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SONIC BOOM AND NATURAL DETERIORATION EFFECTS ON BUILDINGS: WHITE SANDS, N.M. STRUCTURE RESURVEY

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16. Abstract

The structures used for testing during the White Sands National Sonic Boom Program conducted in 1964-65 were reexamined to compare the damage experienced during the program. The seven years since that program showed that the natural deterioration effects of the structures was probably greater than that caused by the 5 psf overpressure booms.

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PREFACE

The J. H. Wiggins Company wishes to thank Mr. J. K. Power and Mr. Thomas H. Higgins of the Noise Abatement Division of the Federal Aviation Administration for many valuable discussions, evaluations, and suggestions regarding this survey.

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(A SUPPLEMENT REPORT TO REPORTS SST 65-15 (VOLS. 1 AND 2) AND SST 65-18)

A. INTRODUCTION:

The purpose of this study is to evaluate the current state of natural deterioration of the structures used for sonic boom testing purposes by the FAA at the Oscura Range Camp, White Sands Missile Range, New Mexico in 1964-65 and to compare that state with the damages caused by the 1494 sonic booms generated during the tests.

Beginning on November 18, 1964 and ending February 10, 1965 the FAA conducted structural response tests under sonic booms ranging in intensity from 1.5 psf. to 38 psf. Six structures were constructed for the test and were continually and intensively monitored during the boom testing phase. Fifteen other existing structures were also observed for damage evaluations. The principal purposes and scope of the White Sands program was to determine the cause and extent of "instantaneous" as well as "cumulative" damage. A detailed description of the tests and results is contained in the reports listed in the title.

Since the testing program, seven years of natural forces resulting from sun, wind, moisture and soil movements have taken place. Two investigations were made subsequent to February 10, 1965 (March 1, 1965 and May 10, 1965). It is of great interest, therefore, to reexamine these structures some seven years later and determine the amount of naturally occurring cumulative damage that has taken place over the years. This damage can then be compared with that experienced under the program sonic booms. Analyses can be made about the relative damageability of booms in relation to naturally occurring forces. This investigation would give a seven year baseline to the sonic boom studies previously conducted by the FAA.

B. GENERAL DESCRIPTION OF THE RESURVEY

(1) Interviews on Thursday, February 24.

I was admitted to the Oscura Range Camp by Mr. Richard Bradley, Station Chief of the Oscura Range Camp Communication Station located at the camp. He provided an escort for me during the investigation.

Prior to the investigation, interviews of the local civilians in and about the facility were conducted in order to obtain an idea of the sonic boom and bombing activity that had taken place during the intermittent years.

Personal interviews included: Mr. William Lawrence, Mr. Robert M. Rodgers, Mr. Richard M. Bradley, Mr. Jack R. Hefker, all stationed at the ORC station, and Mr. Pat Withers and Mrs. Nadine Withers, local ranchers. Interviews were also conducted in Carrizozo to determine the general intensity level of those heard on the range. These interviews allowed me to obtain a perspective of the frequency and probable intensities of sonic boom strength experienced by the structures during the time between Feb. 10, 1965 and Feb. 25, 1972. A summary of the impressions of both boom and bomb intensity is presented later in the report.

(2) General Investigation of the ORC Station

Mr. Bradley noted to me that the ORC Station had been completely redecorated, painted and all cracks caulked about 6 months prior to Feb. 24, 1972. Yet this concrete block building showed new cracks which had been photographed in the chief's office (Fig. 1) and new cracks in the power room (Fig. 2) and bathroom facilities. No booms of any significance had taken place since the time of redecoration.

In the power room of the communications building Mr. Bradley pointed out a crack which was approximately a

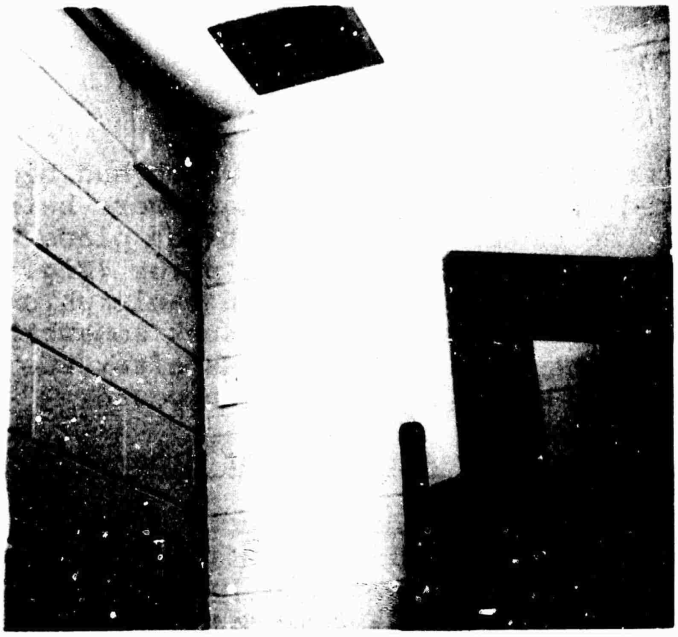


Fig. 1 An old crack has opened up in the Station Chief's office at the ORC Station 6 months after redecoration.

Fig. 2 Cracking has continued after caulking but not repainting in the ORC Station Power Room after 6 months time.

quarter to a half inch wide which had been recently caulked but not painted. There were hair-line cracks about the caulking that had taken place since the caulking was made six months prior (Fig. 2). He also mentioned that a subterranean vault which contains the cabling for the station had sunk somewhat requiring replacement of the vinyl tiles after the depressions were build up by a grouting compound.

(3) <u>General Investigation of Other "Out" Buildings</u>

I visited the "Abandoned Ranch" shown in Figs. 3 and 4. Its condition is still bad with the additional glass damage. It was reported by Mr. Withers that the glass was broken by vandals some time earlier.

The Withers ranch (Fig. 5) is virtually in the same condition as it was seven years earlier (Note Fig. B2-3, SST 65-15, Vol. 2). It has been redecorated on the interior twice since the program and appears in excellent condition. Fig. 6 can be compared to Fig. B2-2, SST 65-15, Vol. 2.

On the exterior of the ranch house a crack was found which Mr. Paul Freund monitored throughout the program which flew 10 psf. and larger boom intensities over the property. No movement was noted during the program beyond the mark in Fig. 7. In the last seven years, however, settlement has caused the crack to extend.

During my interview with Mr. & Mrs. Withers some additional information was revealed. Of the 50 chickens given to the Withers after the program (all had been incubated and hatched under 5 psf booms, averaging more than 30 per day) 15 were still alive and were laying an average of 265 eggs per year. Recognizing that the average age for White Leghorns is between 4-5 years and that egg production drops with age, these were rather remarkable chickens.

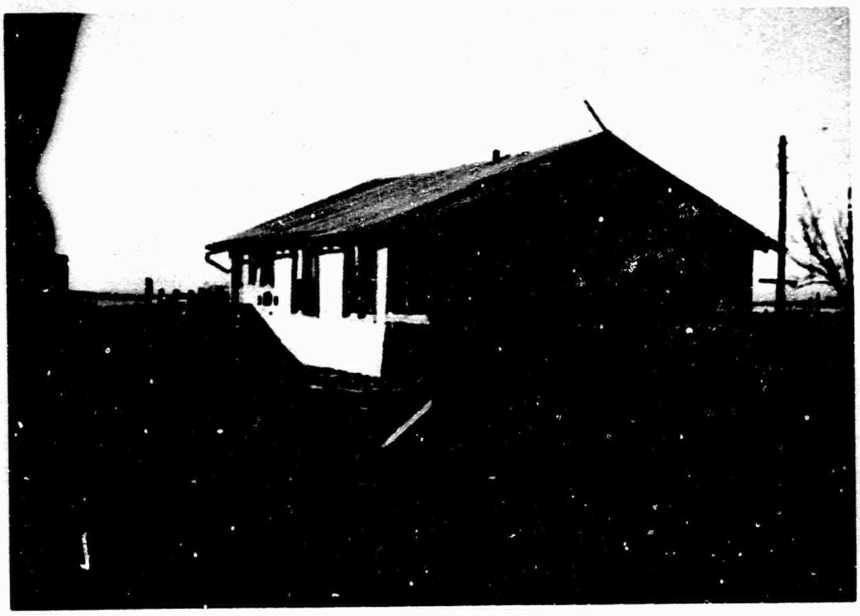


Fig. 3 "Abandoned Ranch" is still in bad condition. The windows were broken by vandals, as reported by Mr. Withers. All were new and unbroken at the beginning and end of the program.

Fig. 4 The interior of the "Abandoned Ranch" is still in bad condition.

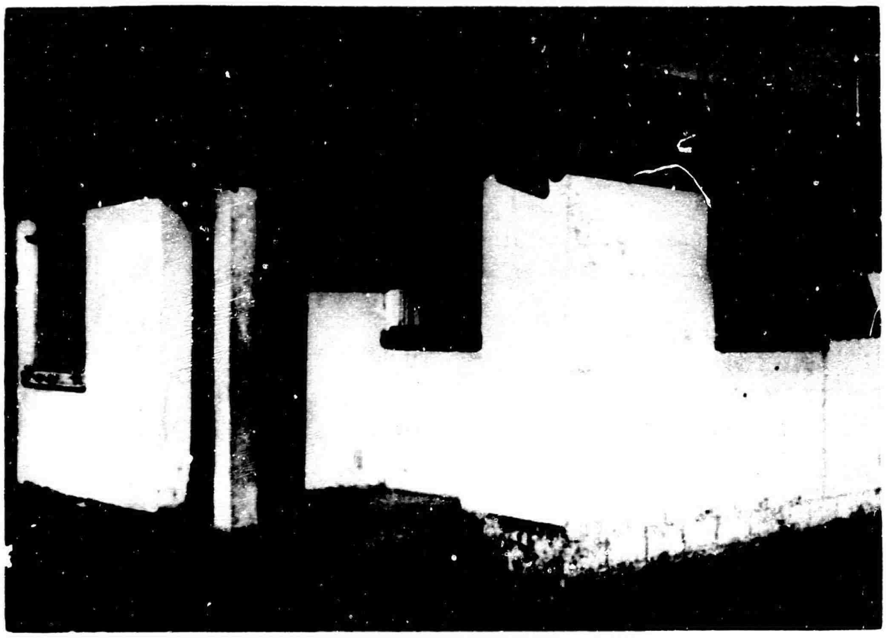


Fig. 5 Wither's ranch exterior

Fig. 6 Interior of Wither's ranch house.

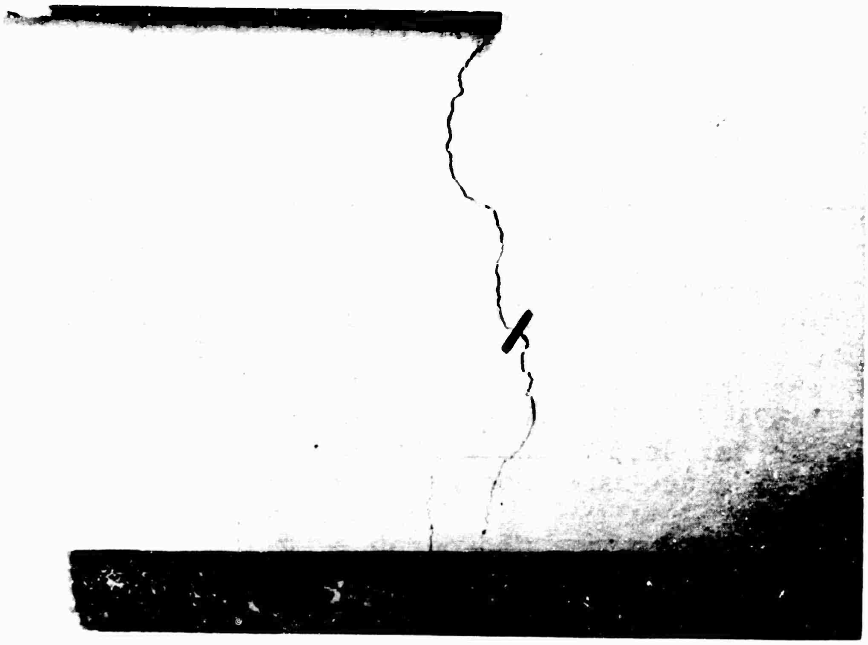


Fig. 7 Crack extension over the last seven years at Wither's ranch.

Fig. 8 Sonic Boom Chickens (Rooster) still doing fine.

(4) General Investigation of "In" Buildings

I was then escorted by James Jennings and made visual examination of all of the major infield test facilities including C-1 (Figs. 9-13), W-2 (Figs. 14-20), W-3 (Figs. 21-27), W-4 (Figs. 28-33), 2S-5 (Figs. 34-40) and PF-6 (Figs. 41-47). I also investigated the Store-Front building (Figs. 48-50) and the H building (Figs. 51 and 52), used to house the boom personnel during the program.

