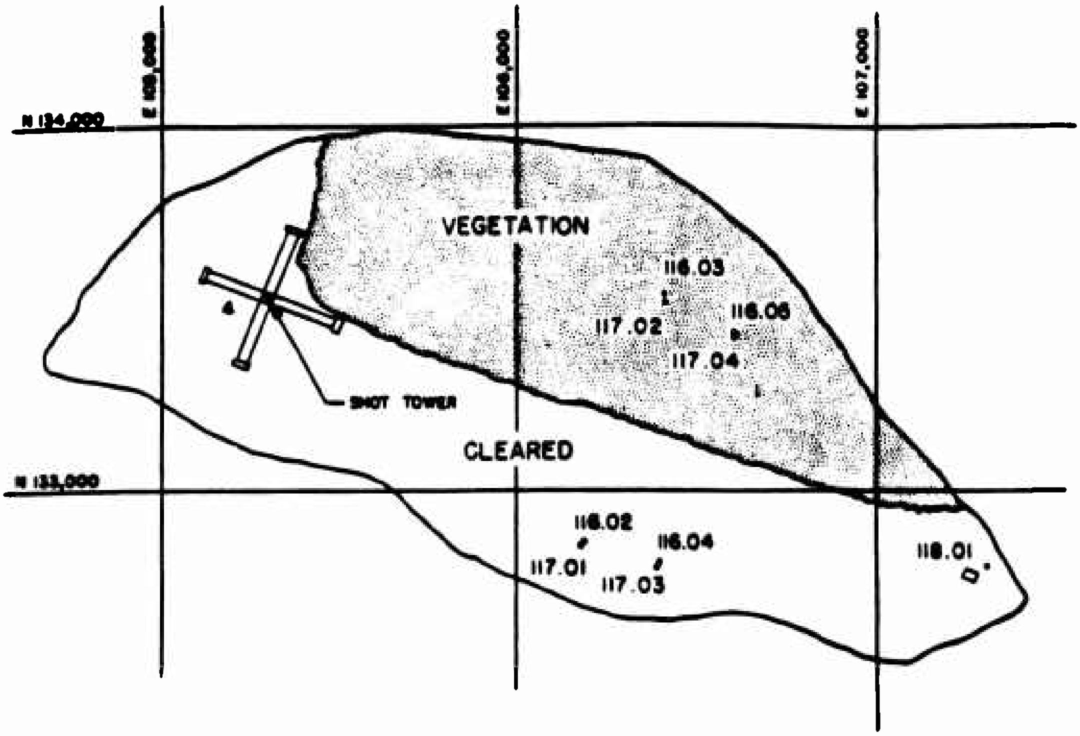

Figure 2.1 Gage layout for Shot Inca, Site Pearl.

TABLE 2.1 INSTRUMENTATION AND PREDICTED PARAMETERS FOR SHOT INCA

Station	Gage	Surface	Ground Range	Arrival Time	Over-pressure	Dynamic Pressure
			ft	sec		
116.02	602GBC	Cleared	1114	0.21		
117.01	701q3C, 701P3C, 701S3C	Cleared	1114	0.21		
116.03	603GBV	Vegetation	1114	0.19		
117.02	702q3V, 702P3V, 701S3V	Vegetation	1114	0.19		
116.04	604GBC	Cleared	1309	0.288		
117.03	703q3C, 703P3C, 703S3C	Cleared	1310	0.289		
116.05	605GB	Vegetation	1309	0.268		
117.04	704q3V, 704P3V, 704S3V	Vegetation	1309	0.268		

front of the gages. This latter requirement was to give a few milliseconds of recording after shock arrival, during which it was known that missiles were not striking the gages.

The vegetation consisted of some vine (Ipomoea) and grass cover, plus almost complete coverage with broadleaf shrubs (Scaevola) 10 to 15 feet high. Figure 3.6 is an aerial photograph of the site taken before the shot.

