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NOTES ON POGO STAFF MEETING
29 December 1951

BLAST MEASUREMENTS FOR IVY AND SNAPPER

PRESENT AT MEETING:

Sandia Corp:	E. F. Cox
	H. E. Lenander
	M. Merritt
	B. Murphey
	J. Shreve
	L. J. Vortman
LASL - J-113:	R. Aamodt
	C. Cowan
	A. Embry
	G. Felt
	J. Malik
	W. Ogle
	F. Porzel
	D. Seacord
	L. Seely
	B. Watt
	J. Whitener
	E. Zadina
LASL - J-6:	R. Campbell

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I. INTRODUCTION AND GENERAL IVY PLANNING

The meeting was held to complete the planning for the blast measurements to be made on Ivy by Sandia and Group J-10, LASL, and to arrive at firm decisions on placement of stations, numbers and types of gauges, and other details. A small portion of the afternoon's meeting was also devoted to a preliminary discussion of blast measurements for Snapper.

The latest plans for Ivy were outlined to the Sandia group. The Super will be fired on Elugelab, and the predicted yield is 1 - 10 MT, with a fairly remote possibility of its going as high as 50 - 90 MT. The important point for blast considerations is that it will be effectively a surface shot, with the bottom of the bomb some 5 ft above ground level. While the percentage probability of the higher yield's being realized is not definitely fixed--it may be ~ 0.1 per cent or slightly higher--it is felt that one should instrument for the nominal predicted yield of 5 MT, which would appear as a blast yield of 10 MT because of ground reflections. A few gauges might perhaps be included to cover the higher yield range.

A causeway will be built between Elugelab and Bogon, with some cables along it which it is hoped can be kept down to the level of the road. Krause's recording station will be on Bogon; he will have no large structures on the shot island. Re perturbations to the blast, the shield for his experiment will be E.N.E. of the bomb: there will be steel shields for a photographic experiment S.S.E., and a Dewar which will weigh some 20 tons. The cab itself will be the usual structure, mostly I beams.

If the 500-KT shot is made, it will be an air drop over either Aomon or Runit. It has not yet been decided whether it would precede or come after the Super shot. So far, there are effectively no requirements for measurements except alpha and yield. Others may be desirable, but this will be discussed at a later date.

Facilities for timing signals presently exist at the following locations:

All islands from Bogallua to Bogon
Rigili
Engebi
Muzin
Kirinian
Aomon
Biijiri
Rojoa
Runit
Artificial Island (Photo tower)
Aniyaanii
Parry
Eniwetok
Coral Head

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In the following discussions, an attempt was made to locate stations where such facilities are already present.

II. IVY BLAST PROGRAM*

Table I is a summary of the discussion. The measurements are discussed in detail below.

A. Air Pressure vs Time and Distance at Ground Level (SC)

Wiancko gauges will be used. The location of these gauges as finally agreed upon is shown in Table I.

The question of whether or not to instrument for the higher yield range was discussed at length. Since placement and recording of another gauge in a station already built constitutes little additional effort, it was agreed that in those locations where recording shelters are provided, gauges to cover the higher range may be included.

All gauges will be battery operated, thus requiring no power. Timing signals will be used where available. Where they are not, the gauges will be started with a blue box and alarm clock, since it is desired to have filaments running about one-half hour before shot time. For the first five stations listed on the table, recording will be done at Bogon, requiring wires from these stations. At all the other stations, data will be recorded directly at the instrument. As noted, some recording shelters exist from Greenhouse.

The recorder will be of the NOL type which scratches pressure-time records on a drum. A system to give 1 msec time resolution is desired, and it is planned to have 6 minutes of recording on the tape. This length of time is desired for several reasons: 3 minutes of recording are needed at the far stations, and Sandia also plans to record the close measurements of afterwind on the same recorders. Too, in order to get arrival time with any accuracy, zero time is required on the record. (These gauges still do not get arrival time as accurately as one would like. However, Cox pointed out that this determination also necessitates a measurement of acoustic velocity and any way one can measure time of arrival is probably better than any measurement of acoustic velocity.)

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* Reference is made to J-9092, Memo fm Ogle to Graves, 23 Nov 51, "Ivy Blast Program" and SC Ltr Sym: 1(181), Landry to Tyler, 3 Dec 51, "Sandia Laboratory Participation in Operation Ivy" for a detailed statement of objectives of the measurements.