As can be seen from the photographs, all of the buildings were in disrepair and had suffered considerable damage since the last reading taken May 20, 1965 by William Walker and me. In general, all of the buildings that were plastered suffered the greatest interior damage.

The figures reveal the following general observations. The stucco also suffered considerable damage on the exterior of W-2 and W-3. The dry wall inside W-3 was in remarkably good condition, however, in compari' n to the interior walls of the plastered buildings, i luding the interior walls of the plastered concrete block (C-1) building.

The upper living room ceiling in 2S-5 had collapsed and the second floor east wall had also been broken out about 2 inches. The brick work on the fireplace in 2S-5, however, was in absolutely perfect condition and suffered no damage during the last seven years. The wooden floors were quite weathered and some of the ceilings showed minimal leakage. There was some water damage in many of the buildings.

The exterior wood sidings on W-4 and PF-6 had deteriorated considerably. The wood was warped and most of the paint was off the buildings.

It was noted that no repairs what-so-ever have been made to the buildings since the sonic boom program, however.

The Store-Front had two windows broken. The center solar gray glass (panel b) in the left three panels had broken. The mechanism of damage to the large window on the right

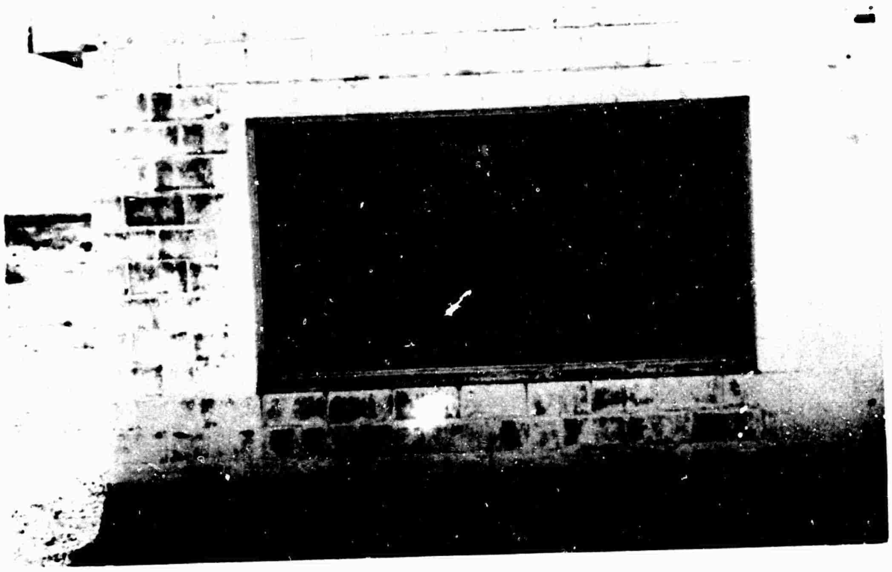


Fig. 9 C-1, Northerly exterior

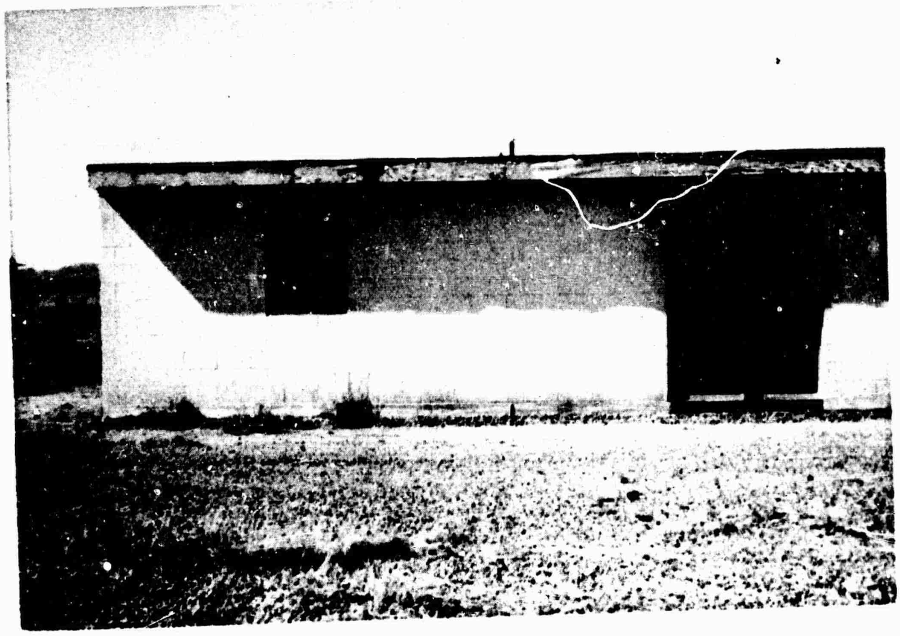


Fig. 10 C-1, Easterly exterior

Fig. 11 C-1, Southerly exterior

Fig. 12 C-1, Westerly exterior

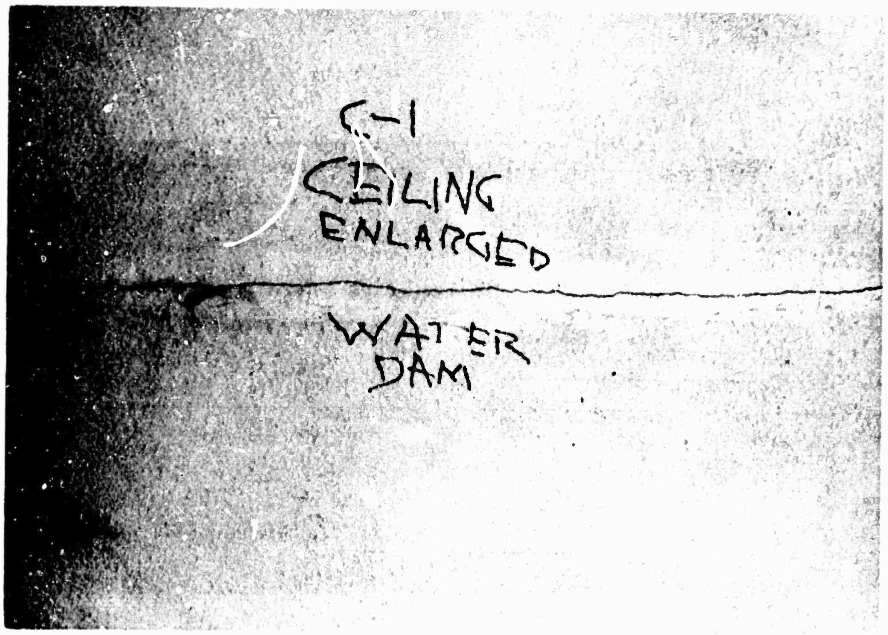


Fig. 13 Typical enlarged crack in C-1

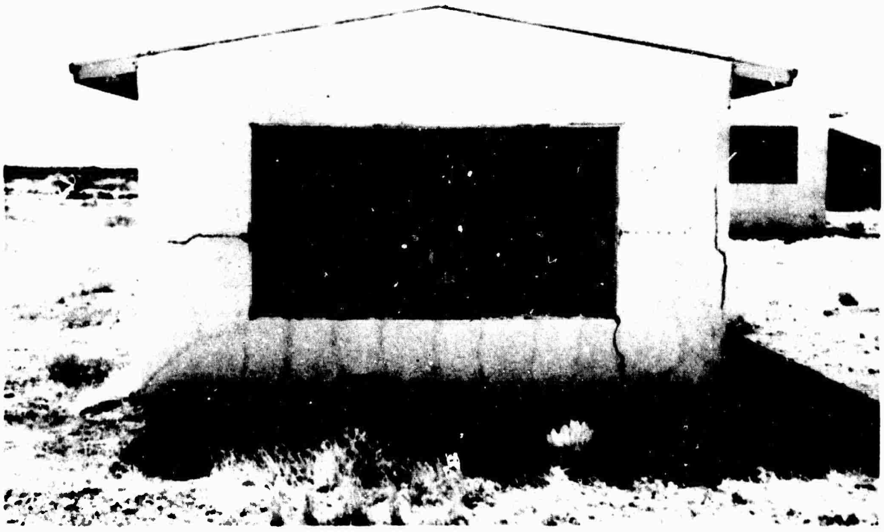


Fig. 14 W-2, Northerly exterior

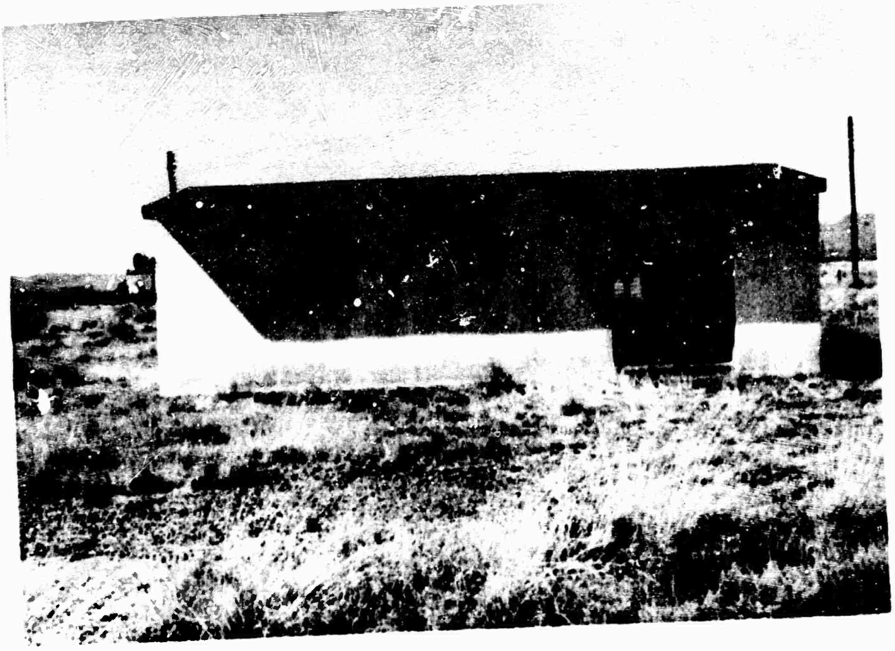


Fig. 15 W-2, Easterly exterior

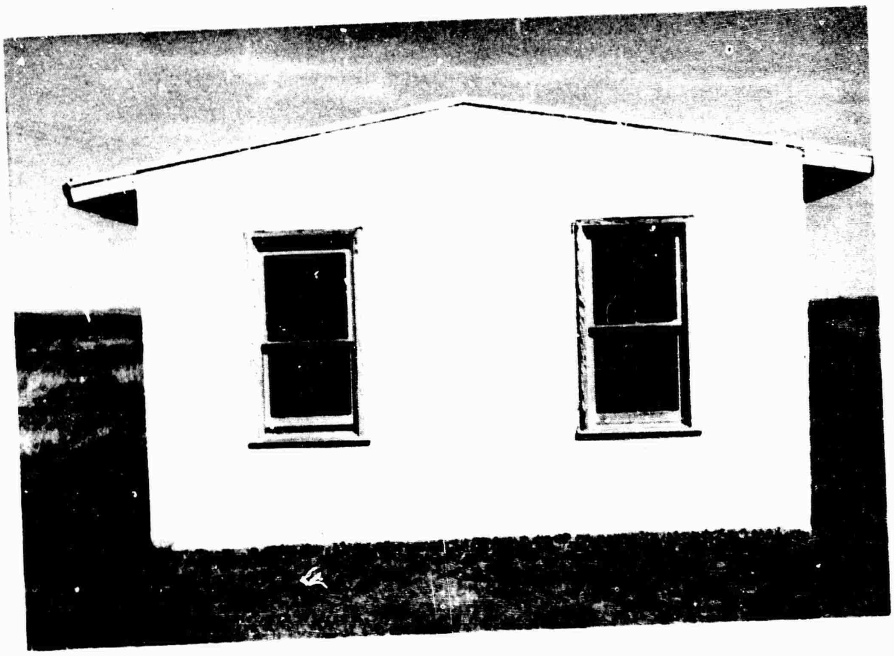


Fig. 16 W-2, Southerly exterior

Fig. 17   W-2, Westerly exterior

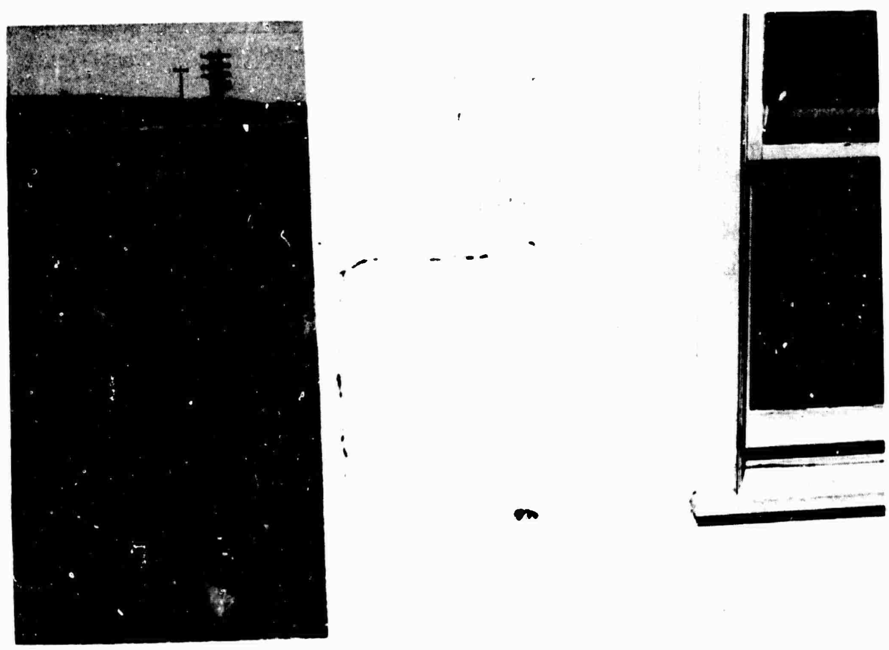


Fig. 18   W-2, Typical exterior stucco cracks

Fig. 19 W-2, Typical water damage around windows

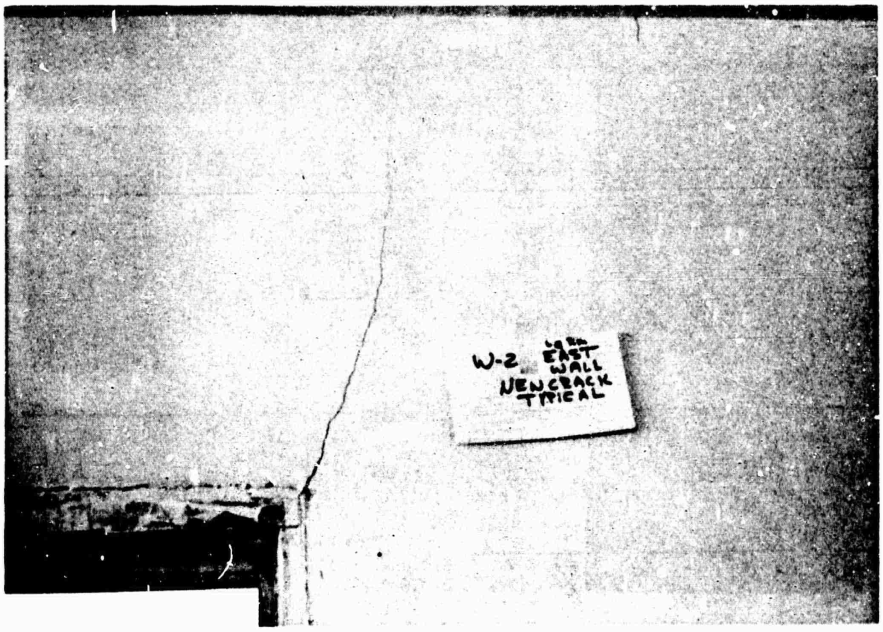


Fig. 20 W-2, Typical new crack

