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US Army Corps of Engineers
Waterways Experiment Station

Forced Entry Testing of Five-Minute Walls

by Charles R. Malone, James M. Watt, Jr.

Prepared for U.S. Department of State,
Office of Foreign Building Operations

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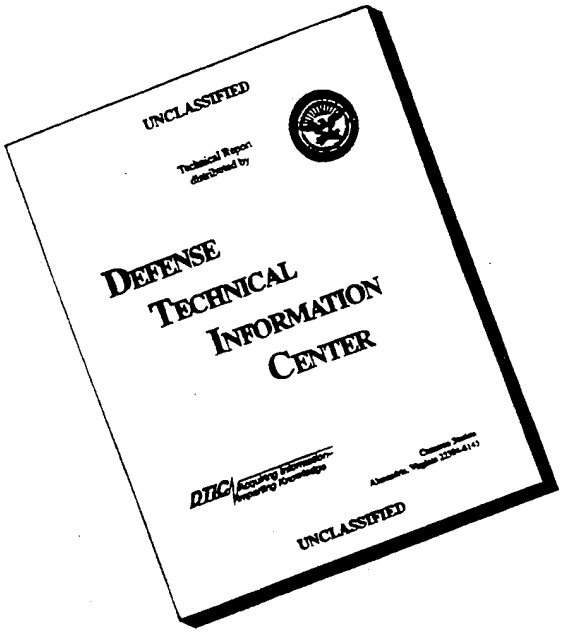

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Final report

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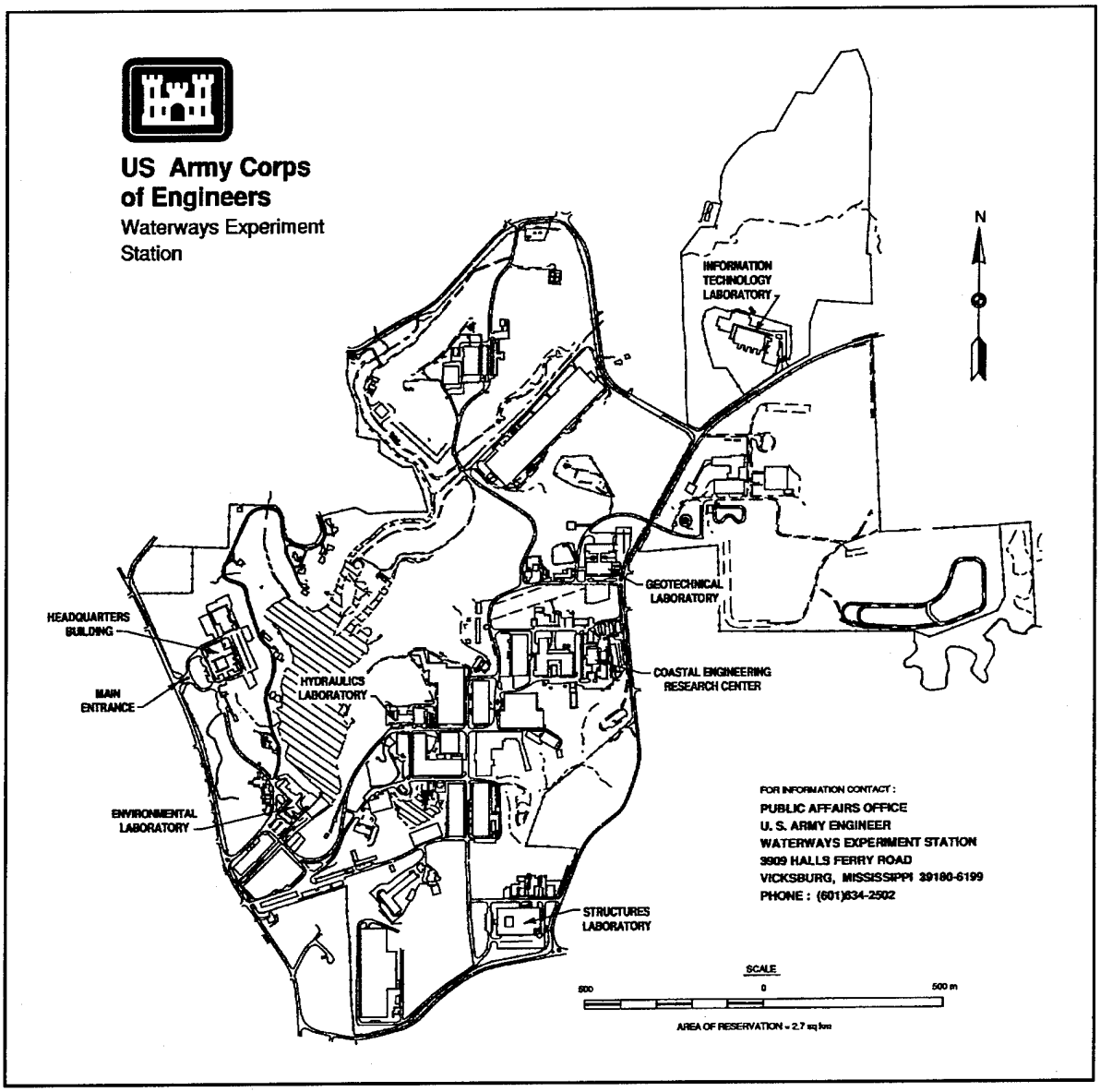

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Preface

This report presents results of a series of forced entry tests conducted in Fiscal Year 1995 by the U.S. Army Engineer (USAE) Waterways Experiment Station (WES) under the sponsorship of the U.S. Department of State (DOS), Office of Foreign Building Operations (FBO). These tests were conducted according to the requirements of Interagency Acquisition Agreement No. S-FBOAD95H0002, entitled "Forced Entry Testing of 5-Minute Walls." Mr. John J. Leimanis was the FBO technical monitor.

Work for this project was conducted under the general supervision of Mr. Bryant Mather, Director, Structures Laboratory (SL), WES, and Dr. Reed Mosher, Chief, Structural Mechanics Division (SMD), SL, and under the direct supervision of Mr. James M. Watt, Jr., Acting Chief, Structural Evaluation Group (SEG), SMD. Messrs. Charles R. Malone and Watt conducted these tests and prepared this report.

Dr. Robert W. Whalin was Director of WES during the conduct of these tests and preparation of this report. COL Bruce K. Howard, EN, was Commander.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	25.4	millimetres
pounds (mass)	0.4535924	kilograms

1 Introduction

Background

The U.S. Department of State (DOS), Office of Foreign Building Operations (FBO), has a requirement to design forced entry resistant walls for DOS facilities world-wide. Based primarily on the results of forced entry tests, FBO may certify a given wall design at one of three levels of forced entry protection. The three levels of forced entry protection defined by FBO (5, 15, and 60 min) imply a wall delay time provided against a specified group of assault tools and number of assault personnel.

In Fiscal Year 1995, FBO tasked the U.S. Army Engineer (USAE) Waterways Experiment Station (WES) to conduct a series of forced entry tests on various wall panels designed by FBO to meet the 5-minute forced entry protection level.

Purpose and Scope

The purpose of the testing described herein was to measure the forced entry delay time provided by various wall panels. The wall panels were constructed with standard construction materials (wood, concrete masonry units (CMU), and gypsum wall board) according to engineering drawings approved by FBO. All testing was conducted in accordance with the testing standard for the 5-minute protection level specified in SD-STD-01.01, *Forced Entry and Ballistic Resistance of Structural Systems*, Revision G (Amended).[1]

This report describes in detail all phases of this effort beginning with wall/frame construction and continuing through the actual forced entry testing. Please note that test results and discussion make no attempt to

[1] U.S. Department of State. (1993). Certification Standard superseding all earlier revisions of SD-STD-01.01 and 01.02.

assign a certification status to any of the wall panels. This decision is left entirely to FBO.

2 Wall Panels and Wall Support Frames

Design Phase

Wall panels

Engineering drawings for the four wall panels built for this series of tests are presented in Figures 1 through 4 (non-SI units) and Figures 5 through 8 (SI units). Note that two of the panels were wood stud walls and two were hollow CMU walls, each measuring 8 by 8 ft with various wood and gypsum board appliques attached to both sides. These walls were designed by FBO with the primary goal of meeting the 5-minute forced entry protection level. Other factors which guided the design effort were construction cost and construction materials availability at foreign posts.

Previous forced entry tests conducted by FBO indicated that wood stud walls generally fail at the point where a stud connects to the top or bottom plate. The desire of FBO to evaluate the performance of several different wood connectors for this critical connection point was reflected in the design of the two wood stud wall panels built for this series of tests. As seen in Figures 1 and 2 (non-SI units) and Figures 5 and 6 (SI units), FBO specified that four different types of wood connectors be used throughout the two wood stud wall panels. Engineering drawings and photographs of these wood connectors are presented in Figures 9 through 16.

Wall support frames

Engineering drawings for the wood stud wall support frame and the hollow CMU wall support frame are presented in Figures 17 and 18, respectively. These frames were designed by the U.S. Army Engineer Waterways Experiment Station (WES) with two goals in mind. First, the frames were designed to restrict wall panel movement during testing. Second, the frames were designed to approximate wall anchoring techniques typically employed in the field.

Note that both frame designs incorporated various steel sections (channel, angle, plate, tubing) welded or bolted together. Both frame designs also specified that the frame be attached to the wall panel and securely anchored to an existing reinforced concrete wall and floor slab. The primary difference between the two frame designs was the number of panel edges supported. The wood stud wall support frame provided support along all four edges (top, bottom, and sides), while the hollow CMU wall support frame provided support along the top and bottom only.

Construction Phase

Initial construction

A total of four wall panels and four wall support frames were constructed prior to the start of forced entry testing. Most of the construction of the wall panels and the wall support frames was done inside Building 5013, a fully enclosed steel frame structure with a concrete floor located on the WES reservation. All wall panels were built entirely in Building 5013; however, much of the cutting and drilling of the steel frame members was done in the WES Welding Shop. Final assembly of the wall support frames and attachment of the wall panels to the frames were done in Building 5013. The four panels were built side by side with approximately 12 in. of space between adjacent panels. Photographs taken at various stages of construction are presented in Figures 19 through 22.

All construction was done by skilled craftsmen (carpenters, masons, and welders) from the WES Engineering and Construction Services Division in accordance with engineering drawings.

Construction modifications during testing

During testing, modifications were made to the two hollow CMU panels. These modifications, made after forced entry tests were completed against the original hollow CMU panels, involved removing the layer of gypsum board and one layer of wood from the assault side of the panel and replacing them with a single layer of gypsum board. (The assault side of the panel is simply the side against which the forced entry assault is directed.) This modification resulted in the two hollow CMU panels having one less layer of wood on the assault side compared to the original design and construction. Forced entry tests were then conducted against the modified panels.

Summary

A total of six 8- by 8-ft wall panels were tested during this project. Four of the panels were built prior to the start of testing. The other two resulted from modifications made to the hollow CMU panels during the course of testing. Prior to the start of testing, each panel was numbered according to the FBO numbering convention for forced entry resistant building components. Table 1 summarizes the construction features of these six wall panels.

3 Forced Entry Testing

Test Team

General

The test team consisted of the staff members listed in Table 2. Major responsibilities performed by each team member are described in the following paragraphs.

Test director

The test director provided management oversight for the testing effort. He met with the DOS representatives and the deputy test director at various times during the course of testing to ensure that test objectives were being met.

Deputy test director

The deputy test director was responsible for the execution of all tests. Specific duties included the following:

a. Briefed the test team on test procedures and safety considerations prior to each test.

b. Started and stopped each test.

c. Watched closely for safety violations and took appropriate measures to correct them when they were observed.

d. Directed the actions of the assault team.

e. Coordinated with the DOS representatives to resolve any issues that arose during testing.

f. Ensured that each test was adequately documented.

g. Coordinated closely with the photographers to ensure that required photographs and video/audio recordings were obtained.

DOS representatives

The DOS representatives observed all testing, ensured that FBO test procedures were followed, and test objectives were achieved. They coordinated with the deputy test director to resolve any issues which arose during testing.

Assault team

The two-man assault team conducted forced entry assaults in accordance with instructions given by the deputy test director. Both members of the assault team (DEL-JEN, WES general construction contractor) were of muscular build and in excellent physical condition. Mr. Joe Jeffers weighed 240 lb, and Mr. Jack Howard weighed 180 lb. Both men were 19 years of age. The members of the assault team had some general construction experience but had no prior forced entry testing experience. A photograph of the assault team is presented in Figure 23.

Technician

The technician provided general assistance to the deputy test director. Some of his duties included inspecting and maintaining the forced entry tools, making construction modifications to certain wall panels, and watching for safety violations. The technician also served as an alternate member of the assault team.

Photographers

The photographers took still photographs and made video/audio recordings in accordance with instructions given by the deputy test director.

Tools and Equipment

Forced entry tools

The group of tools specified in Table 3 were made available to the assault team during each test. A photograph of this tool group is presented in Figure 24.

Wall penetration criterion

Two rigid objects, one box-shaped and the other cylindrical, were provided to the assault team to specify successful penetration of a given wall panel during an assault test. The box-shaped object (dimensions 12 by 12 by 8 in.) was fabricated out of steel sheet, and the cylindrical object (diameter = 12 in., length = 12 in.) was fabricated out of rigid plastic pipe. A photograph of these two objects is presented in Figure 25. A wall panel was considered penetrated when the assault team passed either of the two rigid objects completely through the hole they created in the panel.

Photographic and video/audio recording equipment

Two cameras were used to document the test in still photographs. One camera, a 4- by 5-in. press camera with a 135-mm lens, was used to take black and white photographs. The other camera, a Canon F1 35-mm camera with a 28-mm lens, was used to take color photographs.

The following three devices were used to record video and audio:

a. *Sony M7 video camera with a VO-8800 recorder.* This camera was positioned on a tripod to provide a full frontal view of the assault side of the panel being tested. The clock was also included in the view. Timecode was recorded on the videotape to facilitate videotape editing.

b. *Sony 3000 video camera with a BVU 150 recorder.* This camera was positioned on a tripod to provide a closeup view of the particular region of the panel being assaulted during a given test. After each test, this camera was removed from the tripod and taken to the panel to obtain closeup views of the damage from both sides of the panel. Timecode was recorded on the videotape to facilitate videotape editing.

c. *Panasonic VHS-C Palmcorder.* The palmcorder was used as a backup video/audio recording device. It was positioned on a tripod to provide essentially the same frontal view of the panel being tested as that provided by Sony M7.

Supplemental lighting was provided by two tripod-mounted 500-watt tungsten floodlights. These lights were positioned to provide crosslighting illumination for each test.

Safety equipment

The members of the assault team were provided safety goggles and hard hats to wear during each assault. They were also provided gloves

and duct tape to protect their hands from blistering while swinging the sledgehammers.

Chisel holders were fabricated out of aluminum and made available to the assault team. A photograph of the chisel holders is presented in Figure 26. The purpose of these items was to keep a chisel from becoming a projectile when being driven by a sledgehammer. The chisel holder would allow one person to hold, at a safe distance, a chisel in place while another person drove the chisel with a sledgehammer.

Clock

A digital LED clock displayed time of day (HH:MM:SS, 24-hour format) during the entire testing period. The clock, featuring bright, 8-in.-tall digits and mounted directly above the panel being tested, was plainly visible to all test participants and showed up clearly on the video tape. A photograph of the clock is presented in Figure 27.

Test Procedure

General

The following paragraphs describe general test procedures for each of the 13 forced entry assault tests conducted during the 2-day testing period.

Pretest checklist

The following is a checklist of actions which were completed prior to the start of each test:

a. The deputy test director briefed the assault team on the construction details of the wall panel.

b. The assault team inventoried the forced entry tool group to ensure that all specified tools were present and in good working order.

c. The deputy test director indicated to the assault team the general location of the assault.

d. The deputy test director inspected the wall panel to ensure that it was securely mounted in its frame.

e. The photographers checked all video/audio recording equipment to ensure that it was functioning properly.

f. The deputy test director briefed the test team on test procedures and safety considerations.

Assault test - Initial phase

Each test began with an initial 5-minute assault phase. Upon hearing the deputy test director issue the "GO" command, the assault team immediately began assaulting the wall panel at the general location identified prior to the test. During the course of the assault, the deputy test director announced the elapsed time at 1-minute intervals and counted aloud the last 10 seconds of the 5-minute assault period. At any time during the assault, the assault team could attempt to pass the designated rigid objects through the hole they created in the panel. If the assault team was able to pass either of the rigid objects completely through the hole within the initial 5-minute assault period, the deputy test director immediately stopped the test and noted the elapsed time. If the assault team was unable to penetrate the panel, the test director stopped the test at the 5-minute elapsed time.

Assault test - Continuation phase(s)

If the assault team was unable to penetrate the wall panel during the initial 5-minute assault phase, the deputy test director consulted with the DOS representatives to determine if continuing the assault at the same location was meaningful. If continuing the assault was deemed meaningful, the assault team rested for a few minutes, and then, after receiving the "GO" command from the deputy test director, continued the assault at the same location until they penetrated the wall or until another 5-minute time period elapsed, whichever occurred first. If the assault team was unable to penetrate the wall panel after the second 5-minute assault phase, a third 5-minute assault phase was conducted at the discretion of the deputy test director and the DOS representatives.

Posttest damage assessment

At the conclusion of each 5-minute assault phase, the test team carefully inspected the wall panel to assess and document the damage caused during the assault. Photographs were taken and video recordings were made of the damage from both sides of the panel.

Safety considerations

The primary safety hazards associated with this testing were flying debris generated during the assaults and erratic behavior of the assault tools interacting with the wall panel. To protect each member of the test team from these hazards, the following safety rules were enforced:

a. During an assault test, members of the assault team were required to wear long pants, a shirt, and all safety equipment provided to them.

b. All other members of the test team were required to remain at least 10 ft away from the wall panel during an assault test.

Test Results

Summary

Results of the 13 forced entry tests conducted during the period 31 May through 1 June 1995 are summarized in Table 4. Detailed tests results are presented in the following paragraphs.

Test 1-1

This test was conducted on wall panel XPK-05N-DOS-01. The assault team was directed to assault the lower left-hand portion of the panel (as viewed from the assault side) where the studs connect to the bottom plate. The particular connector used in this region was the Kant-Sag THD26. Results of this test are summarized in Table 5.

The assault began at 09:35:00 on 31 May 95. Sledgehammers, used exclusively during this assault, proved effective at shattering gypsum board and the wood used in the construction of this panel. A rotating technique was employed by the assault team, since the two right-handed hitters could not direct their swings simultaneously toward the same region of the panel. This technique involved the first man taking a single swing and then moving back so that the second man could move in and take a swing. The assault continued in this manner until the assault team pushed the metal box completely through the opening in the panel at 09:39:56. The total penetration time was 4 minutes and 56 seconds. Posttest photographs of the opening in the panel are presented in Figures 28 and 29.

Test 1-2

This test was conducted on wall panel XPK-05N-DOS-01. The assault team was directed to assault the lower right-hand portion of the panel (as viewed from the assault side) where the studs connect to the bottom plate. The particular connector used in this region was the Simpson Strong-Tie LUS26. Results of this test are summarized in Table 6.

The assault began at 10:30:00 on 31 May 95. As in the previous test, sledgehammers were used exclusively during this assault. However, during this test and all subsequent tests, each man took at least five hammer

swings before rotating with his partner. This resulted in a much more efficient assault compared with the single swing rotation employed in test 1-1. The assault continued until the assault team pushed the metal box completely through the opening in the panel at 10:33:11. The total penetration time was 3 minutes and 11 seconds. Posttest photographs of the opening in the panel are presented in Figures 30 and 31.

Test 1-3

This test was conducted on wall panel XPK-05N-DOS-01. The assault team was directed to assault the center portion of the panel approximately chest high. Kant-Sag THD26 connectors were used at the top and bottom of the studs in this region of the panel. Results of this test are summarized in Table 7.

The assault began at 10:55:00 on 31 May 95 with the assault team using sledgehammers. The sledgehammer assault continued until 10:57:32 when the assault team began using the ram to break loose the wood board sheathing on the protect side of the panel. (The protect side is opposite the assault side of the panel.) After using the ram for approximately 8 seconds, the assault team returned to the sledgehammers which they used until 10:58:35 when they pushed the metal box completely through the opening in the panel. The total penetration time was 3 minutes and 35 seconds. Posttest photographs of the opening in the panel are presented in Figures 32 and 33.

Test 1-4

This test was conducted on wall panel XPK-05N-DOS-01. The assault team was directed to assault the upper left-hand portion of the panel (as viewed from the assault side) where the studs connect to the top plate. The particular connector used in this region was the Kant-Sag JA5 (one connector on each side of the stud). The assault team stood on an elevated platform during the entire assault. Results of this test are summarized in Table 8.

The assault began at 11:30:00 on 31 May 95. The assault team, using only sledgehammers, created an opening in the panel through which they passed the metal box at 11:32:45. The total penetration time was 2 minutes and 45 seconds. Posttest photographs of the opening in the panel are presented in Figures 34 and 35.

Test 2-1

This test was conducted on wall panel XPK-05N-DOS-02. The assault team was directed to assault the lower left-hand portion of the panel (as viewed from the assault side) where the studs connect to the bottom plate.

The particular connector used in this region was the Kant-Sag THD26. Mr. Robert Wayne substituted for Mr. Jeffers during this test. Results of this test are summarized in Table 9.

The assault began at 13:40:00 on 31 May 95 with the assault team using sledgehammers. The sledgehammer assault continued until 10:42:00 when Mr. Wayne began jabbing and prying the stud with the crowbar which he continued for approximately 40 seconds. The assault team then spent the remainder of the 5-minute assault period attempting to shatter the stud using the sledgehammers in conjunction with the crowbar and a wood-splitting wedge. When the test was stopped at 10:45:00, the penetration criterion had not been met. Posttest photographs of the opening in the panel are presented in Figures 36 and 37.

Test 2-2

This test was conducted on wall panel XPK-05N-DOS-02. The assault team was directed to assault the center portion of the panel approximately chest high between two studs. Kant-Sag THD26 connectors were used at the top and bottom of the two studs adjacent to the assault location. Results of this test are summarized in Table 10.

The assault began at 14:10:00 on 31 May 95. The assault team, using only sledgehammers, created an opening in the panel through which they passed the metal box at 14:12:50. The total penetration time was 2 minutes and 50 seconds. Posttest photographs of the opening in the panel are presented in Figures 38 and 39.

Test 2-3

This test was conducted on wall panel XPK-05N-DOS-02. The assault team was directed to assault the lower right-hand portion of the panel (as viewed from the assault side) where the stud connects to the bottom plate. The particular connector used in this region was the Simpson Strong-Tie LUS26. Results of this test are summarized in Table 11.

The assault began at 14:45:00 on 31 May 95. The assault team, using only sledgehammers, created an opening in the panel through which they passed the metal box at 14:49:50. The total penetration time was 4 minutes and 50 seconds. Posttest photographs of the opening in the panel are presented in Figures 40 and 41.

Test 2-4

This test was conducted on wall panel XPK-05N-DOS-02. The assault team was directed to assault the upper left-hand portion of the panel (as viewed from the assault side) where the studs connect to the top plate.

The particular connector used in this region was the Kant-Sag JA5 (one connector on each side of the stud). The assault team stood on an elevated platform during the entire assault. Results of this test are summarized in Table 12.

The assault began at 08:15:00 on 1 June 95 with the assault team using sledgehammers. During the course of the assault, the team lost both sledgehammers through the opening they created in the panel. In accordance with the DOS testing standard, they were not allowed to retrieve the sledgehammers. After the first one was lost at 08:18:53, the assault team shared the one remaining. The second sledgehammer was lost at 08:19:40 after which time the assault team attempted unsuccessfully to pass the metal box through the opening in the panel. The assault team spent the last 4 seconds of the 5-minute assault period attempting to enlarge the opening using a 3-lb hammer. When the test was halted at 08:20:00, the penetration criterion had not been met. Photographs taken after this initial assault are presented in Figures 42 and 43.

After the panel was inspected, it was deemed meaningful to continue this test. The second assault phase began at 08:35:00 and continued until 08:35:12, at which time the assault team was able to pass the metal box through the opening in the panel. During this assault period, which lasted only 12 seconds, the assault team used a sledgehammer to enlarge the opening just enough to allow passage of the box. The total penetration time including both assault phases was 5 minutes and 12 seconds. Photographs taken after this second assault are presented in Figures 44 and 45.

Test 2-5

This test was conducted on wall panel XPK-05N-DOS-02. The assault team was directed to assault the upper right-hand portion of the panel (as viewed from the assault side) where the studs connect to the top plate. The particular connector used in this region was the Simpson Strong-Tie LB26. The assault team stood on an elevated platform during the entire assault. Results of this test are summarized in Table 13.

The assault began at 09:10:00 on 1 June 95 and continued until 09:15:00 when the test was halted. The assault team, using only sledgehammers throughout the assault, spent the last 4 seconds of the 5-minute assault period attempting unsuccessfully to pass the metal box through the opening they created in the panel. Photographs taken after this initial assault are presented in Figures 46 and 47.

After the panel was inspected, it was deemed meaningful to continue this test. The second assault phase began at 09:35:00 and continued until 09:35:49, at which time the assault team was able to pass the metal box through the opening in the panel. During this assault period, the team used a 3-lb hammer and a sledgehammer to enlarge the opening just enough to allow passage of the box. The total penetration time including

both assault phases was 5 minutes and 49 seconds. Photographs taken after this second assault are presented in Figures 48 and 49.

Test 3-1

This test was conducted on wall panel XPK-05N-DOS-03. The assault team was directed to assault the upper left-hand portion of the panel (as viewed from the assault side). The assault team stood on an elevated platform during the entire assault. Results of this test are summarized in Table 14.

The assault began at 10:40:00 on 1 June 95 with the assault team using sledgehammers and a wood-splitting wedge. They drove the first wedge for approximately 2 minutes until it became totally embedded in the panel. At 10:41:57 the assault team attempted, unsuccessfully, to drive the second wedge into the panel. At 10:42:20 they began jabbing and prying with the crowbar which they continued for approximately 70 seconds. At 10:43:34 the assault team began hitting the panel with sledgehammers, and this assault continued for approximately 35 seconds. At 10:44:17 they returned to jabbing and prying with the crowbar, and they continued until the assault was halted at 10:45:00. When the assault was halted, the penetration criterion had not been met. Photographs taken after this initial assault are presented in Figures 50 and 51.

