DNA 2729I

URS 788-2

March 1972



# Assessments of House Damage from Event Dial Pack and 100 ton AN/FO Test

Interim Report

Prepared by: C. Wilton, URS Research Company

Prepared for:

DEFENSE NUCLEAR AGENCY
WASHINGTON, D.C.

Contract No. DASA 01-70-C-0011

This work sponsored by the Defense Nuclear Agency under NWER Subtask NA 007.



urs research company

URS

UNCLASSIFIED
Security Classification

# DOCUMENT CONTROL DATA - R & D

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author)<br>URS RESEARCH COMPANY, 155 Bovet Rd, San Mateo, Calif. | 2a. REPORT SECURITY CLASSIFICATION<br>Uncl<br>2b. GROUP |

3. REPORT TITLE

ASSESSMENTS OF HOUSE DAMAGE FROM EVENT DIAL PACK AND 100-TON AN/FO TEST

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim Report

5. AUTHOR(S) (First name, middle initial, last name)

C. Wilton

| | | |
|---|---|---|
| 6. REPORT DATE<br>March 1972 | 7a. TOTAL NO. OF PAGES<br>54 | 7b. NO. OF REFS<br>3 |

| | |
|---|---|
| 8a. CONTRACT OR GRANT NO.<br>DASA 01-70-C-0011<br>b. PROJECT NO.<br>NWER XAXN<br>c.<br>Task and Subtask Code A007<br>d. Work Unit Code 15 | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>URS 788-2<br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)<br>DNA 2729I |

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

| | |
|---|---|
| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY<br>Defense Nuclear Agency<br>Washington, D.C. 20305 |

13. ABSTRACT

This report summarizes the damage sustained by a two-story wood-frame house exposed to a peak incident overpressure of about 1.6 psi from the explosion of a hemispherical charge of Ammonium Nitrate/Fuel Oil (AN/FO) weighing 100 tons, and - after being moved and repaired - to a peak incident overpressure of about 2.7 psi from the explosion of a 500-ton spherical charge of TNT tangent to the ground surface (Event Dial Pack). A moderate amount of damage (including considerable roof rafter damage) was noted after the AN/FO test; considerably more damage (including breakage of all roof rafters) was noted after the Dial Pack test. Preliminary application of a quantitative method for comparing damage (which must be further refined) indicates that damages after the AN/FO test represented about 23% of the original value of the house, while damages after the Dial Pack test represented about 37% of the original value of the house.

Future reports will deal with comparisons of damage sustained by this house, and others similar to it, during a number of both high-explosive and nuclear tests.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| HIGH EXPLOSIVE FIELD TRIALS | | | | | | |
| STRUCTURAL RESPONSE TO AIRBLAST | | | | | | |
| AIRBLAST | | | | | | |
| RESIDENTIAL STRUCTURES | | | | | | |

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# CONTENTS

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This report summarizes the damage sustained by a two-story wood-frame house exposed to a peak incident overpressure of about 1.6 psi from the explosion of a hemispherical charge of Ammonium Nitrate/Fuel Oil (AN/FO) weighing 100 tons, and - after being moved and repaired - to a peak incident overpressure of about 2.7 psi from the explosion of a 500-ton spherical charge of TNT tangent to the ground surface (Event Dial Pack). A moderate amount of damage (including considerable roof rafter damage) was noted after the AN/FO test; considerably more damage (including breakage of all roof rafters) was noted after the Dial Pack test. Preliminary application of a quantitative method for comparing damage (which must be further refined) indicates that damages after the AN/FO test represented about 23% of the original value of the house, while damages after the Dial Pack test represented about 37% of the original value of the house.

Future reports will deal with comparisons of damage sustained by this house, and others similar to it, during a number of both high-explosive and nuclear tests.

# INTRODUCTION

The specific objective of this program was to assess the damages sustained by a test house as a result of the detonation of a 100-ton Ammonium Nitrate/Fuel Oil (AN/FO) event and the 500 ton TNT Dial Pack event.

This program was sponsored by the Defense Nuclear Agency under contract number DASA 01-70-C-0011. A limited amount of instrumentation on event Dial Pack was funded by the Office of Civil Defense (OCD) under SRI Subcontract 12671 (6300A-290).

This investigation was one of a series conducted in recent years to obtain data on the damage sustained by test houses exposed to the blast overpressure from charges ranging in size from 10,000 lb to 500 tons. Previous tests in this series have included:

- Two tests at the Naval Weapons Center (NWC), China Lake (Reference 1), one of which used a single 10,000 lb hemispherical charge which yielded an overpressure of 0.9 psi at the test house and one which used two 5,000 lb hemispherical charges detonated 24 msec apart with 1.1 psi at the test house;

- The 500 ton TNT Prairie Flat event in which the test house was exposed to approximately 1.1 psi (Reference 2).

The basic purpose of these tests was to gain experimental test data to aid in the verification of quantity-distance regulations for the separation of potential explosion sources from sites to be protected. For many years, these regulations have been based on empirical data derived from accidental explosions. These data are also being used in studies for the Office of Civil Defense to determine the blast resistance of existing structures.

## DESCRIPTION OF TEST HOUSE

The test house (Figure 1) was a conventional two-story wood frame house, 33 ft 7 in. long by 24 ft 8 in. wide with full basement and a gabled roof. It was originally built for the Prairie Flat test. The exterior walls were covered with wood siding and it had an asphalt shingle roof. This house was similar to the ones used in the Nevada nuclear weapons tests and was constructed in accordance with the Office of the Chief of Engineers, Department of the Army, Drawing No. 60-08-45, revised July 23, 1959. This was an unstrenthened house with no deliberate attempt to improve its resistance to blast.

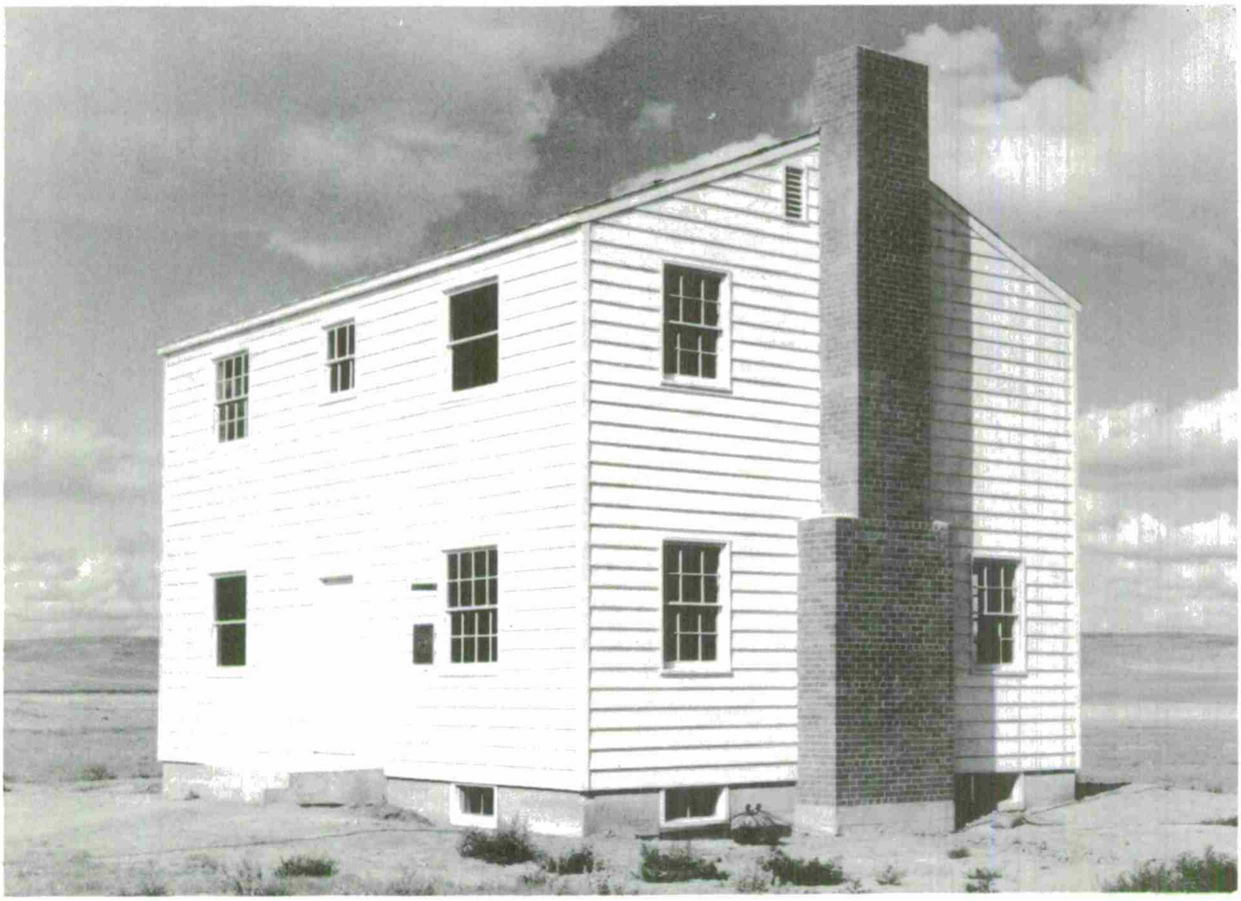

Fig. 1. Two-Story Test House

## AMMONIUM NITRATE/FUEL OIL TEST

### DESCRIPTION

This test was conducted at the Defence Research Establishment, Suffield, Ralston, Alberta, Canada, in July 1969. The test house was located 1,660 ft from a 100 ton hemispherical Ammonium Nitrate/Fuel Oil (AN/FO) charge.* A floor plan of the house is shown in Figure 2. Note in this figure that the long axis of the house was not perpendicular to a line from ground zero.

This house was heavily damaged during the previous Prairie Flat event and was repaired prior to this test. Repairs included replacement of a major portion of the roof, installation of new plaster in an upstairs bedroom and the upstairs hall, repair of several doors and door frames, and replacement of all broken or damaged windows. Minor plaster cracks and the like were not repaired but were noted in a pretest damage survey.

### INSTRUMENTATION

Instrumentation used for this test consisted of:

- Two Ballistic Research Laboratory (BRL) self-recording air blast gages located 50 ft from the south side of the house to monitor the overpressure received by the house
- Two motion picture cameras, one located in the living room and viewing the west part of the south wall, and the second in the attic and viewing the center portion of the underside of the west roof
- Seven maximum displacement (scratch) gages installed at mid-points of selected rafters (Figure 3)**
- Four styrofoam glass traps installed as shown in Figure 2 to obtain glass fragment data**
- An array of ping pong balls placed in the living room to gather blast flow pattern information. This array is pictured in Figure 4.**

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* For a description of the charge fabrication, see Reference 3.