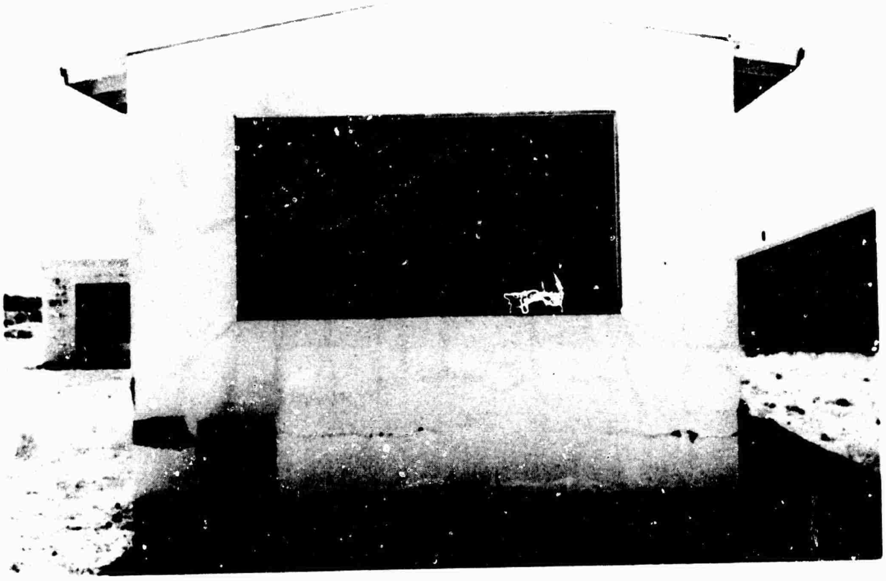


Fig. 21 W-3, Northerly exterior

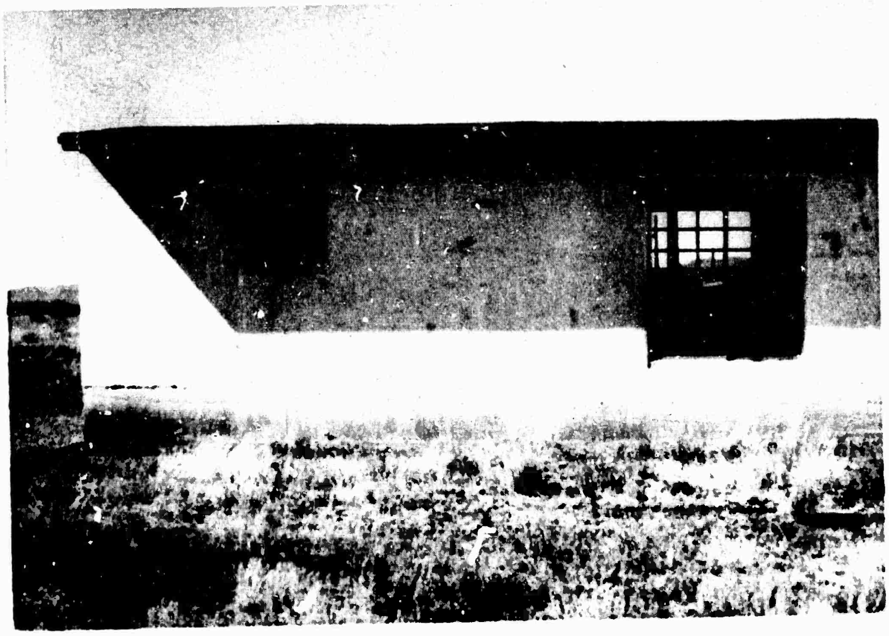


Fig. 22 W-3, Easterly exterior

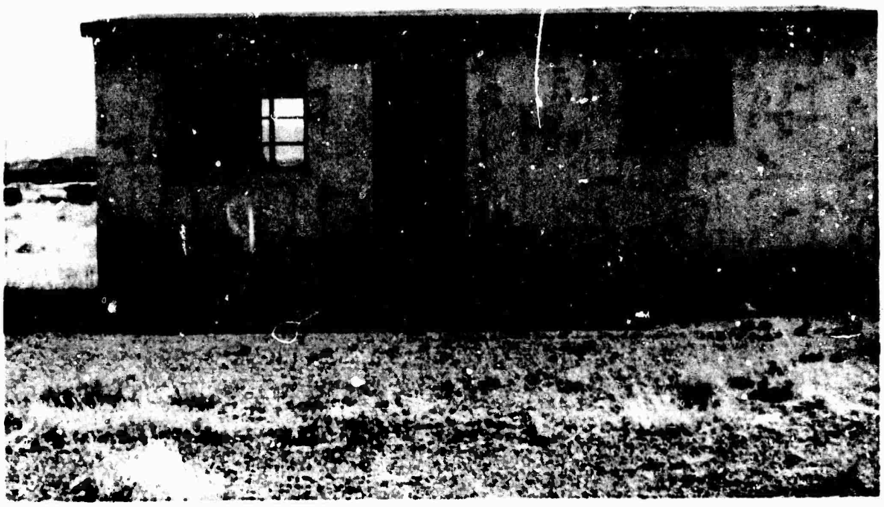


Fig. 23 W-3, Westerly Exterior

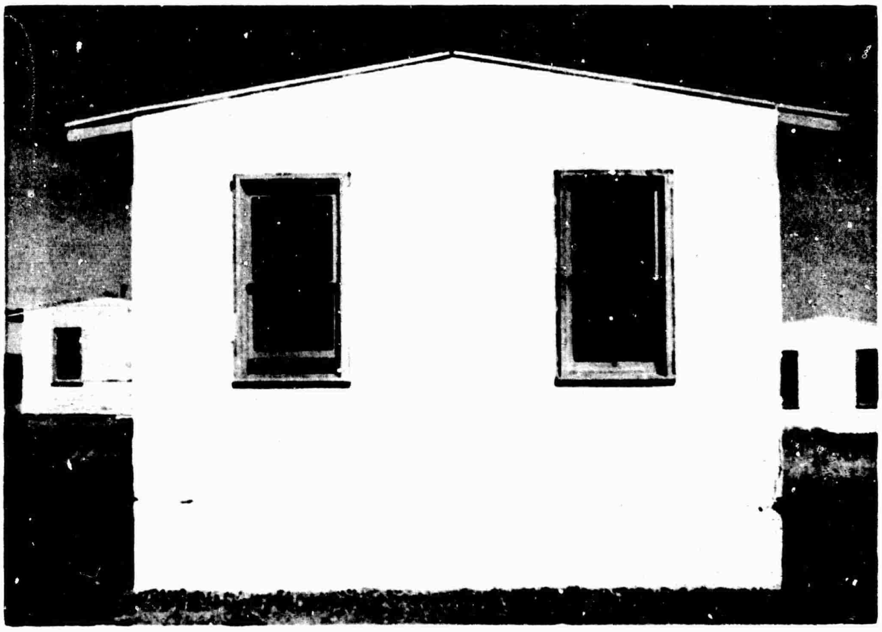


Fig. 24 W-3, Southerly exterior

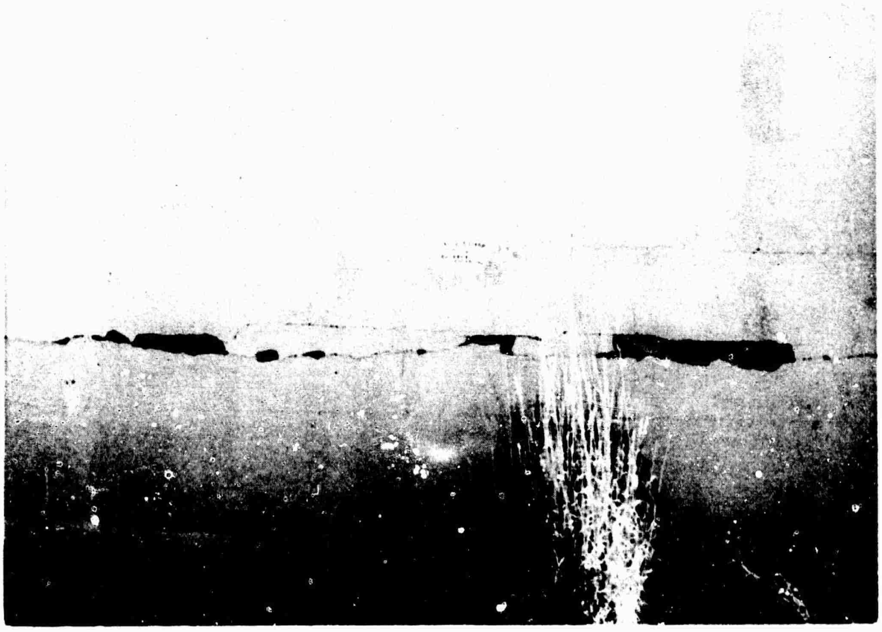


Fig. 25   W-3, Typical Exterior Damage

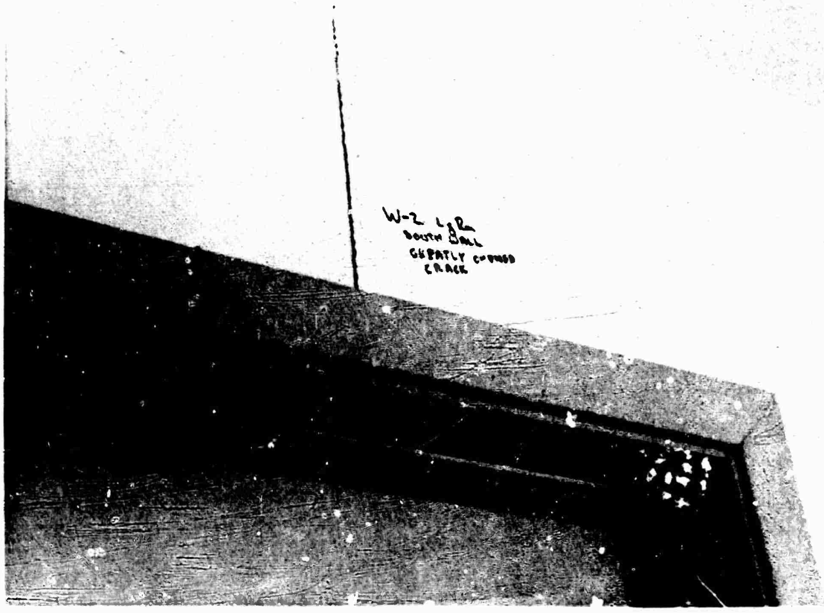


Fig. 26   W-3, Old Crack Marked 5-20-65 Has
Greatly Enlarged

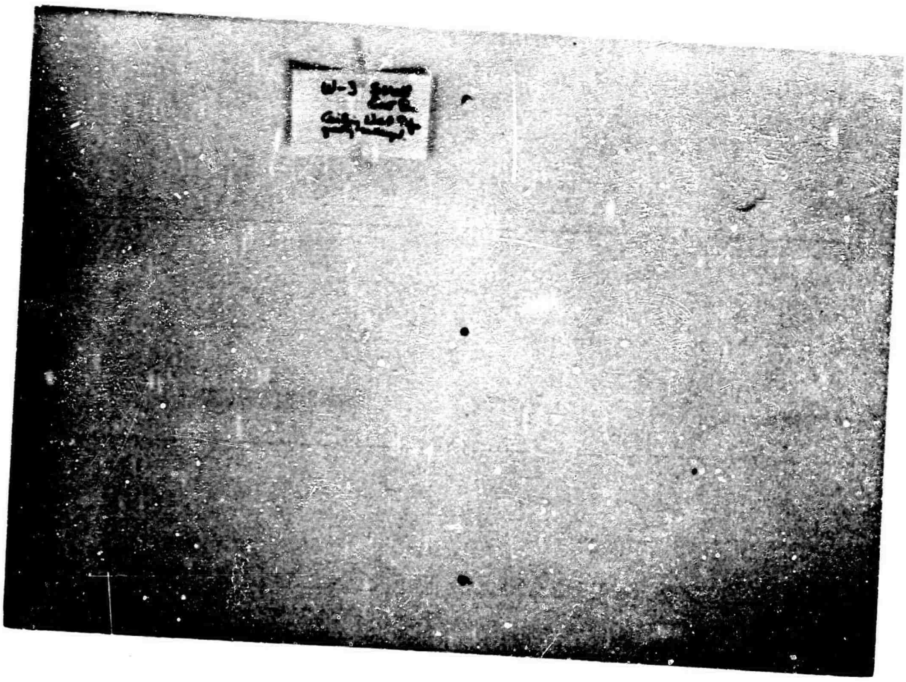


Fig. 27 W-3, New Nail Pops Recorded after the 5-2-65 Inspection. No Nail Pops Occurred as the Result of Booms up to 23.4 psf overpressure During Part B

Fig. 28 W-4, Northerly exterior

Fig. 29 W-4, Easterly Exterior

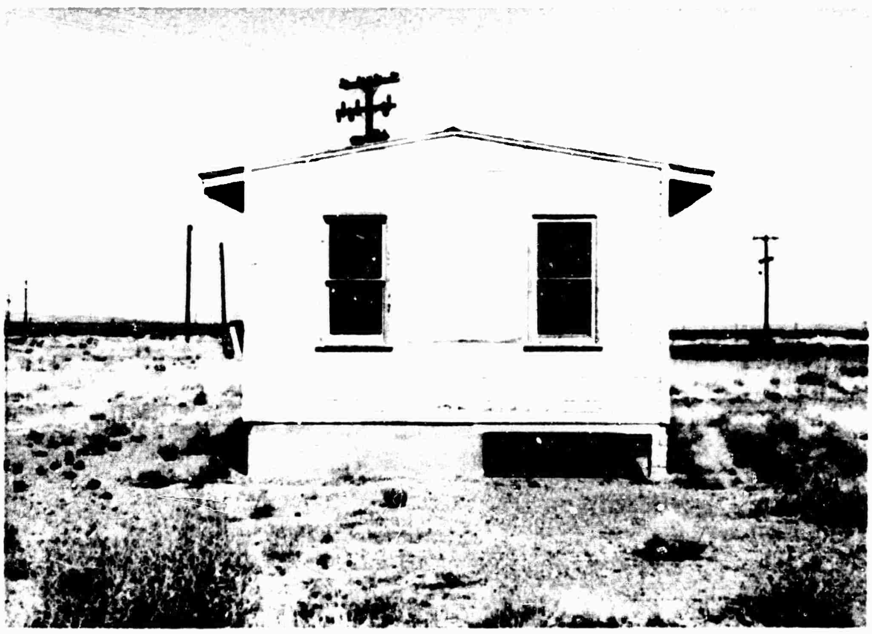


Fig. 30 W-4, Southerly Exterior

Fig. 31 W-4, Westerly Exterior

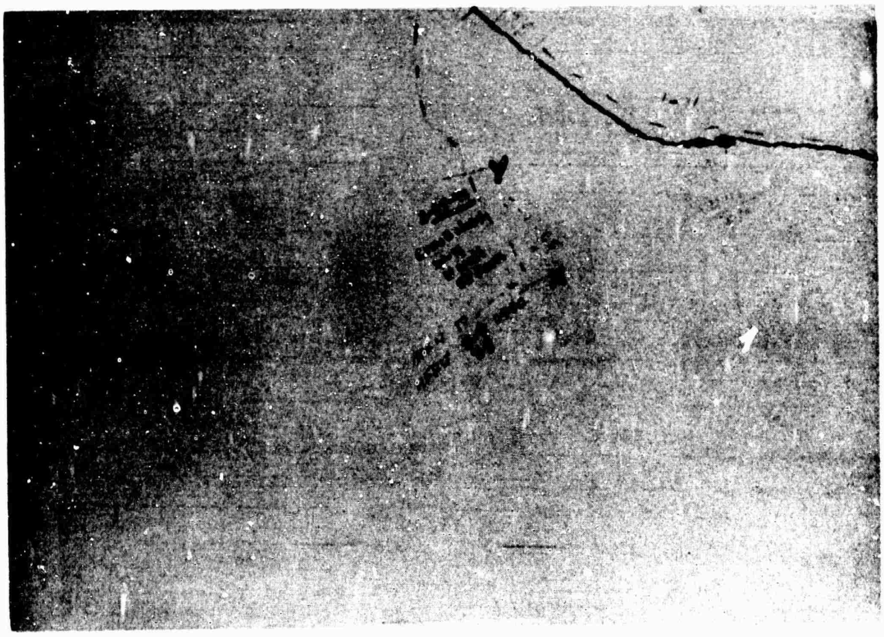


Fig. 32 W-4, Crack Which Had Opened to Point x on 2-9-65, Had Closed to Point y on 2-25-72

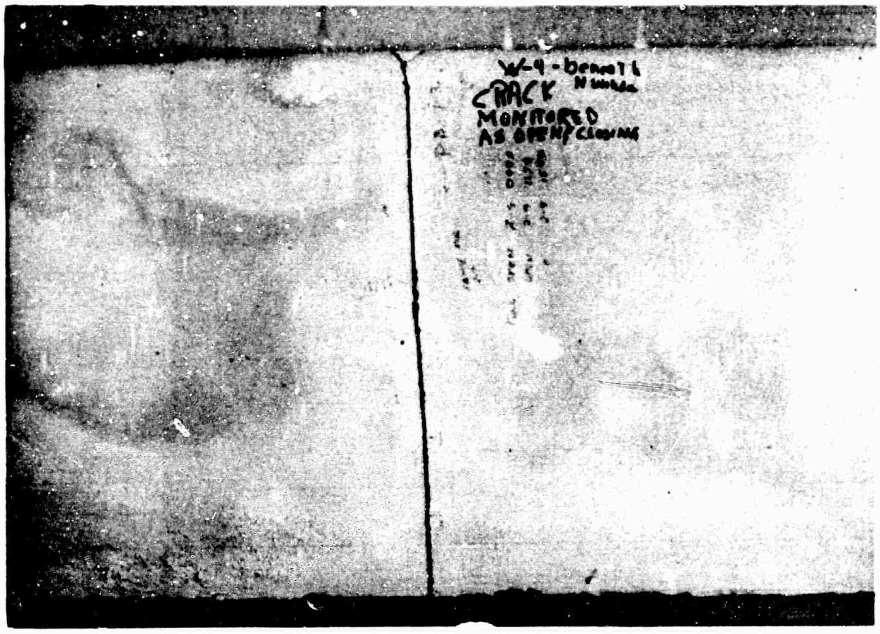


Fig. 33 W-4, Crack Monitored as Opening and Closing During Program is Now Greatly Enlarged