After the panel was inspected, it was deemed meaningful to continue this test. The second assault phase began at 11:10:00 with the assault team attempting to drive the second wedge into the panel, first with the 3-lb hammer and then with the sledgehammers. At 11:11:51, with the second wedge completely embedded in the panel, the assault team began jabbing and prying with the crowbar, and they continued for approximately 45 seconds. At 11:12:41 they began hitting the panel with sledgehammers which they continued for approximately 55 seconds during which time they dislodged one wedge. During the remainder of the 5-minute assault period, the assault team drove a wedge into the panel a few inches above the existing opening with the sledgehammers. When the assault was halted at 11:15:00, the penetration criterion had not been met. A photograph taken after this second assault is presented in Figure 52.

After the panel was inspected, it was deemed meaningful to continue this test for a third and final assault phase. This assault began at 11:35:00 with the assault team continuing to drive the wedge for approximately 28 seconds until it dislodged and fell to the floor. From that point, the assault team used the sledgehammers along with the crowbar to create an opening in the panel through which they passed the steel box at 11:39:31. The total penetration time including all three assault phases was 14 minutes and 31 seconds. Photographs taken after this third assault are presented in Figures 53 and 54.

Test 4-1

This test was conducted on wall panel XPK-05N-DOS-04. The assault team was directed to assault the lower right-hand portion of the panel (as viewed from the assault side). Results of this test are summarized in Table 15.

The assault began at 13:40:00 on 1 June 95 with the assault team using sledgehammers. The sledgehammer assault continued until 13:40:36 when they began driving a wood-splitting wedge with the sledgehammers. They drove the wedge for approximately 2 minutes and 30 seconds until it became totally embedded in the panel. At 13:43:13 the assault team began jabbing and prying with the crowbar, an action which enabled them to completely remove one sheet of gypsum board and three horizontally spanning wood boards over the next 45 seconds. At 13:44:00 the assault team resumed the sledgehammer assault. They continued, along with some jabbing and prying with the crowbar, until the assault was halted at 13:45:00. When the assault was halted, the penetration criterion had not been met. After the panel was inspected it was not considered meaningful to continue this test. Photographs taken after this assault are presented in Figures 55 and 56.

Test 5-1

This test was conducted on wall panel XPK-05N-DOS-05 which was simply a modified version of panel XPK-05N-DOS-04. These construction modifications basically involved removing the layer of gypsum board and one layer of wood boards from the assault side of the panel and replacing them with a single layer of gypsum board. The assault team was directed to assault the lower left-hand portion of the panel (as viewed from the assault side). Results of this test are summarized in Table 16.

The assault began at 14:35:00 on 1 June 95 with the assault team hitting the panel twice with the sledgehammer and then immediately jabbing and prying with the crowbar. By 14:36:21 they had pried off an entire sheet of gypsum board and two of the vertically spanning wood boards, thus exposing the CMU. The assault team then began shattering the CMU with the sledgehammers which they continued until 14:37:15. With the CMU removed, the assault team used the crowbar, sledgehammers, and their feet (kicking) to remove the protect side applique materials. The assault continued until the assault team pushed the metal box completely through the opening in the panel at 14:38:01. The total penetration time was 3 minutes and 1 second. Photographs taken after this assault are presented in Figures 57 and 58.

Test 6-1

This test was conducted on wall panel XPK-05N-DOS-06 which was simply a modified version of panel XPK-05N-DOS-03. These construction modifications basically involved removing the layer of gypsum board and one layer of plywood from the assault side of the panel and replacing them with a single layer of gypsum board. The assault team was directed to assault the lower right-hand portion of the panel (as viewed from the assault side). Results of this test are summarized in Table 17.

The assault began at 15:15:00 on 1 June 95 with the assault team hitting the panel six times with the sledgehammer followed immediately with a jabbing and prying assault with the crowbar. The assault team continued with an alternating sledgehammer and crowbar assault until 15:19:30, by which time they had exposed the plywood on the protect side of the panel. They then picked up the ram and began battering the plywood which completely detached from the CMU at 15:19:38. As it detached, the plywood sheet hit the clock pedestal, thus causing the clock to fall. For this reason the test was temporarily halted at 15:19:38.

When the test was restarted at 15:39:00, the assault team hit the panel with the sledgehammer five times, thus enlarging the opening sufficiently to allow them to pass the metal box completely through the opening in the panel at 15:39:10. The total penetration time, including both assault phases, was 4 minutes and 48 seconds. Photographs taken after this assault are presented in Figures 59 and 60.

Analysis of Results

Wood stud panels

The forced entry delay provided by the two wood stud wall panels was generally less than 5 minutes. All four of the assault tests conducted against panel XPK-05N-DOS-01 and two of the five assault tests conducted against panel XPK-05N-DOS-02 clearly resulted in penetration in less than 5 minutes. In two of the five tests conducted against panel XPK-05N-DOS-02, penetration was clearly not achieved at the end of the initial 5-minute assault phase. The results of test 2-4 were considered inconclusive because the two sledgehammers lost during the course of the test could have been retrieved if the test had been conducted at ground level rather than from an elevated platform. The ability to retrieve the sledgehammers would likely have allowed the assault team to penetrate the panel in less than 5 minutes.

Two of the nine assault tests conducted against the wood stud wall panels were directed at the approximate centers of the respective panels. In each of these tests, the panels were penetrated relatively quickly (3:35 for

panel XPK-05N-DOS-01 and 2:50 for panel XPK-05N-DOS-02). This rapid penetration was facilitated by the convenience of the center assault location. Assaulting the center of the panel allowed the assault team members to swing the sledgehammers in a "baseball-bat" motion which produced extremely powerful and accurate blows. In addition, the assault team members did not have to stoop to access the opening created in the panel. Considering the high probability that an actual assault would be directed against the center of a panel, results of these two tests alone raise serious concerns about the ability of these panels to resist a 5-minute forced entry assault.

Seven of the nine assault tests conducted against the wood-stud wall panels were directed at locations where studs connected to top or bottom plates. The primary purpose of these seven tests was to evaluate the performance of the four different types of wood connectors used to form the stud/plate connections. Table 18 presents the manufacturer's suggested load ratings for the four connector types and summarizes the results of the forced entry tests directed at stud/plate connections. Though somewhat inconclusive, these data, together with posttest damage assessments, suggest the following:

a. The stud/plate connection points are vulnerable to a 5-minute forced entry penetration.

b. The stud/plate connection points, in general, are as resistant to forced entry penetration as the center locations are.

c. The primary failure mode associated with the stud/plate connection assault is shattering and breaking of the stud itself. The connectors generally prevent movement of the stud at the connection point.

d. The THD26 connector provides the most secure stud/plate connection.

Sledgehammers were the most effective tool against the wood stud wall panels. Nearly every impact produced noticeable damage to the panel. A swinging motion was extremely effective against the assault side appliques and the studs; however, a jabbing motion was used on several occasions to impact the protect side appliques. Though less powerful than the swinging motion, the jabbing motion allowed the assault team to direct blows more accurately against the protect side appliques.

In summary, the performance of the two wood-stud wall panels designed and constructed for these tests was largely unsatisfactory (with respect to the 5-minute forced entry protection level). However, the basic concept of wood stud construction providing a 5-minute delay still has merit. Some design upgrades which may improve the performance of the wood stud panels are presented as follows:

a. Multiple wood layers included on one or both sides of the panel.

b. Layer(s) with material properties which would complement those of wood included on one or both sides of the panel. Possible candidates are sheet metal, expanded metal, and polystyrene insulation board.

c. Larger 2- by 8-in. studs used to strengthen the panel and decrease the accessibility of the protect side appliques to the assault team.

Hollow CMU panels

The forced entry delay provided by the two hollow CMU panels (original design and construction) was significantly greater than 5 minutes. Several factors contributed to the good performance of these panels, some of which are cited as follows:

a. The assault side appliques effectively cushioned the sledgehammer blows, thus protecting the CMU. Sledgehammer assaults on exposed CMU generally result in extensive shattering of the CMU and rapid penetration of the panel.

b. The hardness and density of the CMU greatly restricted bending and breaking of the wood on the assault side of the panel.

c. The protect side appliques minimized spalling on the rear face of the CMU.

d. The "sandwich" design of the panels contained the CMU even after it shattered. This CMU rubble contained inside the panels continued to offer resistance to penetration.

The forced entry delay provided by each of the modified hollow CMU panels (one less layer of wood on the assault side) was less than 5 minutes. In the case of the panel with plywood appliques, the delay provided by the original panel was nearly 10 minutes greater than the delay provided by the modified panel. These results clearly point out the need for the additional layer of wood to protect and delay access to the CMU.

Sledgehammers, wedges, a crowbar, and a ram were each used at various times during the assaults conducted against the hollow CMU panels. A sledgehammer and wedge was the tool combination preferred during the assaults conducted against the two original panels, and a sledgehammer and crowbar combination was preferred against the modified panels. The ram was used only against panel XPK-05N-DOS-06 to impact the protect side appliques.

4 Conclusions

Results of the 13 tests described previously in this report lead to the following conclusions:

a. The two original CMU wall panels (XPK-05N-DOS-03 and XPK-05N-DOS-04) provided considerably more resistance to the forced entry assaults than did the two wood stud wall panels and the two modified CMU wall panels. The original CMU panels were the only panels to demonstrate, with a high degree of certainty, the capability to delay forced entry penetration for at least 5 minutes.

b. Of the four wood connectors used in construction of the wood stud wall panels, the Kant-Sag THD26 appeared to provide strongest and most durable stud/plate connection.

c. The sledgehammer proved to be the most frequently used and the most effective tool against all six wall panels.

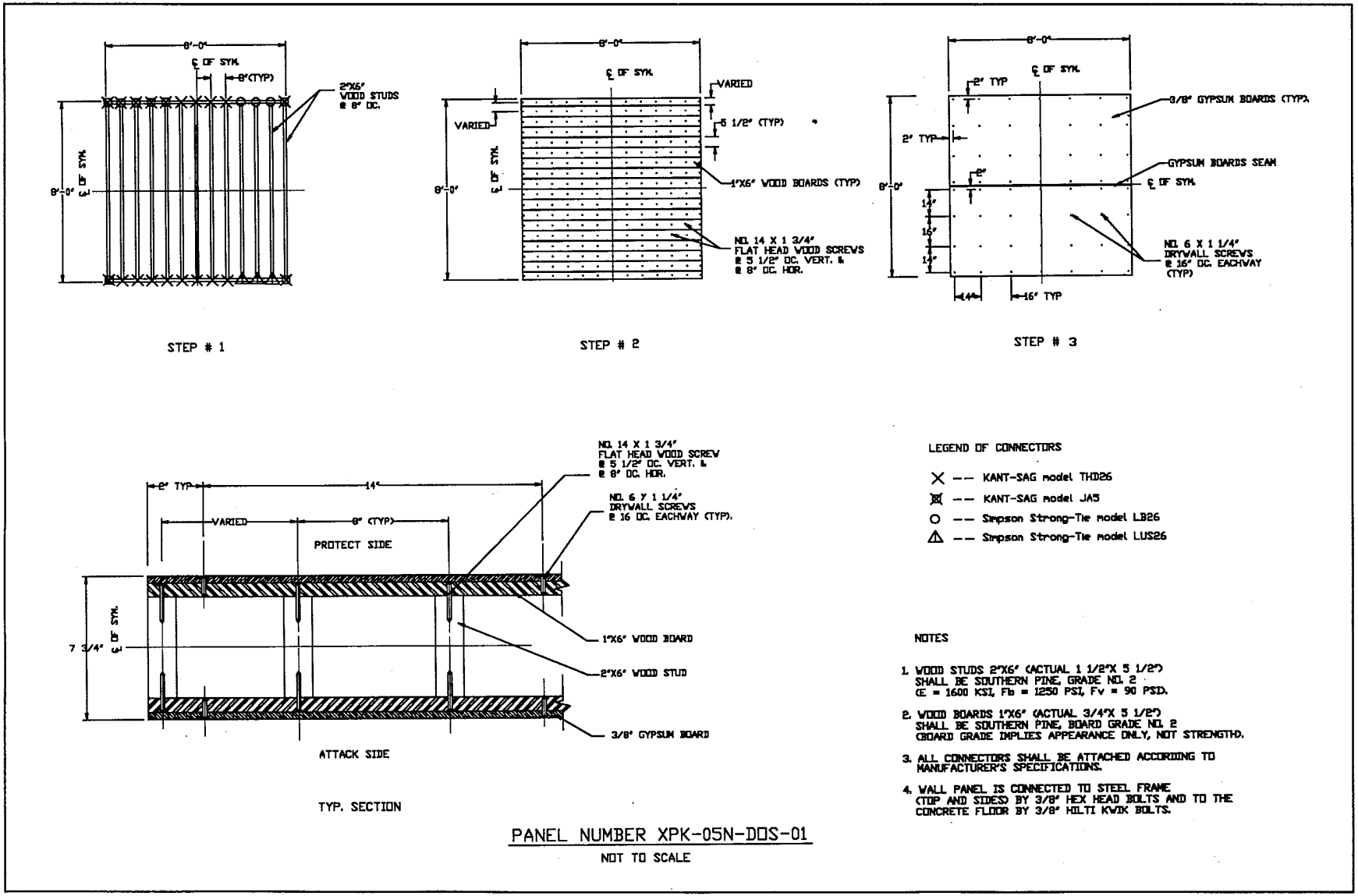


Figure 1. Engineering drawings for wall panel XPK-05N-DOS-01 (non-SI units)

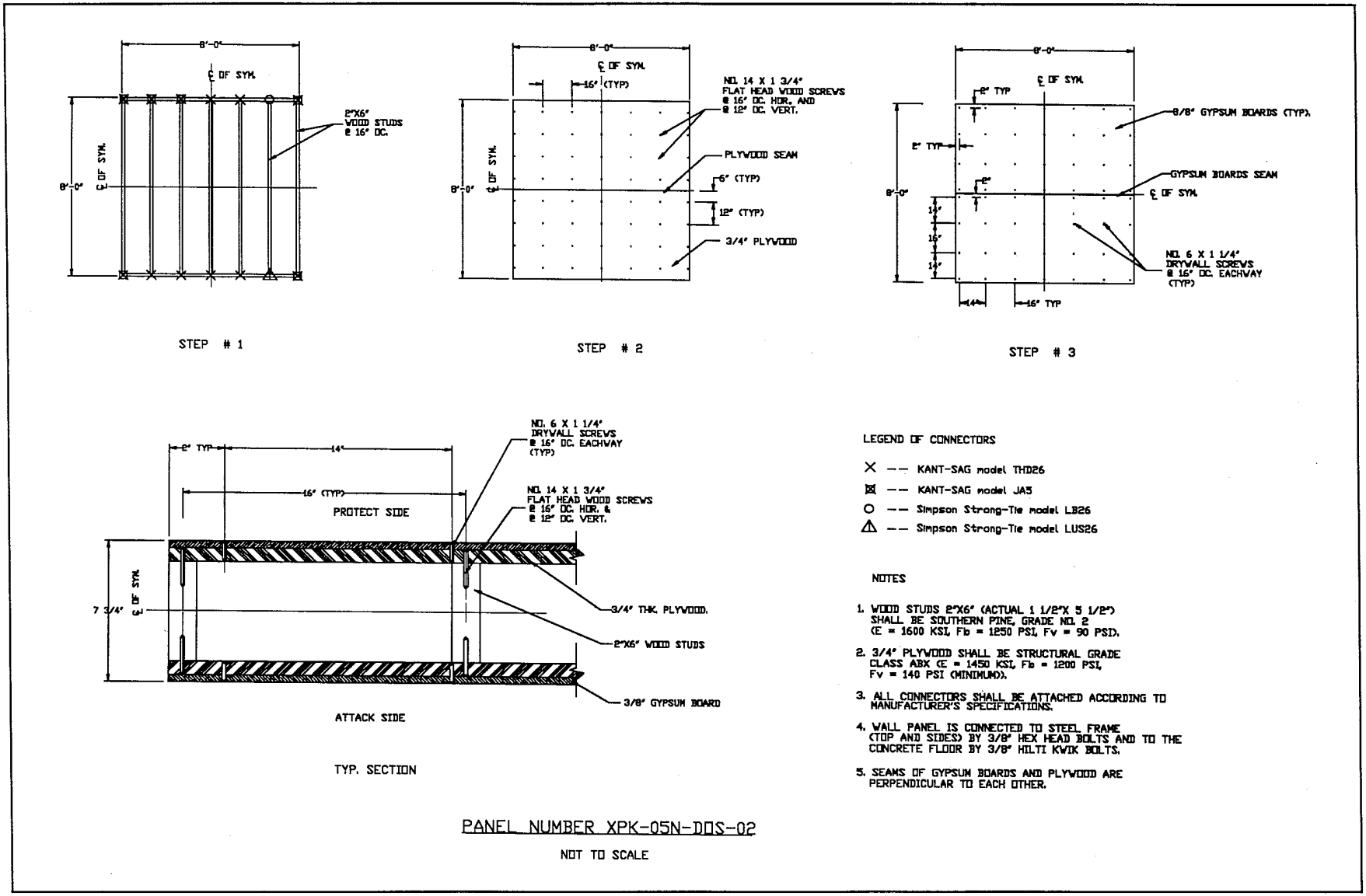


Figure 2. Engineering drawings for wall panel XPK-05N-DOS-02 (non-SI units)

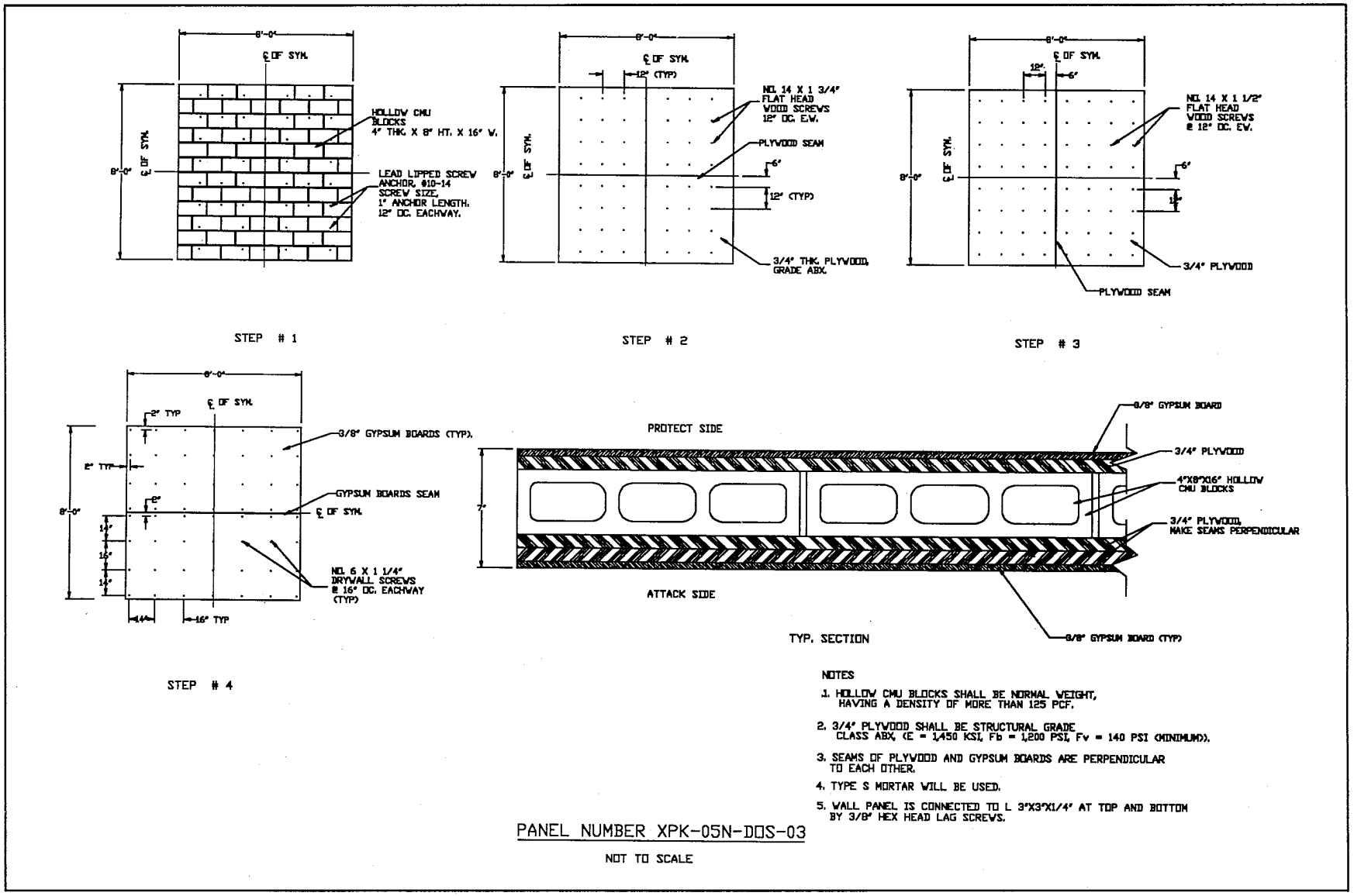


Figure 3. Engineering drawings for wall panel XPK-05N-DOS-03 (non-SI units)

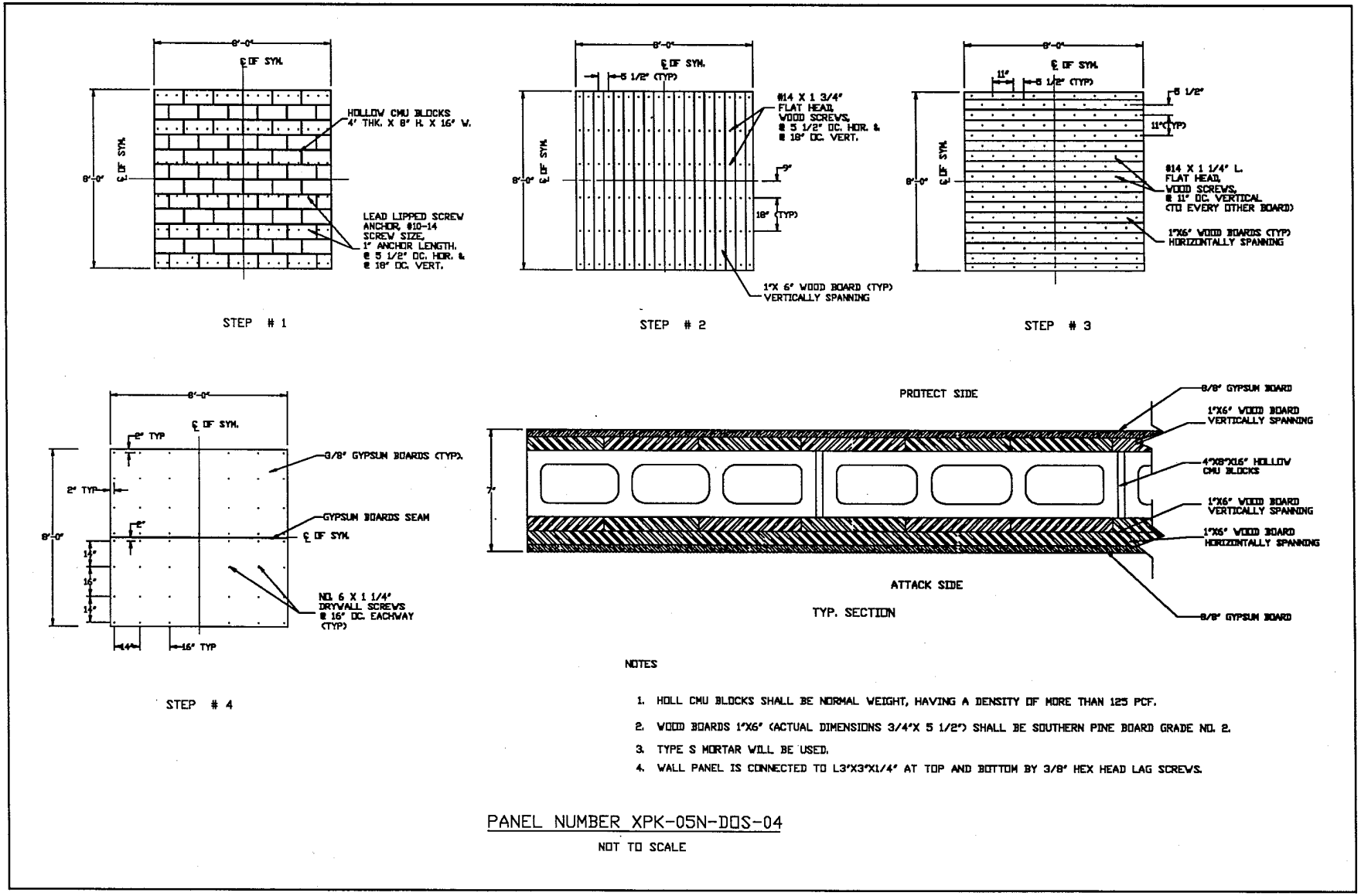


Figure 4. Engineering drawings for wall panel XPK-05N-DOS-04 (non-SI units)