** To date, funds have not been made available for reduction and analysis of these data.

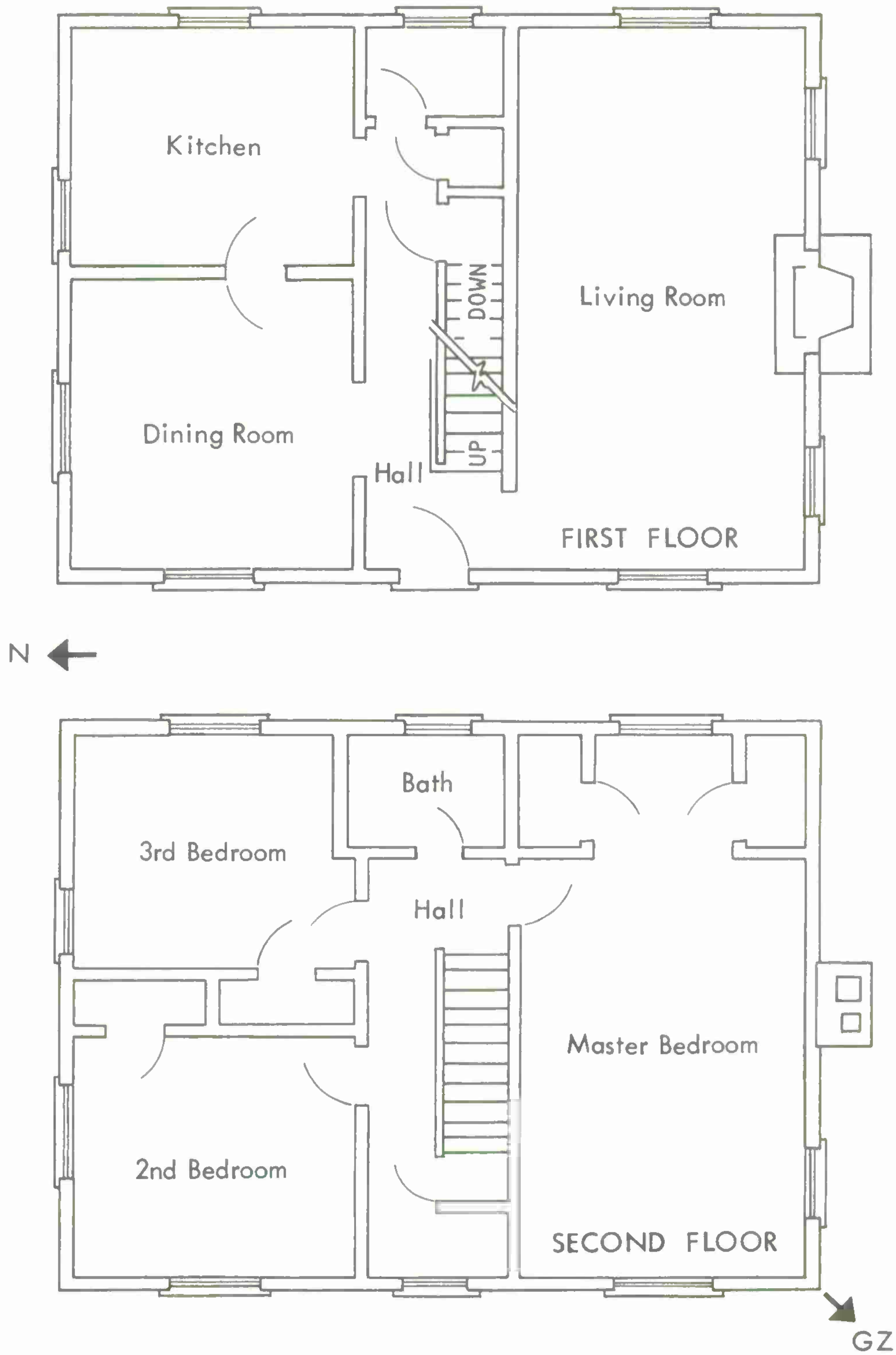


Fig. 2. Floor Plan of Test House

Fig. 3. Maximum Displacement Gage Installed in Attic

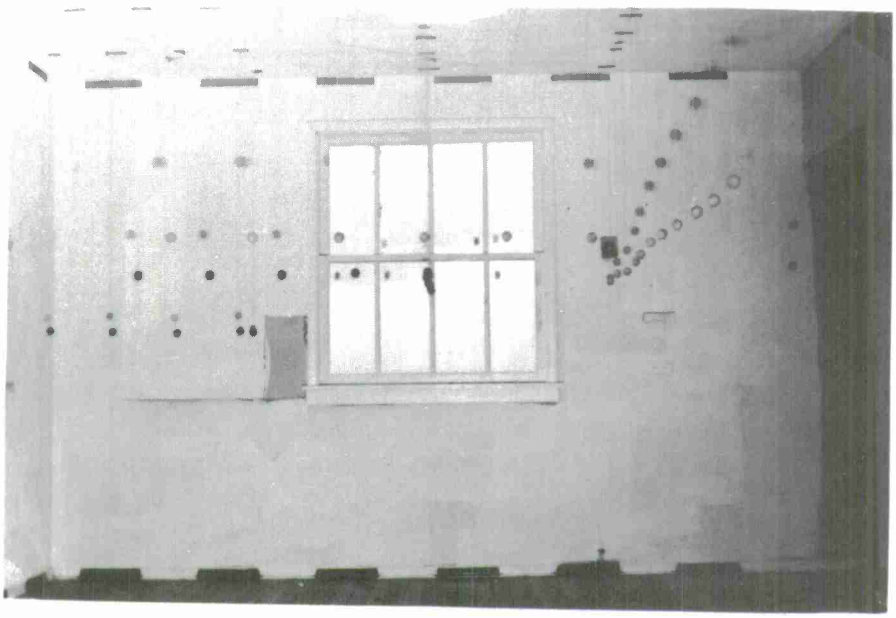

Fig. 4. Ping Pong Ball Array in Living Room

# RESULTS

## Pretest Survey

A comprehensive pretest damage survey was conducted to determine the condition of the house after the repairs were completed and to ascertain the extent of hidden damage which would affect the results of the test.

Minor plaster cracks were noted throughout the house. Especially numerous were those around the windows and over the doorways. Examples of these are shown in Appendix A, Figures A-1 and A-2. More severe plaster cracks were found in the front wall of the house near the bottom corner of the windows. See Figures A-3 and A-4 (photographs of the lower left corner of the front windows of the north and south bedrooms). Upon removal of small sections of the plaster and sheetrock in these areas, it was found that the vertical studs (2 by 4's) were cracked at this point (see Figures A-5 and A-6). No further unrepaired damage was noted.

## Posttest Survey

The peak overpressure as measured by the BRL gages positioned near the house was 1.6 psi. Damage to the test house was similar to that recorded on the Prairie Flat test and consisted of the following:* window glass and window frame failure in the front and sides of the house; ceiling failure in the upstairs bathroom and south rear bedroom; failure of 19 out of 24 roof rafters on the front side of the roof (toward the blast), failure of 2 rafters on the backside of the roof, and failure of 5 out of 8 crossties. The front door was torn off its hinges and the frame was almost completely removed. The house was found to be approximately 3/8 in. out of plumb after the test. A list of the damage is presented in Table I.**

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* See also Figures A-7 through A-18 in Appendix A.

** For room locations, please refer to Figure 2.

Table I

HOUSE DAMAGE AN/FO TEST

| Location | Damage | Photo No. |
|---|---|---|
| Third Bedroom | | |
| West wall | None | |
| North wall | Minor plaster cracks | |
| East wall | Window moulding broken (south side) and window frame pushed in slightly - 2 panes broken | |
| South wall | Door which was closed prior to test was torn off hinges and carried approximately 4 ft into room | |
| Ceiling | Extensive damage. 90% of ceiling sheetrock blown downward. No ceiling joist damage | A-7, A-8 |
| Second Bedroom | | |
| West wall | All panes in window broken and frame badly damaged. Additional plaster and sheetrock removed. No additional stud damage beyond that noted in the pretest survey | A-9 |
| North wall | Minor plaster cracks. Stop on west side window cracked. | |
| East wall | None | |
| South wall | None | |
| Ceiling | None | |

Table I (Continued)

| Location | Damage | Photo No. |
|---|---|---|
| <u>Upstairs Hall</u> | | |
| West wall | All windowpanes broken. Frame broken and two mullions removed | |
| North wall | None | |
| East wall | None | |
| <u>Master Bedroom</u> | | |
| West wall | All windowpanes broken, plaster and sheathing torn loose under window | |
| South wall | Window frame torn loose and carried to north wall, destroying glass trap. Two studs broken on east side of window frame and one stud broken 16 in. west of window opening | A-10 |
| North wall | None | |
| East wall | All windowpanes broken, several mullions removed | A-11 |
| Ceiling | None in bedroom, damaged in closet north side | |
| <u>Upstairs Bath</u> | | |
| West wall | Broken lock set and door partly open | |
| North wall | None | |
| East wall | None | |
| South wall | None | |
| Ceiling | 80% of ceiling sheathing blown downward. No ceiling joist damage | |

Table I (Continued)

| Location | Damage | Photo No. |
|---|---|---|
| Kitchen | | |
| North wall | Minor enlargements of plaster cracks | |
| East wall | None | |
| West wall | None | |
| South wall | None | |
| Dining Room | | |
| West wall | All windowpanes broken, section of plaster and sheathing torn off of south side of window and one stud broken | A-12 |
| North wall | Two windowpanes broken | |
| East wall | None. Glass trap torn loose from fastenings and landed against wall | A-13 |
| South wall | None | |
| Living Room | | |
| West wall | All windowpanes broken; bottom frame partitions removed from opening. Large sections of plaster and sheathing torn loose, three studs broken | A-14 |
| South wall | West window - all windowpanes broken, pieces of frame and bottom sash removed and all but one mullion missing from top sash. Large section of plaster and sheathing removed | A-15 |
| | East window - all windowpanes broken. All but two mullions removed. Top frame of lower sash broken | |
| North wall | None | |
| East wall | Three panes broken. Small holes in three others | |

Table I (Continued)

| Location | Damage | Photo No. |
|---|---|---|
| Downstairs Hall | | |
| West wall | Door torn off hinges. Considerable frame damage | A-16 |
| North wall | None | |
| Stairs | Plywood covers on side of stairs torn off | |
| South wall | Closet door pushed in approximately 1 in. Damaged lock set | |
| East wall | Bathroom door pushed open, breaking jamb and damaging lock set | |
| Attic | | |
| West side | Nineteen rafters and five crossties broken | A-17, A-18 |
| East side | Two rafters broken | |

DIAL PACK TEST

DESCRIPTION

This test was conducted at Suffield in July 1970. For this test the fireplace and chimney were removed, and the house was moved from its foundations and placed on an existing concrete pad 2,256 ft from ground zero with the back of the house toward ground zero. Note in Figure 5, a plot plan of the test site, that the house axis was not exactly perpendicular to a line from ground zero.

REPAIRS

The house had been considerably damaged during the AN/FO test series, had sustained additional damage during removal of the fireplace and chimney, and considerable plaster cracking occurred during the moving process. The majority of the pretest activity consisted of determining the extent of this damage and making repairs which included:

1. Closing the hole left by removal of fireplace and chimney. This involved replacing the 2 by 4 framing, sheathing, and cedar siding.

2. Removal of cracked and damaged plaster and broken studs and replacing them with new studs and 1/2 in. thick sheetrock in the following areas*:

    a. Living room - north and east walls

    b. Dining room - east wall

    c. Master bedroom - north and east walls

    d. Second bedroom - east wall

    e. Third bedroom ceiling

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* For room locations, please refer to Figure 2.

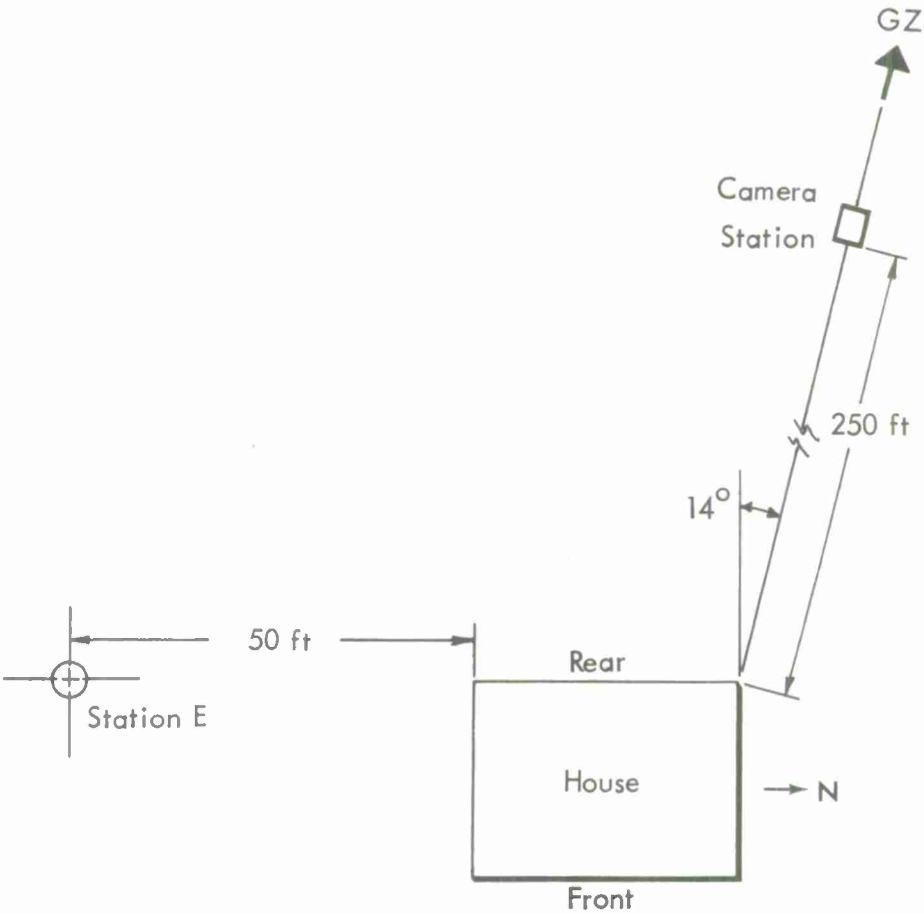


Fig. 5. Plot Plan of Test Site

3. Replacement of broken windows. A number of windows were replaced with double-strength plate glass at the request of Project LN401.

4. Repair of all broken roof rafters. A total of 21 rafters in the attic were broken. Since complete replacement of the rafters would have involved removing and replacing the roof (could not be done with available funds), these rafters were repaired by placing a new 2 by 6 rafter alongside each broken rafter and nailing them together with No. 12 nails spaced at approximately 15 in.