TABLE

Ivy Blast

(Sandia Corporation and Group J-10,

Atoll Location	Distance from Zero (ft)	Predicted Peak Overpressure fm 10-MT Bomb (psi)	P (D,t) Gauges SC	Underwater Pressures (Lagoon) SC	After-Wind SC
Causeway	--	700 - 1000	X		
Causway	4,500	300	X		
Causway	6,000	160	X	X	X
Bogon	8,000	80	X		X
Between Engebi and Bogon	11,500	(40)	X		
Engebi	~16,000	20 ✓	X	X	X
Kkrinian	22,500	12 ✓	X		X
~~Bogon~~ BOKON	29,000	(7)	X		X
Aitsu	35,800	(5)	X		
Acmon**	48,000	3 ✓	X	X	X
Runit	83,000	1.5 ✓	X		
Aniyaanii	101,000		X		
Parry	~115,000	0.8 ✓	X	X	X

NOTES:

○ denotes no timing signals presently available there.
✓ denotes recording shelters already on the island.

* Mitchell cameras to photograph smoke puffs (Guns and Fireworks--LASL) wi

** Cameras to photograph water waves will be on Rigili and Parry.

‡ NRL-Stewart will be asked to make temperature measurements.

The station between Engebi and Bogon was included to bridge the large gap between the 20 and 80 psi regions. A platform of some type is visualized, and Malik may also have $\gamma(t)$ instrumentation there.

It was agreed not to attempt to instrument for asymmetries because of the complexities of recording from stations west of Elugelab. Bogallua was suggested, but Ogle thought the presence of trees there might give assymmetries which were not due to the blast.

B. Underwater Overpressures SC

Two types of set-ups were originally proposed: 6 gauges in the lagoon with wires running back to the same kind of recorders as used for the air pressures studies, and 6 gauges on buoys in the ocean, with the possibility of a self-recording device. The buoys would have to be anchored, and since the ocean is quite deep off Eniwetok, it was felt that their position could not be known accurately enough for good measurements. It was, therefore, agreed to have gauges only in the lagoon. The number of stations was also cut to 3, positioned as shown in Table I, since the group agreed that while this will be interesting data, it is doubtful just what one can apply it to--a Super will probably never be detonated for tactical purposes in this fashion in a lagoon.

The gauges used will be waterproof, of the Wiancko type to measure pressure-time. There is a considerable uncertainty in the range of pressures to be expected. The gauges will normally cover a range of 25:1. Sandia is thinking of using 2 gauges with different sensitivities, so that they will be able to cover a range of roughly 150:1.

C. "SOFAR" Channel Transmission NEL (Sandia will notify)

This entails nothing but alerting the Naval Electronic Laboratory to request operation of the SOFAR station. Sandia Laboratory will do so, through BuShips.

D. Wind Associated with Super-Bomb Shot

This measurement is related to structural damage studies, and also to understanding bomb theory. Sandia proposed to instrument two stations in the high overpressure region to measure afterwinds only. (Watt pointed out that the radius of the fireball is likely to be 3,000 ft, so that to go in closer than 6,000 ft would probably do no good.) From the 80-psi region on out to Parry, Sandia would attempt to measure both the winds in connection with the pressure wave and the afterwinds. In order to do this and to get direction will require from 3 to 5 recording channels per station, depending

on whether gauges are doubled up to cover the higher range. The positions shown in the table were chosen. As noted, four of them already have recording stations. LASL is also working on methods for making this measurement. It will be decided in the near future as to which group will actually perform the work.

E. Earth Motion Studies

It was originally proposed to measure two components of acceleration at each of the stations provided for pressure-time, and in the event that a strain gauge is devised to measure set as a function of time per unit length, this would be included. (It is not known whether or not a third transverse component will be observed--it was on Jangle.) Cox explained that since the proposal was made, they had about decided not to attempt direct displacement and velocity measurements, since they could not quite see how this was to be done, but simply to measure acceleration as a function of time and try to compute the others from this if they are required. Admittedly, this latter is a nasty job, but is possible in theory. They do have instruments which will measure an acceleration of 100 g's.