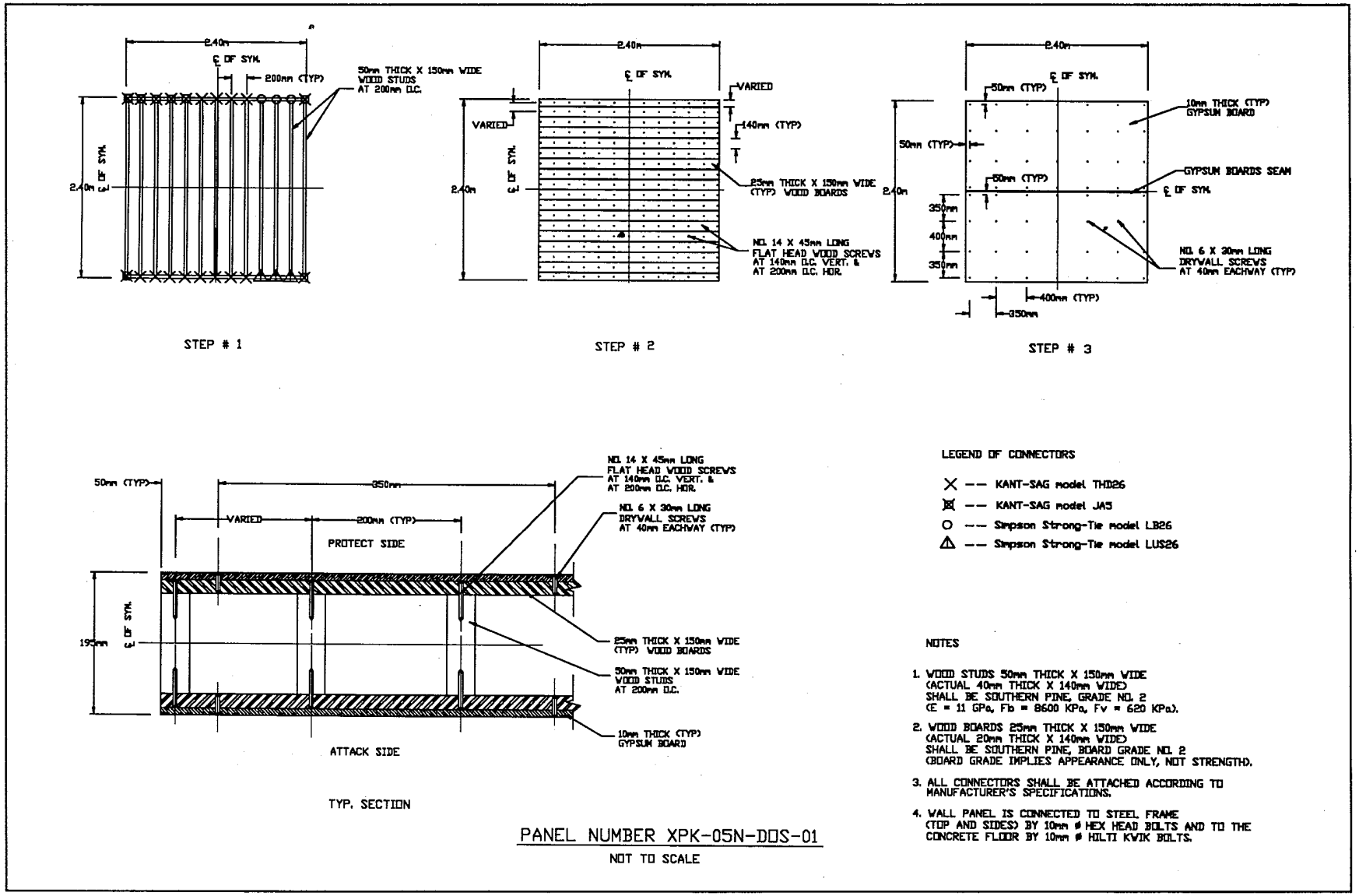


Figure 5. Engineering drawings for wall panel XPK-05N-DOS-01 (SI units)

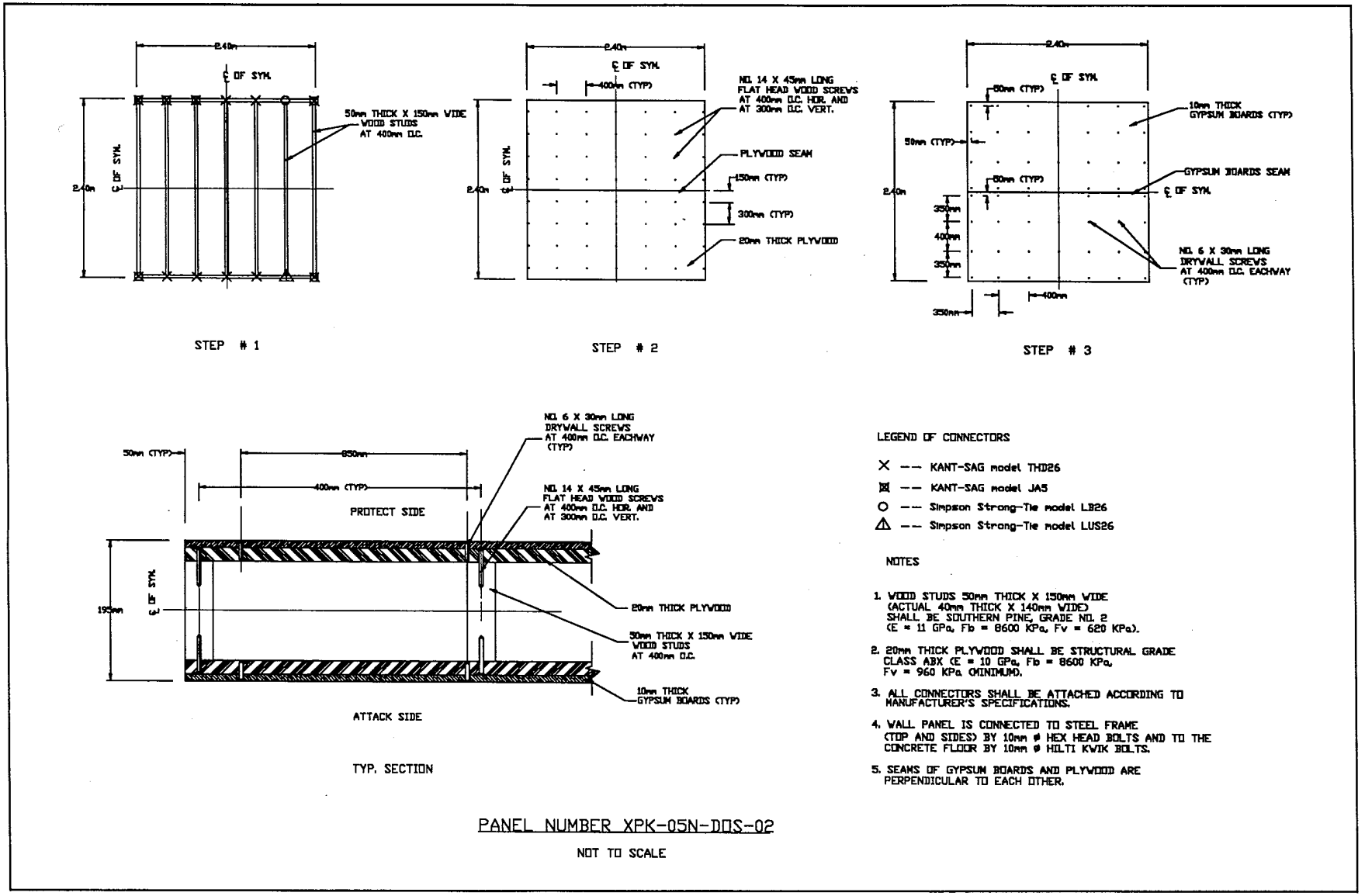


Figure 6. Engineering drawings for wall panel XPK-05N-DOS-02 (SI units)

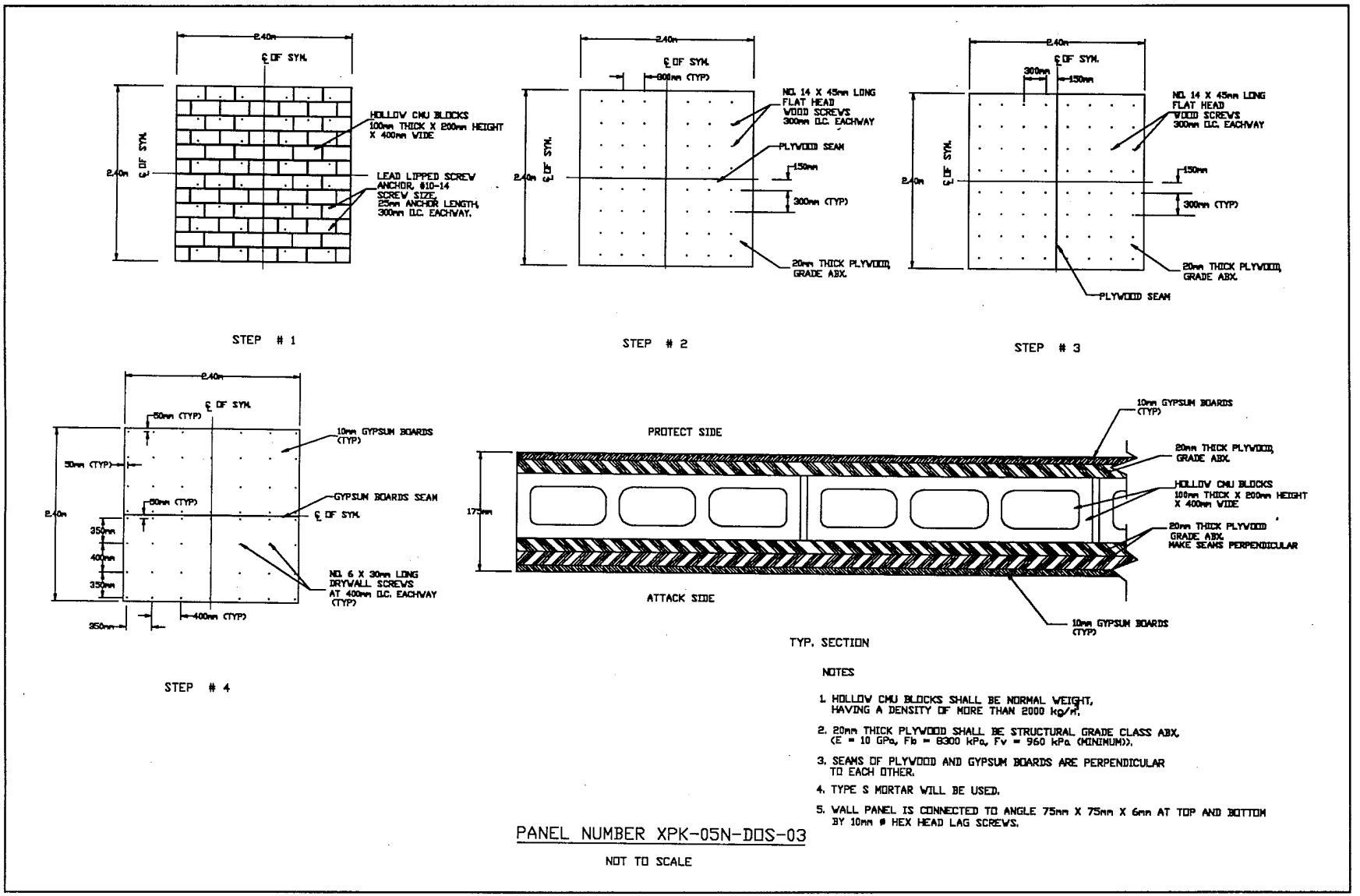


Figure 7. Engineering drawings for wall panel XPK-05N-DOS-03 (SI units)

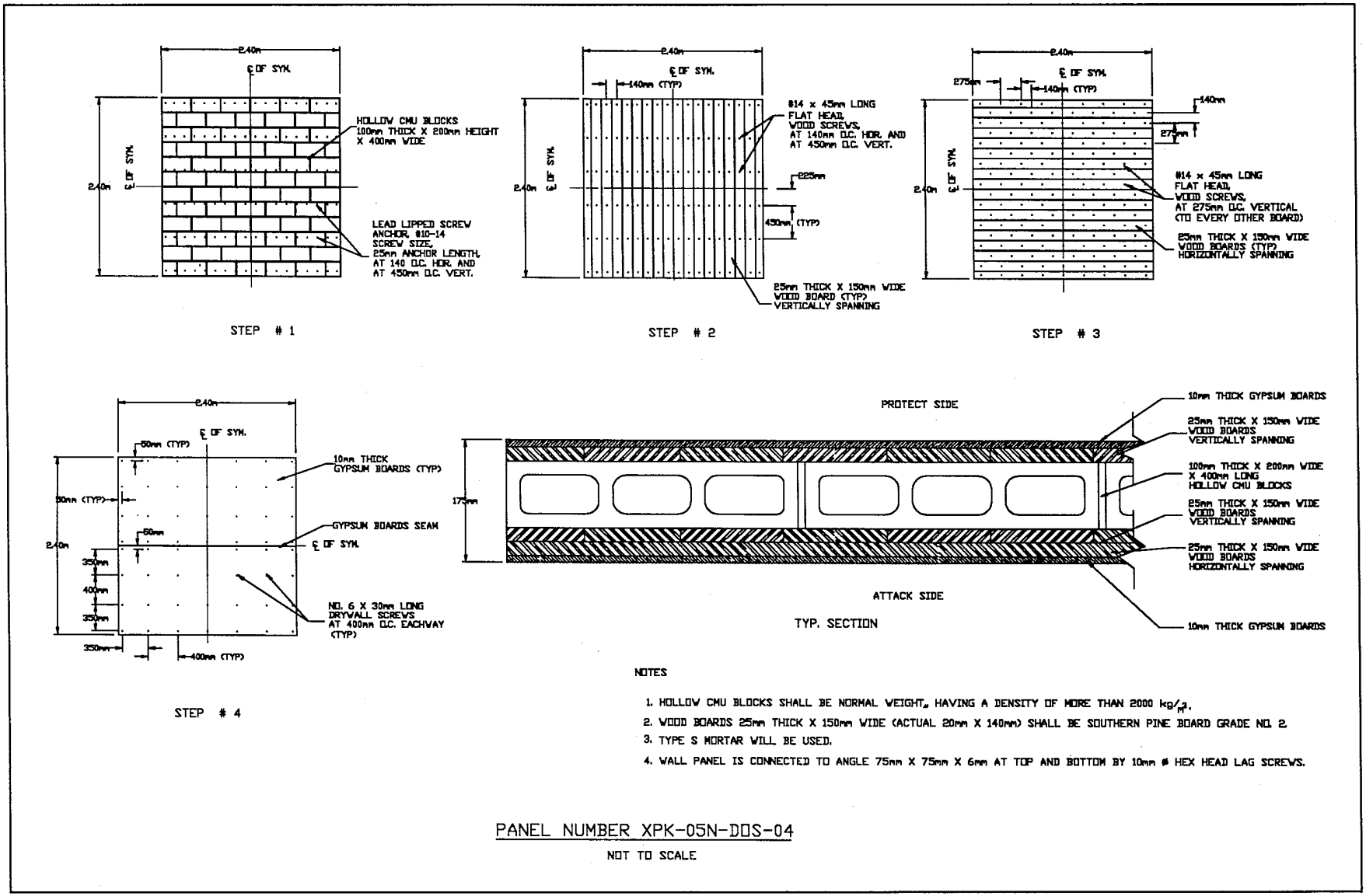
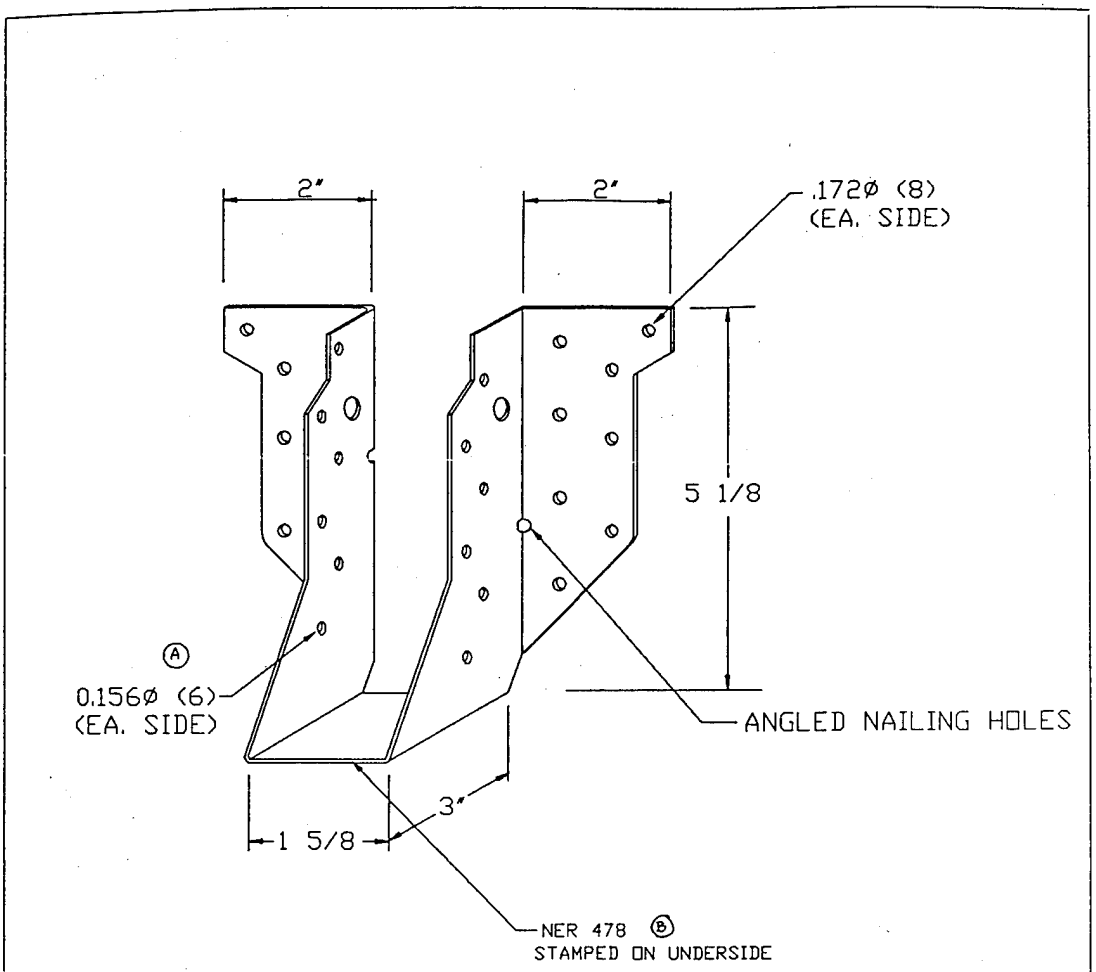


Figure 8. Engineering drawings for wall panel XPK-05N-DOS-04 (SI units)



NO.	DATE	ECO NO.	REVISION	BY
B	10/29/93		ADD NER 478 STAMP/REMOVE ASTM	JAS
A	1/22/91		.156Ø (6) W/ .156Ø (5) 16 GA. W/ 14 GA.	BRW

UNITED STEEL PRODUCTS COMPANY
703 ROGERS DRIVE, MONTGOMERY, MN 56069 PHONE (612) 364 7333

NAME: THD26

MAT'L: 16 GA. GALV. Ⓐ Ⓑ

DR. BY: | DATE: | APPD. BY: TAK | DATE: 10/29/93

TOLERANCES: FRACTIONAL, DEC. .XX, DEC. .XXX, ANGULAR | SCALE: | REF. DIE\172-THD | REF.