5. Fastening of house to concrete pad. At the sides of the house the concrete pad was approximately the same size as the house, so, 2 by 12 timbers were bolted to the concrete pad and lag bolted into the house as shown in Figure 6. At the front and back the concrete pad extended beyond the house and 4 in. by 6 in. steel angles 3/8 in. thick were bolted to the house and concrete pad as shown in Figure 7. This system worked very well since a posttest examination indicated no apparent movement of the house on the slab.

## INSTRUMENTATION

The instrumentation used for this test consisted of:

1. Three Ballistic Research Laboratory self-recording air blast gages located directly in front of the house.

2. Nine piezoelectric air pressure gages; one located 50 ft from the south side of the house (see Figure 5); four located at the front of the house (see Figure 8A and 8B), and four located in the living room of the house, two at the center of the room – one 12 in. high (gage F) and the second 48 in. high (gage G) and two behind the west wall – one directly under the window (gage H) and the second in the corner directly behind D (gage I).

3. Two high-speed motion picture cameras: one located to view the west and north side of the house (Figure 5); and the second in the living room located to view the inside of the west and north walls.

4. Glass traps placed by Project LN401.

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* Data from glass traps will be reported by E. Royce Fletcher, Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico, about January 1972.

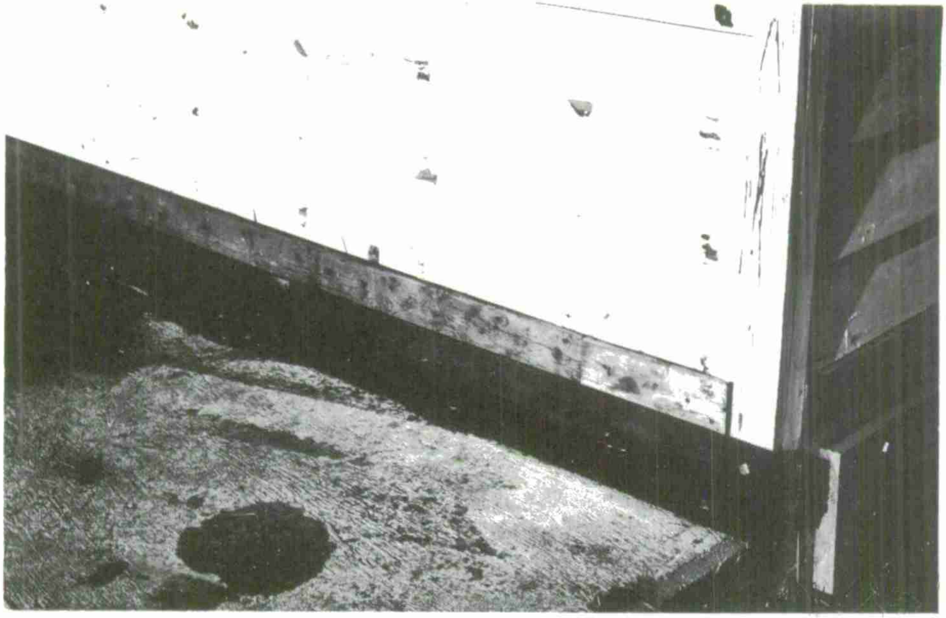


Fig. 6. Method of Fastening House to Concrete Pad, East and West Sides of House

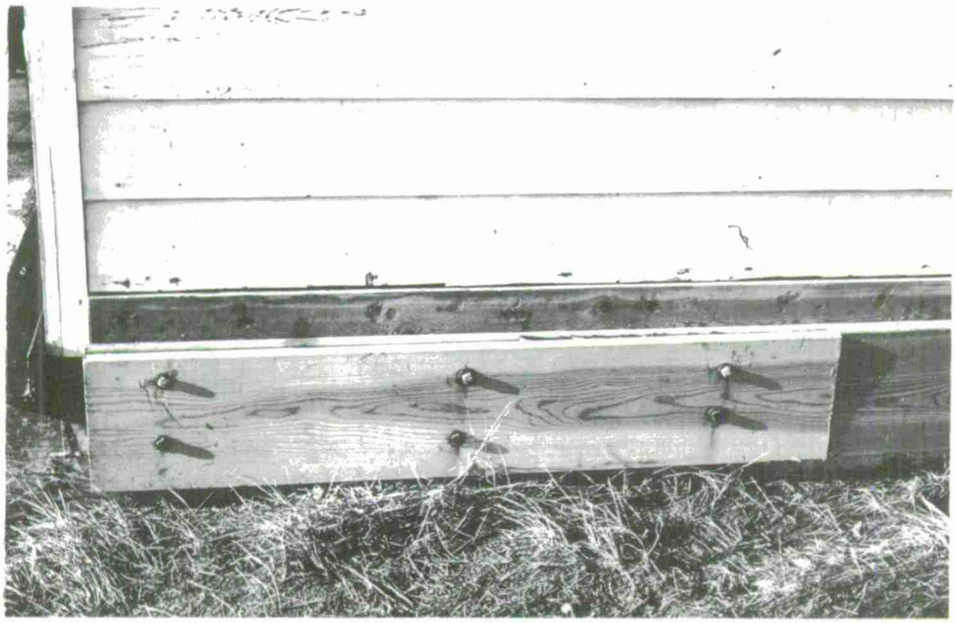


Fig. 7. Method of Fastening House to Concrete Pad, North and South Sides of House

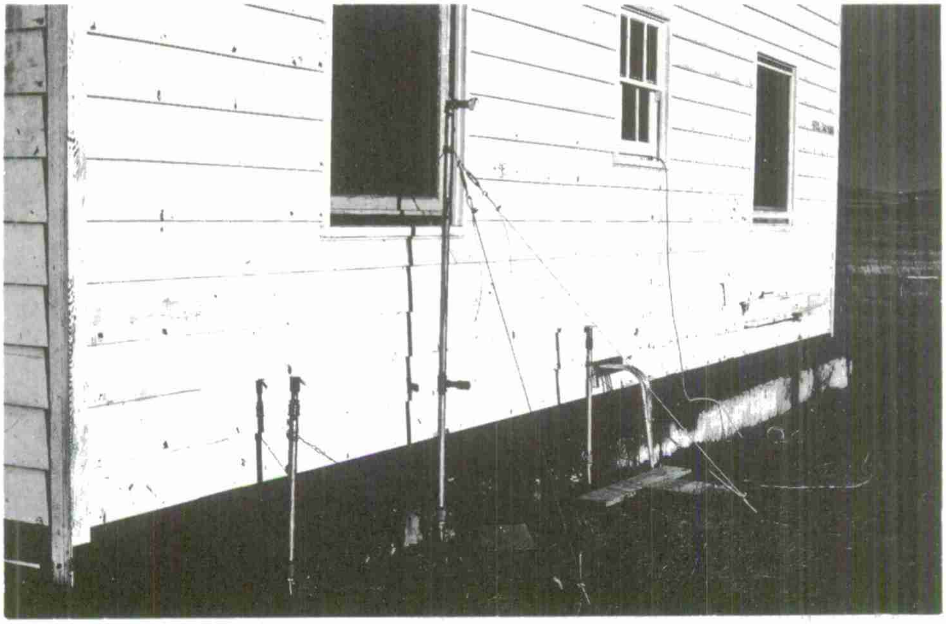


Fig. 8a. Photo of Gages, West Side of House

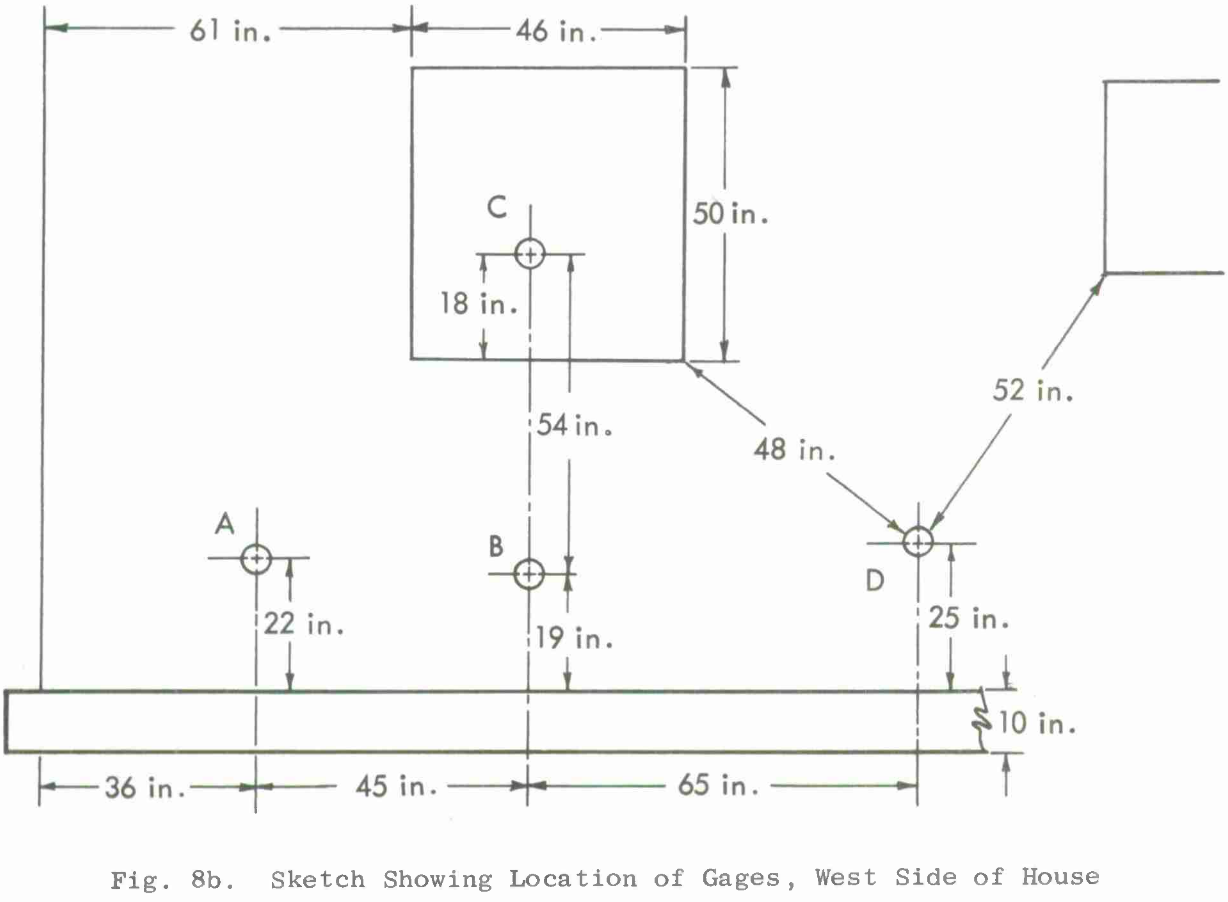



Fig. 8b. Sketch Showing Location of Gages, West Side of House

# RESULTS

## Pretest Survey

During and after the repairs were completed, a comprehensive pretest damage survey was conducted to determine the condition of the house and to ascertain the extent of hidden damage which would affect the results of the test. Some minor plaster cracks were noted in the interior walls, particularly over the doorways. Photographs and measurements were made of these so that significant changes in these cracks caused by the test could be identified.

## Posttest Survey

Pressure Data. A summary of the pressure gage data is presented in Table II. Gages A, B, and C were located along the front of the house and Gage E approximately 50 ft east of the house. Gage F was at the center of the living room 12 in. above the floor and gage G at the same location 36 in. above the floor. Gage H was on the floor directly under the window closest to the blast and Gage I was on the floor nearby in the east corner.

Table II

PRESSURE GAGE DATA

| OUTSIDE | Incident | Reflected | INSIDE | Maximum |
|---|---|---|---|---|
| A | 2.7 | 5.2 | F | 3.3 |
| B | 2.7 | 5.9 | G | 4.3 |
| D | 2.6 | 5.1 | H | 3.3 |
| E | 2.7 | | I | 2.5 |

Of particular interest for a wall geometry with a window opening is the net load as a function of time or the difference between the loading on the front of the wall and the back of the wall. This data is shown in Figure 9 for gages D and I and in Figure 10 for gages H and B. For comparison, the side-on data from gage E is presented in each figure.