This measurement will be done in the hope that one can predict what would happen to other types of ground from measurements at Eniwetok. There is a reasonable doubt that this is possible; in any event one would feel safer with three components to work with. Sandia agreed that if the strain gauges did not look feasible, they would attempt to devise some other method to measure displacement in at least one or two places.

Because of the fact that extrapolation to other terrain does look so difficult, it was suggested that only a minimal coverage be provided. Murphey pointed out that one could be sure the structures people would want to attempt to tie this in with the surface shot data, whether or not it is meaningful, and would not be happy with two or three points. Also, the information may be useful for future tests of bigger bombs at Eniwetok.

The stations indicated on the table were chosen. The choice of one or both of the first two positions was left questionable, since there was some dissension as to whether a gauge on the causeway would mean anything. (The gauge would actually be installed in the coral reef rather than on the causeway.) The apparatus will be similar to the usual accelerometer, and will be mounted solidly to the ground.

Incidentally, Zadina stated that the acceleration on Parry was likely to be from 0.05 to 0.3 g's, assuming no channel or focussing effects.

F. In-earth Pressures

The proposal here was to make pressure measurements at three levels in the earth (at something like 20 --50 ft depths), in order to assess

the advantages of earth cover on instrument shelters and to permit better estimates of damage which a super bomb might do to deep underground installations. Sandia had included the proposal primarily because the effects people wanted it.

Data exist from Greenhouse studies on two buried Navy structures. These seem to indicate no appreciable attenuation by the soil, rather a general smoothing out of the blast wave, so that it looks as though side-on pressure had been applied rather than direct reflected pressure. The object of this measurement would, then, be to verify or disprove these findings, and it is felt that this could better be done in Nevada, where the soil is more nearly like that of the rest of the country. It might be added that some measurements of this type were done in Nevada; the results had anomalies such that the measurement should be repeated there.

It was also questioned whether holes should be dug in the coral and the pressure attenuations measured at $\sim$ 50 ft. This would be below the water table, and Cox doubted that one could expect any significant differences here from the measurements made with underwater gauges in the lagoon. If anything of this type were done, it is felt it should be in the very high over-pressure regions, since presumably a super bomb would only be used against underground installations where the damage from a smaller bomb would not be sufficient. This was discussed in some detail. It was finally concluded that techniques should first be investigated in Nevada. Again, the situation at Ivy will have no relationship to the tactical firing of a super.

AFSWP should be informed that we will make no measurements of this nature on Ivy.

G. Long-Range Seismic Studies

Cox raised the question as to whether AFOAT would make these studies on Ivy. So far, no one has been able to get their reports from previous operations.

The shake that Bikini or Kwajalein would get is not of military significance, but Cox thinks it offers valuable seismic data. He would expect to give the information to a good, Q-cleared seismologist and let him work it over. Before establishing seismic stations on outlying islands, he thought we should find out where the existing stations are and then do only what is necessary to augment the intermediate distances which are not covered. There is one point, however: the seismic stations around Boulder City are about the most complete that Cox knows of, but during Buster-Jangle he found that they have no way of measuring amplitudes, accelerations, velocities, and the like--all they could say was that a signal arrived and whether it was large or small.

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There will be a meeting here in January with a group of seismologists to discuss possible damage to the Atoll, and Ogle suggested that this question also be taken up with them at this time. Cox agreed. He would like to arrange to alert some of the existing stations, and then discuss with the seismologists the question of whether other stations should be set up.

H. Microbarometric Studies

Cox is now studying maps of the Pacific to find real estate for these studies. No locations have yet been picked; Sandia will let us know when they are decided.

The various layers of the atmosphere may be pictured somewhat as in Fig. 1. A balloon will be sent up to measure temperature to about 50,000 ft. Next, one must establish the ozonosphere layer in order to do anything with the higher layers. The other stations will be located out far in order to get some information on the layers above the ozonosphere. Distances of the order of 1500 - 1800 miles are being thought of. One must pick places where real estate exists and where one can get waves back down in quantity from the high altitude layers.

Cox felt that radio communications were essential, and that the stations could not be operated without communications. This may be a problem.