DWG. NO. THD 26 | 1 – 1

Figure 9. Engineering drawing for Kant-Sag THD26 wood connector

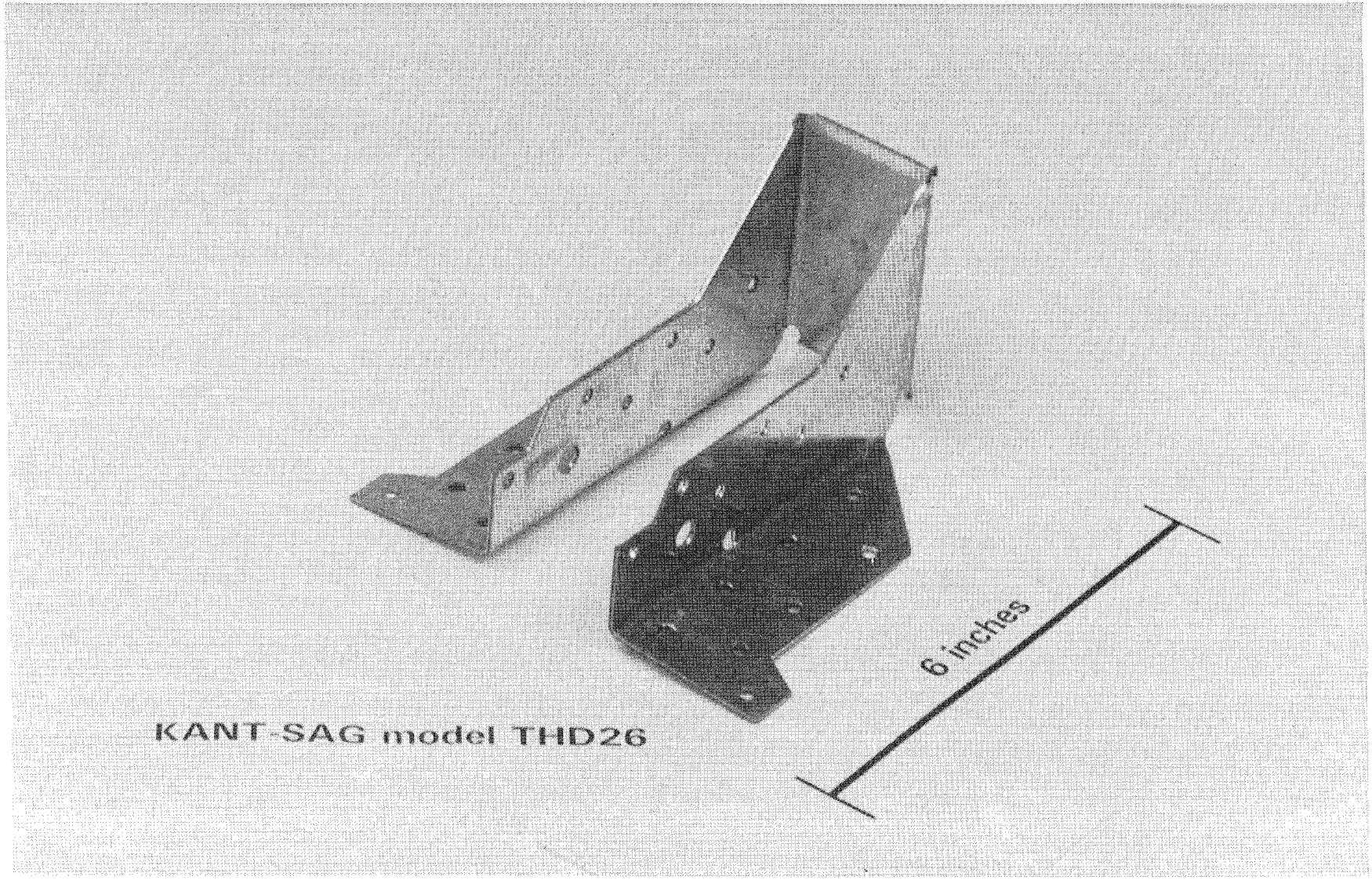


Figure 10. Kant-Sag THD26 wood connector

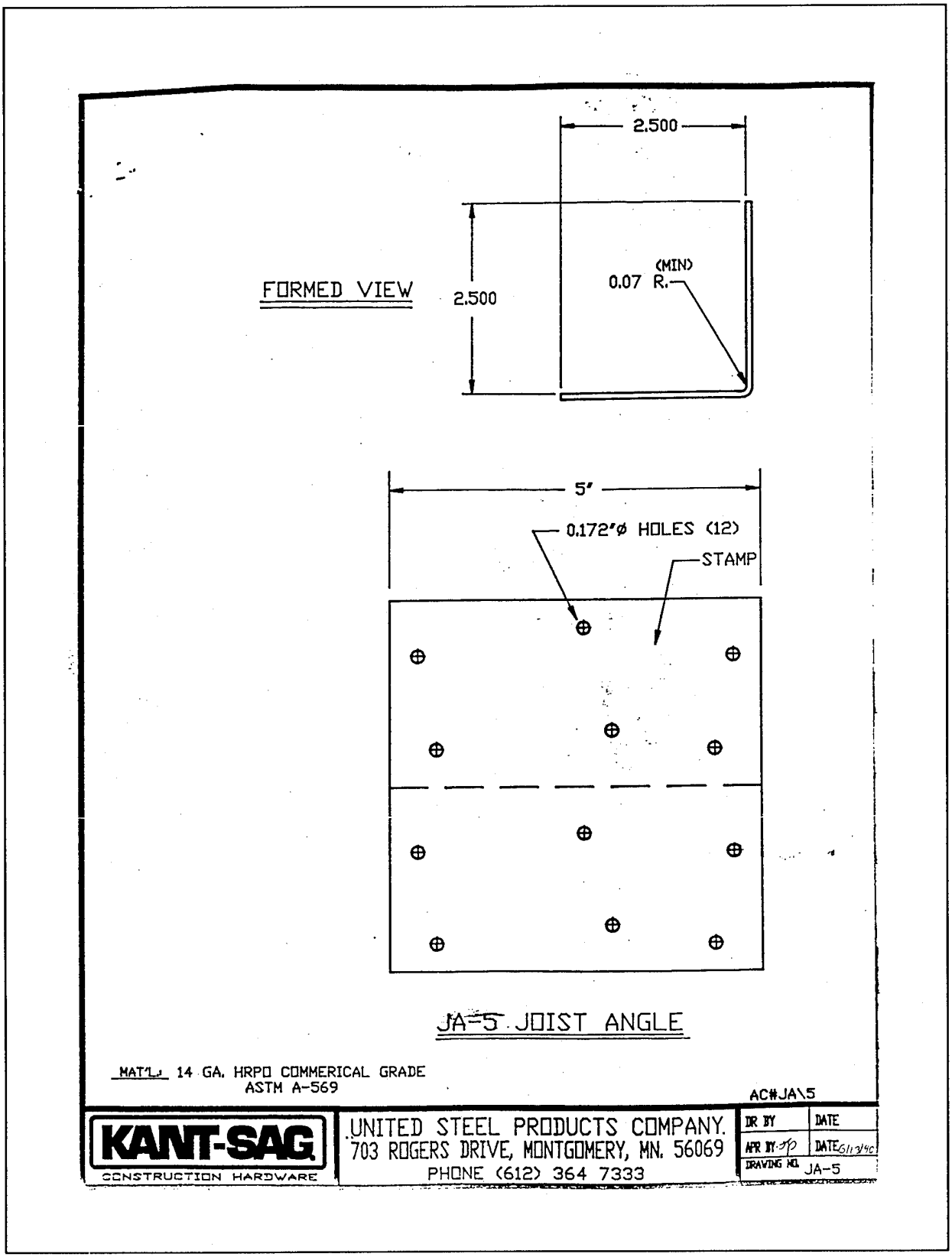


Figure 11. Engineering drawing for Kant-Sag JA5 wood connector

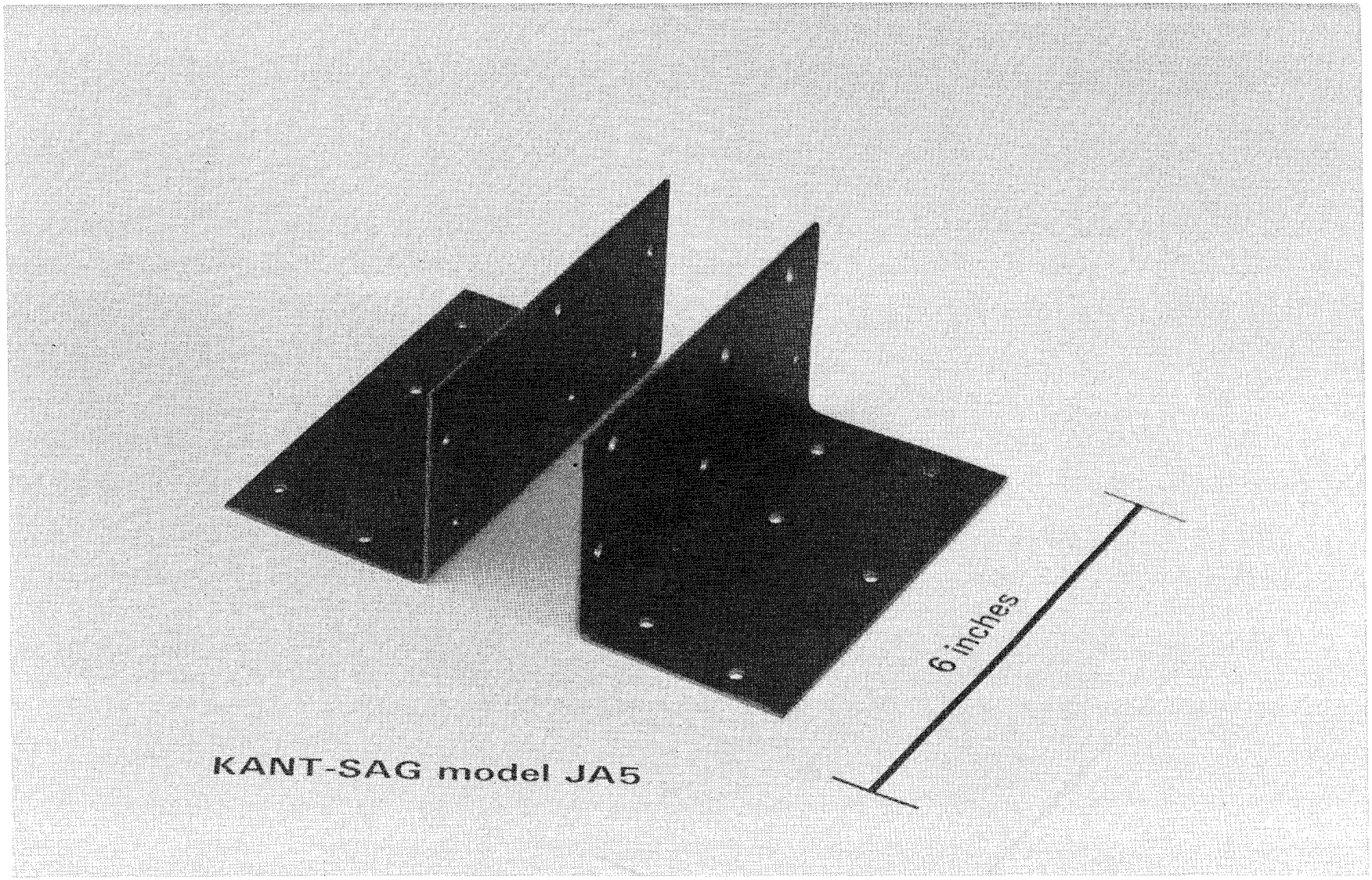


Figure 12. Kant-Sag JA5 wood connector

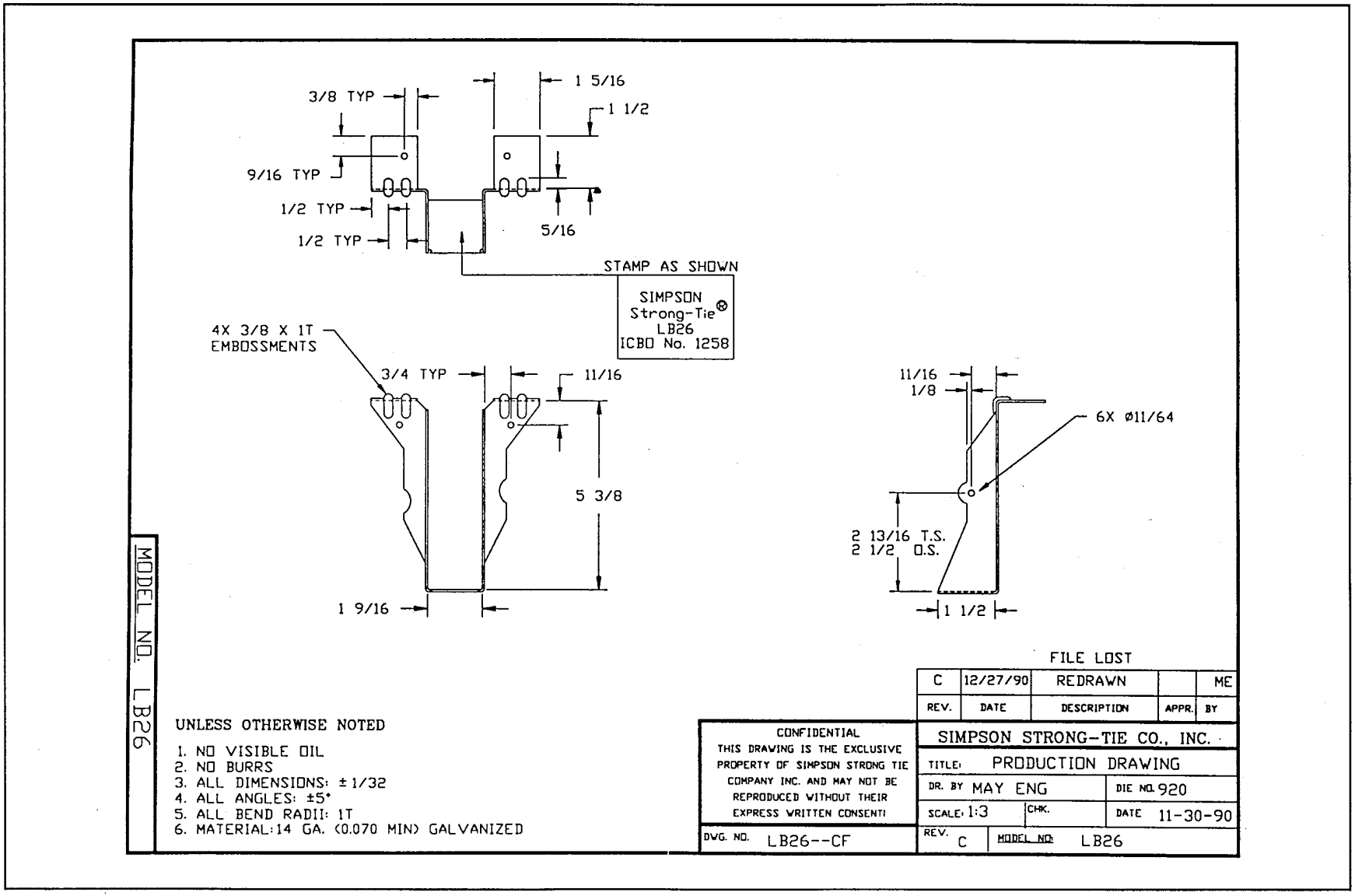


Figure 13. Engineering drawings for Simpson Strong-Tie LB26 wood connector *(Courtesy of Simpson Strong-Tie Co., Inc.)*

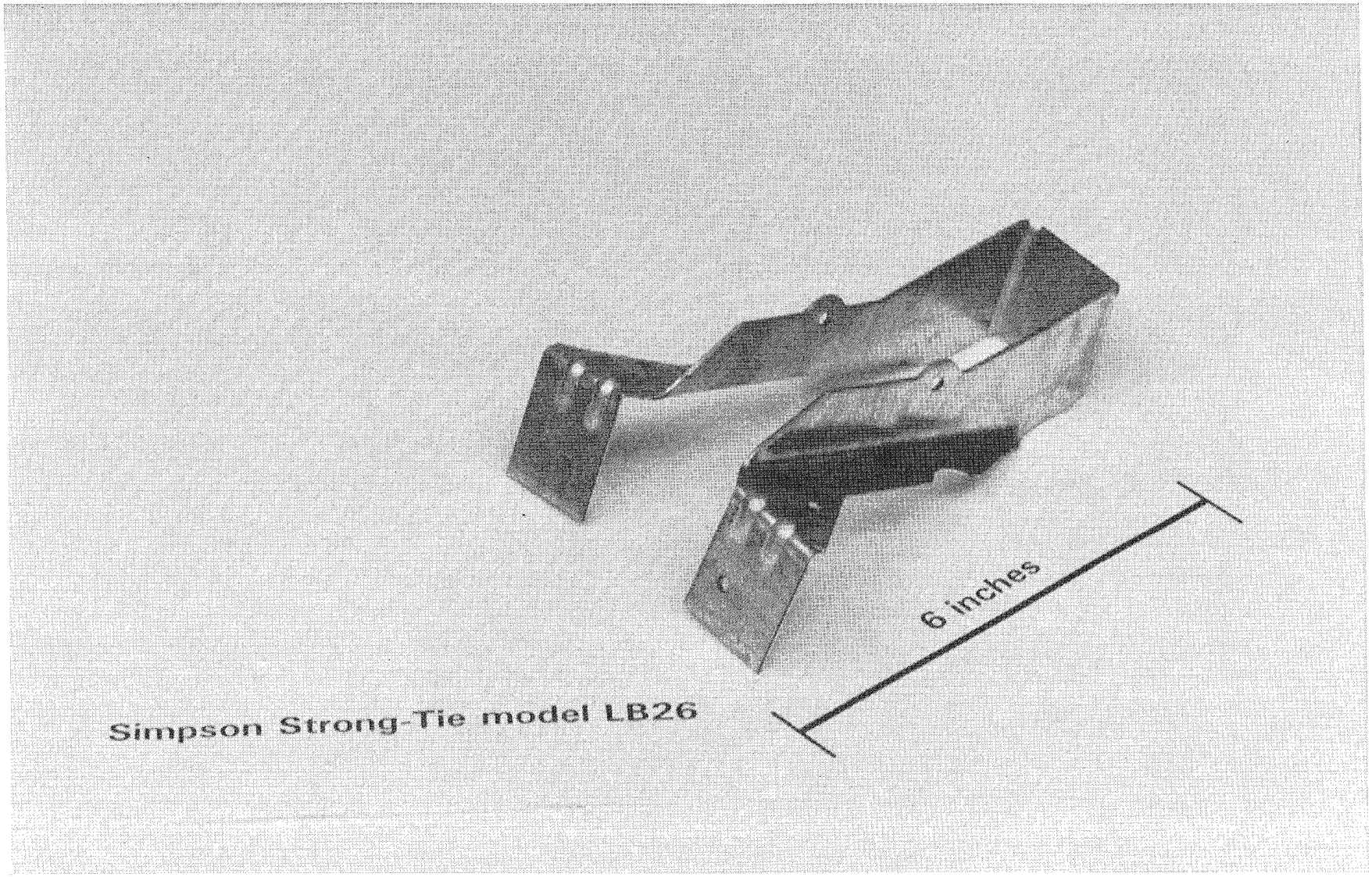


Figure 14. Simpson Strong-Tie LB26 wood connector

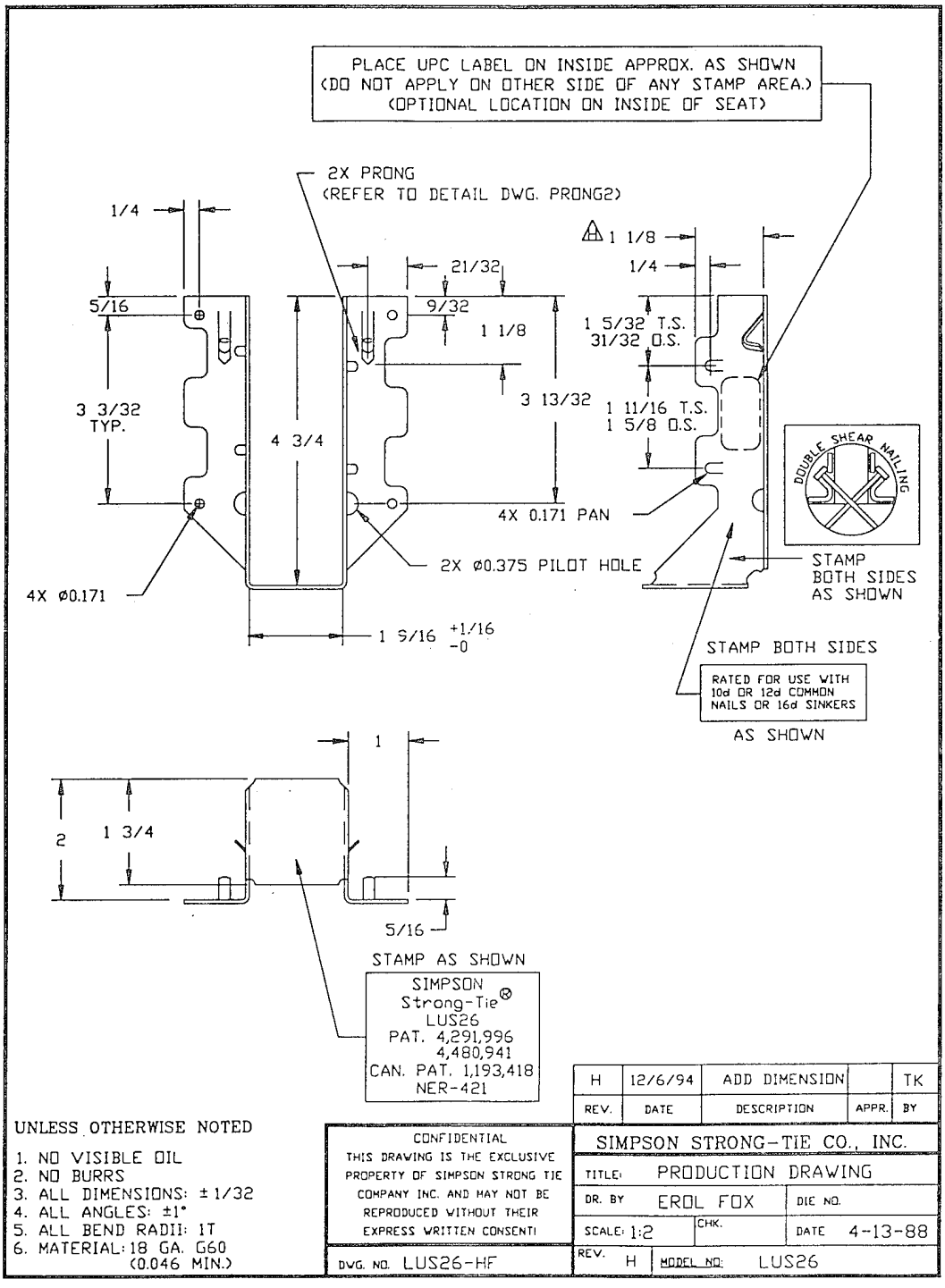


Figure 15. Engineering drawing for Simpson Strong-Tie LUS26 wood connector
(Courtesy of Simpson Strong-Tie Co.,Inc.)