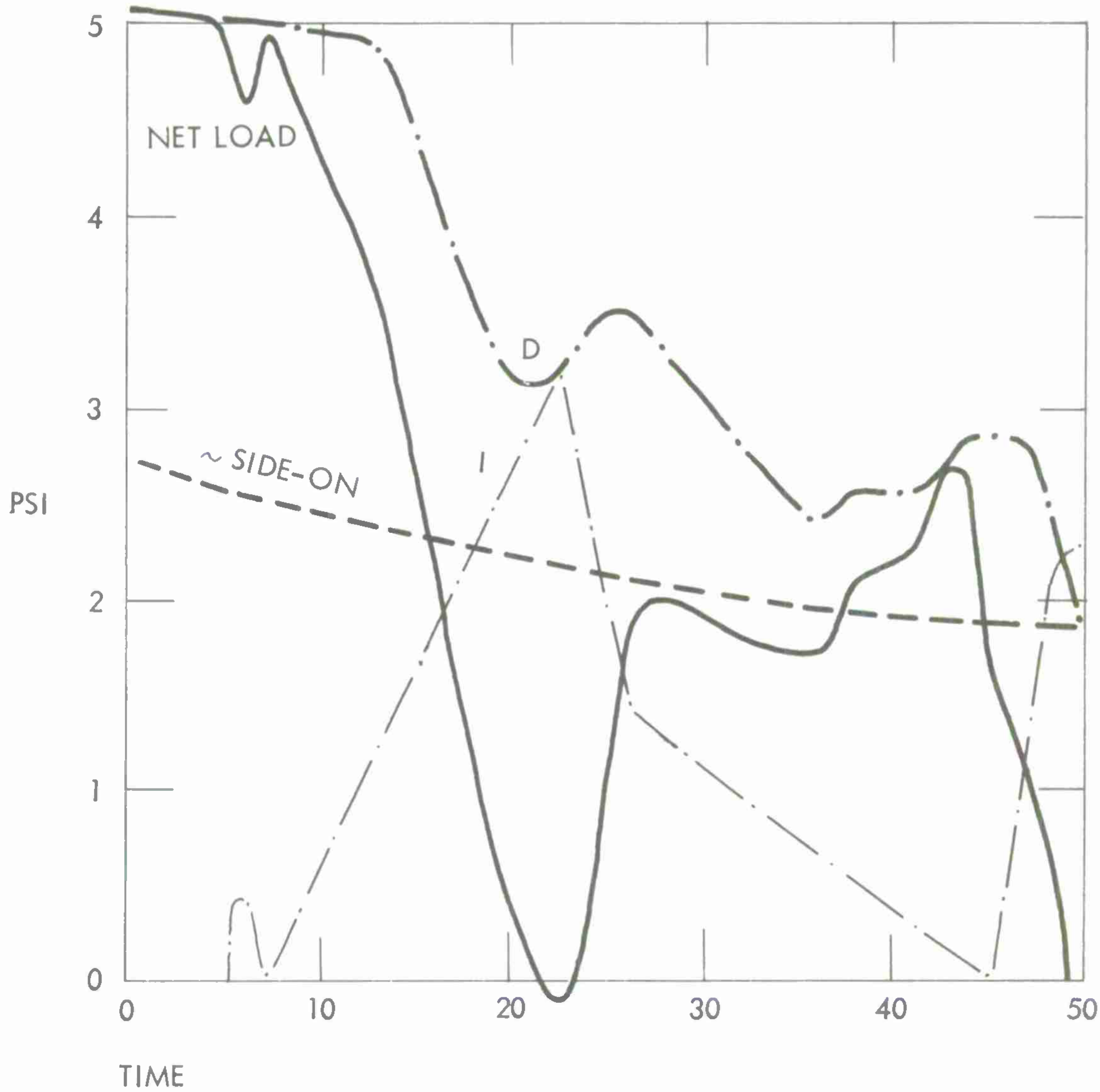



Fig. 9. Net Load and Pressure Data for Gages E, D and I

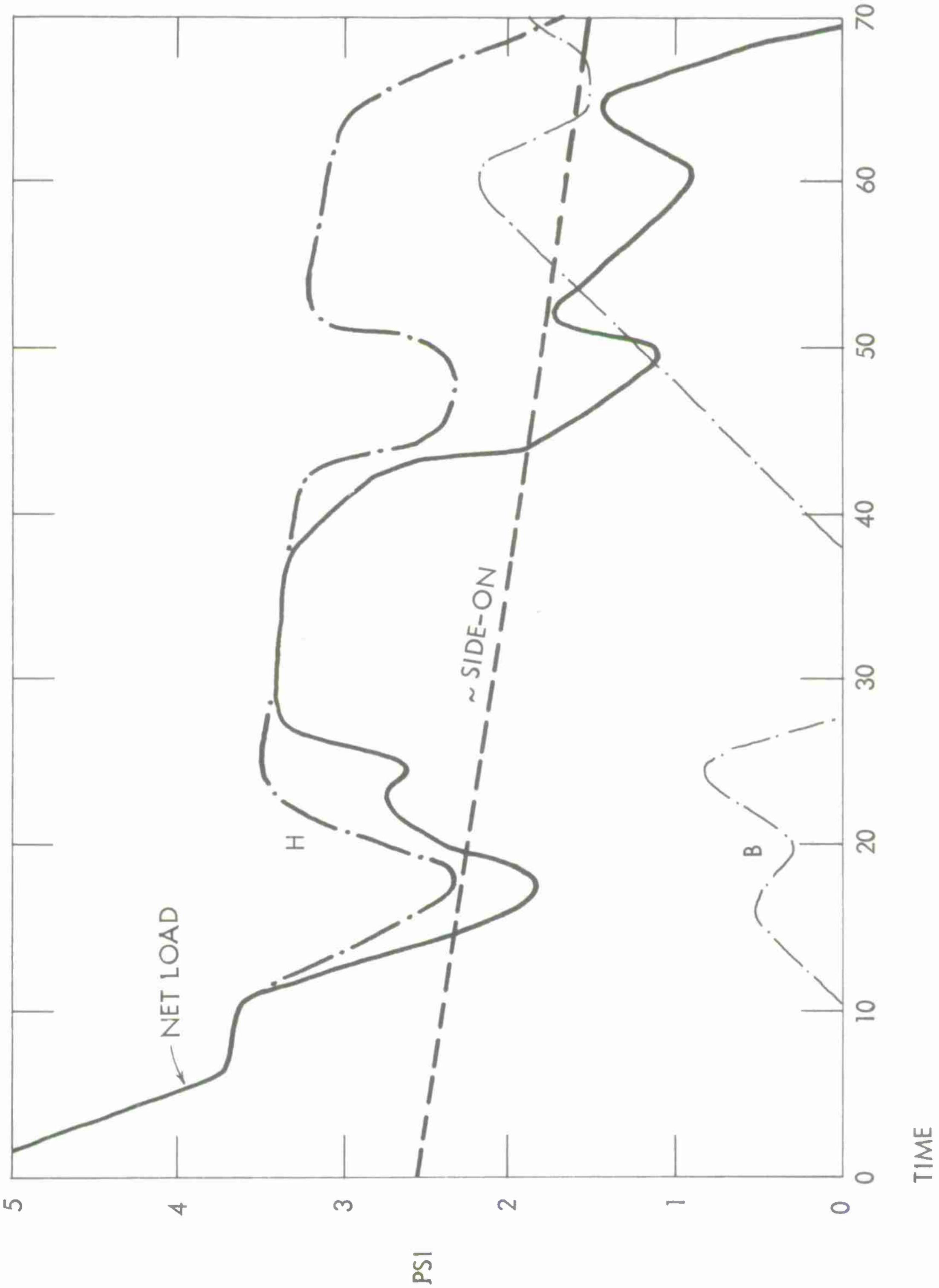



Fig. 10. Net Load and Pressure Data for Gauges E, B and H

Structural Damage. In this section, a sketch of each of the more heavily damaged rooms is presented along with a discussion of damage to the room. The arrows on the sketches indicate the following: those arrows nearest the walls show the general motion of the walls as inferred from the structural damage, those running parallel to the walls indicate shear behavior and those which are normal to the walls indicate flexural behavior. For purposes of this report, shear and flexural failure are defined as follows:

- Shear Failures - two types are considered:
  1. Shear failures in the bending of timber components such as beams, studs, and rafters indicated by horizontal splitting of the timber near the support.
  2. Shear failures of wall panels which is characterized by the formation of diagonal cracks.
- Flexural Failure - two types are considered:
  1. Flexural failure in the bending of timber beams is associated with fiber failure in the central portion of the beams which results in the splitting and splintering of the beam.
  2. Flexural failure of a plaster wall is indicated by cracks caused by deflection of the wall normal to its plane.

Living Room

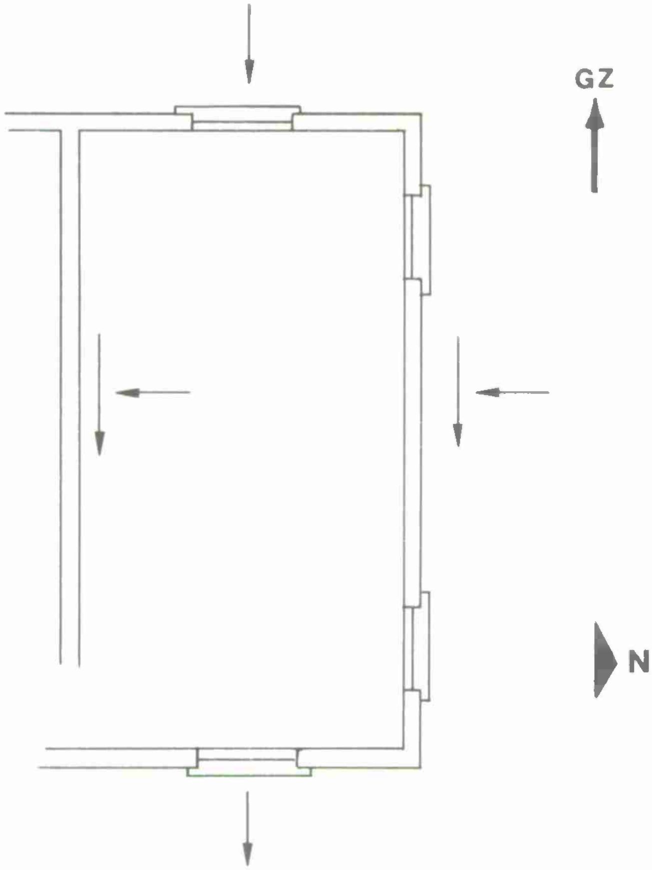
A sketch of the living room is shown below and a description of the damage to each of the walls is given in the following paragraphs.

I. East Wall

The window in the east wall was apparently blown outward and there was moderate damage to the sheetrock. Repair would require replacement of 25 percent of the sheetrock and renailing and retaping of the entire wall.

II. North Wall

Both windows were blown inward. There was failure of eighteen 2 by 4 studs out of a total of 26, all in flexure and in the inward direction. About 40 percent of the sheetrock was removed and repair would require complete




replacement (see Figures B-1 and B-2). There was indication of shear motion in the wall; i.e., motion along the seams.

III. West Wall

The window was blown inward and nine out of a total of ten studs were broken inward in flexure. Approximately 50 percent of the plaster was removed (see Figure B-3).

IV. South Wall

Three out of a total of 18 studs were broken and approximately 10 percent of the plaster was removed. There was extensive damage to the remainder consisting of both flexure cracks at joints and diagonal shear cracks.

## Dining Room

I. East Wall

The glass was blown inward and three studs were broken at the north side of the window and there was a $1\frac{1}{2}$ in. inward deformation. No sheetrock was removed; however, approximately 35 percent replacement would be required to inspect and repair the studs.

II. North Wall

Minor shear cracking occurred in the plaster, and some patching would be required.

III. West Wall

The door between the dining room and the kitchen was blown inward off its hinges and came to rest in the doorway (see Figure B-4). Several flexural cracks were noted and removal and replacement of approximately 25 percent of the plaster would be required to fix the damaged door casing, etc.

IV. South Wall

The glass was blown inward and seven out of a total of ten studs were broken inward in flexure. Approximately 20 percent of the plaster was broken inward (flexure) and considerable shear deformations were noted. Repair would require 100 percent replacement.

V. Ceiling

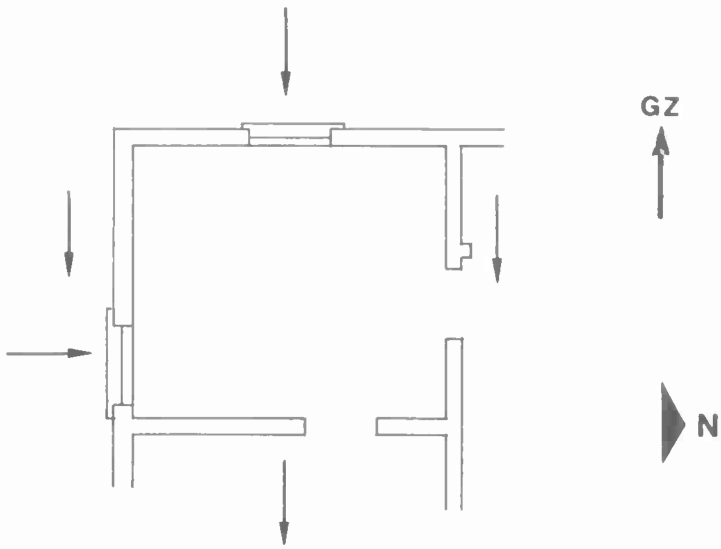
Only minor damage consisting of small cracks was noted.