The use of [redacted] for the planning yield gives a scaled height of burst of [redacted] This is closer to the Upshot-Knothole [redacted] conditions than Teapot [redacted] However, Upshot-Knothole [redacted] had much greater reductions in overpressures than any other shot. Also, precursor effects in the Pacific do not seem to be as strong as in Nevada. This is why Teapot [redacted] overpressures, which were higher than Upshot-Knothole [redacted] are used. Dynamic pressures in the precursor, on the other hand, do not seem to depend appreciably on the height of burst, so there is no difference in using Teapot [redacted] rather than Upshot-Knothole [redacted] The asphalt data were used for lack of any better. The vegetation should resemble the asphalt qualitatively in the production of smoke and vapors but may not reduce the amount of dust in the air as much.

These uncertainties in the phenomena must be combined with an uncertainty in the yield and in the capabilities of the transducer and recording system. With regard to the latter, a factor of about two greater than set range and a factor of about four smaller can be covered without loss of accuracy. Because of this limitation, set ranges were chosen somewhat higher than these predictions.

Chapter 3

RESULTS

The results for overpressures and dynamic pressures are given in Tables 3.1 and 3.2 and are presented versus ground range in Figures 3.3, 3.4 and 3.5. The values given contain no corrections for effect of Mach number on the gage reading. No results were obtained from the sound-speed gages after zero time. An examination of the transistorized amplifiers shows that the transistor gain had been reduced to such an extent that the amplifiers no longer functioned. The damage appears to be somewhat more severe than subsequent studies have shown is to be expected from nuclear radiation alone. The damage is probably a combination of effects of nuclear radiation and a large electromagnetic transient induced in the circuits at zero time.

The yield was actually [redacted] instead of the [redacted] for which the experiment was planned. This, of course, means that the gages experienced larger pressures than expected; however, no malfunctioning or loss of information resulted.

3.1 OVERPRESSURES

Figure 3.1 gives a comparison of the overpressures to the desert and asphalt data from Teapot [redacted] the latter scaled to [redacted] An ideal [redacted] curve is shown. Two features of the data stand out. First, the ground-level pressures in the cleared area are much less than the 3-foot-level pressures, while in the vegetation they are about the same. Higher pressures above the ground than at ground level have often been measured in Nevada. The present data are too meager to permit a comparison between the Nevada and Pacific sites on the relative spread between the ground and above-ground measurements. The overpressures measured by the pitot-static gage have been calibrated in wind-tunnel tests and found to be high about 10 percent of the dynamic pressure for Mach 0.9 on axis flow. For upward flow expected during the first few milliseconds the gage may read low. Since this gage responds to dust in an unknown way, no good estimate of Mach number can be made. However, if the dynamic pressure is assumed to be all due to air and none to dust, an upper limit is found by calculating the Mach number M (Reference 10) from

$$\frac{P_p'}{P_s'} = \frac{q' + \Delta P' + P_0}{\Delta P' + P_0} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma - 1}}$$

where P_p' is as read total pressure and P_s' is the as read static pressure. Using the peak value of ΔP for gages 701 P3C and 702 P3V and measured q's at corresponding times, we find $M = 0.65$ and $M = 0.95$. Thus, since dust very apparently was contributing, the actual Mach number is lower than this and the correction is probably less than this 10 percent of q and cannot explain the difference between surface and 3-foot measurements. Second, the wave over the cleared area has a front porch,[1] while over the vegetation nothing that could really be called such is ap-

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[1] By a "front porch" is meant a rise to an intermediate steady pressure preceding the main peak.

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parent; rather, the wave is just a slow-rising pressure pulse. Arrival times bear out this observation, since arrival time is earlier in the cleared area than in the vegetation. However, the main peaks occur at about the same time over both surfaces.

The scaled height of burst , of this shot was about near the scaled heights of the The pressure waves on those shots were also noted for the short length of their front porches and the early death of the precursors, as compared to Nevada shots.