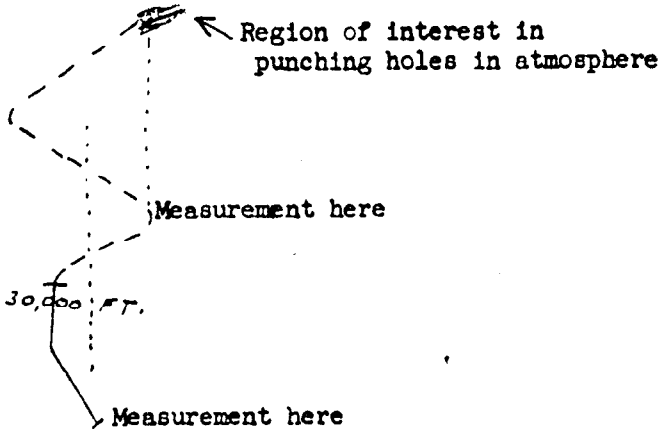

Fig. 1

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I. Pressure-time at Various Altitudes (Smoke-puff Photography)

1. High Altitudes (Guns)

Ten guns to launch smoke to cover five areas for photography are proposed. These areas would be as shown in Fig. 2. It was agreed to

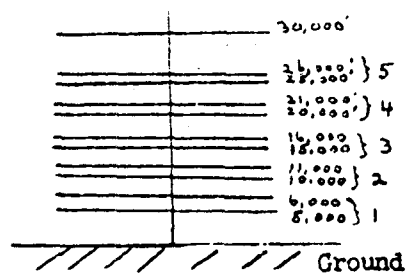

Fig. 2

to place them on Bogon; Porzel said recovery of the launching guns was not essential. The cameras will be on Rigili.

Timing signals will be required to fire the guns, and a concrete pad to hold the trunions will be necessary.

Zadina suggested another vertical line--say, on Engebi-- to really track the propagation of the blast wave and to get a notion of its departure from the hemispherical. Ogle questioned that another line would accomplish this. As a compromise, one extra point was suggested instead. This would require another camera, or might be done by sacrificing one of the points in the vertical line and using that gun to place the smoke in a different position. However, this must be decided before the camera station is erected, since the camera positions are being built in.

One fundamental difficulty with this measurement is the fact that cloud coverage may result in complete loss of data. However, since the method is the simplest way of obtaining the information sought, it is felt the chance is worth taking.

2. Low Altitudes (Fireworks)

Here, small paper mortars will be used to launch smoke puffs to a few hundred feet; again, photography will be from Rigili. Felt suggested that the smoke should go to 500 ft, if possible, since 200 ft, as first planned, would be right on the horizon from Rigili. Porzel agreed.

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Ten cameras have been arranged for, and it was agreed that the launching stations would be at the same places as Sandia's p(t) gauges, omitting the first, very high pressure region and not going beyond Runit, except for a station on Parry, with the camera also there. The reason for this amount of coverage is essentially the same as for the Wiancko gauges--one would like to be able to draw a reliable pressure-distance curve. Also, the effort at the launching stations is quite small, the major part of it being the cameras.

Timing signals may be used where available, or a photocell can be used to trigger the mortars. These require nothing but holes for placement. Mortar velocities are about 150 ft/sec, time of flight $\sim$ 5 sec.

J. Measurements of Temperature, Air Absorption, Density, Sound Velocity, etc.

The subject was raised of attempting to measure these related parameters which are quite important in evaluating and tying together the data from ground and high altitude measurements. The Sandia group agreed that such measurements would be quite valuable and thought they might have at least some effort to expend on them. They hope to try on the Snapper series some equipment which may prove of use in measuring the temperature of the air--we are specifically interested in this during the period after the bomb goes off and before the shock hits the gauge--and could possibly use it on Ivy if it turned out to be satisfactory.

The β densitometer might be used for measurements of density and the amount of dust in the air. Cox suggested that Lenander's group could, by getting the design of the successful one used at Greenhouse, make up the equipment in time to use it on Snapper and again on Ivy. He felt they could possibly try about four temperature and four density measurements in addition to the items listed in Table I. Their doing it was suggested because such measurements go with the ground stations and putting a few more channels in the recorders would not be a major job. However, the personnel situation in Lenander's group is not clear at the moment--at present he does not have enough people to install half a dozen gauges.

This statement amazing—no! DAT 4/15

(The Sandia group had to leave at this point, and it was agreed to discuss this with them again at a later time.)