## Kitchen

A sketch of the kitchen showing gross wall behavior is shown below.

I. West Wall

Heavily damaged with window blown in, 90 percent of the sheetrock removal and six of seven studs were broken (Figure B-5).




II. North Wall

Numerous shear cracks were noted and there was crushing of the plaster at the intersection of the west and north walls. Approximately 25 percent reconstruction of the wall would be required.

III. East Wall

The damage to this wall was similar to that noted for the west wall of the dining room.

IV. South Wall

The window was blown inward. Four out of a total of nine studs failed in flexure. Twenty-five percent of the plaster was blown inward and the remainder showed considerable evidence of shear failure. As a result, the entire wall would need to be replaced.

V. Ceiling

The only damage noted was minor plaster cracking.

## Entry Hall and Bath

### I. West Wall

The window and frame were blown into the bathroom. One stud on the north side of the window was broken inward in flexure and 25 percent of the plaster was blown inward.

### II. East Wall of Bathroom

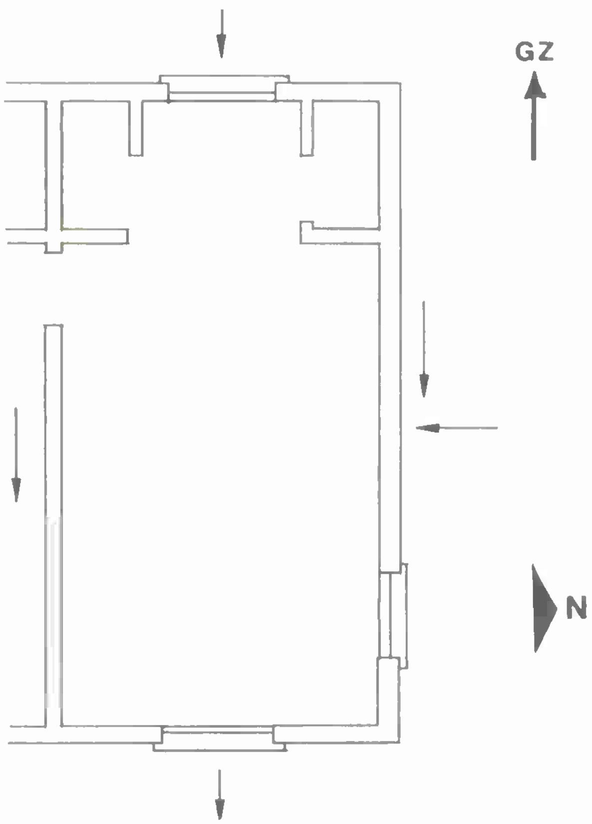
The door was blown out and landed near the front door. Only minor plaster damage (i.e., cracks) was noted.

### III. Entry Hall

The front door was blown into the house and both closet doors were damaged (Figure B-6).

## Master Bedroom

Sketched below is the master bedroom showing gross wall motion.



I. North Wall

The window was blown inward. Twelve out of a total of 21 studs were broken inward in flexure. All sheetrock was damaged severely and 75 percent was blown inward (Figure B-7). There was also evidence of shear deformation in the remaining sheetrock.

II. East Wall

The plate glass window was not broken, and was the only window remaining in the house. However, this particular location was protected by a glass trap placed by Project LN-401. Very minor damage to the sheetrock was evident.

III. South Wall

The door was left open and was undamaged. No studs were damaged. Minor crack damage in the plaster was noted and there was little evidence of shear deformation.

IV. West Wall

The window was blown inward. The only stud damage noted was the splitting of a short stud under the north corner of the window. The plaster was generally loose and would require complete replacement.

V. Ceiling

The entire plaster ceiling was blown into the room. Major pieces ranged from 16 by 48 in. to 48 by 72 in. The ceiling was constructed of 16 by 48 by 3/8 in. plaster board with expanded metal strips at the edges and at 4-ft intervals. Covering was 3/8-in. plaster. No ceiling joist damage was noted (Figure B-8).

VI. Northwest Closet

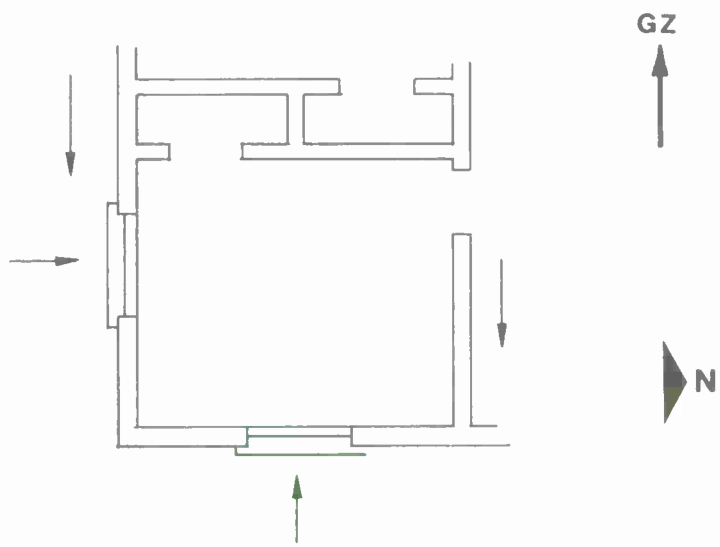
This door, which was closed prior to the test, was almost removed from its hinges and the jamb was severely damaged. One out of three studs was broken in both the north and west walls of the closet. There was complete destruction of the plaster on the north wall with 80 percent removed by the blast; extensive damage to the plaster on the west wall was noted. The entire ceiling was blown into the closet. Repair would require complete replastering of the north and west walls and ceiling.

VII. Southwest Closet

The south wall shows evidence of shear deformation and the entire ceiling was blown downward.

Second Bedroom

A sketch of the second bedroom is presented below.



I. North Wall

The door, which was closed prior to the blast, was blown off its hinges and into the room. The only other damage noted was minor plaster cracking with some evidence of shear deformation.

II. East Wall

The window was blown inward and a large quantity of glass was embedded in the glass trap. Out of a total of seven studs, only those two adjacent to the window were damaged. About 25 percent of the plaster board was damaged; however, 50 percent replacement would be required to repair the studs.

III. South Wall

The window was blown inward. Of the seven studs in this wall, two multiple studs adjacent to the windows were broken. Significant plaster damage (40 percent) in both flexure and shear was noted. This would probably require 75 percent replacement to repair both plaster and studs.

IV. West Wall

No visible damage was inflicted by the test.

V. Ceiling

The entire ceiling (plaster) was broken into the room without failure of any ceiling joists. The pieces of debris were mostly 16 by 48 in. which is the underlaying plasterboard size.

VI. Closet

The entire ceiling was blown into the closet, but no other damage was detected.

Third Bedroom

I. North Wall

Considerable plaster damage was noted, including local crushing at the intersection of the north and west walls and some shear cracking. The total plaster damage would require about a 40 percent replacement.

II. West Wall

The window was blown inward and five of the seven studs were broken in flexure. Most (75 percent) of the plaster was blown into the room, and repair would require complete replastering.

III. South Wall

The window was blown into the room. Four out of ten studs were broken in flexure. The plaster showed both flexure and shear failure and would require about 75 percent replacement (Figure B-9).

IV. East Wall

The closet door was blown into the closet. No apparent stud damage was noted and only minor plaster cracking was found.

V. Ceiling

The ceiling was completely blown into the room. Again, no damage was sustained by the ceiling joists. The major sheetrock pieces were:

Two 4 ft by 8 ft sheets
Two 4 ft by 5 ft sheets
Three 3 ft by 4 ft sheets

These were basically the pieces put up during repair. The closet ceiling was blown into the closet.

Second Floor Hall and Bath

I. Bath Area

The window on the west wall was blown inward and the door on the east wall was blown outward (easterly) and almost removed from its frame. The studs on both sides of both the window and the door failed in flexure. Although the plaster on the east wall and west wall was only moderately damaged (50 percent), repair would probably require the replastering of the entire walls.

II. Ceiling

The hall and bath ceiling area of the house was not removed but was severely damaged. It is interesting to note that, as in previous tests, the leeward portion (easterly) of the ceiling was more severely damaged than the blastward part. This type of damage was characteristic of the entire upstairs. Repairs would require the replacement of the entire ceiling on the second floor.

Roof System and Loft

All rafters on the blastward side were broken in flexure. Also, all the blastward rafters were pulled loose from the ridge, apparently in tension rather than in shear. No failure was detected in any of the leeward rafters (Figures B-10 and B-11).

All nine 2 by 4 in. crossties were removed during the failure. All rafter to tie joints failed in shear, and four of the ties were broken in flexure.

A few breaks are seen in the blastward sheathing, but they appear to have occurred after the rafter failure, i.e., as a result of excessive roof deformations.

House Exterior

I. East Wall

Some siding damage was noted at the corner of each window (Figure B-12).

II. North Wall

Some differential motion normal to the plane of the wall at a splice can be observed. This was caused by the lack of continuity in the sheathing at the fireplace patch. Continuity of the sheathing would have little effect on the extent of wall failure as the studs on both sides of the splice failed.

III. West Wall

Considerable siding damage was observed under each window in the region of stud failure (Figure B-13).

IV. South Wall

Relatively insignificant siding damage was observed under each window.

# COMPARISON OF RESULTS

In order to compare the results from this test with those from other tests in the series, it was necessary to develop a quantitative method for damage comparison.

The method developed is a cost-oriented one, and requires first that the plans for a structure being considered be examined in some detail to determine the relative costs of its various elements. Approximations were made for this house and the results are shown in Table III.

It is then possible to estimate the damage cost from the observed damage (for example, 80 percent of windows were destroyed; windows account for 6 percent of the building cost; therefore, the cost of window damage is 4.8 percent of the total building cost). A summary of the observed damage for the AN/FO test is presented in Table IV and for the Dial Pack test in Table V.

Using this method, it is estimated that for the AN/FO test the damage cost was approximately 23 percent of the original value of the house; for the Dial Pack test, the damage cost was approximately 37 percent of the original value of the house. It should be noted that these damage cost values are approximate only, and that a more accurate evaluation is now being conducted as part of a summary report on house damage which is now in preparation.

Table III

RELATIVE COST OF HOUSE ELEMENTS

| ITEM | % TOTAL COST |
|---|---|
| EXCAVATION, FOUNDATION BASEMENT | 20 |
| FLOOR JOISTS & FLOORING | 10 |
| WALL FRAMING | 11 |
| ROOF | 7 |
| EXTERIOR WALLS | 12 |
| INTERIOR WALLS | 21 |
| DOORS | 4 |
| WINDOWS | 6 |
| MISCELLANEOUS - Stairs, Fireplace, Paint, Trim | 9 |

Table IV

DAMAGE FROM DIAL PACK TEST

CHARGE SIZE - 500 ton

OVERPRESSURE - 2.7 psi (rear of house toward blast)

- WINDOWS (% destroyed)

  Front 85  Left 100  Right 100  Rear 100

- STUDS (number broken)

  Front 5  Rear 18  Northside 50  Southside 23

- ROOF RAFTERS (number broken)

  Front 2  Rear 23

- CEILING PLASTER (% destroyed)

  1st floor 0  2nd floor 100

- WALL PLASTER (% destroyed)

  1st floor 50  2nd floor 50

Table V

DAMAGE FROM AN/FO TEST

CHARGE SIZE - 100 ton

OVERPRESSURE - 1.6 psi (front of house toward blast)

- WINDOWS (% destroyed)

  Front 100  Left 20  Right 100  Rear 0

- STUDS (number broken)

  Front 19  Rear 2

- ROOF RAFTERS (number broken)

  Front 19  Rear 2

- CEILING PLASTER (% destroyed)

  1st floor 0  2nd floor 20

- WALL PLASTER (% destroyed)

  1st floor 15  2nd floor 16

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1. Wilton, C. and J. Zaccor, Evaluation of Simultaneity Tests, URS 698-3, URS Research Company, Burlingame, California, January 1969.

2. Operation PRAIRIE FLAT Preliminary Report, Volume I, Edited by M. J. Duclash, DASA 2228-1, January 1969.

3. Sadwin, L. D. and M. M. Swisdak, Jr., AN/FO Charge Preparation for Large Scale Tests, NOLTR 70-205, Naval Ordnance Laboratory, White Oak, Maryland, October 8, 1970.