3.2 DYNAMIC PRESSURES

ground range. The cleared area exhibited higher pressures than the vegetated area, particularly at the closer stations where the precursor was stronger. At the stations farthest from ground zero, the dynamic pressures were well below the Teapot curves, indicating an early cleaning up of the precursor.

At about 0.2 second after shock arrival at the two stations in the vegetation, an anomalous rise in the q records was observed (Figure 3.3). A check of the instrumentation indicated that these signals actually came from the gages but did not represent a real q but rather, as post-shot inspection showed, were caused by the pitot opening (the front opening on the gage) becoming clogged with dust and vegetation carried by the precursor. Since the side or static opening was not clogged, its pressure continued to drop, while the pressure at the front remained constant because of the plugging. This, of course, led to an increasing differential that was recorded as a q.

The dynamic-pressure measurements are reported as read with no corrections for Mach number characteristic of the gage. It has been pointed out in the AFSWP conference previously mentioned that with only the pitot tube no valid correction can be made because of the unknown

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effect of the dust, and in any case the upper limit of the correction has been shown to be small in the overpressure discussion.

3.3 EFFECT OF VEGETATION

Figure 3.6, taken before the shot, and Figure 3.7, a postshot photograph, emphasize the effect of the blast on the vegetation, with the island swept completely clear of all standing shrubs. Underfoot is a thick matting of dead sticks, vines, and grass in a sort of mulch mixed with sand. There is a definite lack of evidence of charred or burned material, indicating that whatever vegetation burned was blown clear of the island by the blast.

The precursor was weaker in the vegetation: Arrival times were later and overpressures in the vegetation were higher than ground-level pressures in the cleared area, though lower than the 3-foot pressures there. Dynamic pressures were less than over the cleared line.

All these differences must be attributed to the vegetation. The most interesting result is the fact that pressures at both levels in the vegetation were essentially the same. This was probably due to mechanical interaction of the vegetation with the shock, since the vegetation did provide almost continuous cover to a 10-foot height. The resulting turbulence could easily have produced a uniform layer at least 3 feet thick on the ground. An additional factor is that there may have been some uniformity even before shock arrival, because the foliage would have absorbed energy at various heights above the ground, promoting uniformity of itself and increasing turbu-

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Figure 3.6 Site Pearl before Shot Inca.