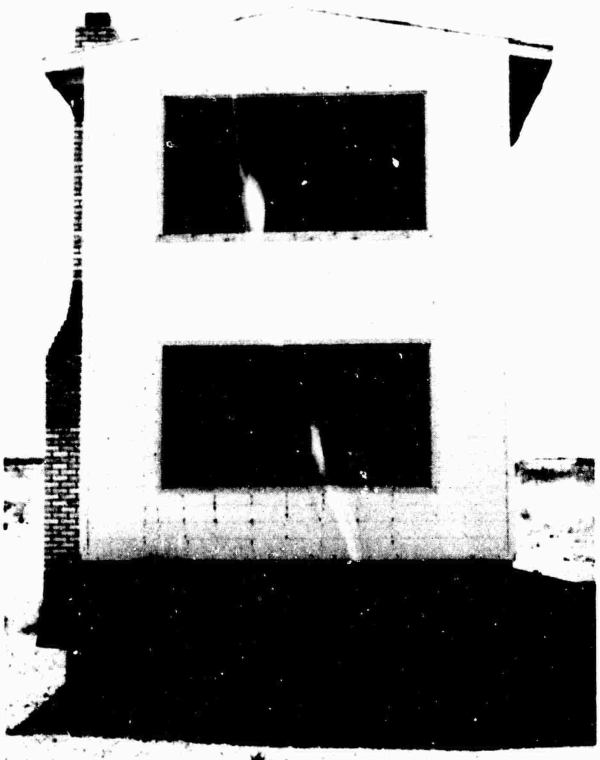


Fig. 34 2S-5, Northerly Exterior

Fig. 35 2S-5, Easterly Exterior

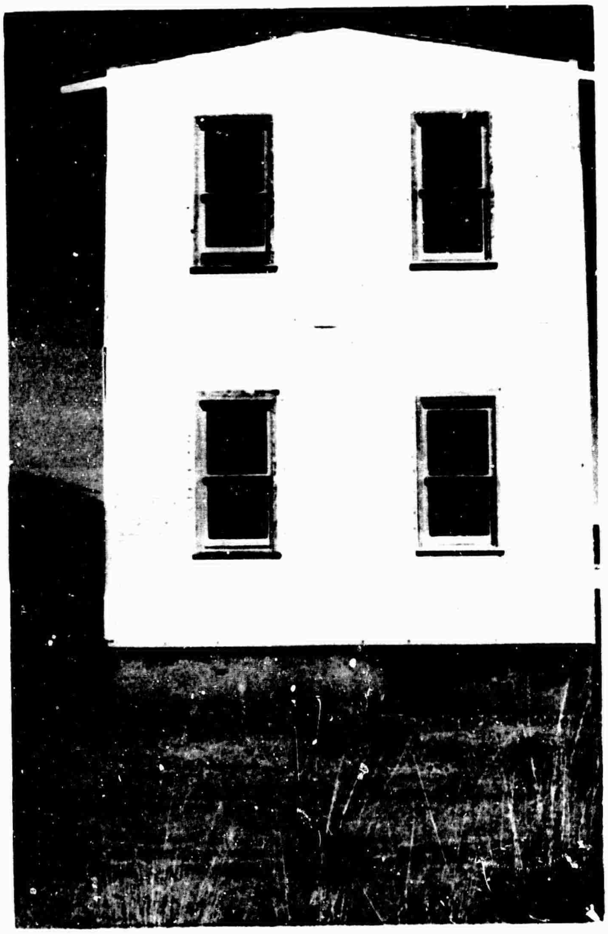


Fig. 36 2S-5, Southerly Exterior

Fig. 37   2S-5, Westerly Exterior

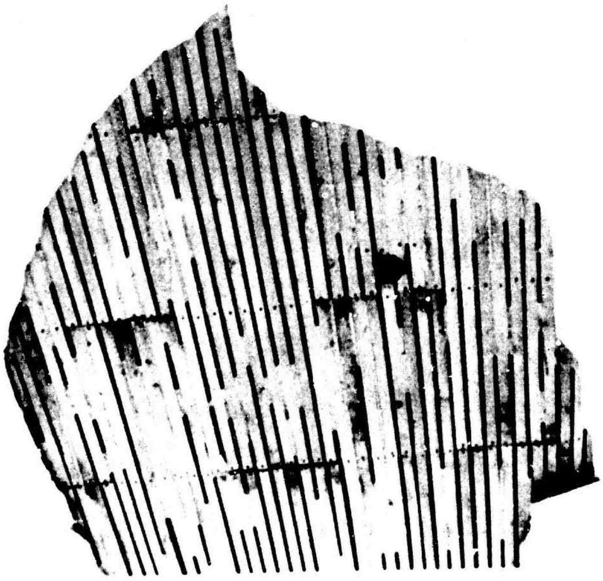
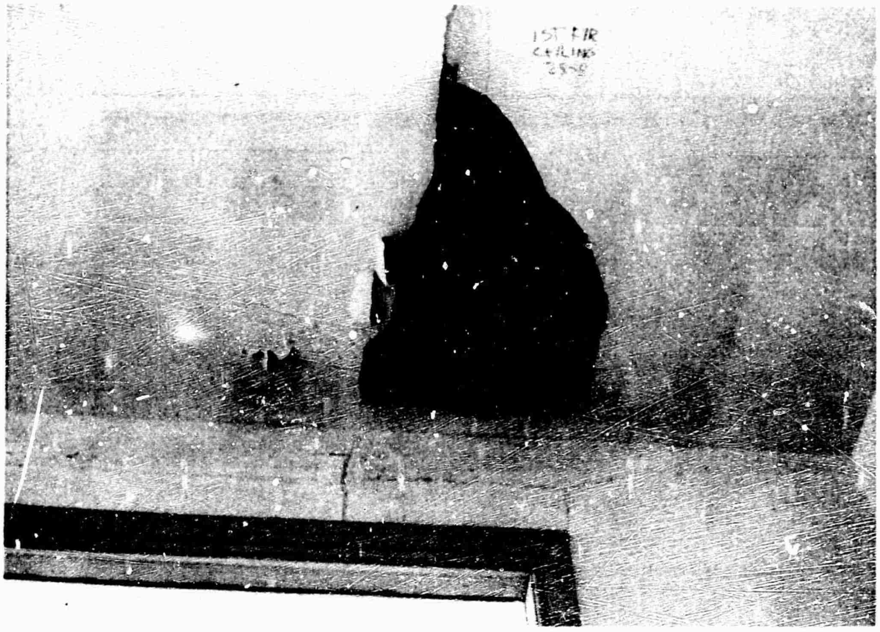


Fig. 38   2S-5, Fallen Ceiling in Second Story, Plaster on Wood Lath



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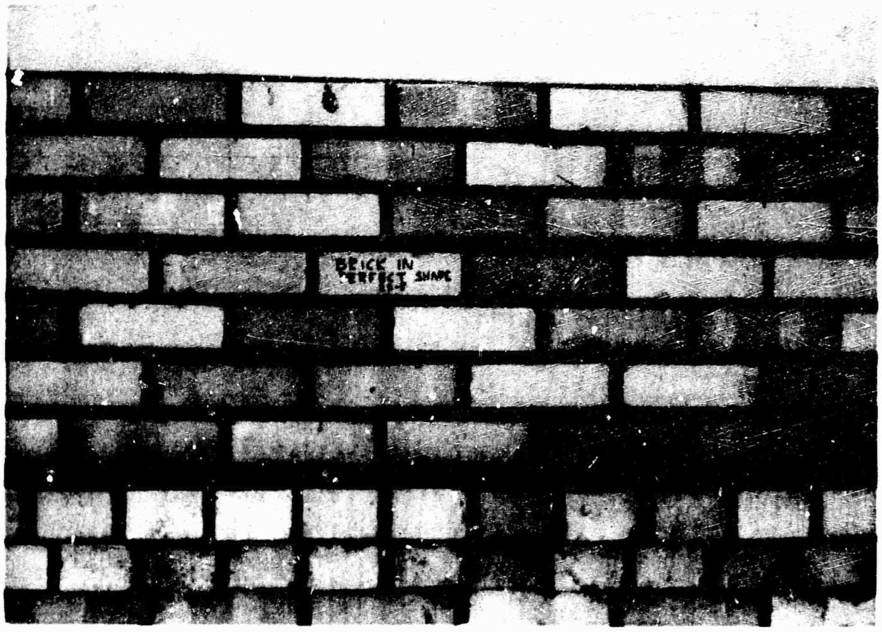

Fig. 40   2S-5, Fireplace Masonry in Perfect Condition

Fig. 41 PF-6, Northerly Exterior

Fig. 42 PF-6, Easterly Exterior

Fig. 43 PF-6, Southerly Exterior

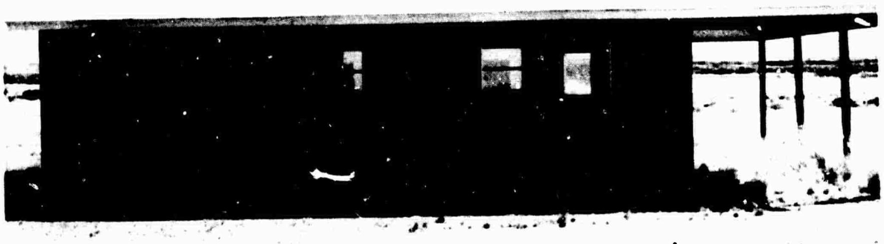

Fig. 44 PF-6, Westerly Exterior

Fig. 45 PF-6, Closeup of Northwest Corner Damage

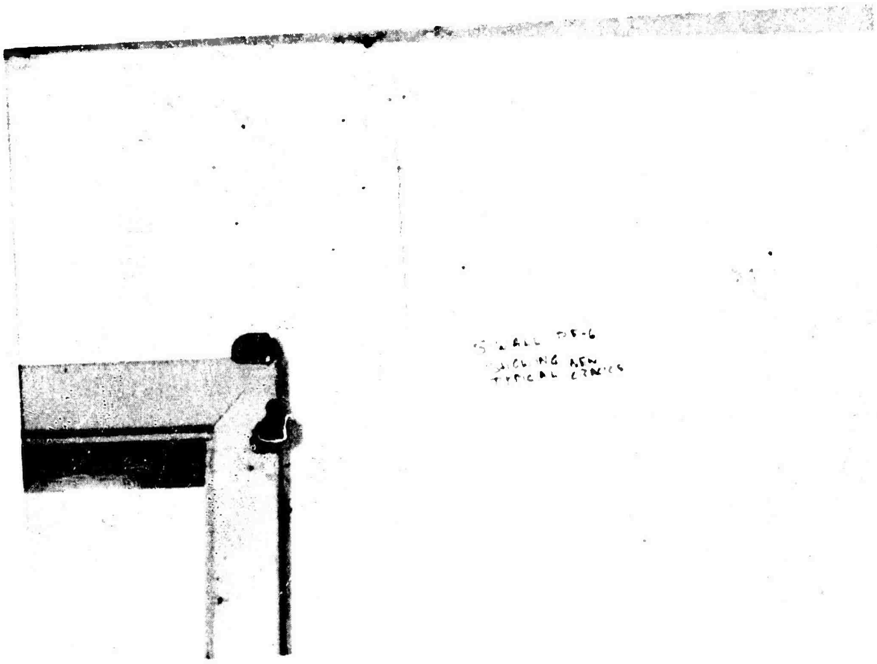

Fig. 46 PF-6, Typical New Cracks. Note Wasp's Nests.

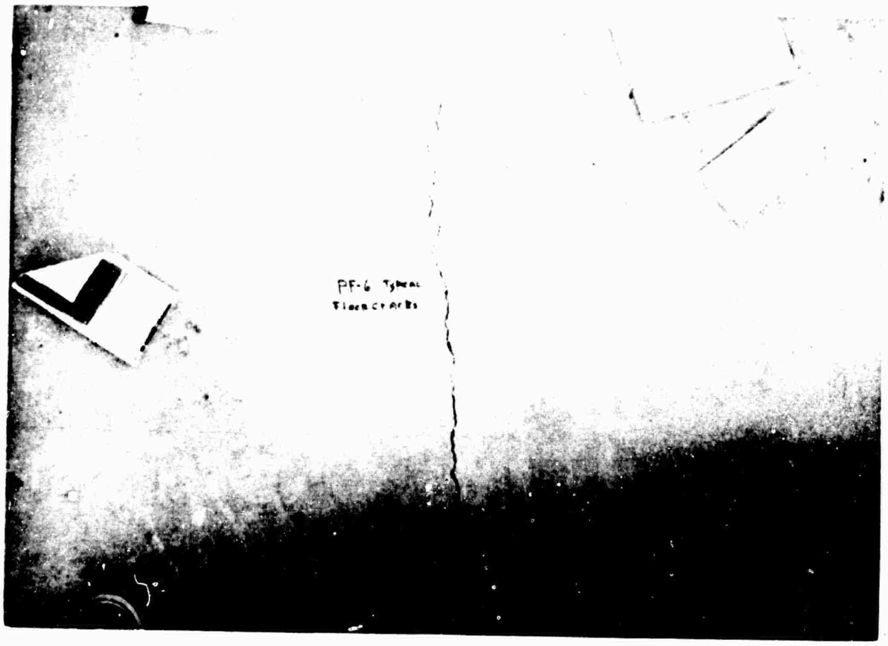

Fig. 47 PF-6, Floor Cracks in Building Not Found in C-1, W-2 due to Different Slab Design (See SST 65-15 (Vol. 2) Dwg B-3 and B-9).

Fig. 48 Store Front, Window on Right and Solar pane on left are Broken

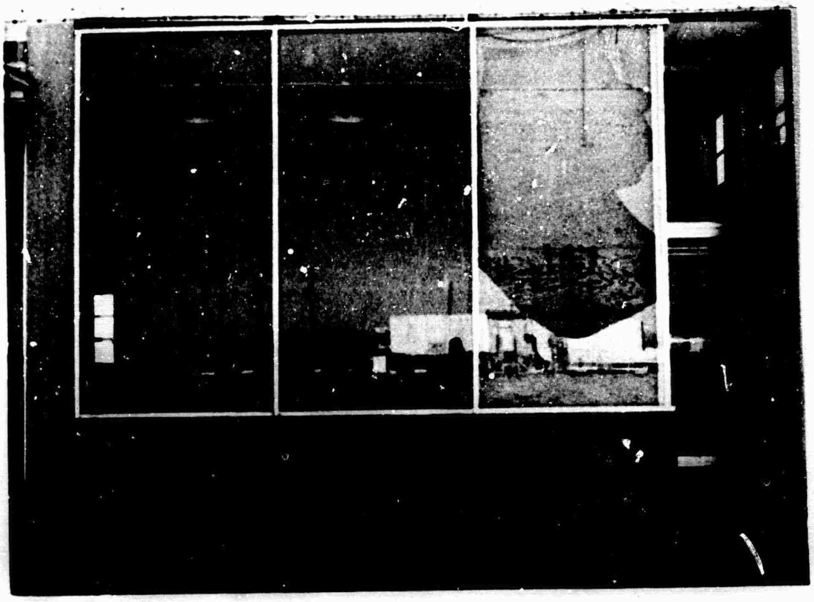

Fig. 49 Store Front, 5' 0" x 9' 6" x 13/64" (actual thickness) Broken Pane

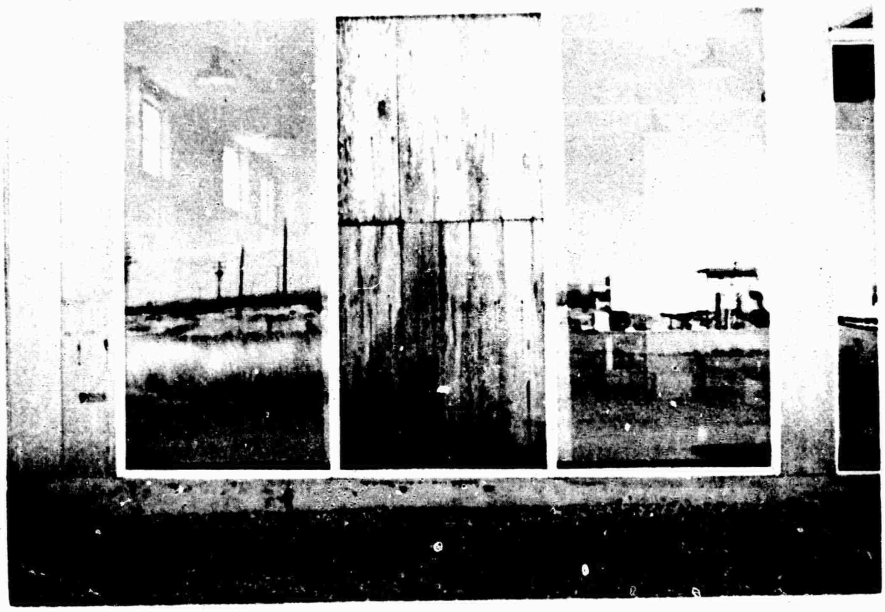

Fig. 50 Store Front, 5' 3" x 10' 8" x 13/64" (actual thickness) Broken Pane

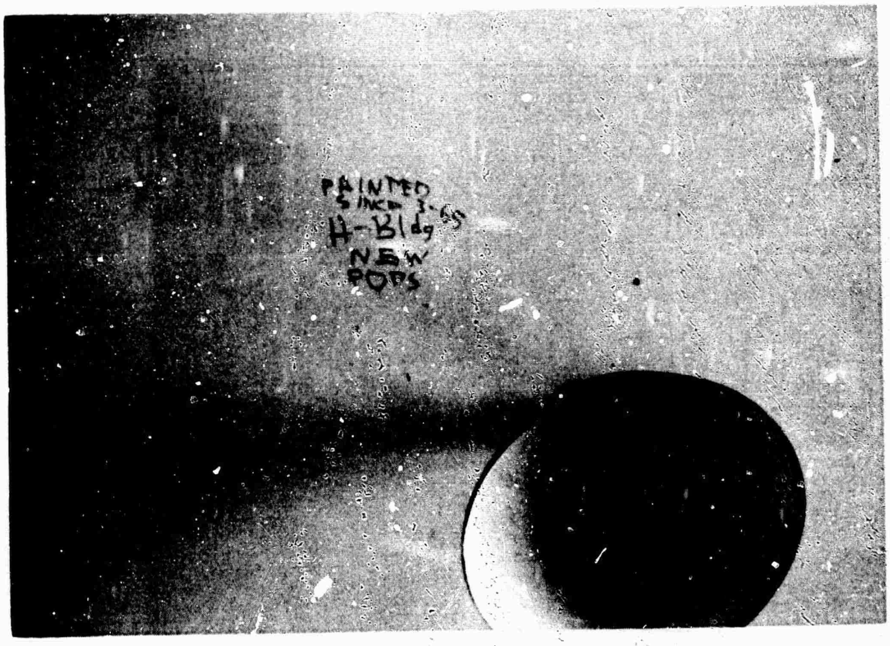

Fig. 51 H-Building, New Nail Pops after Redecoration Between Inspection Periods.