## Appendix A

## PHOTOGRAPHS FROM THE AN/FO TEST

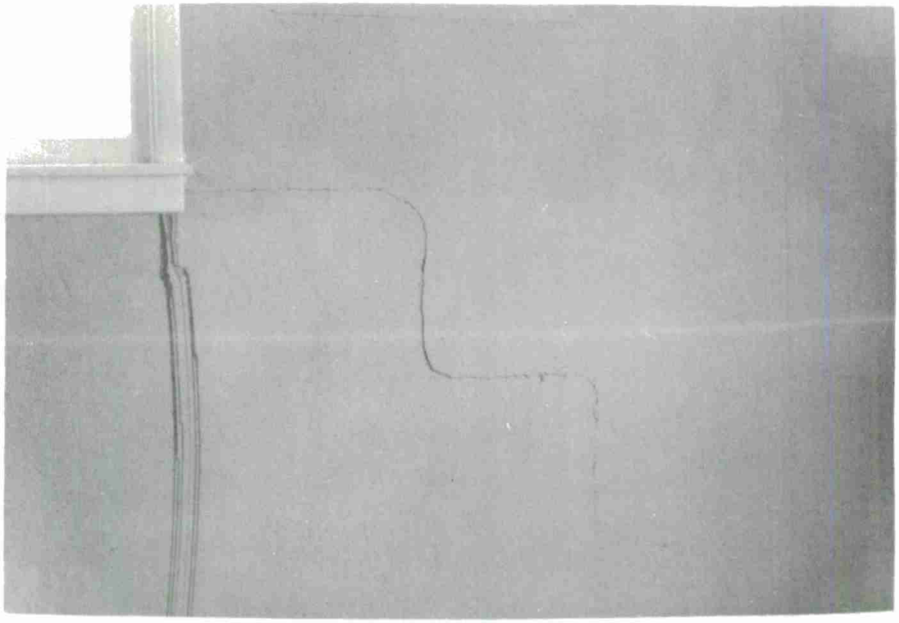

Fig. A-1. Pretest Plaster Cracks, Kitchen North Wall (vertical marks are water stains, not cracks)

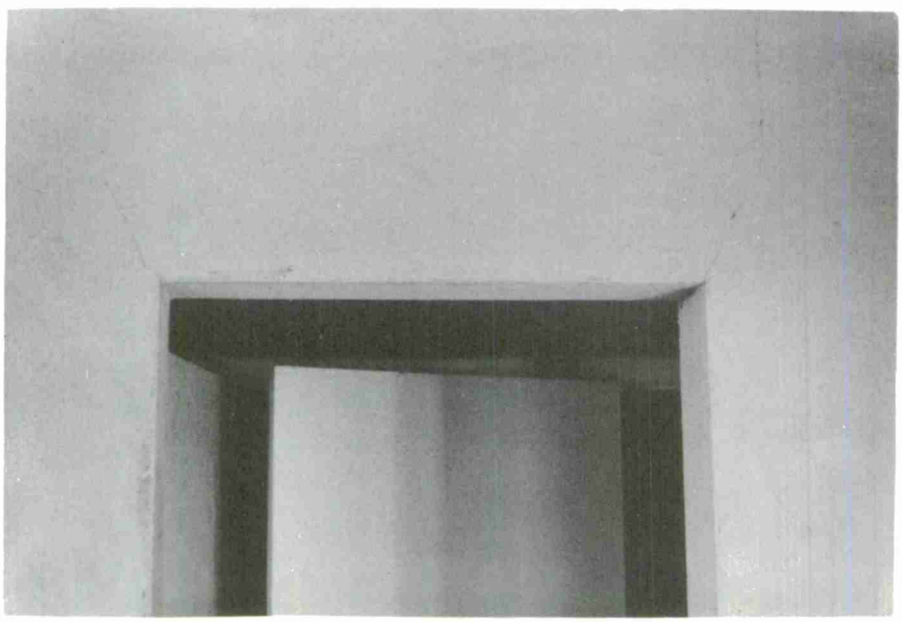

Fig. A-2. Pretest Plaster Cracks, Kitchen Door

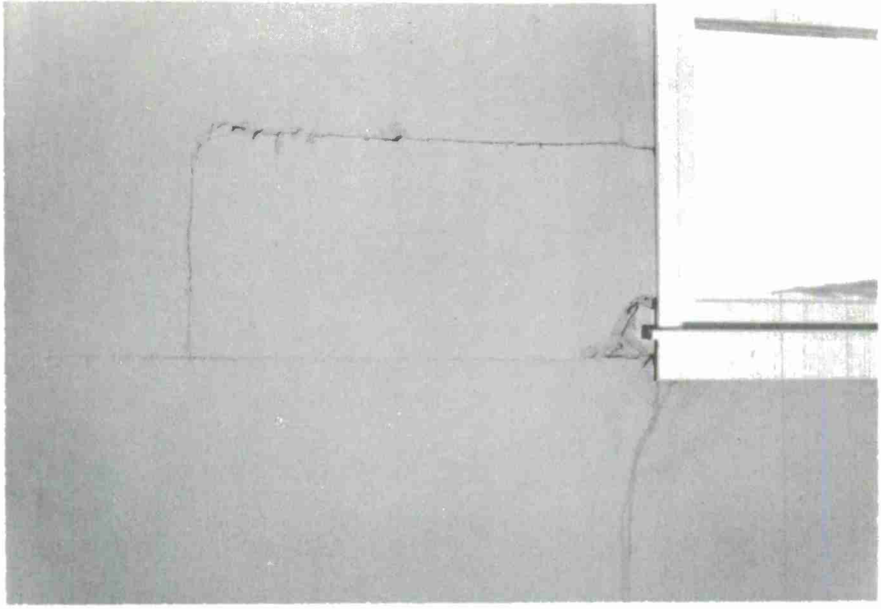

Fig. A-3. Pretest Plaster Cracks, South Bedroom, Front Window

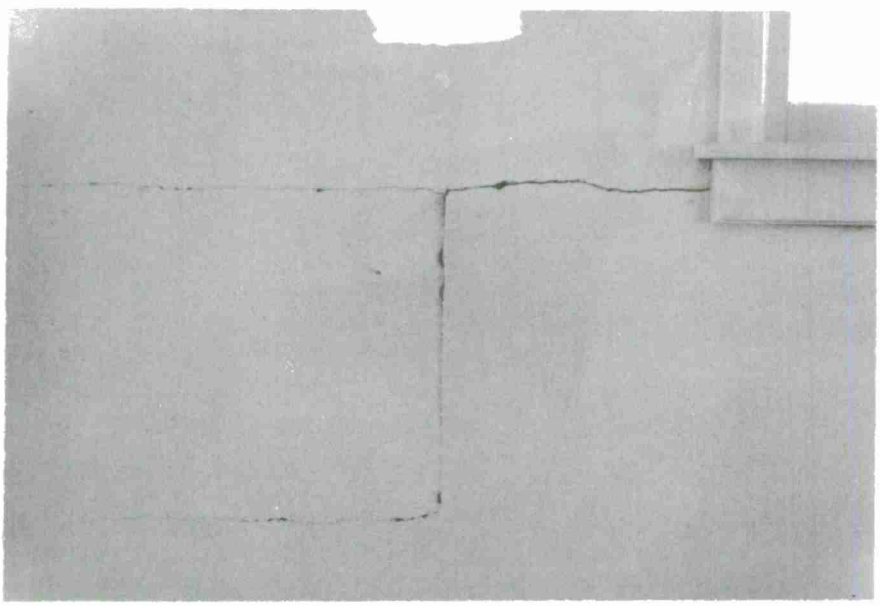

Fig. A-4. Pretest Plaster Cracks, North Bedroom, Front Window

Fig. A-5. Pretest Close-up of Cracked 2 by 4, North Bedroom, Front Window

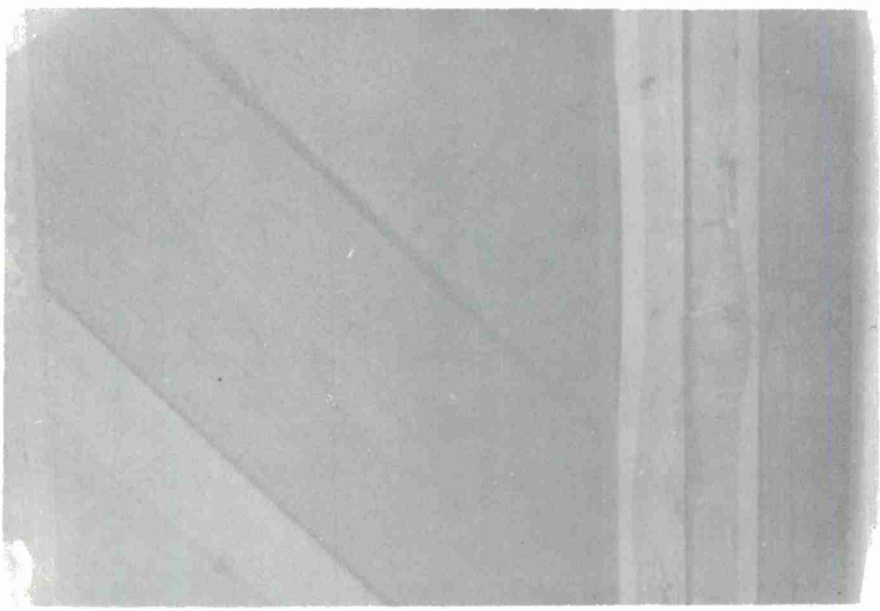

Fig. A-6. Pretest Close-up of Cracked 2 by 4, South Bedroom, Front Window

Fig. A-7. Posttest Ceiling Damage, Upstairs Rear North Bedroom

Fig. A-8. Posttest Door and Ceiling Sheathing on Floor of Upstairs Rear North Bedroom

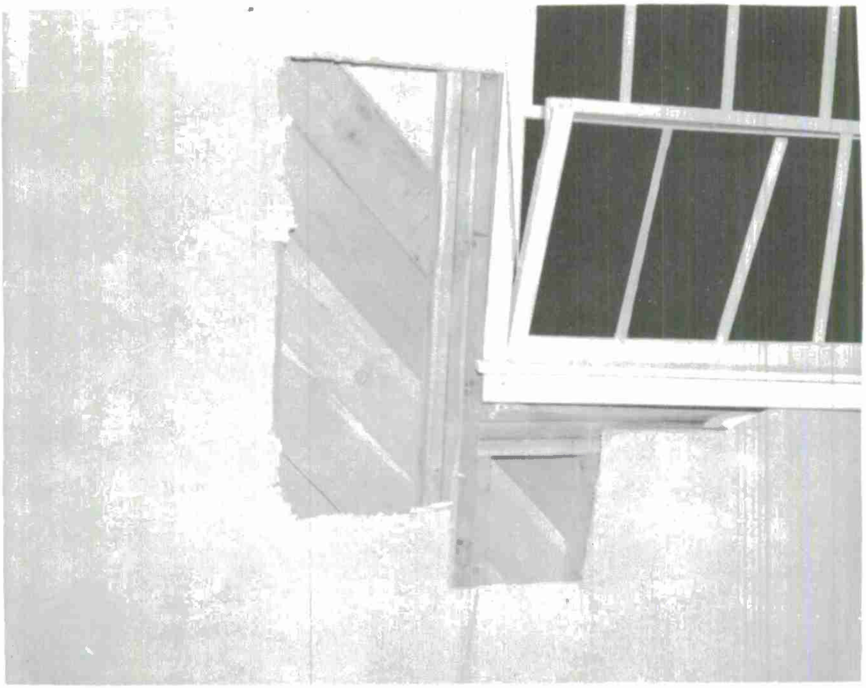

Fig. A-9. Posttest Upstairs Front Bedroom, North Side

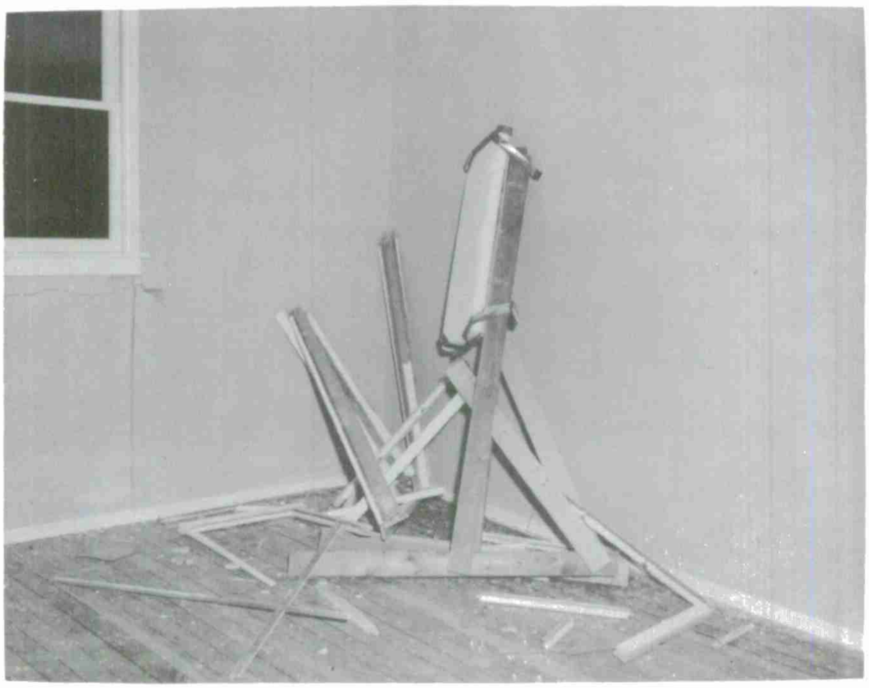

Fig. A-10. Posttest Northwest Corner, Master Bedroom, Showing Window From South Wall and Glass Trap