Continuing the discussion, it is possible that Group J-10 has enough effort to make at least the density measurement with the β densitometer . This device worked very satisfactorily on Greenhouse but with one drawback--the effect of gamma rays. One could not hope to get inside the 8 - 10 psi region on a conventional bomb with this because of the gammas in that region. However, on a super Porzel felt there was a chance of the device's really coming into its own. Because of the longer time scale of events, the relative time resolution would be better by at least a factor of ten.

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The critical region seems to be from 20 psi down to about 7 psi. Disagreements are almost a factor of three in this region. This is again applicable to the question of post-detonation - pre-shock measurements, i.e., what happens to the air after the bomb goes off and before the shock hits it? Before the shock ever comes along there is dust over the ground and absorption by thermal radiation.

Porzel said that one could not measure the dust in the air before the shock arrives by measuring density, because the change is only a fraction of a per cent--although it still may have a significant effect in absorption. He thought that for this determination one should measure the temperature rise. Various methods for doing this were discussed. It was suggested that NRL-Stewart might be asked to measure pre-shock temperature and air absorption both on Ivy and Snapper.

Both air temperature and density enter into the shock equations, but it was suggested that sound velocity enters even more directly. It was thought that this could be measured rather simply in the pre-shock period, and it may be in some cases the parameter of most interest. (Whitener is working on an acoustic interferometer for use in measuring the afterwinds conceivably this could get sound velocity as well.)

The question was raised: if sound velocity measurements are made, does one also want to know the density or temperature? Whitener thought the first would preclude the latter only if the equation of state of the gas is the same after detonation as before, and one can say this situation is governed by the ideal gas laws. If this condition does not apply, then the sound velocity measured may not give $\gamma P/\rho$, which is what one wants. However, in any case, one needs to know sound velocity in this perturbed region containing dust and air.

The important question in all this is, of course, whether these effects--dust, temperature changes, etc.--change the shock pressure. Ogle asked that before any decision was made, Porzel and Zadina look more thoroughly into this to decide just what factors are pertinent, and whatever they are, that we measure them at at least a few points. Zadina emphasized that this must be done before Snapper, anyway.

The stations indicated on Table I were chosen for measurements of the parameters decided to be important. The positions were picked for regions of interesting pressures, and in addition, there are already structures on Engebi and Aomon which can be used. As noted above, NRL will be asked if they can measure temperature and air absorption; the responsibility for sound velocity and density will belong to Sandia and/or J-10.

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K. Water Wave Motion

LASL has agreed to make this measurement. The technique to be used here is not as yet clear; photographing a light on a float or something of this nature has been talked of. So far, we have tentatively arranged arranged for cameras on Rigili and Parry, and there has also been some talk of a recording instrument that could be placed at other points.

It is felt that results would be more meaningful from deep water, because this is a homogeneous medium, and that there is not much point in many instruments in the shallow lagoon. Ogle did not think measurements just in the region of Rigili and Parry sufficient. He felt there should be some point only a mile or so away from zero. However, the cameras must be 4,000 - 5,000 yds away, and even then fall-out may affect them.

George White, of T-Division, has been making a study of water waves and should have a report out in a week or so. It was agreed that the decision on station positions will await the issue of this report. In the meantime, it was suggested that J-10 consider some methods of observing wave motion which are independent of photography.

Incidentally, White has said it appears there will be a wave on Parry of amplitude about 3 ft.

L. High Altitude Waves

J-10 has agreed to investigate methods of measuring this phenomenon. Again, George White plans to look into what might be expected as soon as he finishes the water wave study. Until this has been done, it is difficult to say what instrument should be used. For getting the gauge up in the air, Zadina had thought of the high-altitude, cosmic-ray type of balloon. Telemetering would probably be required for getting the information back, since recovering the baloons at some future time from stations spread around the Marshalls does not look hopeful.