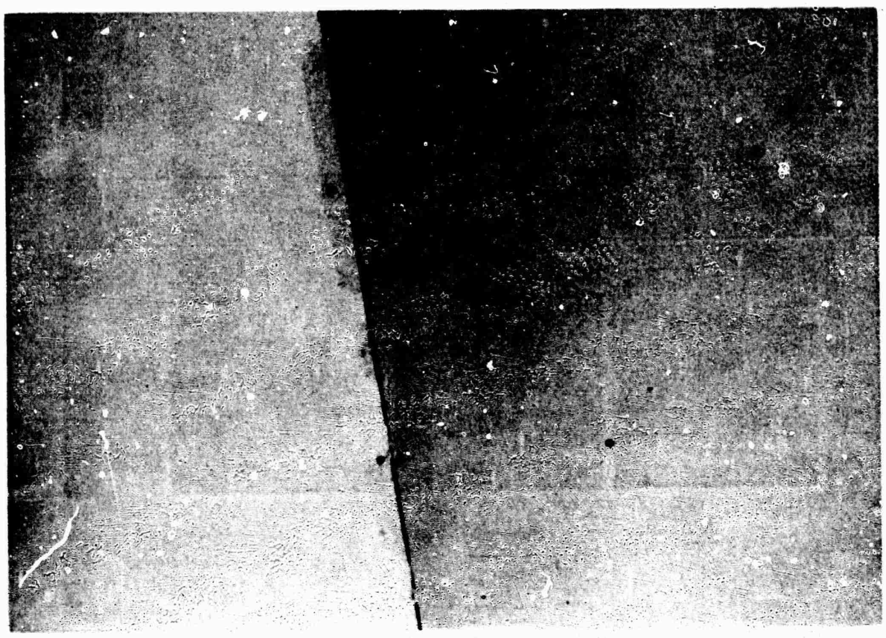

Fig. 52 H-Building, Replaced Ceiling Since Program and Since Redecoration.

side of the Store-Front building did not look like sonic boom damage since it was highly localized in the top center portion of the frame. Using the techniques described by Wiggins* the probabilities computed for these two windows to be broken by sonic boom and not panels d and e leaves doubts as to sonic boom being the cause of damage.

The approximate probabilities that panes b and h would be broken by sonic boom and not panes d and e (which are weaker as shown by the Dec. 2, 1964 incident reported on page 192 of SST 65-18) are shown in Table 1 using linear and non linear theory.

These probabilities suggest that booms did not break the panes of glass. Further, since the broken panes were boarded up, panes d and e are considered to be the original panes used on the program and have not been replaced since 5-20-65.

Part of the H building had been repainted and nail-pops and ceiling damage sufficient to warrant replacing part of the ceiling had occurred since the boom program. Even so nail-pops have reappeared in the ceiling and walls.

One thing that was noted upon examining the original test site was that the green house was totally absent. It had been cleared away and only the foundation remained.

It is obvious that these buildings have not been kept at internal uniform temperatures since some windows are ajar thus the internal temperature conditions are virtually the same as the external temperature conditions.

*Wiggins, John H., Jr, Effects of Sonic Boom, J. H. Wiggins Company, Palos Verdes Estates, Calif. (1969).

TABLE 1 Approximate Probabilities Associated With Glass Breakage by Sonic Boom to Panes b and h as Compared With Non Breakage of Panes d and e

Hypothesis	Theory on Glass Breakage Mechanism	
	linear	non linear
(1) Both windows broke on sonic boom from low flying aircraft	16	6400
(2) Windows broke on separate incidents from low flying aircraft	8	164
(3) Both windows broke on same super boom from high flying aircraft	4100	260,000
(4) Both windows broke on separate incidents from high flying aircraft	128	2.5×10^9

C. ANALYSIS OF THE STRUCTURES

During the White Sands Structural Response Program two buildings on raised foundations, W-3 and W-4, were measured periodically for differential settlement of the foundation and expansion and contraction of the wood flooring (see SST 65-18, pp. 129 and 130). The corners of the structures were resurveyed with a transit and the nail points on the floors remeasured. The data are presented in Tables 2 and 3.

The foundations have moved considerably since the program, however, the floors remained constant, as would be expected since the concrete foundations govern the nail point locations along the lines of measurement.

As a result of the interviews with the six personnel mentioned earlier in the report the sonic boom and explosion number has been estimated. Table 4 summarizes the results. The term "Lo" refers to low pressure, 1-2 psf strength sonic booms whereas the term "Hi" refers to 8-20 psf strength booms. The calibrations were derived from Mr. Hefker and Mr. and Mrs. Withers who were present during the entire White Sands Program and had been psychologically "calibrated" to boom strengths. These calibrations were then applied to uncalibrated observers.

Note from Table 4 that approximately the same total number of explosive pressure events, 802, have taken place since the end of the program on 2-10-65 to 2-25-72 as were recorded during Part "B", 803, conducted from 1-15-65 to 2-10-65.

Table 5 summarizes all of the crack data recorded for Part "B" and at the three dates subsequent to 2-10-65. All of the potential influences controlling the cracking are also reported in this table: average overpressure, boom frequency, Carrizozo temperature, precipitation and wind conditions. Oscura weather conditions were unobtainable, however, both the average weather

TABLE 2 Relative Movement of Building Corners (ft.)
(From Zero Day Datum)

Date	Day[1]	NW		NE		SE[2]		SW	
		W-4	W-3	W-4	W-3	W-4	W-3	W-4	W-3
11-18-64	0	0.00	0.00	0.00	0.00	0.00	--	0.00	0.00
11-24-64	6	0.00	0.00	0.00	0.00	--	--	0.00	0.00
12-3-64	15	-0.02	0.00	0.00	0.00	--	--	0.02	-0.01
12-16-64	28	-0.02	--	-0.01	--	--	--	0.01	--
1-22-65	65	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
1-24-65	67	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
1-26-65	69	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01
1-28-65	71	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01
1-30-65	73	-0.01	0.00	0.00	0.00	0.00	-0.02	0.00	-0.01
2-3-65	77	0.00	0.00	-0.01	0.00	0.00	-0.02	0.00	-0.01
2-6-65	80	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	-0.01
2-25-72	2651	-0.12	-0.21	-0.06	0.15	0.00	0.00	-0.12	0.19
				Relative Current Degree of Level					
2-25-72	2651	-0.05	0.00	-0.04	0.09	0.00	0.00	-0.03	0.04

(1) days after construction

(2) on 2-25-72 the datum used was the NE corner since original datum was removed.

TABLE 3 Floor Expansion and Contraction (ft.)

Measurement	W-4			W-3		
	A	B	C	A	B	C
datum (1-18-64)	18.85	18.83	29.35	18.85	18.83	29.35
program (+) range	0.01	0.03	0.01	0.00	0.01	0.01
program (-) range	0.03	0.01	0.01	0.01	0.01	0.01
datum (2-25-72)	18.86	18.82	29.34	18.86	18.83	29.34

TABLE 4 Sonic Boom and Bomb Activity During the Period 2-10-65 to 2-25-72

year 19__	season ¼	Lawrence Lo*	Lawrence Hi	Rodgers Lo*	Rodgers Hi	Bradley Lo*	Bradley Hi	Hefker Lo*	Hefker Hi	Withers Lo*	Withers Hi	Lo-total	Lo-Av	Normal-izing #	Hi-total	Hi-Av
65	2/10-4/1							14	3	7	.3	39	11	2	5½	2
	2							26	5	13	½	39	20	2	5½	3
	3							26	5	13	½	39	20	2	5½	3
	4							26	5	13	½	39	20	2	5½	3
66	1							26	5	13	½	39	20	2	5½	3
	2							26	5	13	½	39	20	2	5½	3
	3							26	5	13	½	39	20	2	5½	3
	4							26	5	13	½	39	20	2	5½	3
67	1							26	5	13	½	39	20	2	5½	3
	2			33	3			26	5	13	½	72	24	3	8½	3
	3			32	3	13	½	26	5	13	½	84	21	4	9	2
	4			33	3	13	½	26	5	13	½	85	21	4	9	2
68	1			32	3	13	½	20	2	26	½	91	23	4	6	2
	2			33	3	13	½	20	2	26	½	92	23	4	6	2
	3			32	3	13	½	20	2	26	½	91	23	4	6	2
	4			33	3	13	½	20	2	26	½	92	23	4	6	2
69	1			32	3	13	½	39	2	26	½	110	28	4	6	2
	2			33	3	13	½	39	2	26	½	111	28	4	6	2
	3	26	½	32	3	13	½	39	2	26	½	136	27	5	6½	1
	4	26	½	33	3	13	½	39	2	26	½	137	27	5	6½	1
70	1	26	½	32	3	13	½	39	2	26	½	136	27	5	6½	1
	2	26	½	98	3	31	½	39	2	68	½	262	52	5	6½	1
	3	86	½	167	3	31	½	39	2	68	½	391	78	5	6½	1
	4	26	½	98	3	13	½	39	2	26	½	202	40	5	6½	1
71	1	26	½	32	3	13	½	20	2	26	½	117	23	5	6½	1
	2	26	½	33	3	13	½	20	2	26	½	118	24	5	6½	1
	3	26	½	32	3	13	½	20	2	26	½	117	23	5	6½	1
	4	26	½	33	3	13	½	20	2	26	½	118	24	5	6½	1
72	1/1 to 2/25	18	0	22	2	8	½	14	1	18	0	80	10	5	3½	1
													746			56