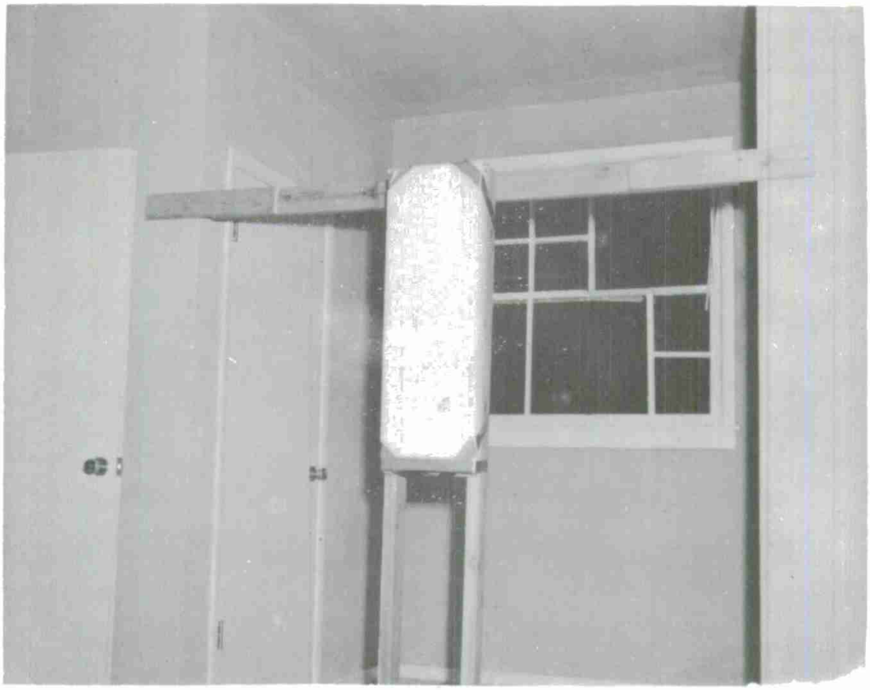

Fig. A-11. Posttest East Wall, Master Bedroom

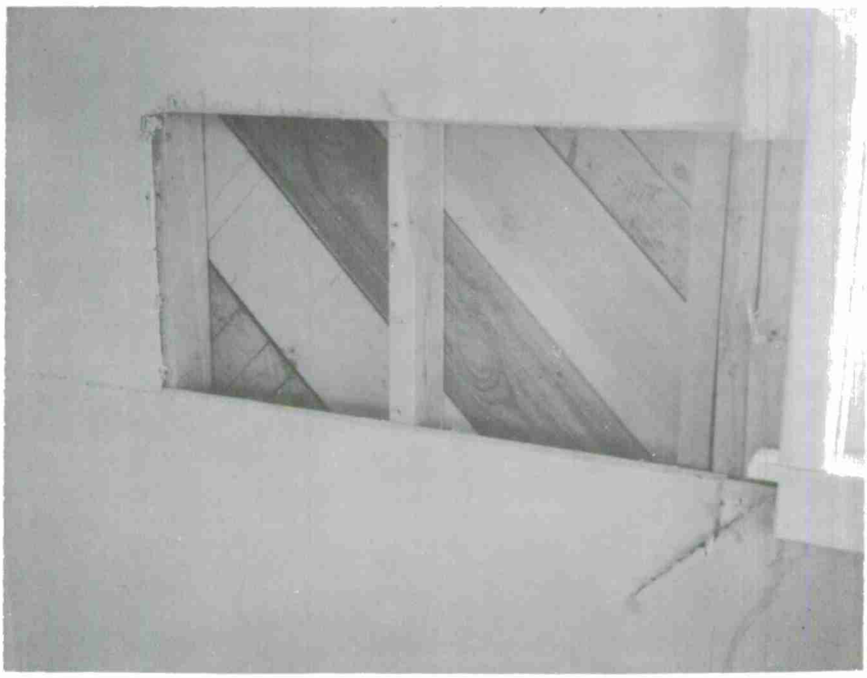

Fig. A-12. Posttest Dining Room, West Wall

Fig. A-13. Dining Room East Wall, Showing Damaged Glass Trap

Fig. A-14. Living Room, West Wall

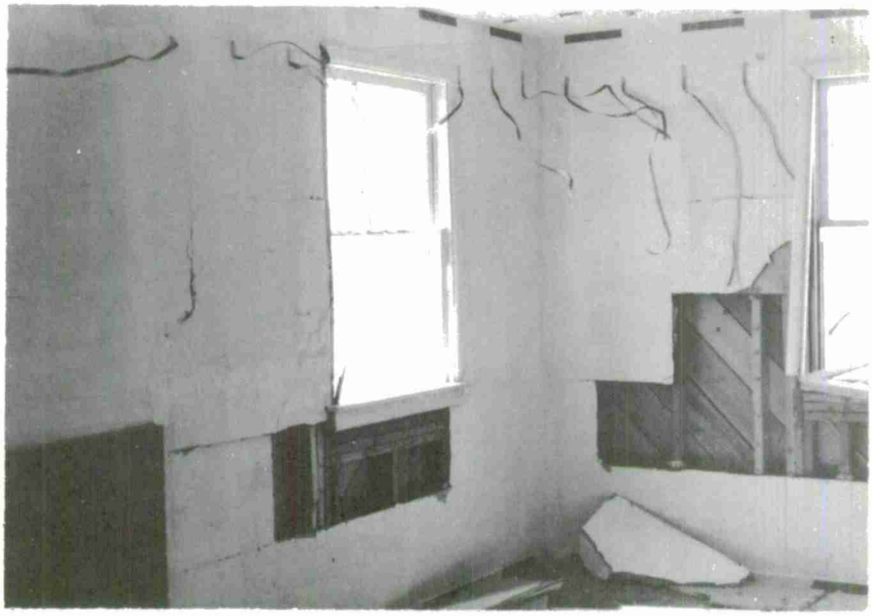

Fig. A-15. Posttest Living Room, Southwest Corner

Fig. A-16. Posttest View from Dining Room into Hall
Showing Location of Door

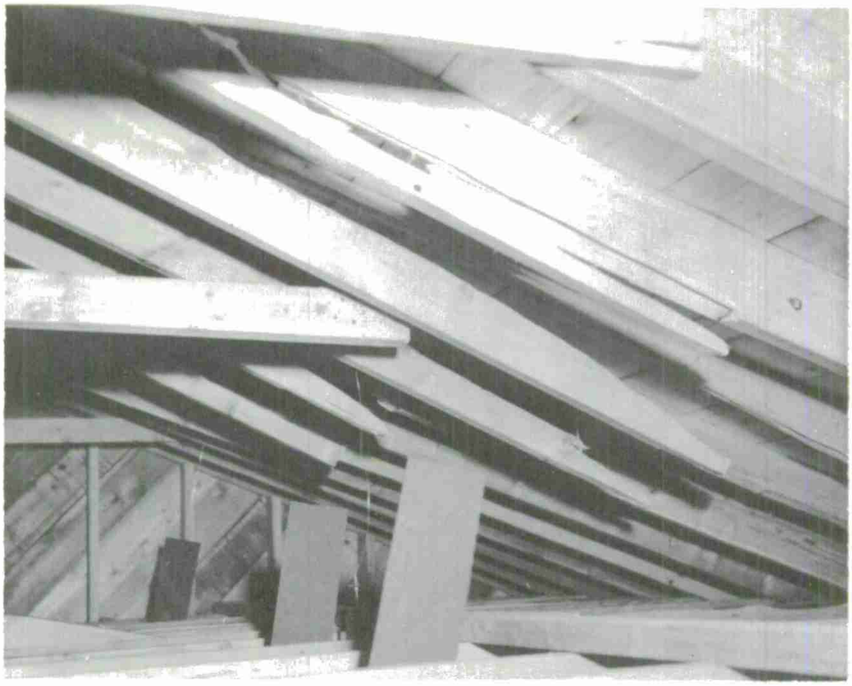

Fig. A-17. Posttest Attic, Westside, View Looking North

Fig. A-18. Posttest Attic, Westside, View Looking South

## Appendix B

## PHOTOGRAPHS FROM THE DIAL PACK TEST

Fig. B-1. Posttest Living Room, North Wall Looking East

Fig. B-2. Posttest Living Room, North Wall Looking West

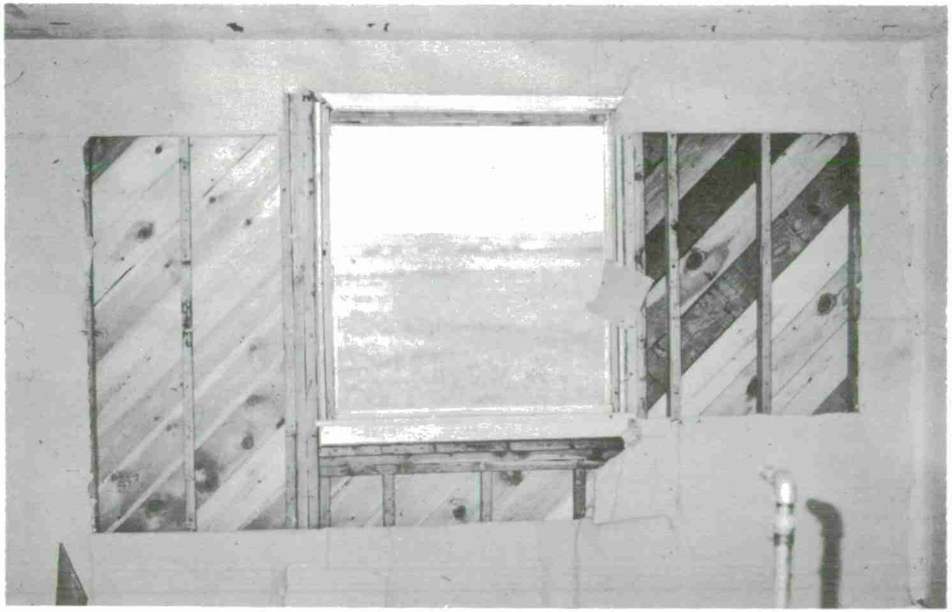

Fig. B-3. Posttest Living Room, West Wall