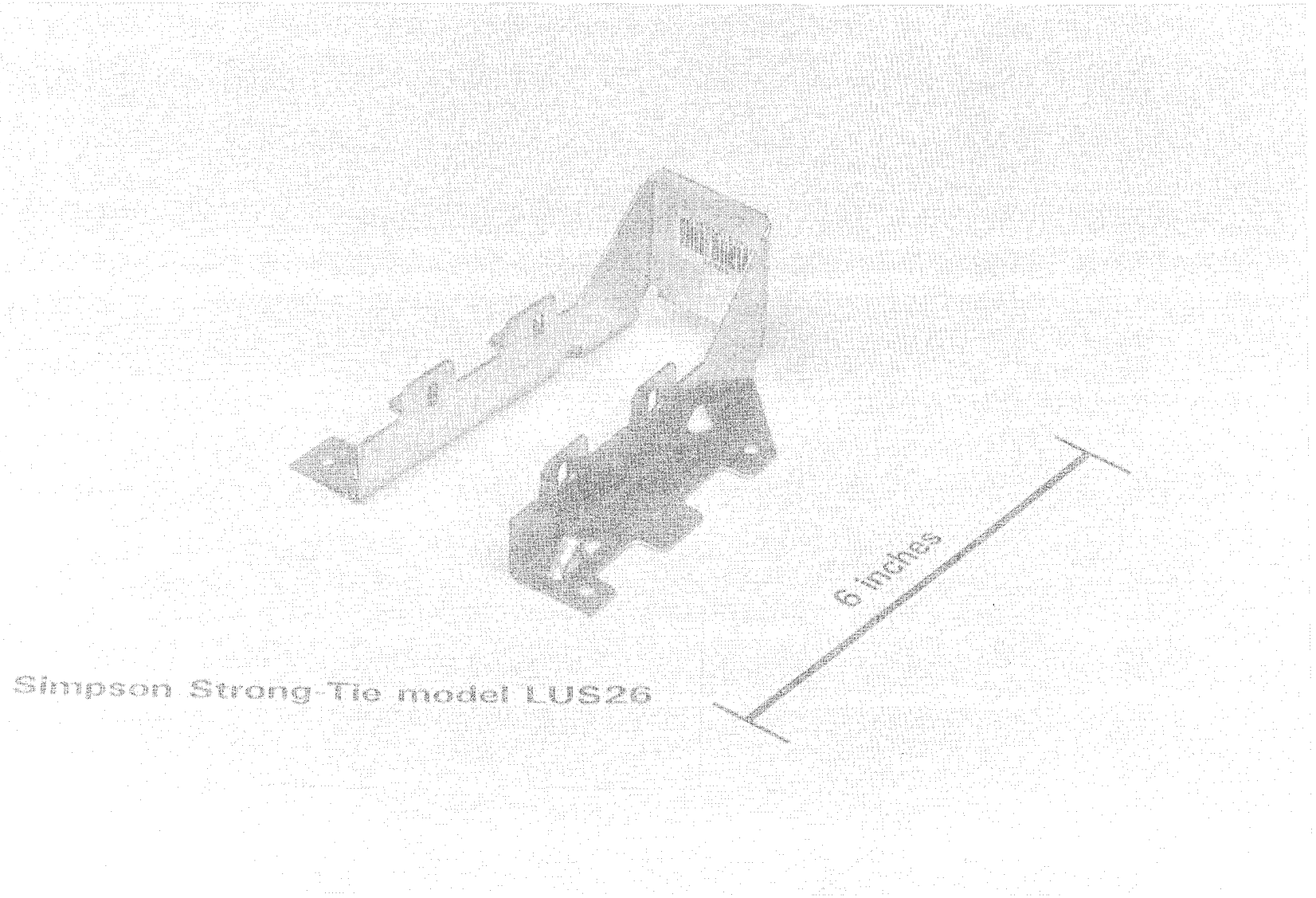


Figure 16. Simpson Strong-Tie LUS26 wood connector

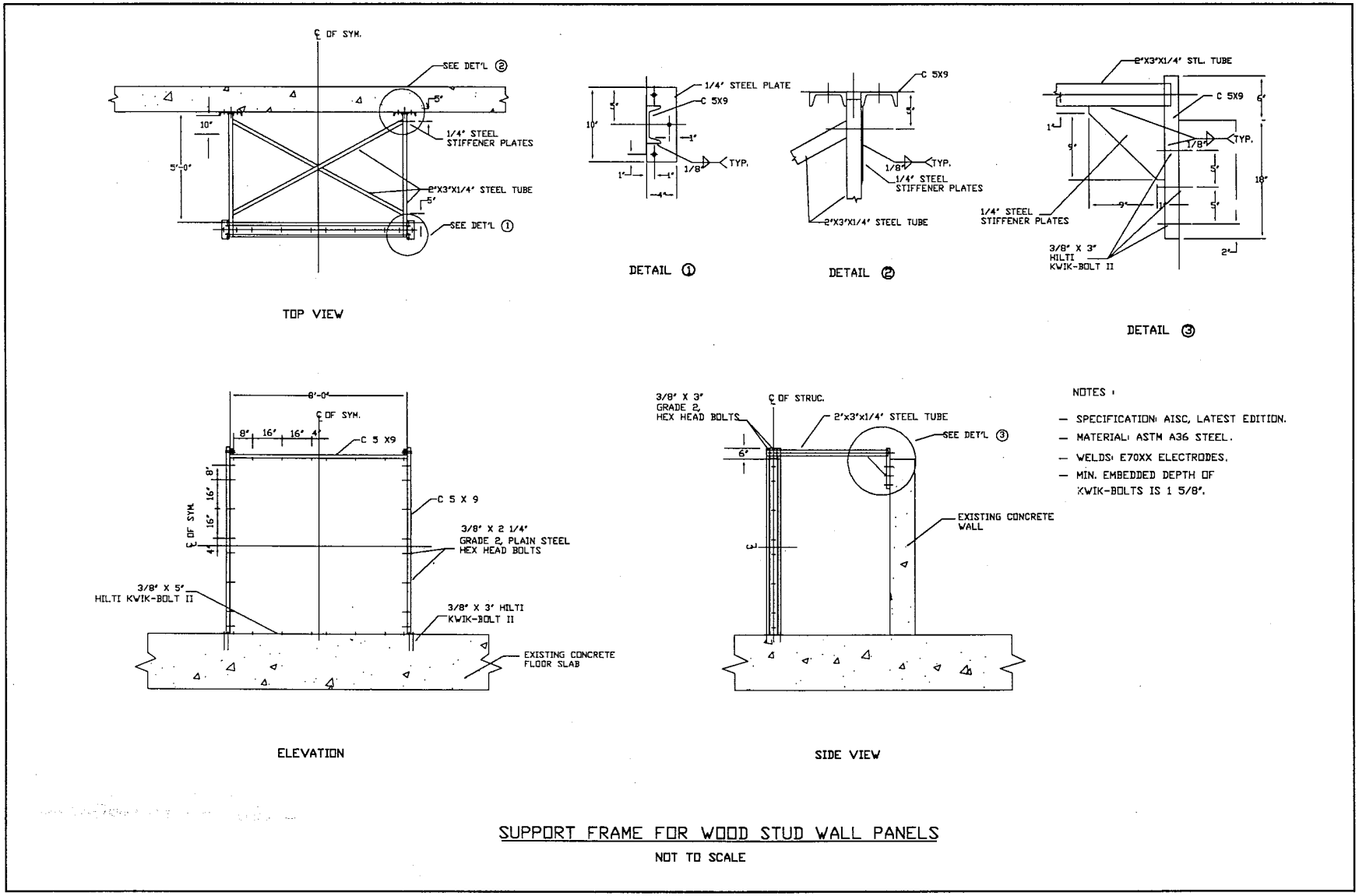


Figure 17. Engineering drawings for wood stud wall panel support frame

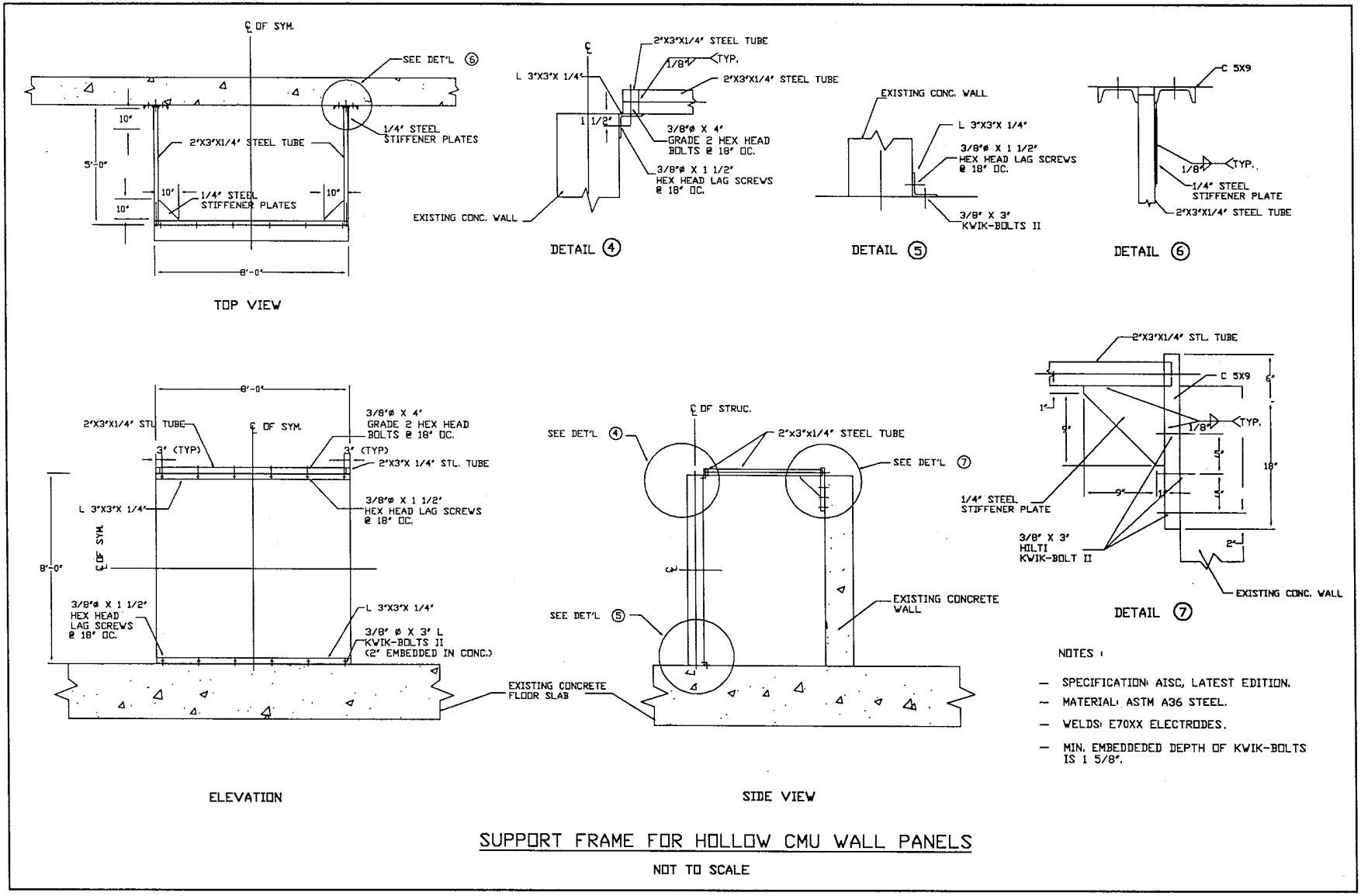


Figure 18. Engineering drawings for hollow CMU wall panel support frame

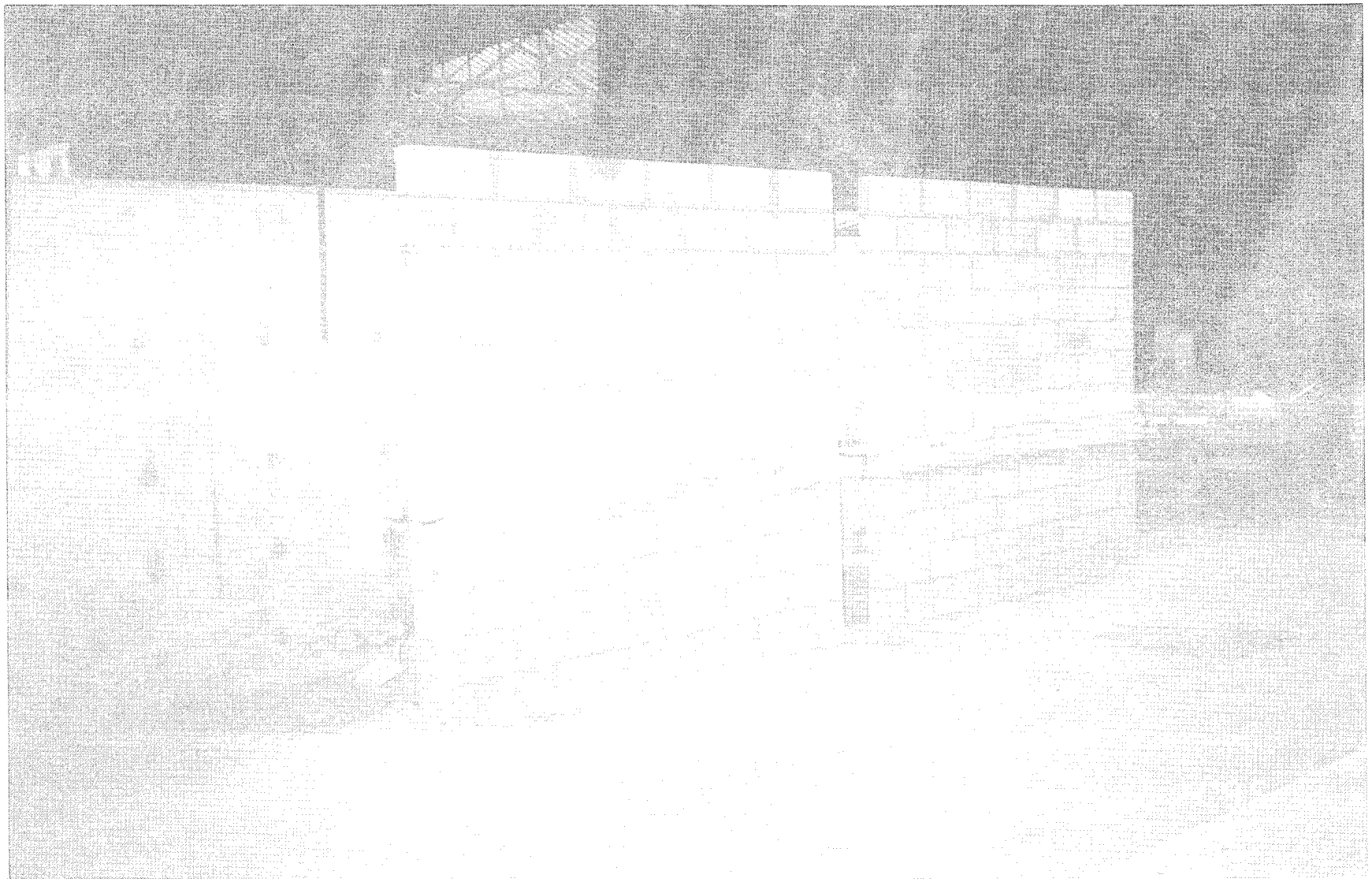


Figure 19. Hollow CMU walls before the wood and gypsum board were attached

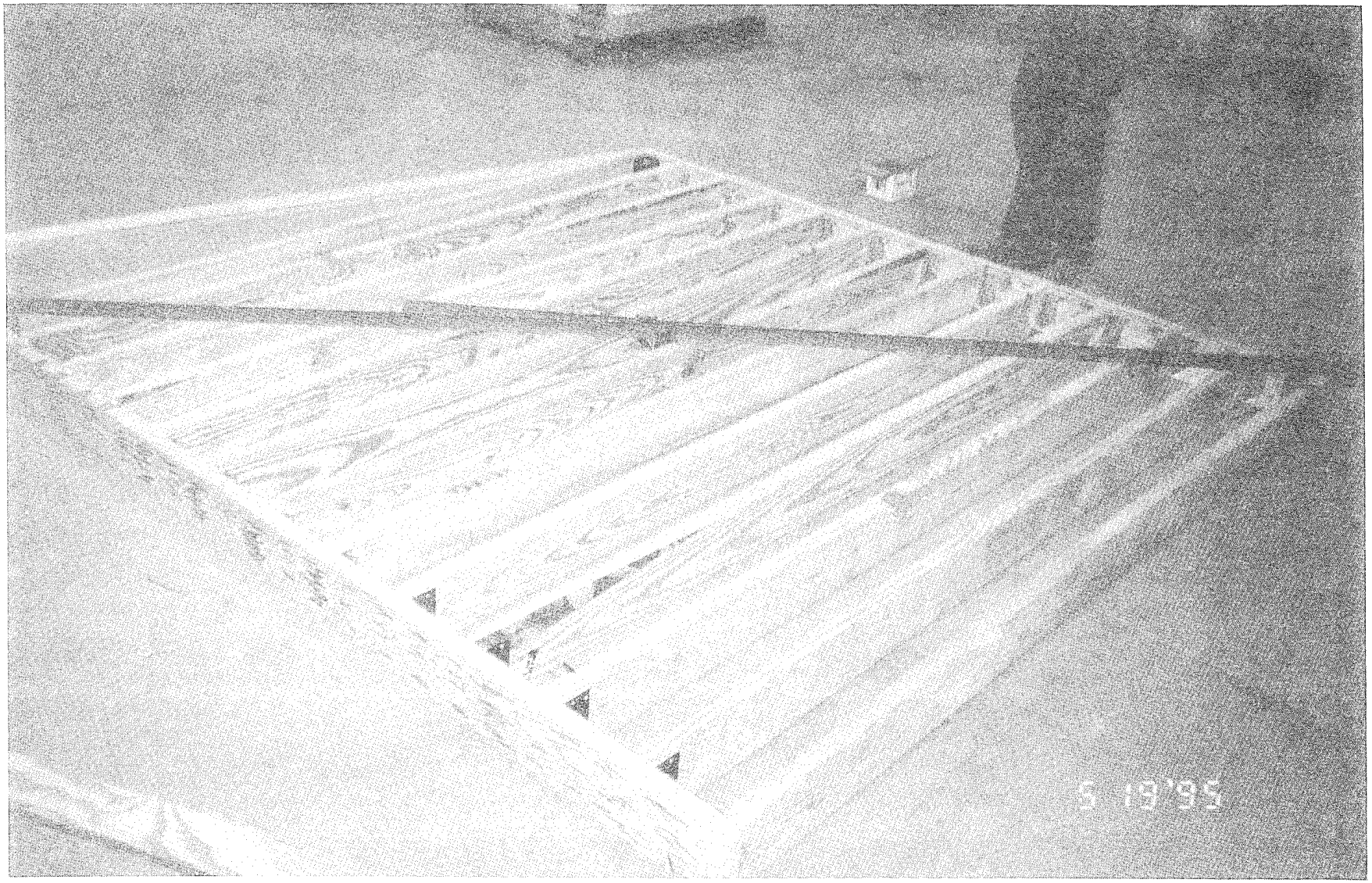


Figure 20. Squaring a wood stud frame with a bar clamp

Figure 21. Wood stud wall with one layer of wood boards attached to the protect side