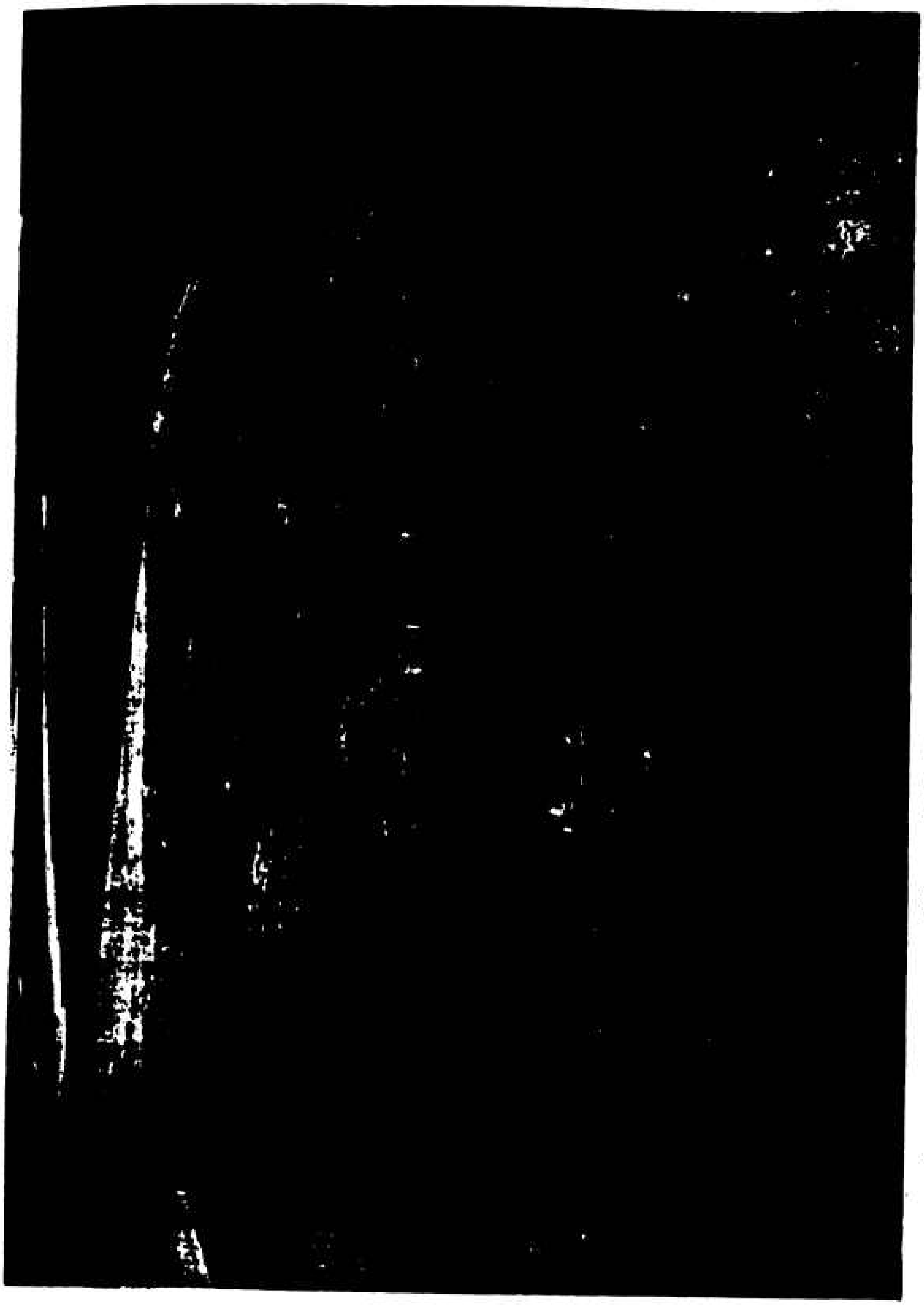

Figure 3.7 Site Pearl after Shot Inca.

lent convection.

In Section 2.5, by analogy to Teapot asphalt and desert lines, a stronger precursor, i. e., earlier arrival times and lower overpressures, was predicted over the vegetation than over the cleared area. This analogy was used for lack of anything better. The experimental results did not follow this prediction, as has been pointed out above. The principal difference between the vegetation and the asphalt surfaces is the spatial extension of the vegetation above the surface. This affects the precursor growth, both by changing the distribution of the thermal energy deposition in the air and by providing a mechanical diffuser to slow down the wave and make the pressure through the vegetation layer uniform.

Projecting these results to other vegetated surfaces, it appears that qualitative prediction of precursor strength can be made on the basis of density, height, and strength of the vegetation.

Chapter 4

CONCLUSIONS

Vegetation consisting of grass, vines, and 10-foot shrubs reduced the severity of a precursor compared to one over a clear sandy surface. Overpressures were about the same at the ground and 3-foot levels in the vegetation, while over the cleared area the 3-foot level had much higher pressures than ground level. Overpressures in the vegetation were higher than ground-level pressures in the clear, but lower than 3-foot pressures there. Dynamic pressures were much reduced in the vegetation.

A qualitative prediction of precursor severity for various forms of vegetation can be made from these and Teapot results, i. e., the higher, denser, and stronger the vegetation, the weaker the precursor. With our, as yet, incomplete understanding of details of precursor phenomena, further measurements over other surfaces would be required if more quantitative predictions are required.

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