*includes bombs

TABLE 5 Cracking Characteristics and Associated Forcing Functions

Period	Date	Days	Average Δp* (psf)	Total	no*	W-2 Σno.	W-3 Σno.	W-4 Σno.	2S-5(1) Σno.	2S-5(2) Σno.	PF-6 Σno.	$\bar{\Sigma}$	Carrizozo T°max	Carrizozo T°min	Carrizozo Precip(in)	Carrizozo Wind MPH	Carrizozo ΔT	
	1-15-65	0	6.8	30,	0	12	15	1	2	4	7	7	58	23	0	12	35	
	16	1	4.5,4.3	59,	5	13	19	5	28	16	20	17	62	24	0	2	38	
	17	2	8.3	89,	5	21	25	12	31	20	22	21	56	20	0	8	36	
	18	3	6.1	119,	5	27	28	14	31	25	25	25	60	25	0	15	35	
	19	4	2.2,4.2	147,	10	27	28	14	36	26	25	26	59	25	0	15	34	
	20	5	4.5	166,	10	27	28	14	39	30	28	28	58	28	0	20	30	
	21	6	5.7,3.4	195,	26	27	28	15	43	30	30	29	47	33	T	9	14	
	22	7	4.2	228,	26	27	28	15	44	30	30	29	59	28	0	20	31	
	23	8	4.5,3.5	261,	43	27	37	20	46	32	32	32	51	25	0	15	26	
	24	9	4.8	300,	43	27	49	25	56	42	32	39	52	23	T	25	29	
	25	10	4.2	330,	43	30	58	26	60	44	32	42	49	30	0	25	19	
	26	11	5.1,3.5	364,	61	31	58	27	62	46	32	43	43	16	0	10	27	.69" mean
Sonic Boom Program	27	12	5.1	394,	61	31	60	31	68	47	32	45	42	14	0	10	28	for period
	28	13	4.9	433,	61	31	66	34	70	48	32	47	47	19	0	10	28	
	29	14	5.2	468,	61	31	66	36	86	51	32	50	55	23	0	15	34	
	30	15	4.4	498,	61	40	66	36	100	51	35	55	60	31	0	2	29	
	31	16	4.6	528,	61	42	68	43	112	59	36	60	63	31	0	15	32	
	2- 1-65	17	4.7	559,	61	44	72	46	114	60	36	62	65	33	0	12	32	
	2	18	4.3	589,	61	47	76	56	117	61	36	66	63	23	0	5	40	
	3	19	4.6	619,	61	53	77	58	119	63	44	69	63	22	0	4	41	
	4	20	5.8	649,	61	85	77	59	127	67	50	78	65	20	0	8	45	
	5	21	9.4	679,	61	85	77	67	133	71	53	81	63	25	0	10	38	
	6	22	10.3	703,	61	95	77	72	134	72	55	84	61	28	0	30	33	
	7	23	11.2	731,	61	95	81	74	144	78	57	88	59	39	.05	15	20	
	8	24	no boom	--		95	81	74	144	78	57	88	47	29	.14	12	18	
	9	25	13.9	736,	61	98	81	75	150	82	57	91	37	28	.28	30	9	
	10	26	19.3	742,	61	98	81	77	152	86	58	92	42	33	T	20	9	
			total =	803									Mean	Mean	Total**	Mean		
Low	3- 1-65	45	2.0-10	808		117	84	82	163	88	61	98	51	19	.40	--	31	
Boom															.76			mo. mean
Acti-	5-20-65	126	2.0-10	828		164	108	104	187	133	81	130	71	39	2.28	--	32	
vity	2-25-														1.14			mo. mean
	72	2598	2.0-10	1605		239	237	223	324	257	223	249	71	41	92.23	--	30	yearly mean

*left hand no. is F-104, right hand no. is B-58
**Mean total

conditions for Alamogordo (Table 6), some 45 miles to the southwest at elevation 4104 ft. and Carrizozo (Table 7), some 20 miles to the northeast at elevation 5438 ft. are reported for interpolation purposes of weather conditions at the Oscura Range Camp at elevation 4532 ft.

Table 8 presents the average crack lengths reported during the program and at the post-program inspection periods for all buildings except C-1. This table can be used to normalize the crack data in Table 5, however, it was not deemed feasible to do so for this report.

From the crack data and from an understanding of the physical behavior of materials under natural conditions an attempt was made to deduce the underlying statistical mechanism of crack production. Cracks with and without booms were studied. Based on current research on creep and shrinkage in concrete the inhomogenous Poisson process should provide a probability distribution model for non-boom cracks due to drying and shrinkage. The generating probability potential function is of the form,

$$\Phi_n (Z) = \exp [p(t) (Z^c - 1)],$$

where

$$p(t) = \int_0^t \lambda (\tau) \, d\tau$$

For the shrinkage type of process it has been found that $\lambda(t) = \lambda/t$ is a good model. Based on this expression one would expect the rate, $\lambda(t)$, to plot as a straight line on log-log paper and the cumulative crack number to plot as a straight line on semi-log paper. This was demonstrated in SST 65-15 (Vol. 1). Figure 53 illustrates the data in Table 5.

If the cracking during the boom period were caused predominantly by the same shrinkage process, the slope of a cumulative boom crack curve should be the same as that of the non-boom cumulative curve. If booms in addition to drying processes added their effects to

TABLE 6 Alamogordo Weather

AWS CLIMATIC BRIEF — HOLLOMAN AFB/ALAMOGORDO, NEW MEXICO — PERIOD: 1942-65B — WBAN # 23002 — WMO #

Prepared by ETAG (NOV 1970) — N 32 51 W 106 06 — ELEVATION: 4104 ft — STN LTRS: KHMN

MONTH	TEMPERATURE (°F) Extreme Maximum	Mean Daily Maximum	Mean Daily Minimum	Extreme Minimum	PRECIPITATION (in) Mean Total	Maximum in 24 Hours	Mean Snowfall	Max Snowfall in 24 Hours	WIND (KT) Prevailing Direction	Mean Speed	Extreme (Peak) (Gust) Speed	MEAN Relative Humidity (%) 0400	Relative Humidity (%) 1300	Dew Point (°F)	Vapor Pressure (in Hg)	Pressure Altitude 99.95% (Feet)	MEAN NUMBER OF DAYS Precip ≥ 0.01 in	Precip ≥ 0.5 in	Snowfall ≥ 0.1 in	Snowfall ≥ 1.5 in	Thunderstorms	Fog (< 7 miles)	Temp Maximum ≥ 90	Temp Maximum ≥ 80	Temp Minimum ≤ 32	Temp Minimum ≤ 0	Mean Clouds (Tenths)
JAN	78	55	28	-11	0.5	1.2	2	4	S	5	67	65	42	24	.13	4500	3	#	1	#	#	2	0	0	22	#	4
FEB	80	60	32	0	0.4	0.6	1	4	SSE	6	49	57	33	24	.13	4500	2	#	1	#	#	1	0	#	15	#	4
MAR	86	66	37	18	0.3	1.3	#	2	S	7	51	48	26	23	.12	4500	2	#	#	#	1	1	0	1	9	0	4
APR	94	76	46	23	0.2	0.7	#	#	S	7	49	41	22	27	.15	4450	1	#	0	0	2	#	1	11	1	0	4
MAY	103	85	54	31	0.3	1.8	0	0	S	7	57	39	19	32	.18	4450	2	#	0	0	3	0	8	26	#	0	3
JUN	107	94	64	44	0.6	1.9	0	0	S	6	55	42	20	42	.27	4450	3	#	0	0	6	#	24	30	0	0	3
JUL	108	94	68	55	1.1	1.4	0	0	S	6	47	58	30	54	.42	4250	7	#	0	0	11	#	25	30	0	0	5
AUG	104	93	67	56	1.0	0.9	0	0	S	5	43	60	31	54	.42	4200	6	#	0	0	10	#	24	31	0	0	4
SEP	102	87	60	38	1.1	2.1	0	0	S	5	45	58	31	47	.32	4300	4	1	0	0	4	1	12	26	0	0	3
OCT	92	77	48	30	0.8	0.9	0	0	S	4	45	59	32	38	.23	4350	3	1	0	0	2	1	#	12	#	0	3
NOV	81	63	34	12	0.3	1.2	#	4	SE	5	41	58	33	27	.15	4450	2	#	#	#	#	1	0	#	13	0	3
DEC	75	56	28	2	0.4	0.9	1	7	N	5	42	66	41	24	.13	4450	3	#	1	#	#	1	0	0	22	0	4
ANN	108	75	47	-11	7.0	2.1	4	7	S	6	67	54	30	35	.20	4450	38	2	3	#	39	8	94	167	82	#	4
EYR	21	21	21	21	21	21	18	18	23	23	13	23	23	23	23	18	21	21	18	18	19	19	21	21	21	21	20

REMARKS

RUSSWO POR: Hourly Obs: Sep 42-Feb 46, May 46-Nov 65
Daily Obs: Sep 42-Feb 46, May 46-Oct 64

NOTE; *DATA NOT AVAILABLE. #LESS THAN 0.5 DAY, 0.5 OR 0.05 INCH, OR 0.5 PERCENT (%) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CIG less than 3000 feet and/or VSBY less than 3 miles	00-02	4	2	1	1	#	#	#	#	1	1	1	3	1	21
	03-05	4	3	1	1	0	#	#	#	1	1	1	4	1	21
	06-08	5	3	2	#	#	#	#	#	1	1	2	4	2	23
	09-11	6	4	3	1	#	#	#	#	2	1	[illegible]	4	2	23
	12-14	6	4	5	3	1	#	1	0	1	1	2	4	2	23
	15-17	4	4	7	5	2	1	#	#	1	1	2	2	2	23
	18-20	3	2	4	4	2	1	1	#	1	#	1	3	2	22
	21-23	4	2	2	2	#	1	#	#	1	1	1	2	1	22
	ALL HOURS	5	3	3	2	1	#	#	#	1	1	2	3	2	
CIG less than 1500 feet and/or VSBY less than 3 miles	00-02	3	2	1	1	#	#	#	#	#	1	1	1	1	21
	03-05	3	1	1	1	0	#	#	#	#	1	1	2	1	21
	06-08	3	2	1	#	#	#	0	0	1	1	1	3	1	23
	09-11	4	3	3	1	#	0	#	#	1	#	1	3	1	23
	12-14	3	3	4	3	1	#	#	0	1	1	1	2	2	23
	15-17	3	3	6	5	2	1	#	#	1	1	1	2	2	23
	18-20	2	2	4	4	2	1	1	#	#	0	1	2	2	22
	21-23	2	1	2	2	#	1	#	#	1	#	1	1	1	22
	ALL HOURS	3	2	3	2	1	#	#	#	#	1	1	2	1	
CIG less than 1000 feet and/or VSBY less than 2 miles	00-02	2	1	#	#	#	#	#	#	#	#	#	1	#	21
	03-05	2	1	1	1	0	#	#	#	#	#	#	2	1	21
	06-08	2	2	1	#	0	#	0	0	1	1	1	3	1	23
	09-11	3	2	2	#	#	0	#	#	#	#	1	2	1	23
	12-14	2	2	2	2	1	0	#	0	#	1	1	2	1	23
	15-17	2	2	4	3	2	1	#	#	#	#	1	1	1	23
	18-20	1	1	3	3	1	1	1	#	#	0	#	1	1	22
	21-23	1	1	1	1	#	1	#	0	#	#	#	1	1	22
	ALL HOURS	2	1	2	1	1	#	#	#	#	#	1	2	1	
CIG less than 200 feet and/or VSBY less than ½ mile	00-02	#	#	0	#	0	0	0	0	0	0	0	1	#	21
	03-05	#	#	0	#	0	#	0	0	#	0	#	1	#	21
	06-08	1	1	#	#	0	#	0	0	#	#	#	1	#	23
	09-11	1	#	#	#	0	0	0	0	0	0	#	1	#	23
	12-14	#	#	1	#	#	0	0	0	0	#	#	#	#	23
	15-17	#	#	1	1	#	#	0	0	0	0	#	#	#	23
	18-20	#	#	1	#	#	#	0	#	#	0	0	1	#	22
	21-23	0	#	0	#	0	#	0	0	0	0	0	#	#	22
	ALL HOURS	#	#	#	#	#	#	0	#	#	#	#	1	#	

TABLE 7 Carrizozo Weather

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

In Cooperation with the UNM Bureau of Business Research

LATITUDE: 33° 39' N
LONGITUDE: 105° 53' W
ELEV. (GROUND): 5438 Ft.

CLIMATOLOGICAL SUMMARY

STATION: CARRIZOZO NEW MEXICO

MEANS AND EXTREMES FOR PERIOD OF RECORD: 1930 - 1960

	Temperature (°F)								Precipitation Totals (Inches)								Mean number of days					
	Means			Extremes								Snow, Sleet						Temperatures				
																		Max.		Min.		
Month	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Mean degree days **	Mean	Greatest daily	Year	Mean	Maximum monthly	Year	Greatest daily	Year	Precip. .10 inch or more	90° and above	32° and below	32° and below	0° and below	Month
(a)	30	30	30	30	--	30	--	30	30	30	--	30	30	--	30	--	30	30	30	30	30	(a)
Jan.	50.9	23.3	37.0	73	1953	- 4	1948	870	0.67	1.28	1941	2.9	19.0	1936◆	6.0	1936◆	2	0	1	27	*	Jan.
Feb.	55.9	25.9	40.9	78	1935	- 5	1951	670	0.71	1.09	1940	2.5	12.0	1931	7.0	1948	2	0	1	23	*	Feb.
Mar.	61.8	31.1	46.4	86	1934	10	1948+	580	0.79	1.05	1953	1.9	12.0	1932	6.0	1932	2	0	*	18	0	Mar.
Apr.	71.3	38.6	55.0	92	1936◆	15	1936	300	0.63	1.16	1931	0.8	10.0	1949	6.0	1949	2	0	0	8	0	Apr.
May	79.6	47.3	63.5	98	1951	24	1944	90	0.86	1.60	1954	T	T	1944+	T	1944+	2	2	0	*	0	May
June	89.2	58.2	72.7	104	1930	37	1955	0	1.19	1.11	1943	0	0	--	0	--	3	16	0	0	0	June
July	90.4	60.5	75.3	110	1930	48	1934	0	2.32	2.23	1938	0	0	--	0	--	6	19	0	0	0	July
Aug.	88.5	59.2	73.8	102	1930	48	1944	0	2.32	2.28	1932	0	0	--	0	--	8	15	0	0	0	Aug.
Sept.	83.3	52.8	68.0	100	1945	35	1957+	30	1.83	3.52	1941	T	T	1945	T	1945	4	6	0	0	0	Sept.
Oct.	72.8	41.8	57.2	88	1947+	19	1945	250	1.00	1.85	1931	0	0	--	0	--	3	0	0	4	0	Oct.
Nov.	59.8	28.1	43.9	79	1950	2	1938	830	0.57	0.92	1941	1.0	8.5	1934	4.5	1934	2	0	0	22	0	Nov.
Dec.	52.5	23.4	38.0	72	1939	- 3	1953	840	0.73	1.03	1931	2.3	17.2	1931	8.5	1959	2	0	1	27	*	Dec.
Year	71.3	40.7	56.0	110	July 1930	- 5	Feb. 1951	4260	13.82	3.52	Sept. 1941	11.4	19.0	Jan. 1936	8.5	Dec. 1959	36	58	3	127	*	Year

* Less than one half.
** Base 65° F (estimated).
(a) Average length of record, years.