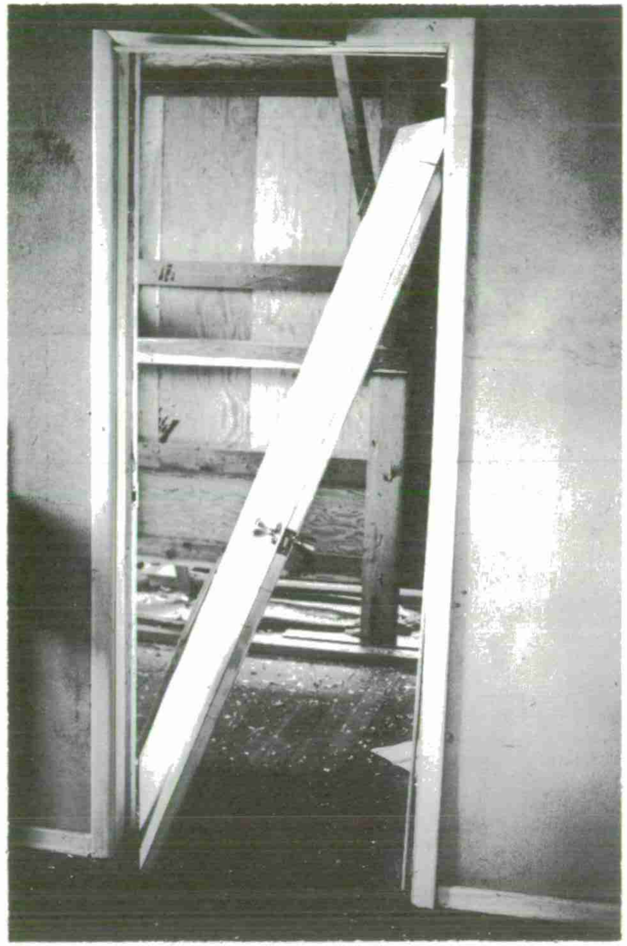

Fig. B-4. Posttest Dining Room, West Wall

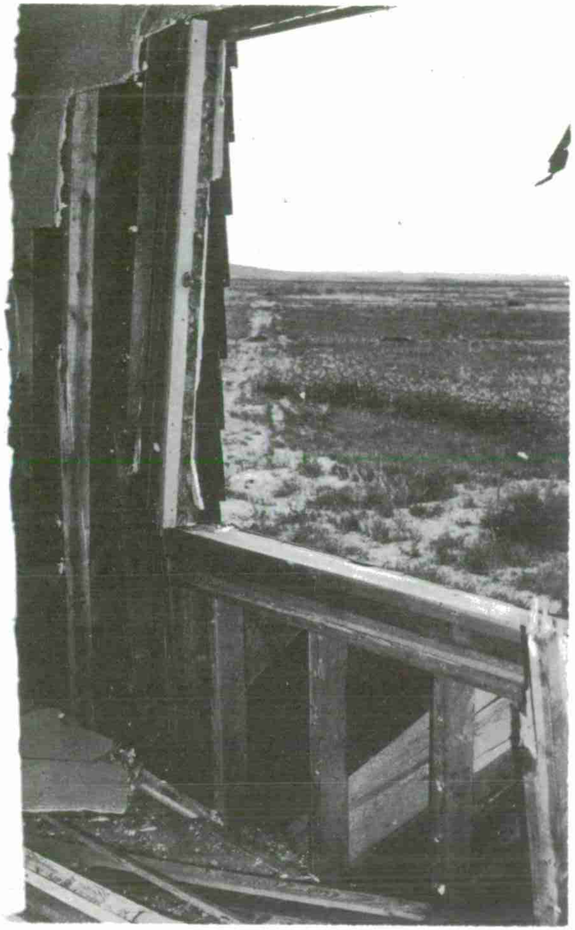

Fig. B-5. Posttest Kitchen, West Wall

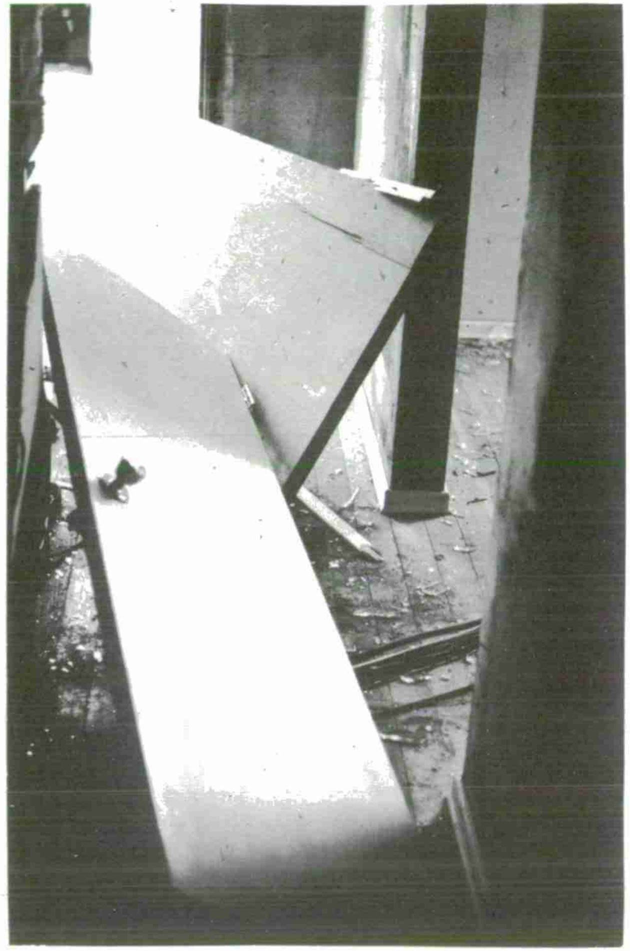

Fig. B-6. Posttest Entry Hall Looking East

Fig. B-7. Posttest Master Bedroom, North Wall

Fig. B-8. Posttest Master Bedroom, Ceiling

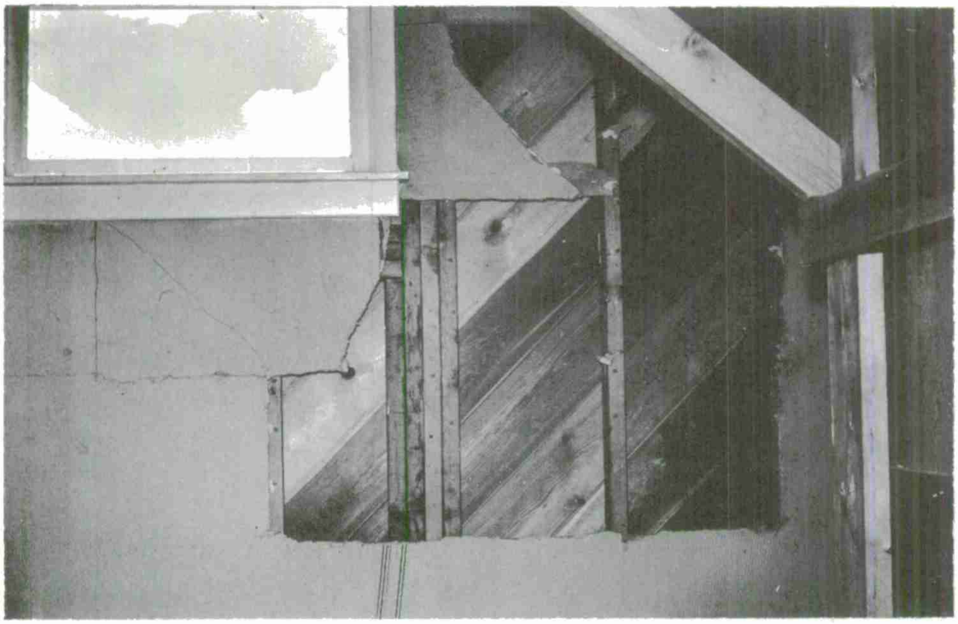

Fig. B-9. Posttest in Third Bedroom, South Wall

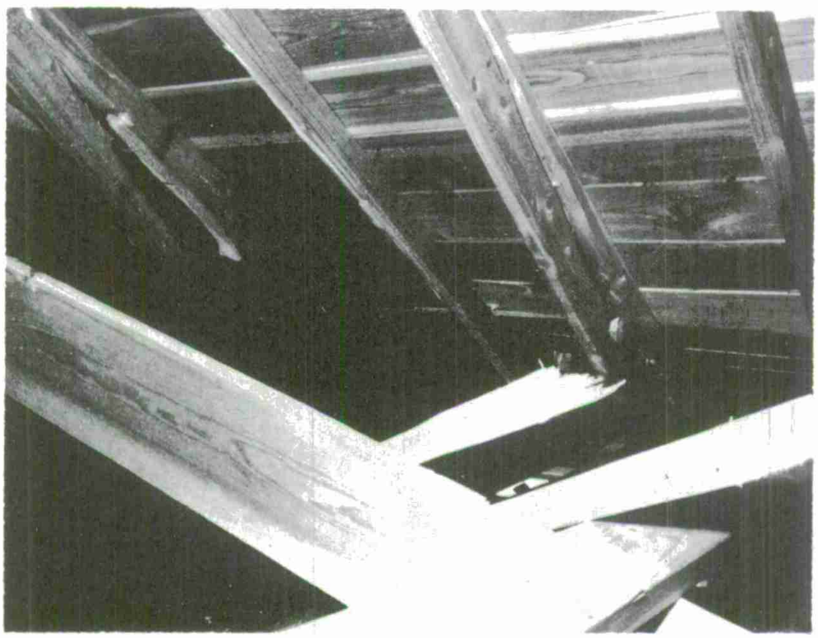

Fig. B-10. Posttest Roof System, Blastward Side

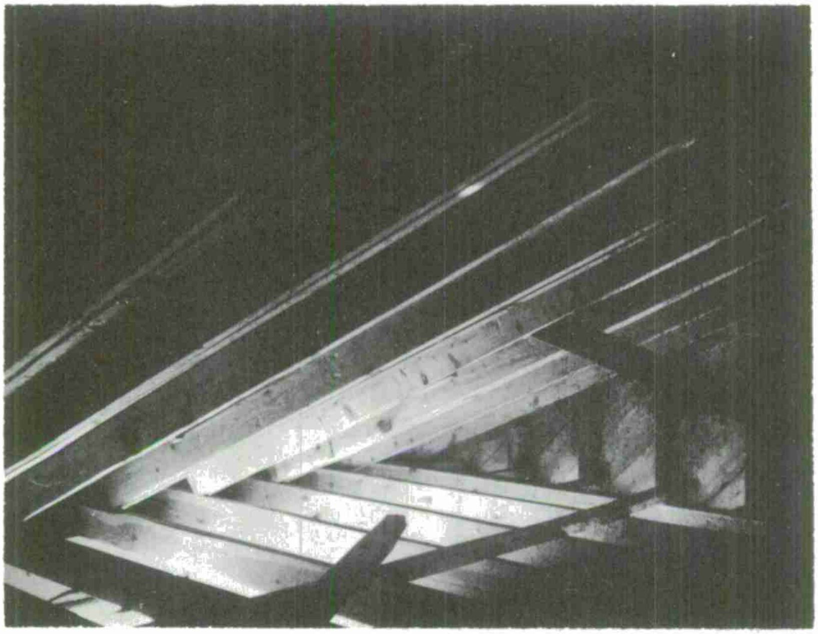

Fig. B-11. Posttest Roof System, Leeward Side

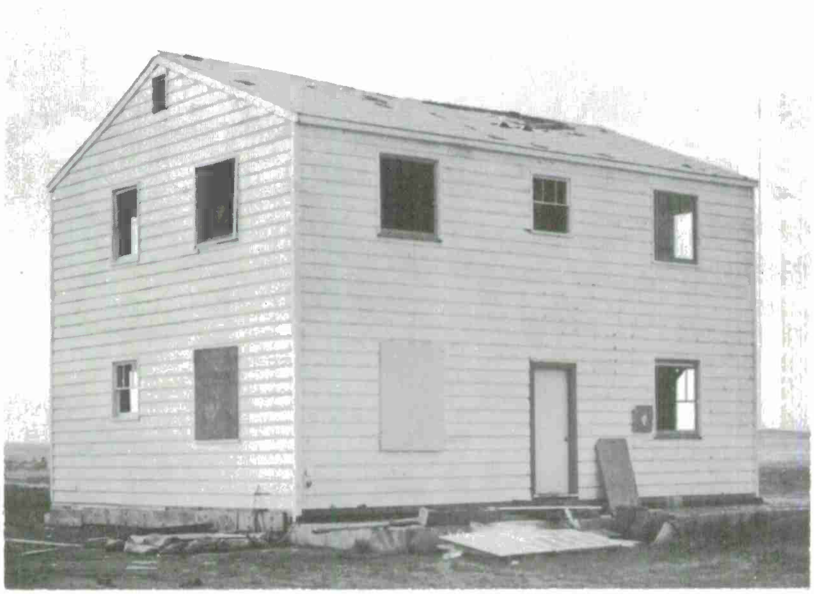

Fig. B-12. Posttest House Exterior, East and South Sides

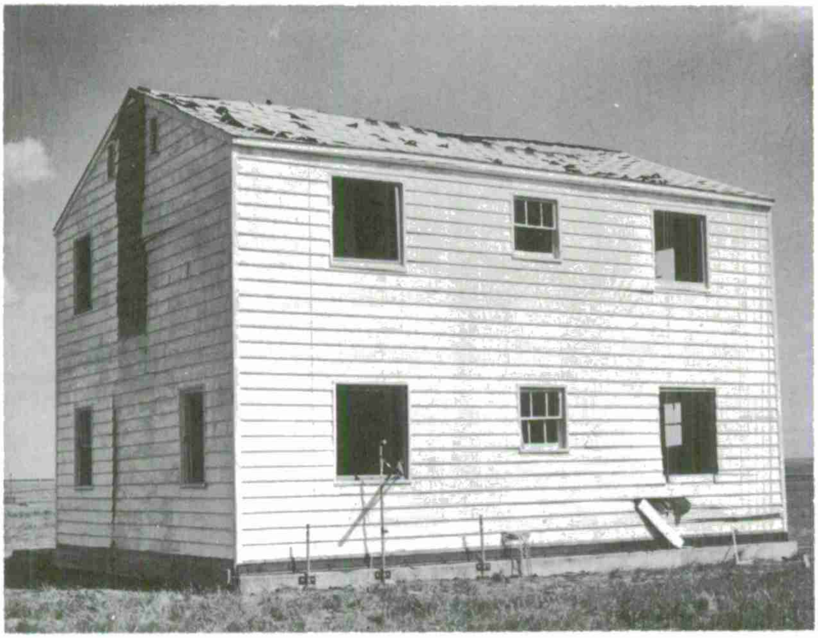

Fig. B-13. Posttest House Exterior, North and West Sides

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