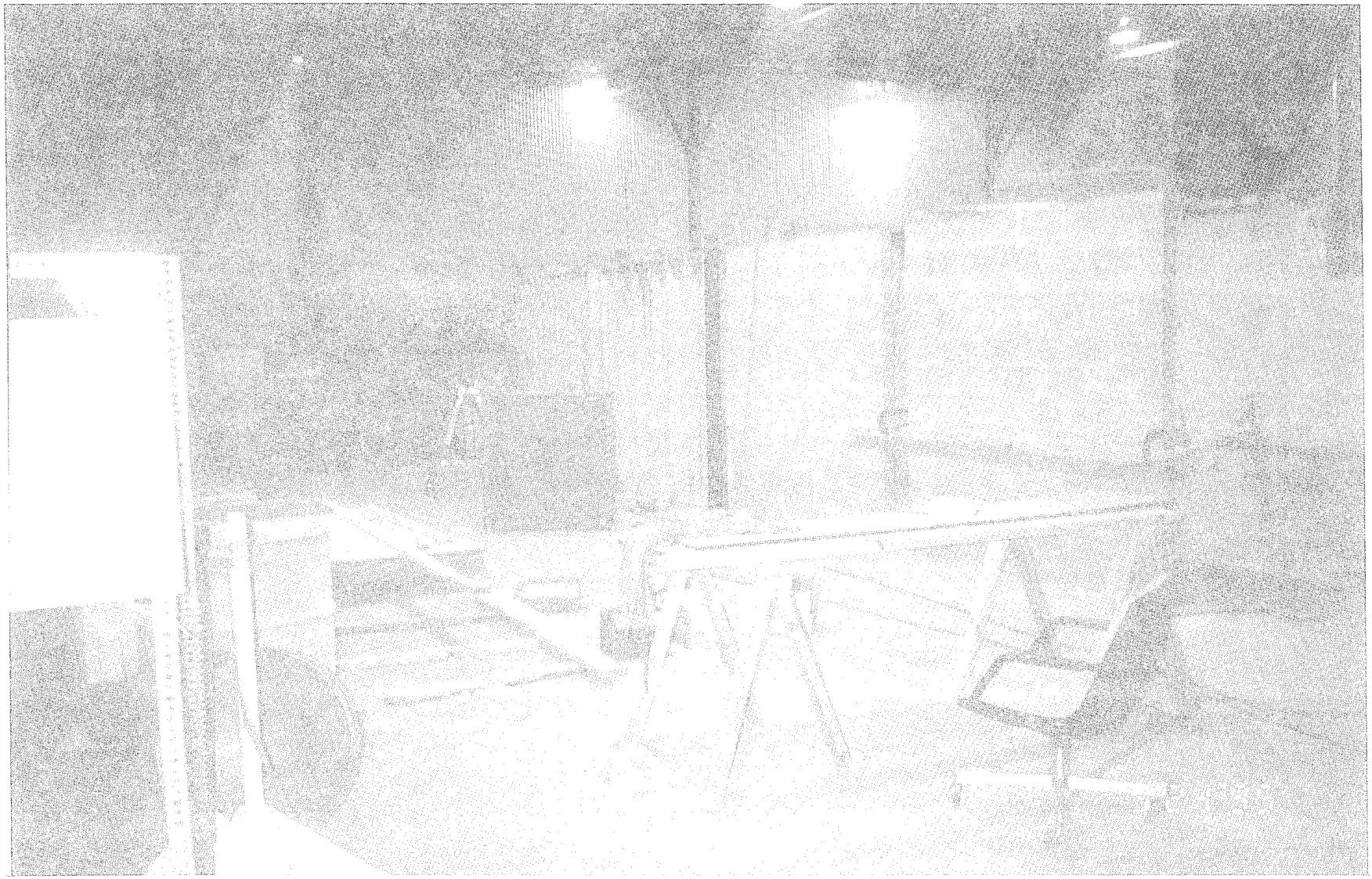


Figure 22. Four wall panels positioned side-by-side during construction

Figure 23. Assault team

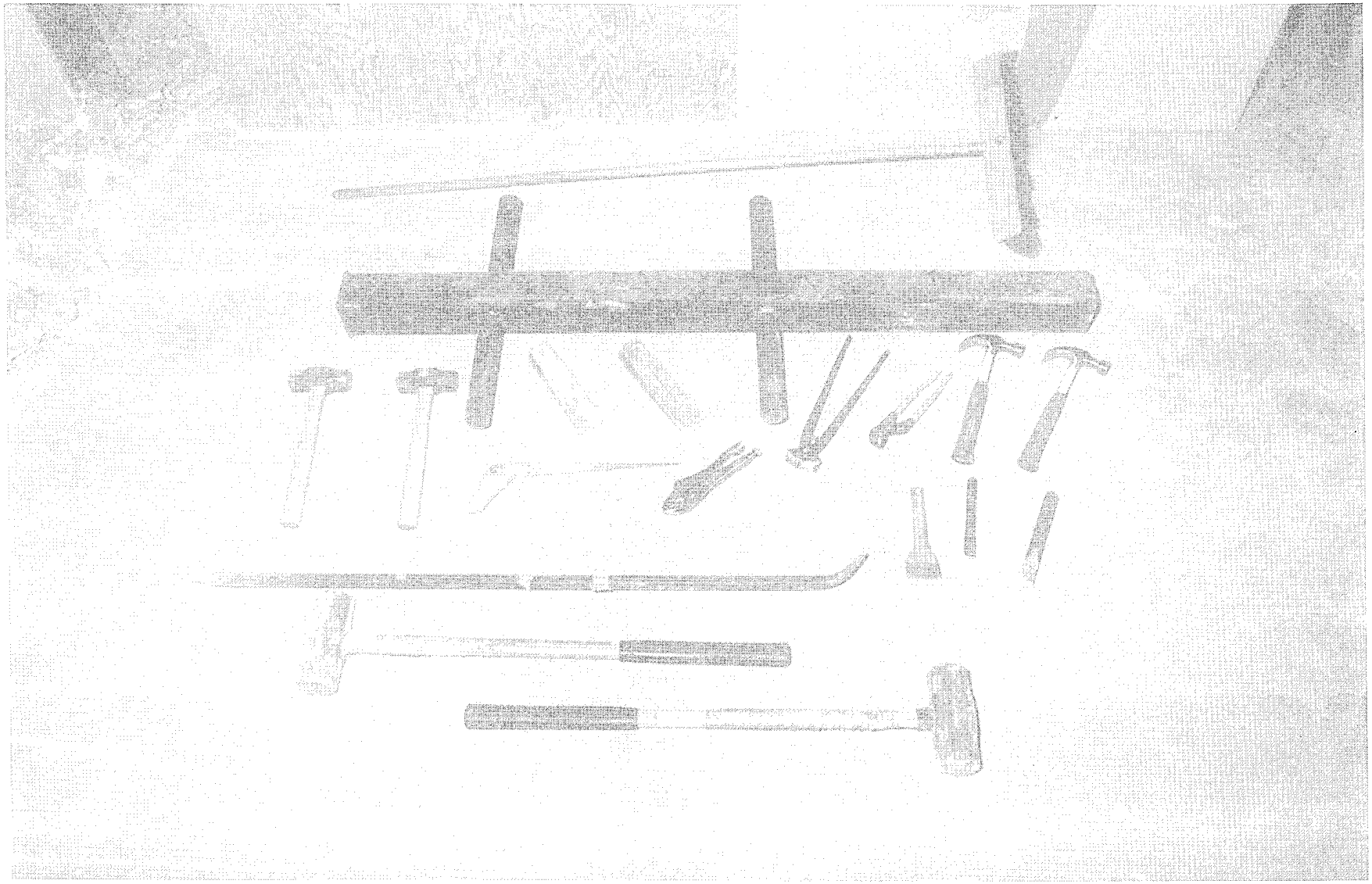


Figure 24. Forced entry tool group

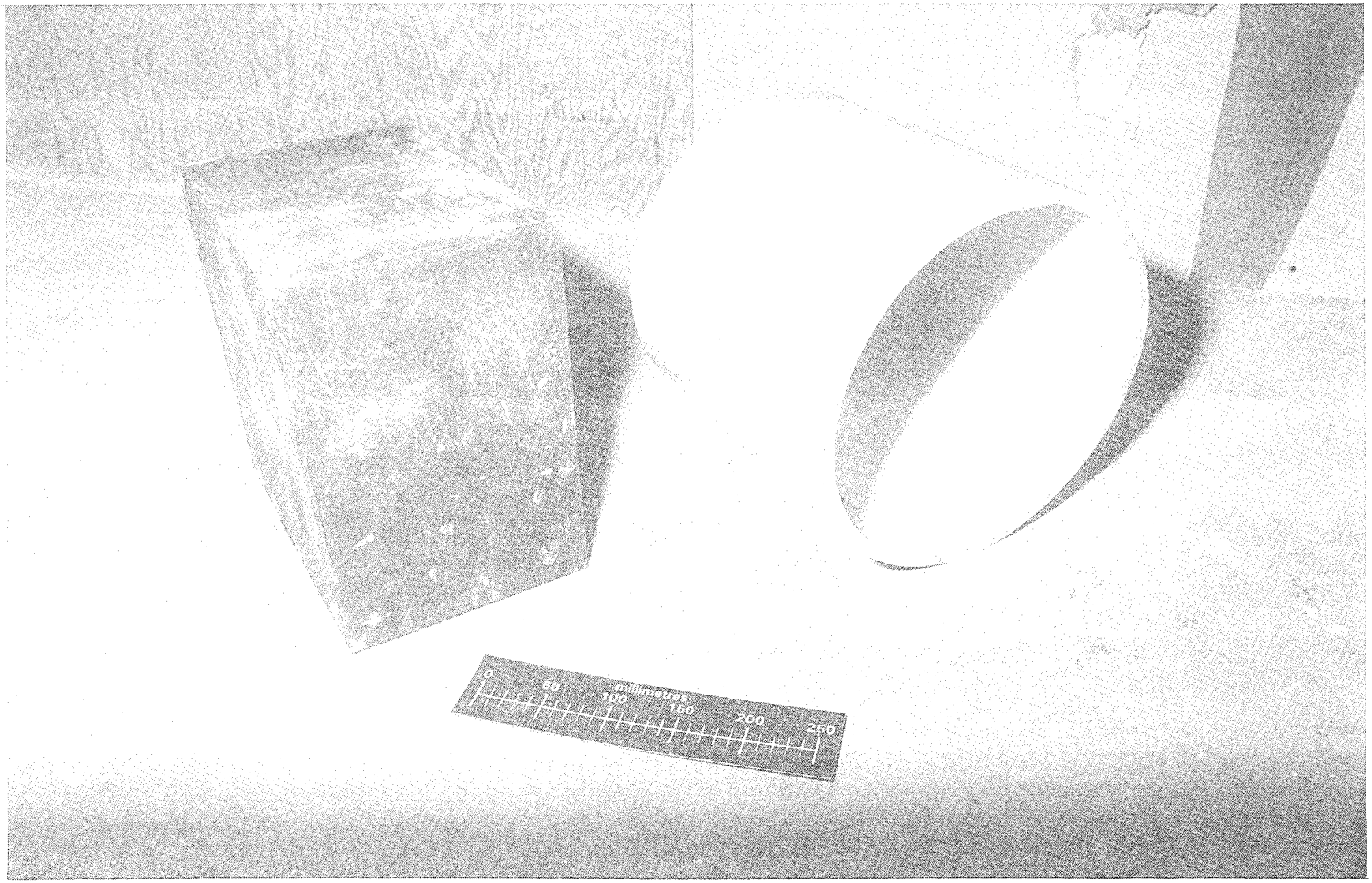


Figure 25. Rigid objects for determining wall penetration

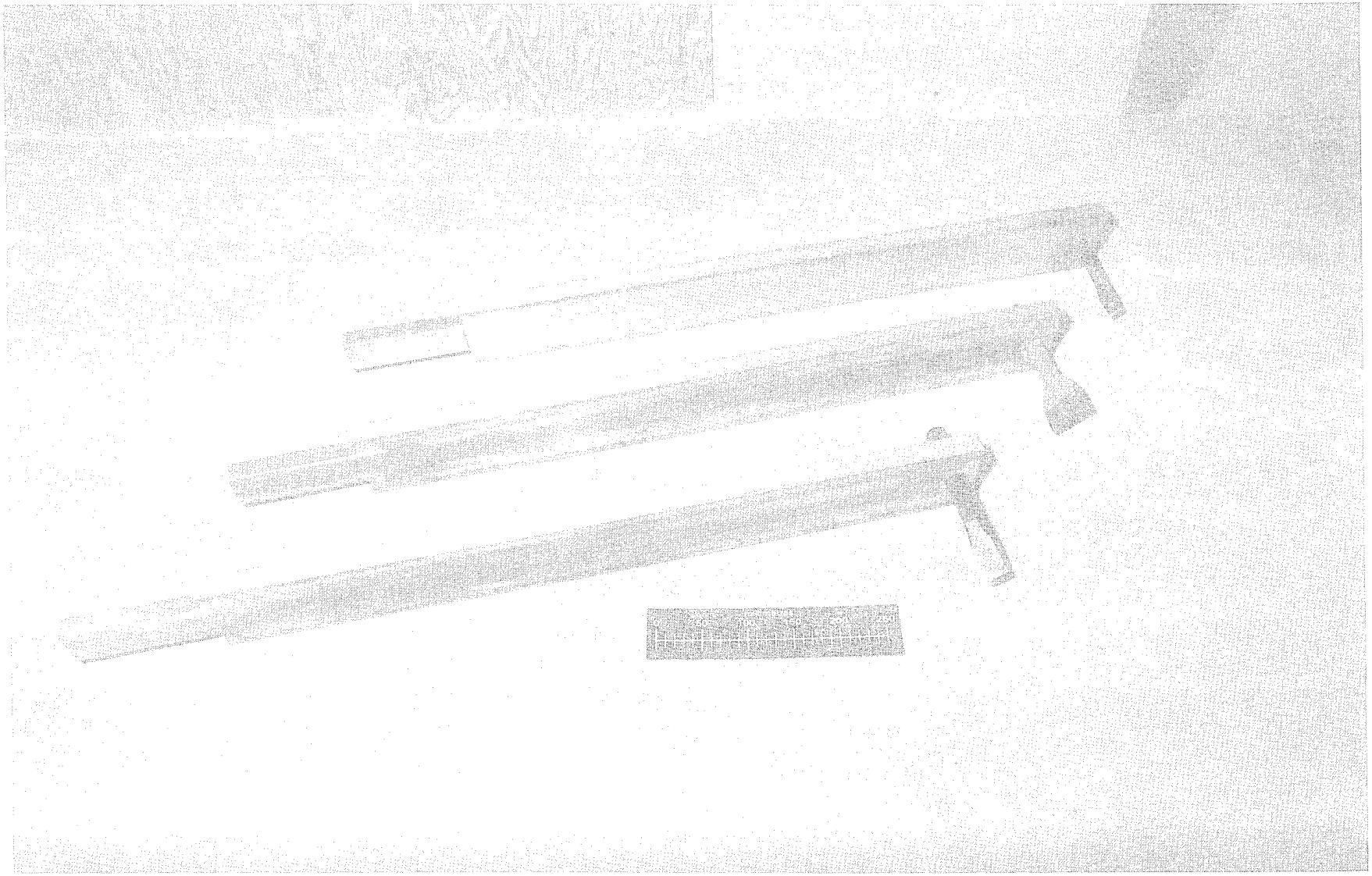


Figure 26. Chisel holders

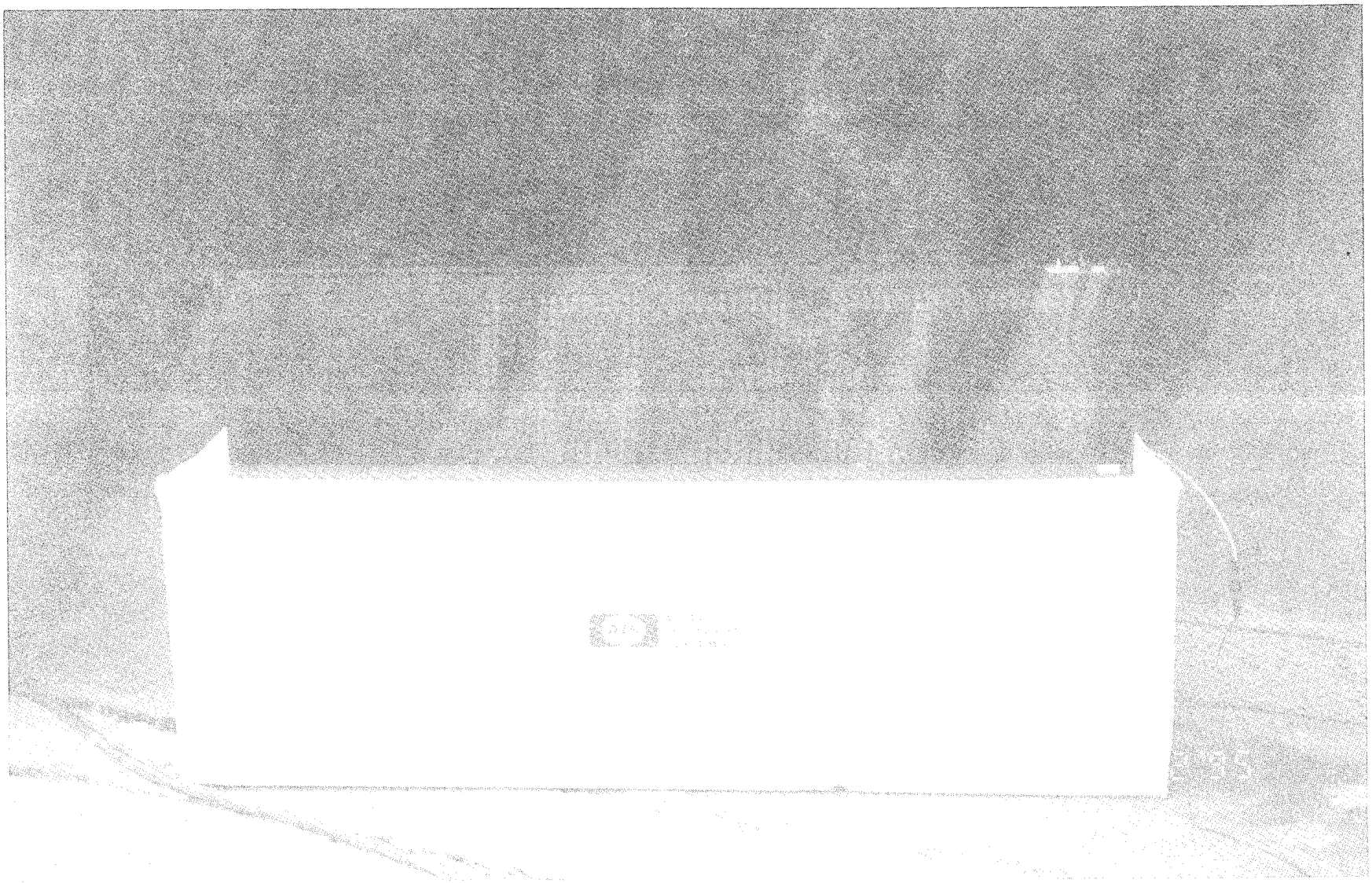


Figure 27. Digital LED clock

Figure 28. Assault side of panel XPK-05N-DOS-01 after test 1-1

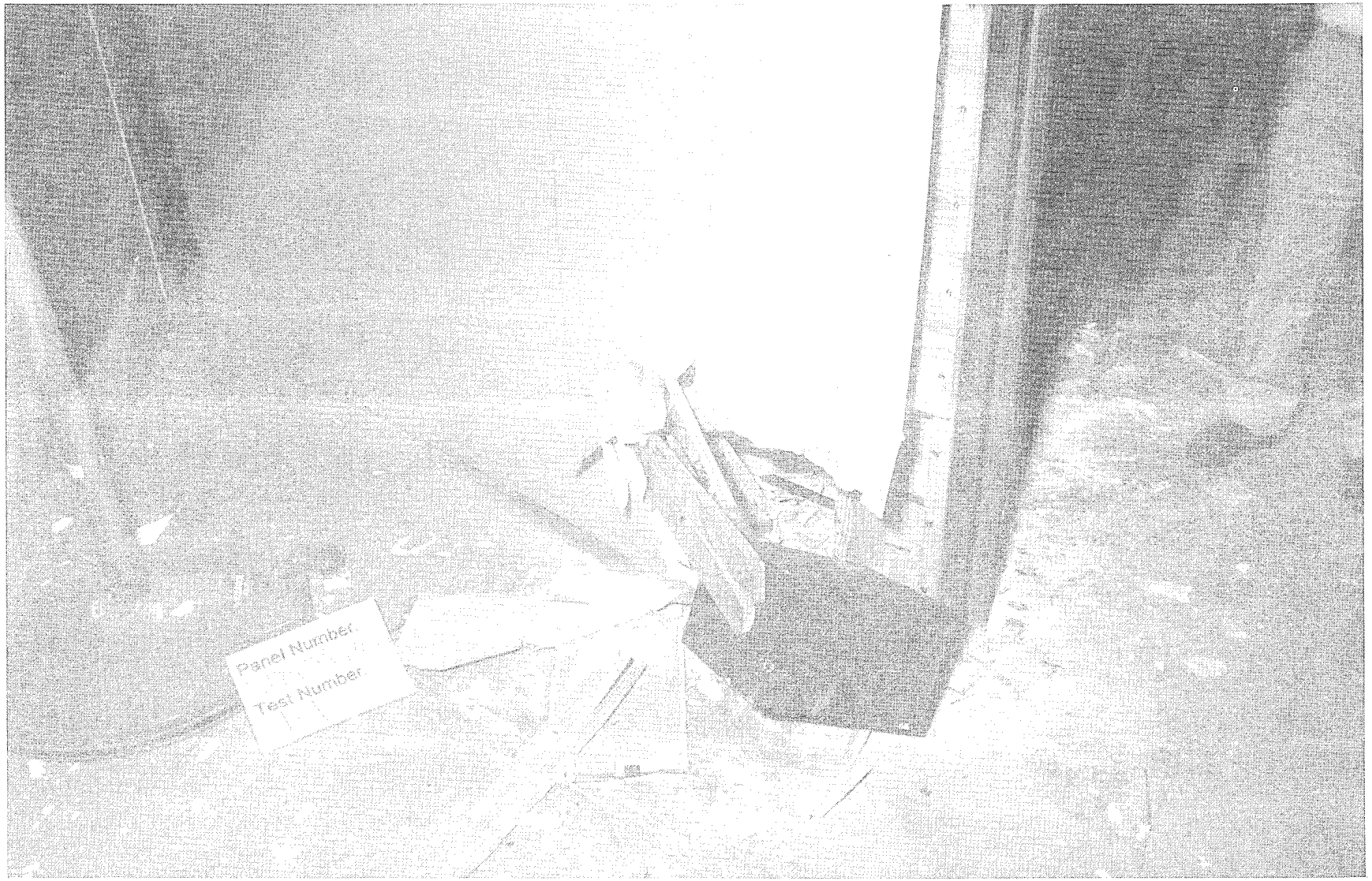


Figure 29. Protect side of panel XPK-05N-DOS-01 after test 1-1

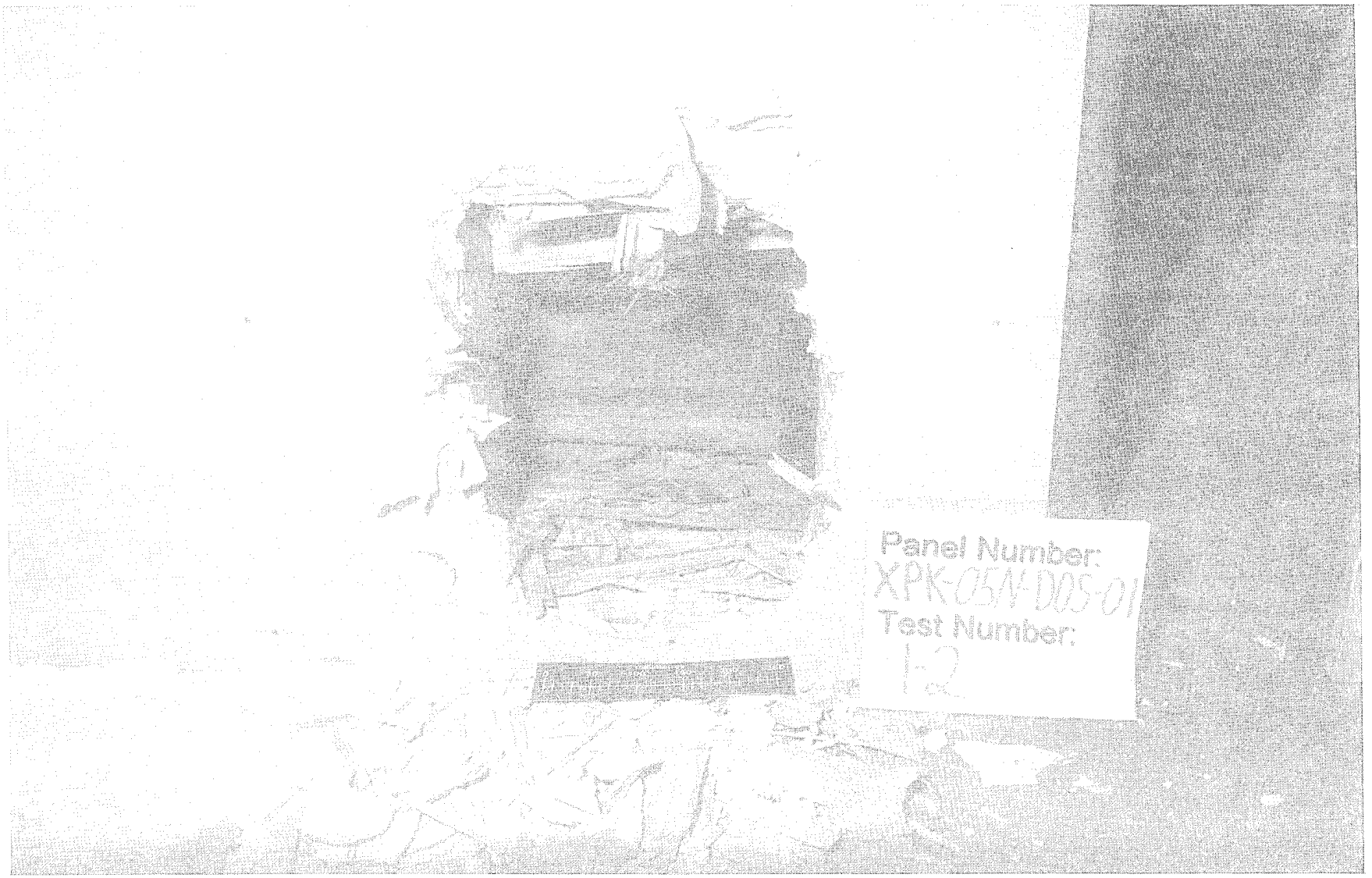


Figure 30. Assault side of panel XPK-05N-DOS-01 after test 1-2

Figure 31. Protect side of panel XPK-05N-DOS-01 after test 1-2

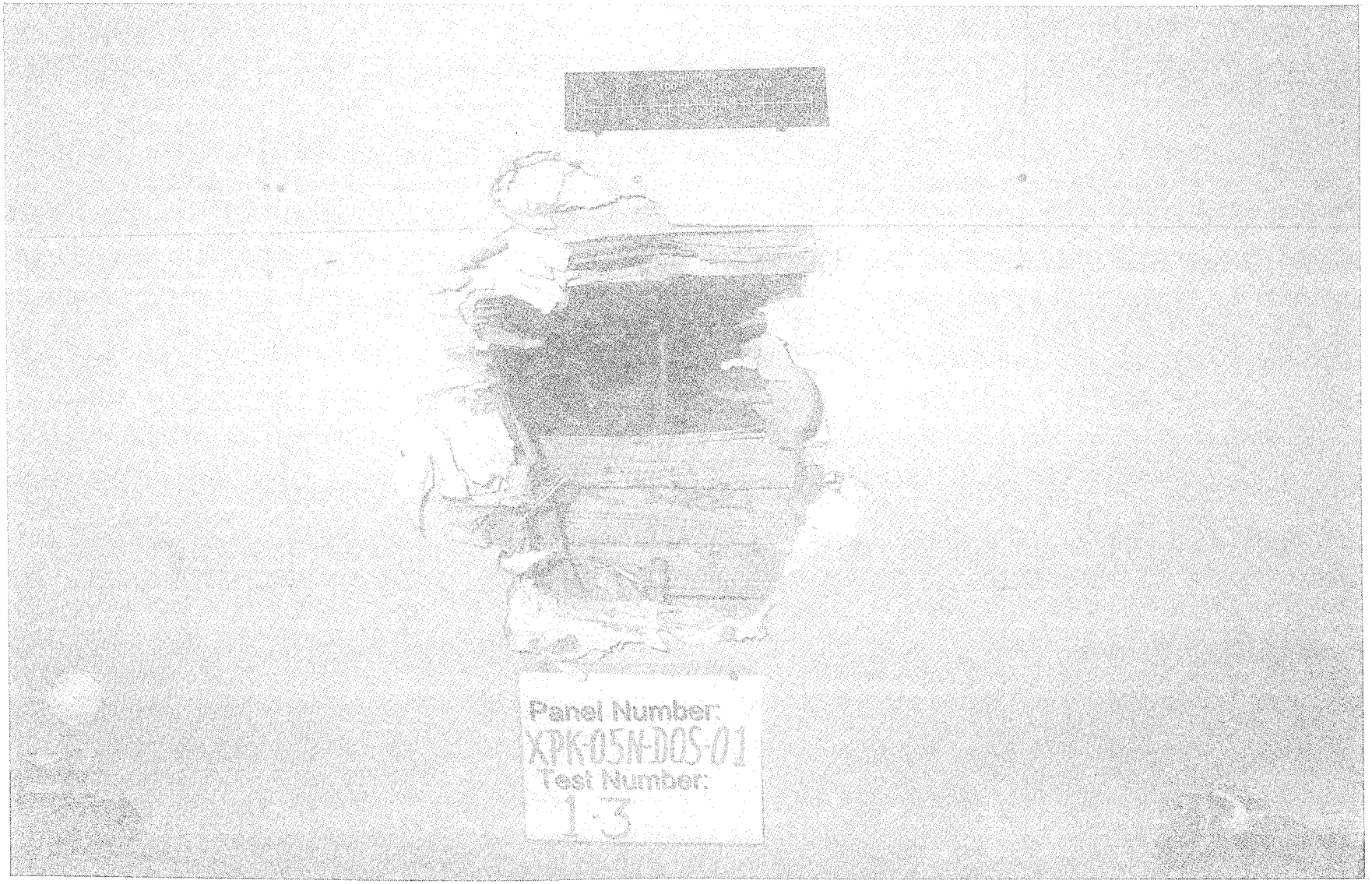


Figure 32. Assault side of panel XPK-05N-DOS-01 after test 1-3

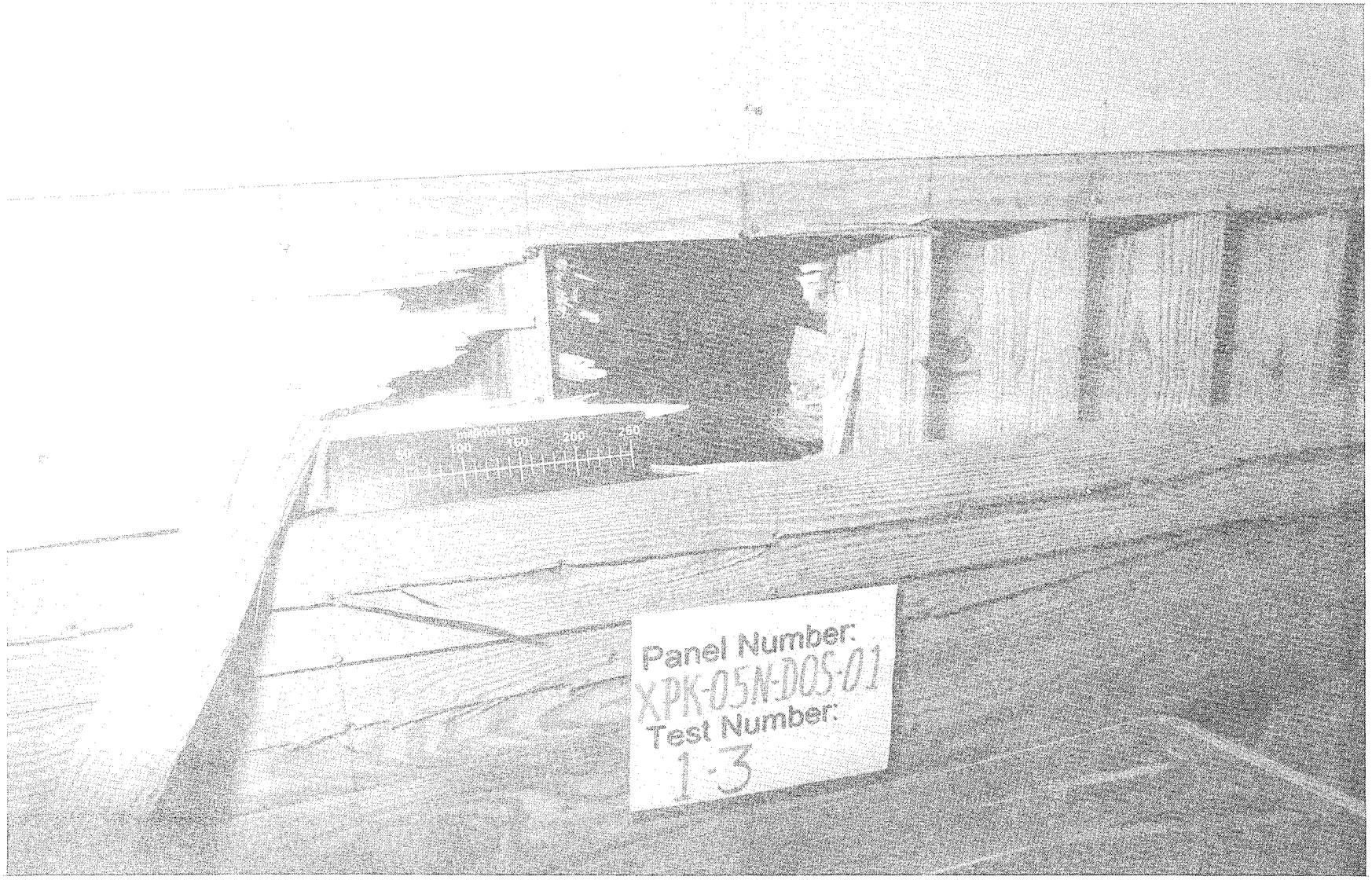


Figure 33. Protect side of panel XPK-05N-DOS-01 after test 1-3

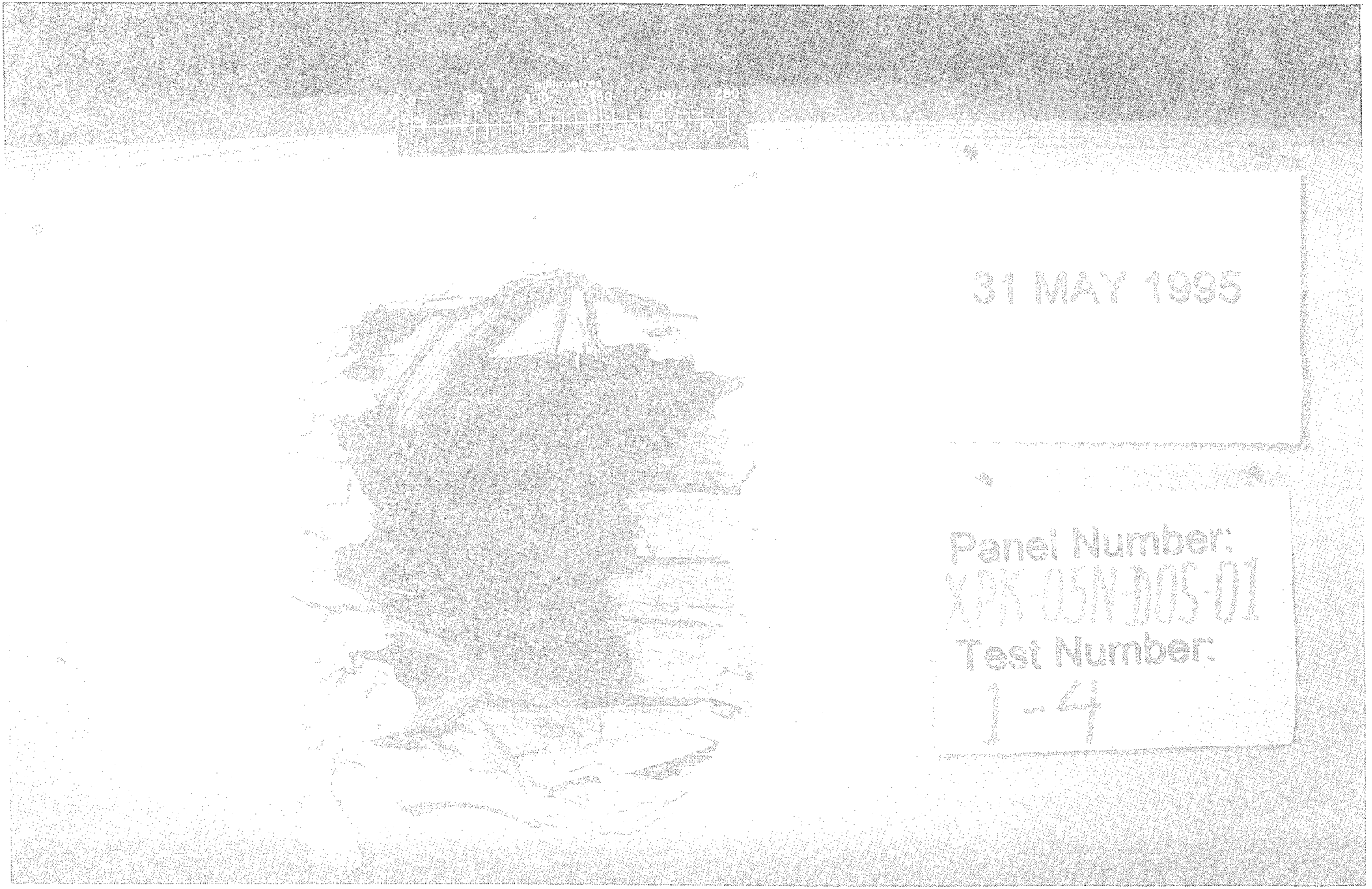


Figure 34. Assault side of panel XPK-05N-DOS-01 after test 1-4