T Trace, an amount too small to measure.
\+ Also on earlier dates, months, or years.
◆ Partial year's record considered.

CLIMATE OF CARRIZOZO, NEW MEXICO

Carrizozo is the county seat of Lincoln County in south-central New Mexico. The city is situated in the northwestern section of the county and the northern end of the Tularosa valley, a closed basin extending southward to the Texas plains. A few miles to the east are the foothills of the Sierra Blanca and Capitan mountains--the eastern border of this portion of the basin. Some 25 miles to the west the Sierra Oscura hills form the western border of the northern end of the valley. The city is served by the Southern Pacific Railroad and is at the crossroads of U.S. Highways 380 and 54. The surrounding country is primarily a ranching area.

Weather records, which began in Carrizozo in 1908, have been fairly continuous since then. This summary includes only the last complete 30 years of record, excluding the partial year of 1936. The available records for 1936 were used in determining extreme values.

Carrizozo has a semiarid, continental climate. Summers are moderately warm, with maximum temperature exceeding 90° about half the time from June through August. During most summers the high temperature exceeds 100° on a few days. The elevation and generally dry, clear air favor rapid cooling at night; and summer minima usually fall to the low 60s in the warmer summer months. More than 60 per cent of the yearly precipitation normally falls during the June-October period, most of it coming during brief but occasionally heavy thundershowers. During the warmer summer months these showers, usually occurring in the afternoon or early evening, greatly relieve the summer heat. Hail accompanies some storms, but only minor damage results, for there is little agriculture in the area. Small tornadoes have been reported in the area; but they, too, have caused little damage.

Winters are mild and considerably drier than summers. From November through May an average of only two days a month gets as much as 0.10-inches of moisture. Daytime winter temperatures usually range from the mid-40s to the mid-50s, with an average of only three days experiencing shade temperatures under the freezing mark. Freezing temperatures can be expected at night from early November to the latter part of March, but only 12 days in 30 years had low readings of zero or below. Much of the midwinter precipitation comes as snow, but falls of six inches or more are rather rare, and snow seldom lies on the ground for more than a few days.

Relative humidity at Carrizozo averages about 45 per cent for the year. During the cool morning hours humidities range from near 50 per cent in dry spring months to near 65 per cent during the summer, when showers are more prevalent. The relative humidity falls rapidly as temperatures rise during the day, generally averaging close to 20 per cent during the warmer spring hours and around 30 per cent during the heat of the day in midsummer. Sunshine can be expected more than 75 per cent of the possible hours of the year. Fall and spring months are especially sunny, with many months having sunshine more than 90 per cent of the daylight hours. Wind records are not available for Carrizozo, but the average hourly velocity for the year probably is around 12 miles per hour. Spring months are windiest, and occasionally during late winter and spring moderately strong winds cause some blowing dust. Carrizozo has an average growing season of 192 days. The average date of the last freeze is April 17; the average date of the first freeze is October 26.

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Albuquerque, New Mexico

TABLE 8 Average Crack Length (in.)

Bldg.	Boom	No Boom	Total	Avg.	3-1 -65	5-20 -65	2-25 -72
	1-15 to 2-10-65						
W-2	22.84	25.93	48.77	24.38	18.06	18.02	26.60
W-3	5.68	23.37	29.05	14.53	7.66	19.04	28.27
W-4	12.08	15.25	27.33	13.67	5.40	23.54	42.55
2S-5(1)	15.47	15.10	30.57	15.29	24.73	29.96	38.53
2s-5(2)	13,69	15.91	29.60	14.95	37.00	26.91	35.23
PF-6	13.50	32.66	46.16	23.08	37.30	15.25	31.89
TOTAL	83.26	128.22		105.90	130.15	132.72	203.07

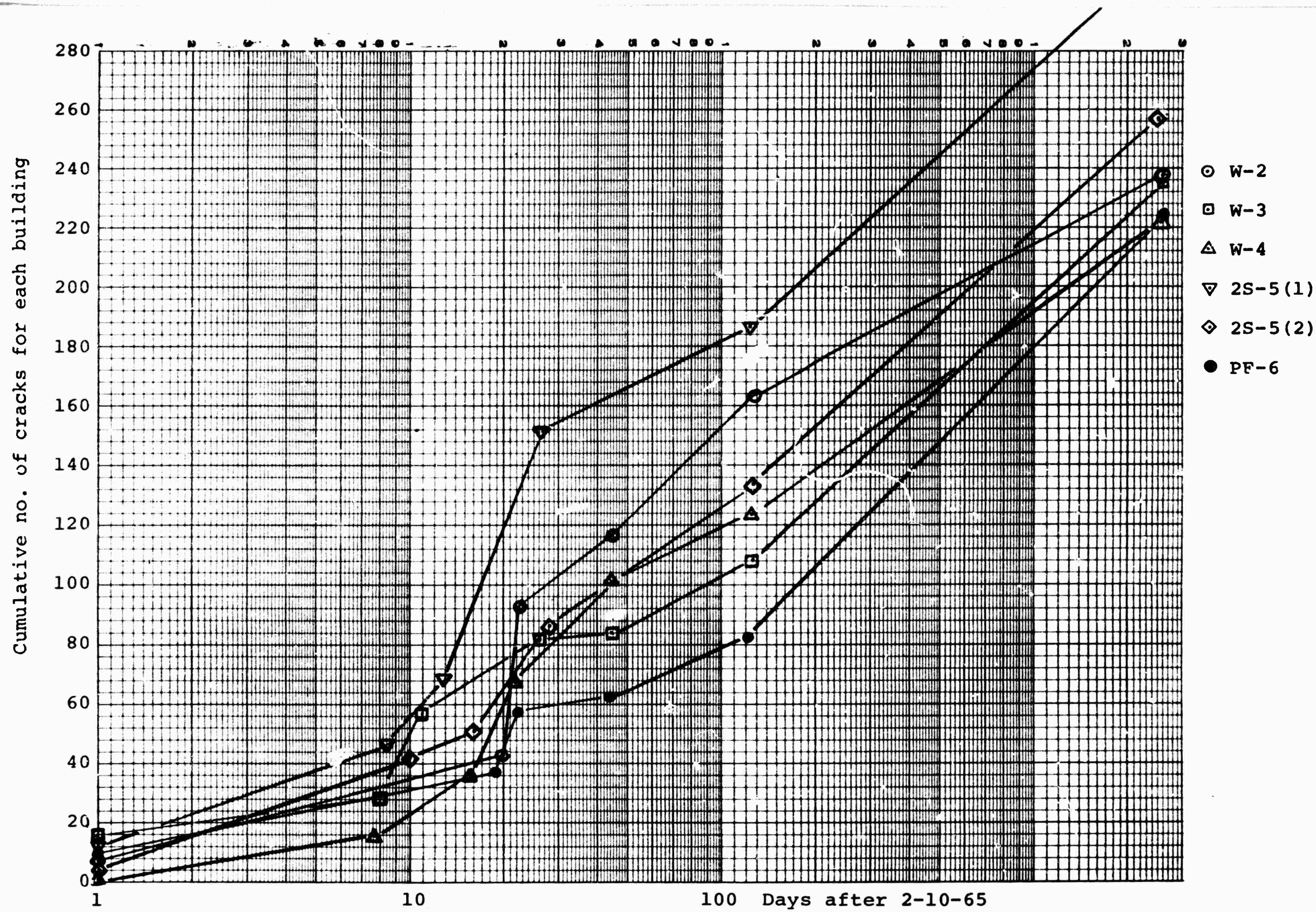

Fig. 53 Cumulative Damage Plotted only for Inflection Points

cause further damage, one would expect at some overpressure level the slope increase over and above that caused by the drying and settlement processes. This slope increase is obvious for each of the "buildings". However, in order to identify any real effects we plotted the average cumulative number of cracks for all the buildings along with temperature differential (Fig. 54). Slope increase is obvious on days of increasing temperature differential as well as overpressure increase. These data infer that cumulative damage is indeed difficult to identify as a function of boom strength and number. However, the greater slope of the curve in the post-boom periods suggests strongly that natural deterioration conditions far outweigh boom influences regarding cumulative damage.

D. RECOMMENDATIONS

1) Further, in-depth analysis of the data is required to identify more closely the influence of sonic boom on cumulative damage.

2) A program conducted at the Oscura Range Camp with explosives, if not sonic booms, or similar new as well as these existing structures may be required in order to pinpoint cumulative damage effects on structures.

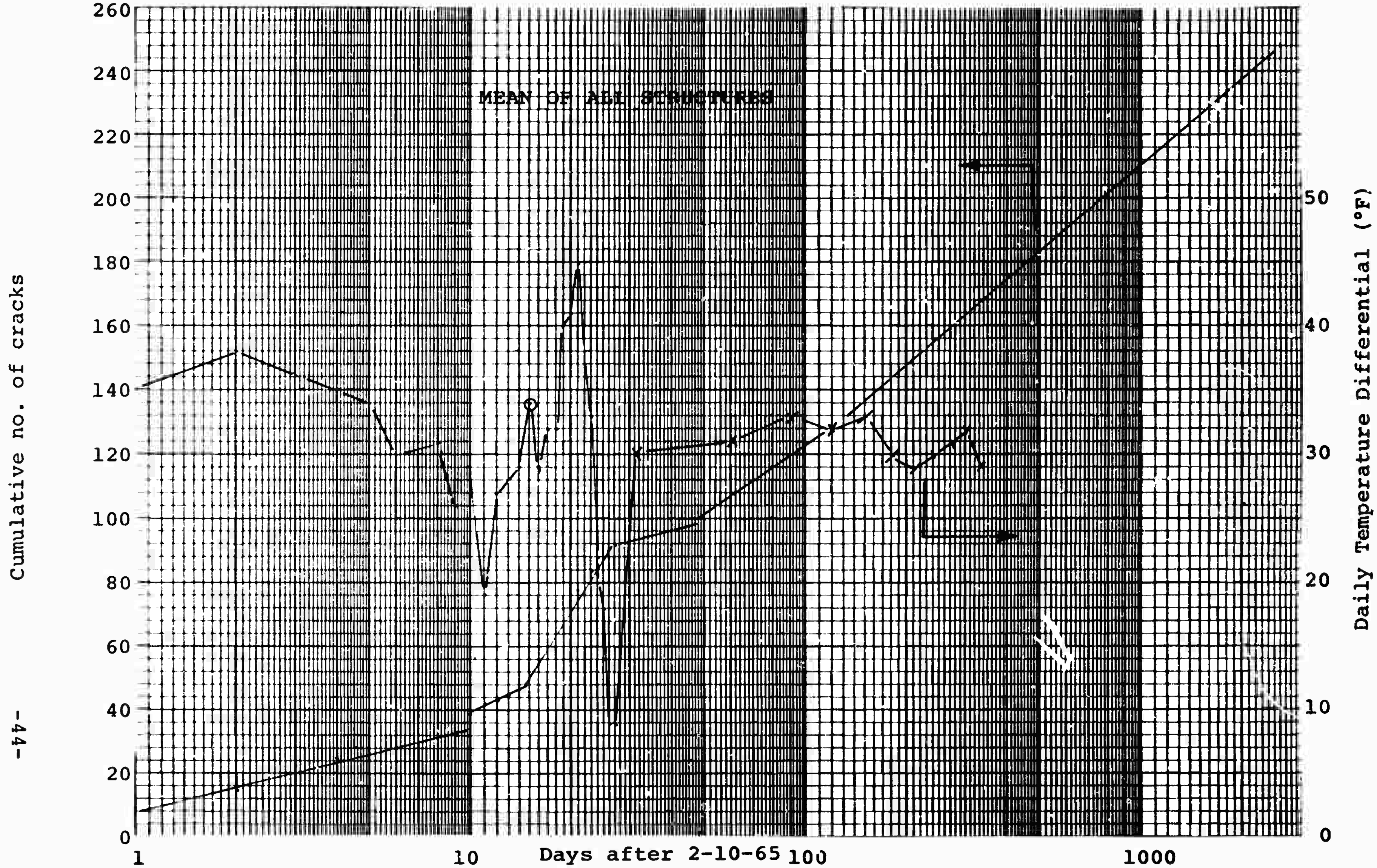

Fig. 54 Mean Crack Rate for All Structures Correlated with Temperature Differentials