Zadina believes it does appear probable that if the bomb goes at 10, 15, 20 MT, waves will occur in the upper atmosphere similar to waves in water. An accelerometer may be able to measure these disturbances. The eruption of the volcano Krakatoa, (see Fig. 3) which according to G. I. Taylor's calculations had an energy release of about 500 MT distributed over a very

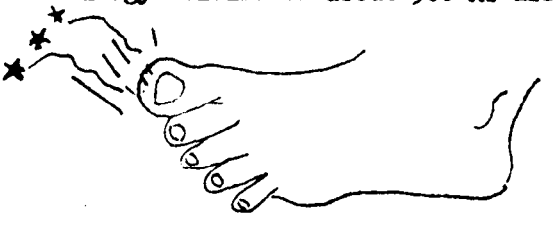

Fig. 3

large area, gave rise to waves which went clear around the earth and rebounded several times.

As for the objectives of such studies: it is conceivable that they may have some practical use in the future, e.g., remote detection, knocking aircraft or missiles out of the sky--but at the moment, the primary point of such a measurement would be just to study the waves.

If balloons are to be used, they must be ordered in the very near future. Telemetering methods and equipment must also be looked into, and a requirement will exist for communications, at least of the same order as Cox's microbarographic stations. Zadina was doubtful that J-10 could take on this measurement and suggested AFOAT be asked to do it. (Again, the objection was raised that one cannot get their data.) He pointed out that it requires someone to find an instrument to measure the phenomena which White says will occur, a balloon expert, telemetering equipment and channels, etc. Porzel agreed that this is Frolich's Greenhouse experiment ten times over.

Aamodt suggested a possible method: looking at the ionosphere. Watt thought this could be quite useful, since that layer will certainly have been disturbed, and presumably it could be observed at a reasonably late time. Whitener suggested visiting at White Sands or Inyokern to ask them about their equipment and methods of detection.

The subject obviously needs more study before instruments or stations can be chosen. In the meantime, J-10 was asked to look into (a) balloons, (b) telemetering, and (c) methods of observing the ionosphere.

III. BLAST STUDIES ON SNAPPER

Porzel outlined the tentative blast program which is being discussed for Snapper. It would include:

1. Free Air

   a. Rockets - Time of Arrival - (NOL)
   b. Mass motion (guns) -(LASL)

2. Mass Motion - 200 ft or more above ground - (LASL)

3. Pressure-Time at Surface

   a. NOL)
   b. Sandia Corp) independent measurements
   c. Buck gauges (LASL)

4. Phenomenology

a. Temperature vs time (pre-shock) -(NRL)
b. Density vs time (β densitometer) -(LASL)
c. Pre-shock changes in pressure (perhaps with microbarographs) - SC
d. Acoustic interferometer -(LASL)

1-a and 1-b are duplications, to be sure, but are planned since this offers such a good chance to get a free-air curve. 1-b is essentially a dress rehearsal for Ivy.

The division of effort among the agencies indicated--NOL, LASL, SC, NRL--is purely tentative, and has not been worked out in detail. For example, we have no definite commitments with NOL for work on Snapper, and this must be discussed further. It was Porzel's feeling that because of the pressure from the services for these data, independent measurements by both NOL and SC are desirable. Too, he doubted that LASL or SC have the necessary effort to make the rocket measurement, so suggested NOL for that also.

The general instrumentation plan is as follows (for an air drop):

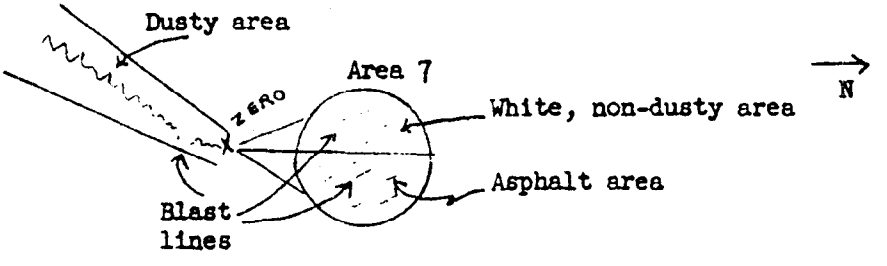

Fig. 4

A dusty area and a stabilized area would be presented to the blast wave. If the plan above were followed, NOL and SC would have three blast lines each.

The group were not in agreement as to the desirability of complete duplication in the surface pressure-time measurements. If one could ignore the political implications, it would certainly not be necessary, and may even be less desirable than one set of very good measurements. This, as well as NOL's participation in future J work, will be discussed again in detail.

Notes Edited By:
W. E. Ogle:djw:ak

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