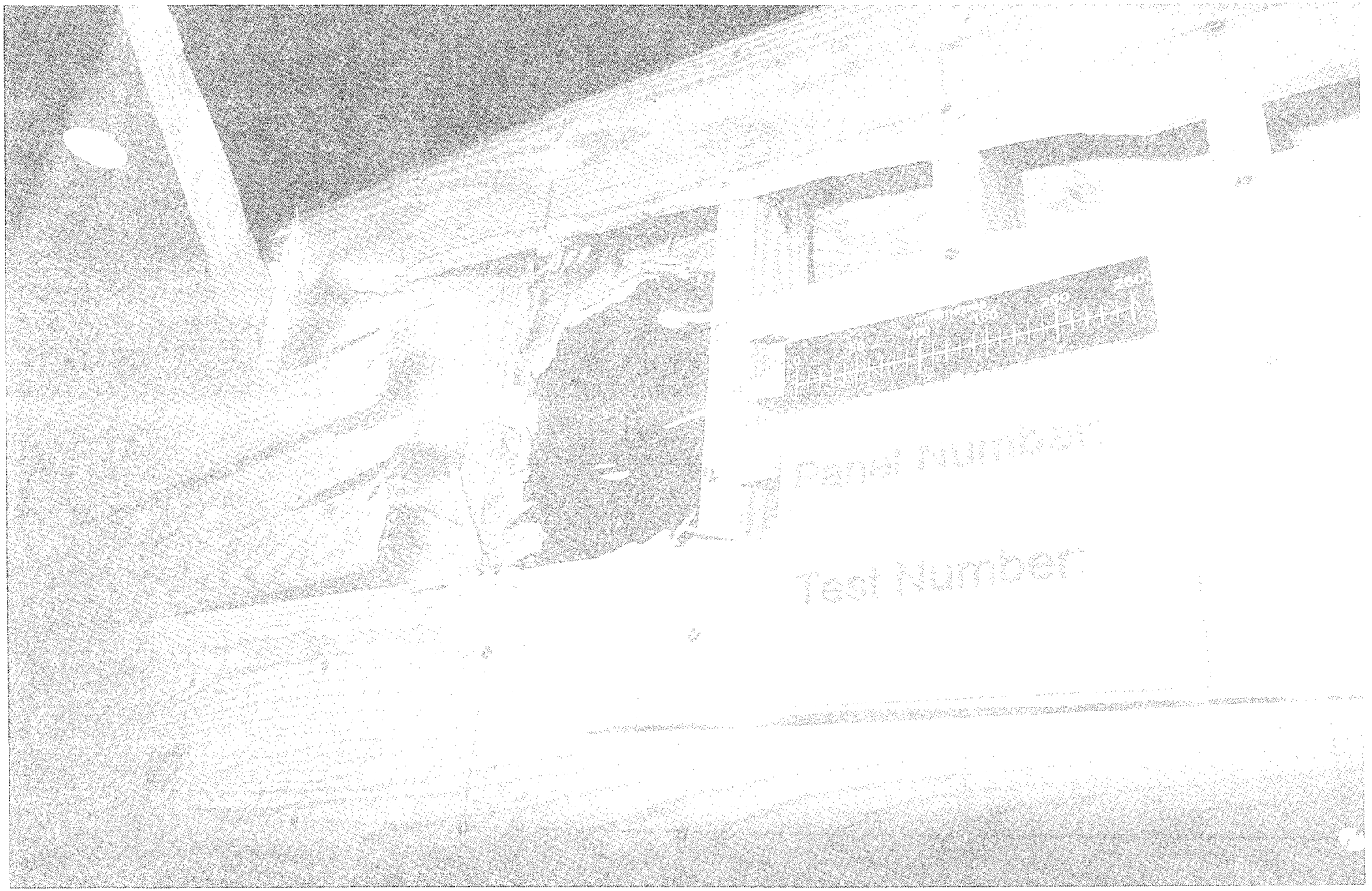


Figure 35. Protect side of panel XPK-05N-DOS-01 after test 1-4

Figure 36. Assault side of panel XPK-05N-DOS-02 after test 2-1

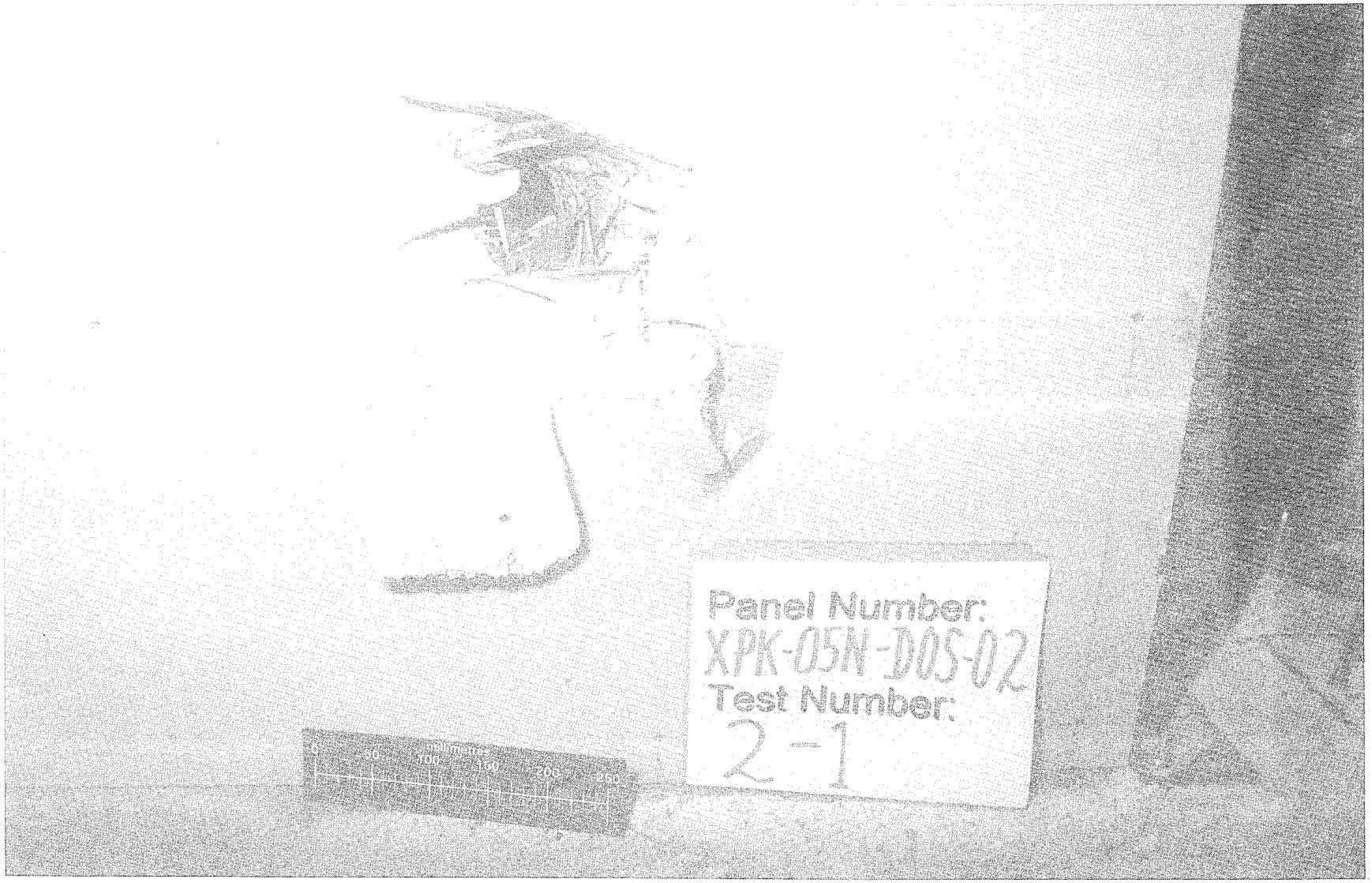


Figure 37. Protect side of panel XPK-05N-DOS-02 after test 2-1

Figure 38. Assault side of panel XPK-05N-DOS-02 after test 2-2

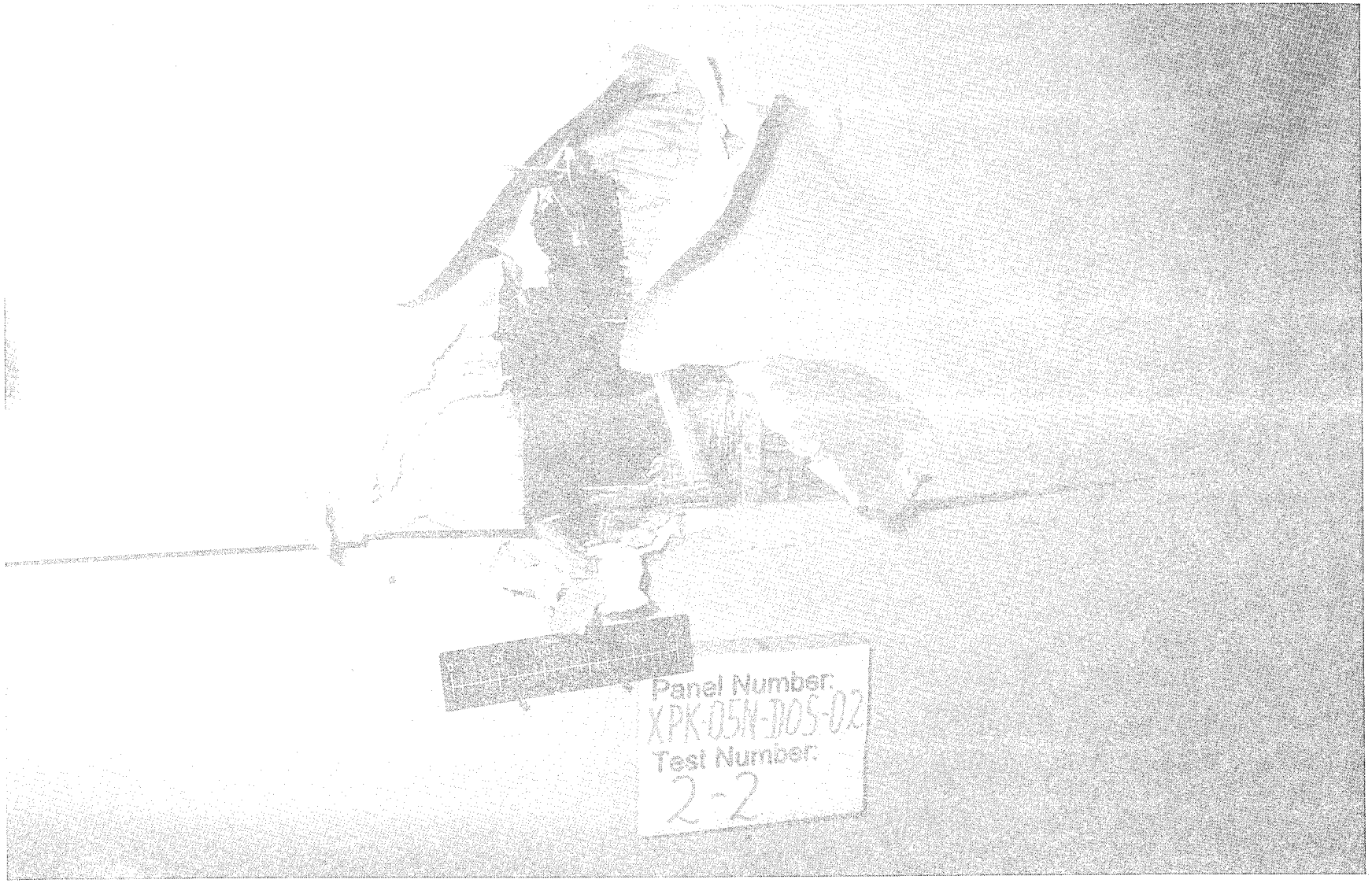


Figure 39. Protect side of panel XPK-05N-DOS-02 after test 2-2

Figure 40. Assault side of panel XPK-05N-DOS-02 after test 2-3

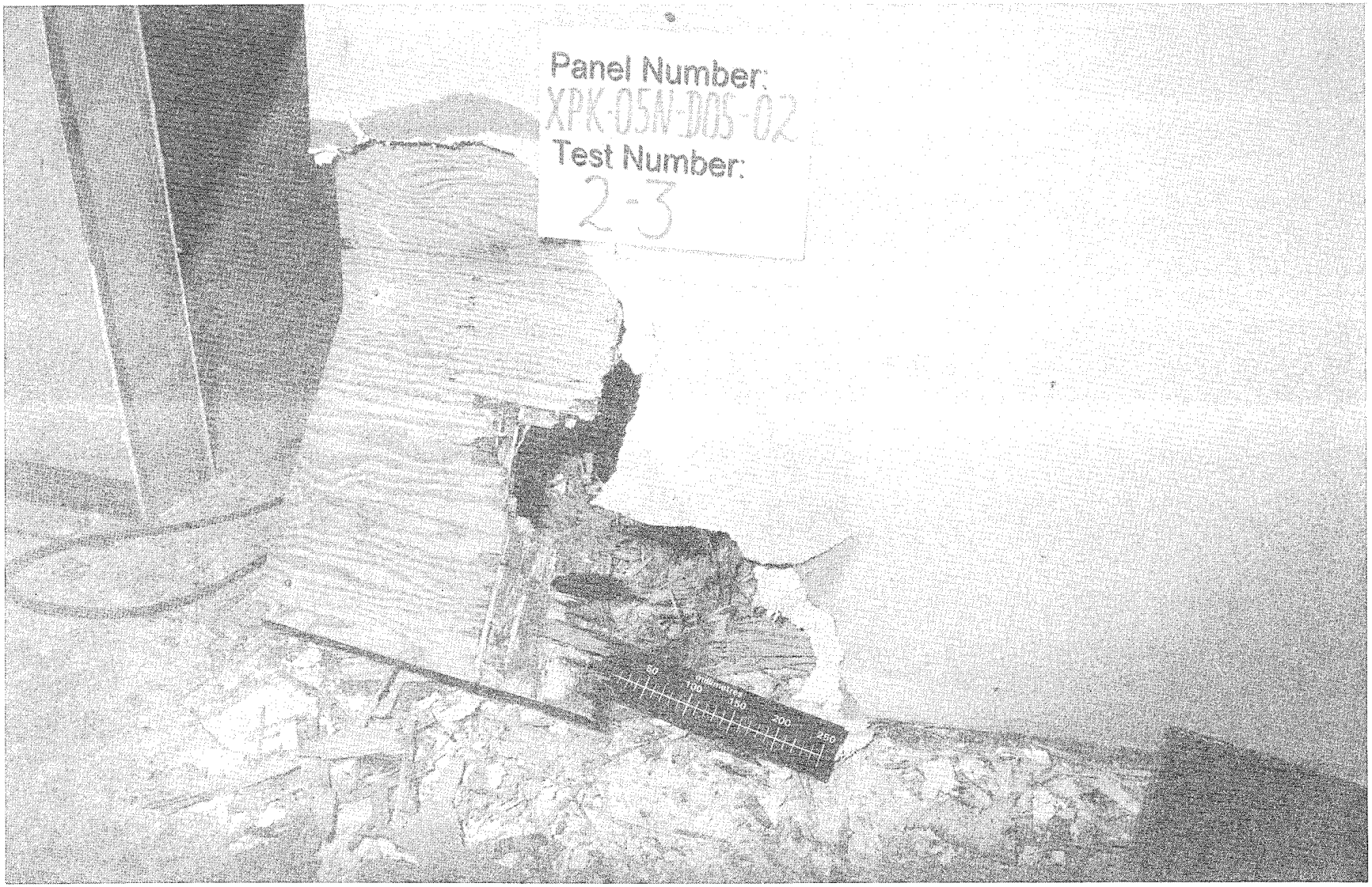


Figure 41. Protect side of panel XPK-05N-DOS-02 after test 2-3

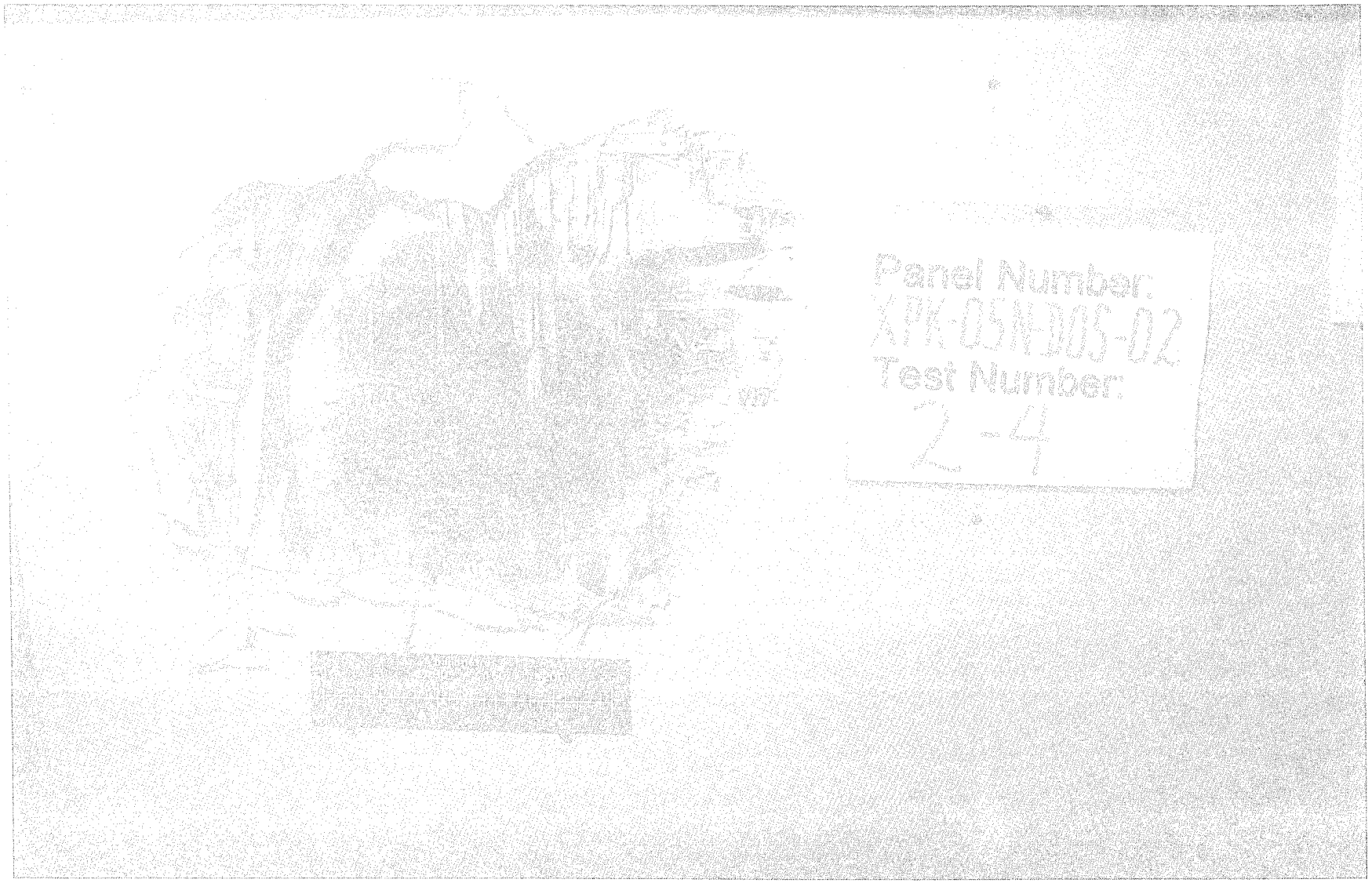


Figure 42. Assault side of panel XPK-05N-DOS-02 after the initial assault phase of test 2-4

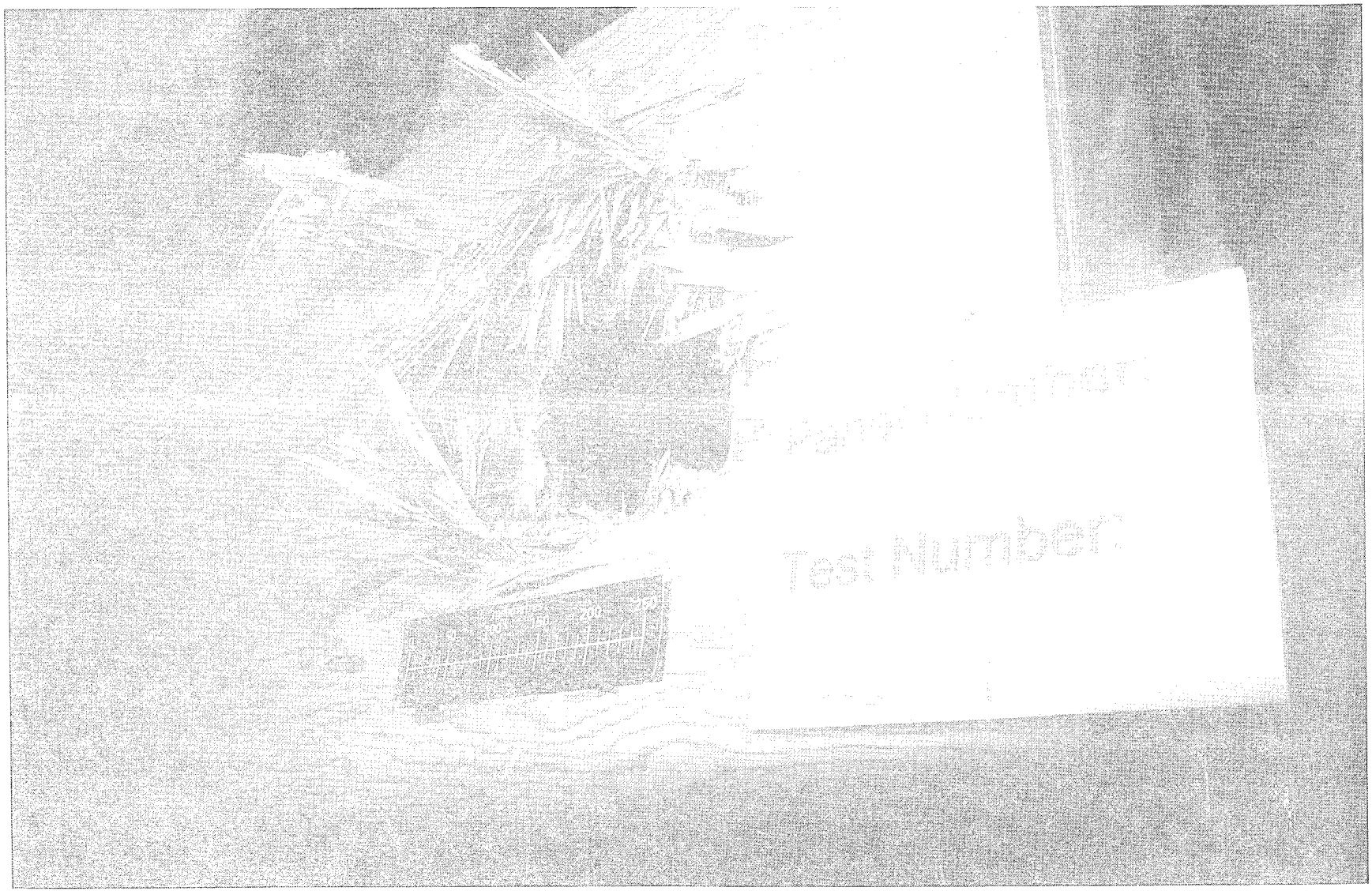


Figure 43. Protect side of panel XPK-05N-DOS-02 after the initial assault phase of test 2-4

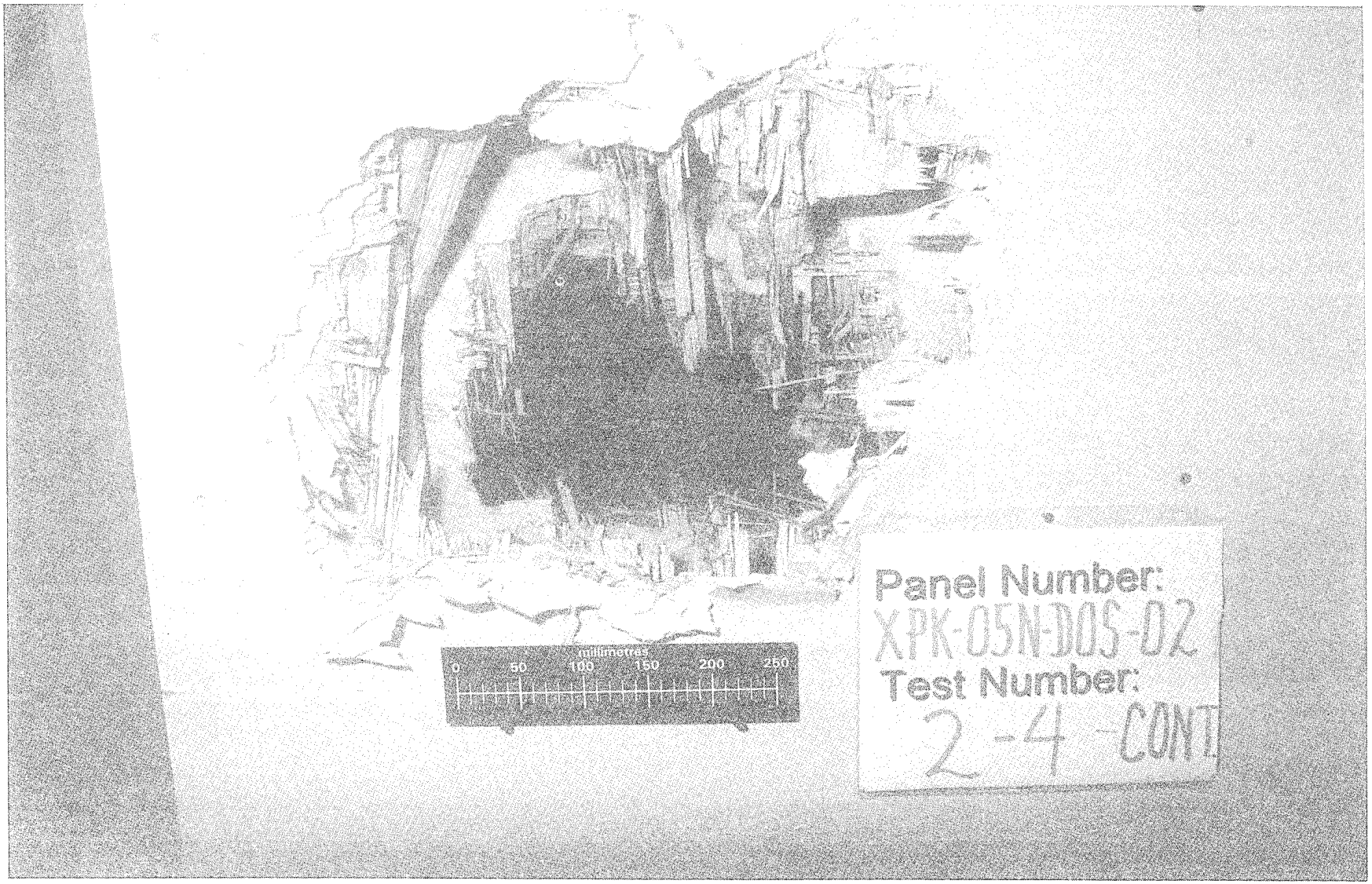


Figure 44. Assault side of panel XPK-05N-DOS-02 after the second assault phase of test 2-4

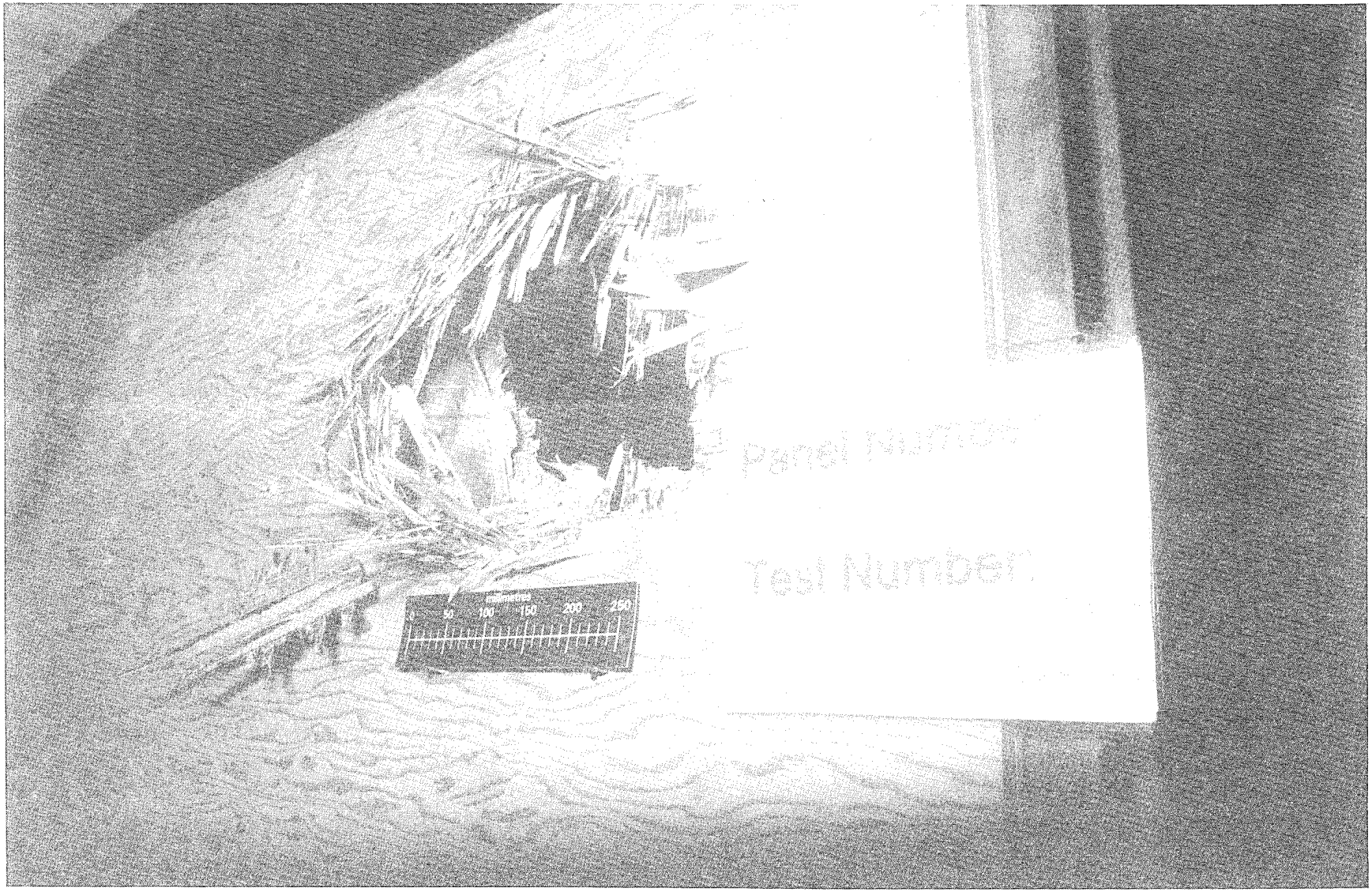


Figure 45. Protect side of panel XPK-05N-DOS-02 after the second assault phase of test 2-4

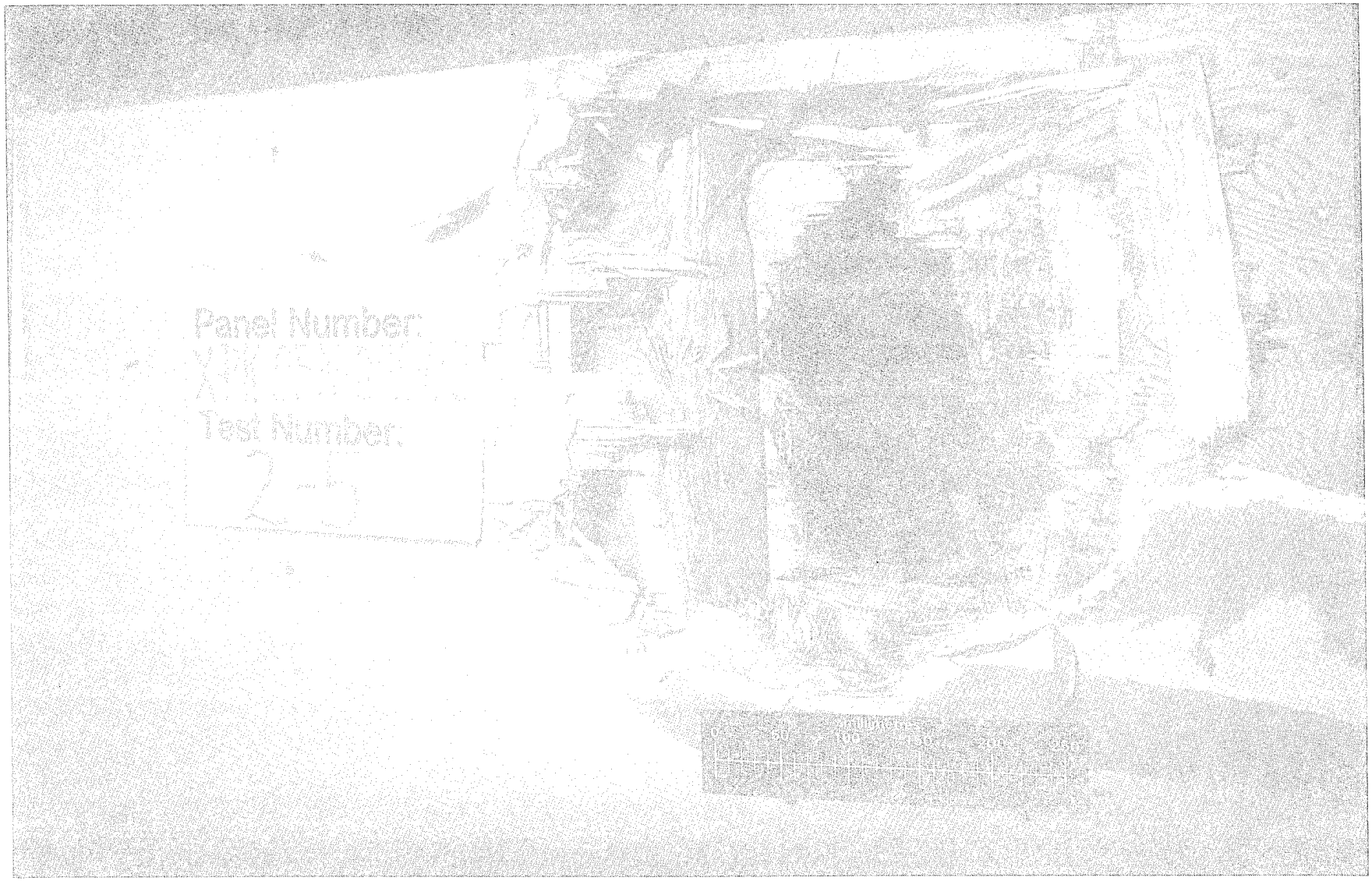


Figure 46. Assault side of panel XPK-05N-DOS-02 after the initial assault phase of test 2-5

Figure 47. Protect side of panel XPK-05N-DOS-02 after the initial assault phase of test 2-5

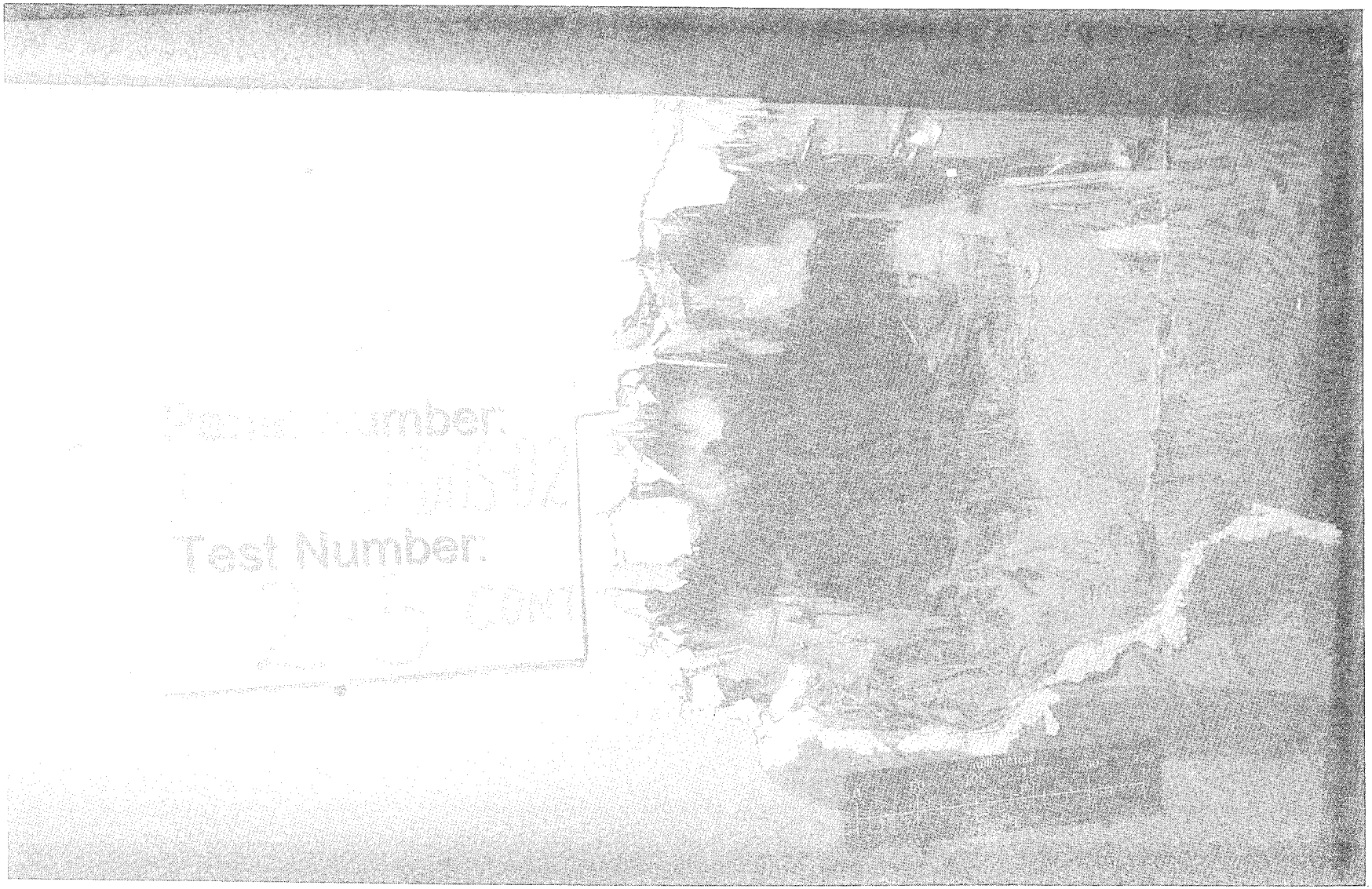


Figure 48. Assault side of panel XPK-05N-DOS-02 after the second assault phase of test 2-5

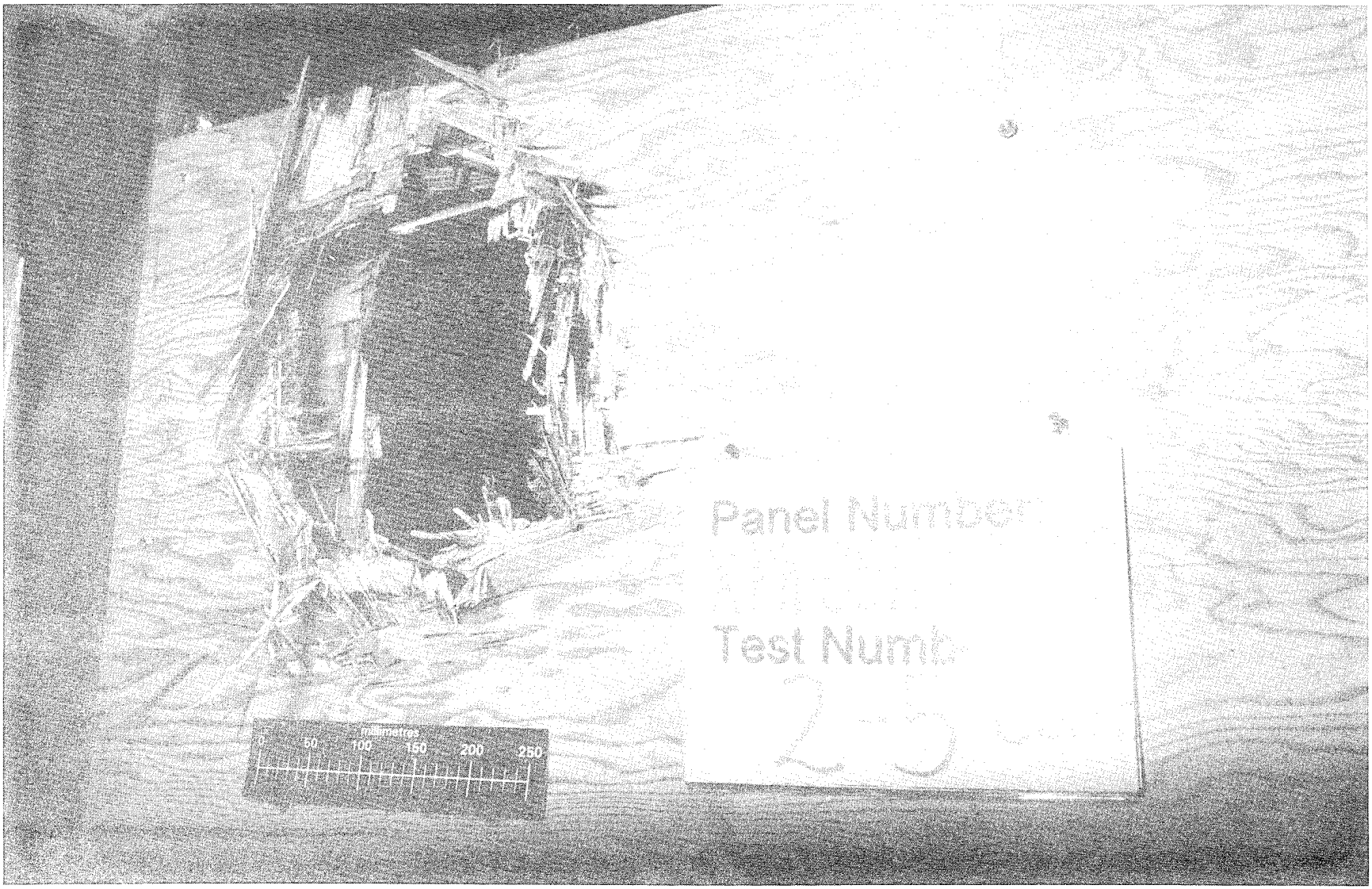


Figure 49. Protect side of panel XPK-05N-DOS-02 after the second assault phase of test 2-5

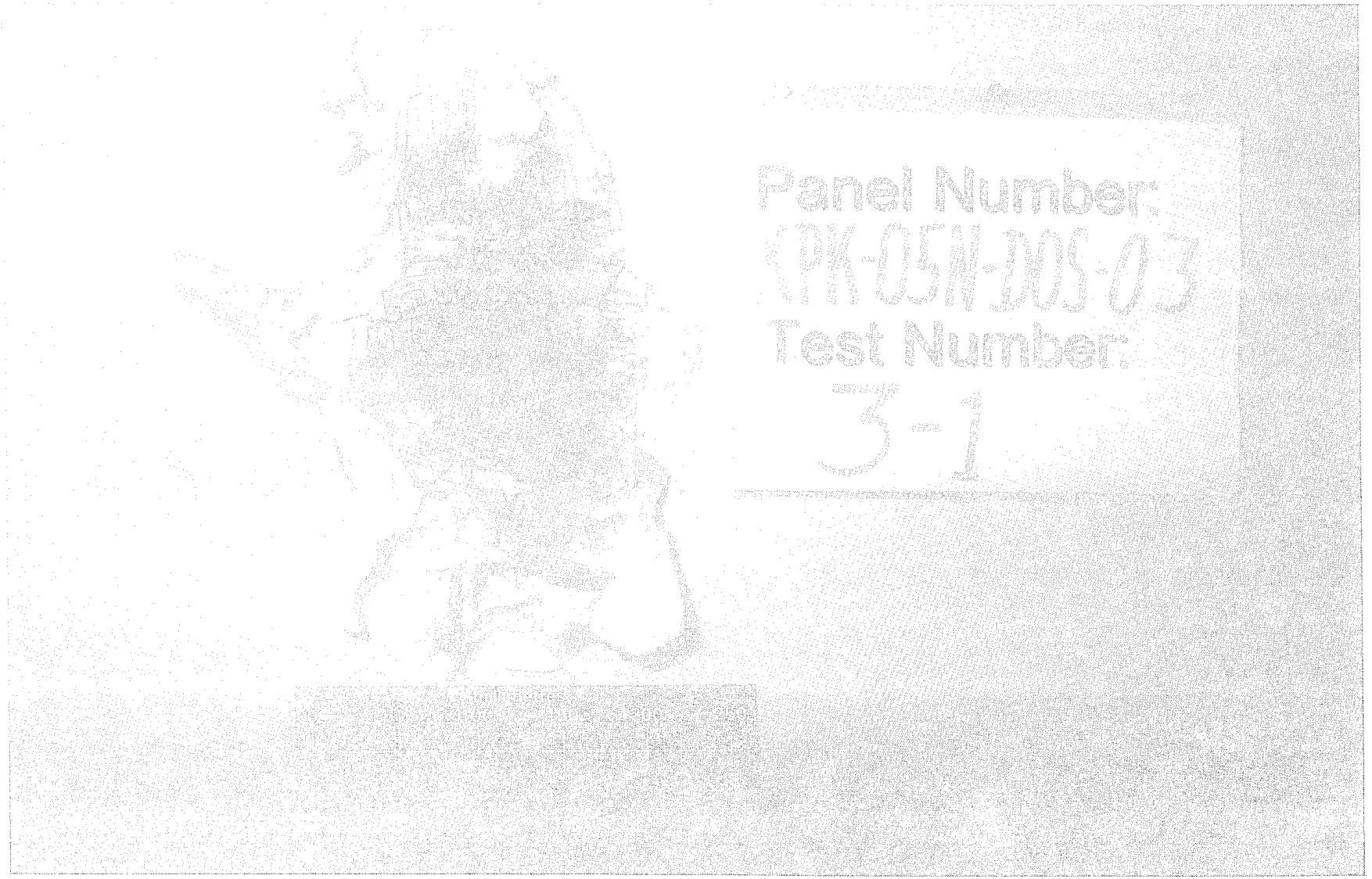


Figure 50. Assault side of panel XPK-05N-DOS-03 after the initial assault phase of test 3-1

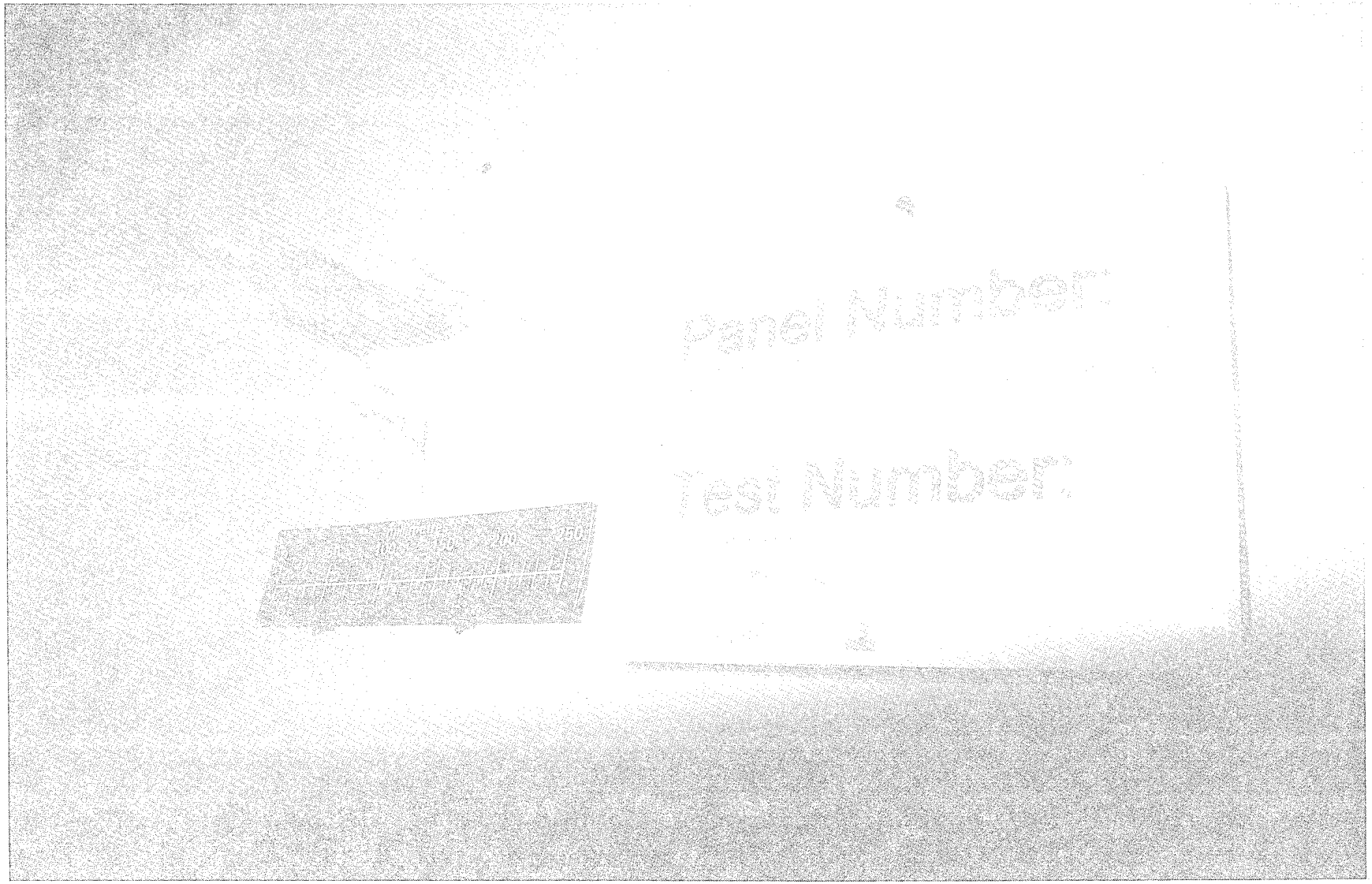


Figure 51. Protect side of panel XPK-05N-DOS-03 after the initial assault phase of test 3-1

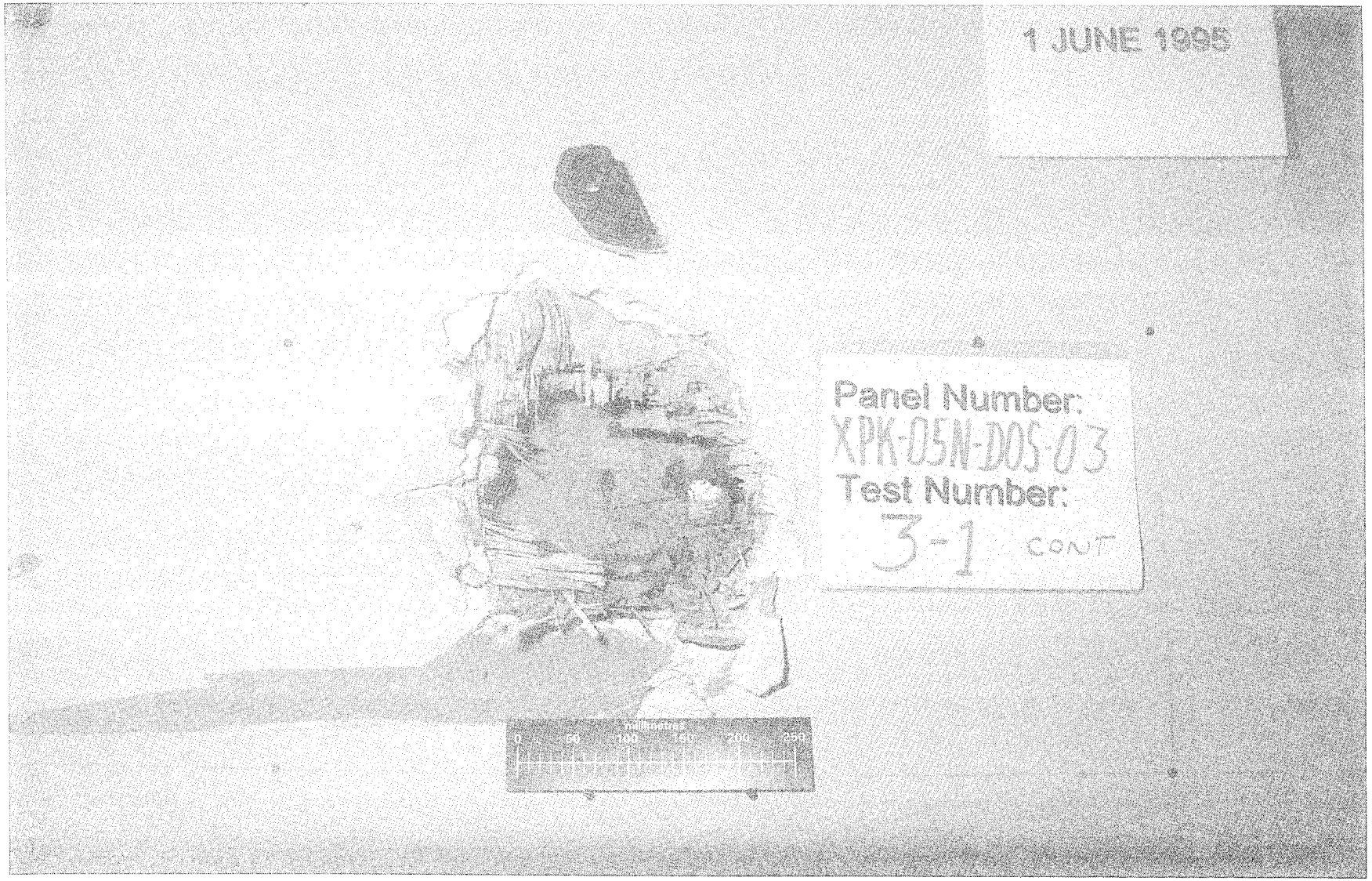


Figure 52. Assault side of panel XPK-05N-DOS-03 after the second assault phase of test 3-1

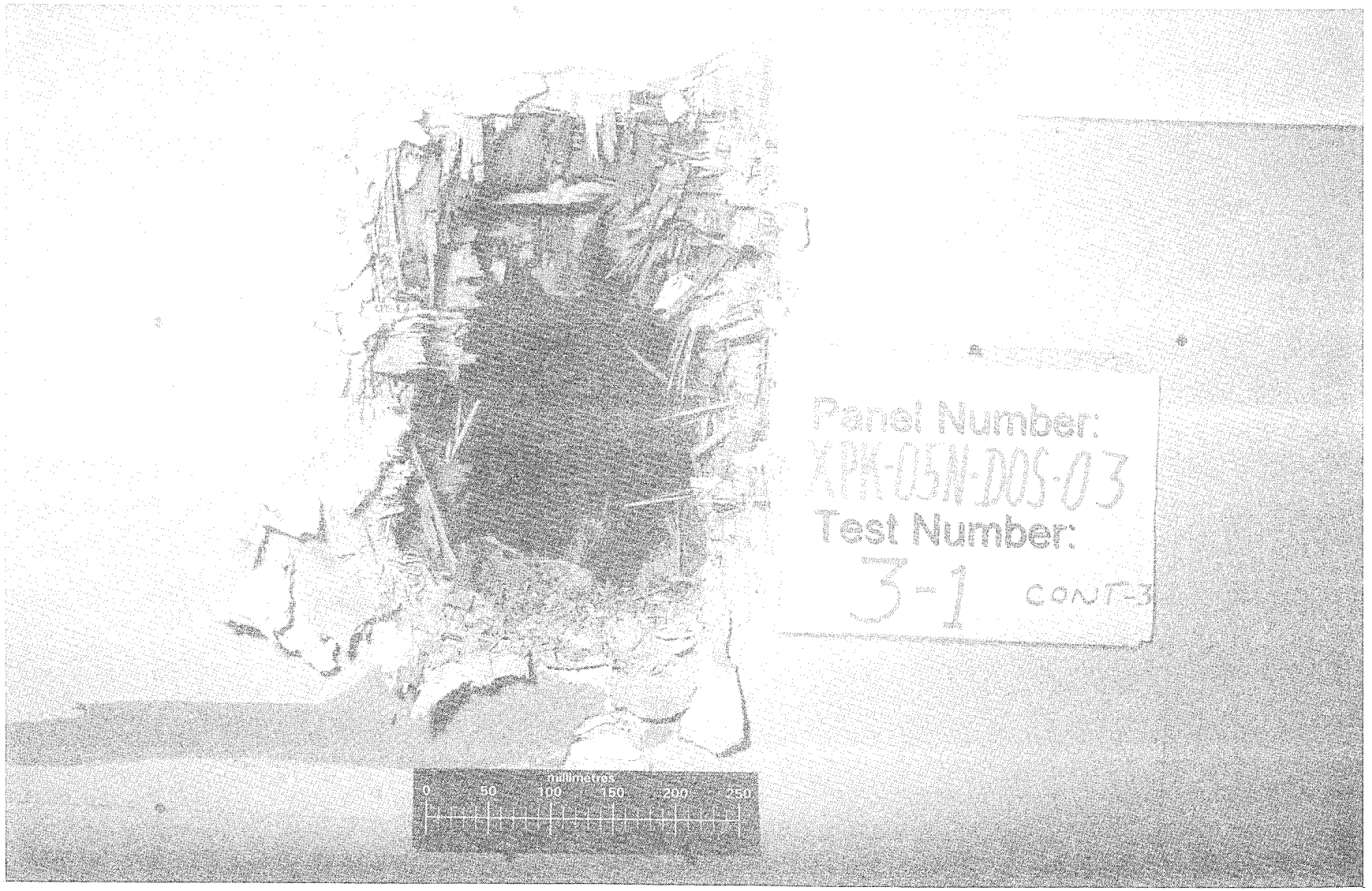


Figure 53. Assault side of panel XPK-05N-DOS-03 after the third assault phase of test 3-1

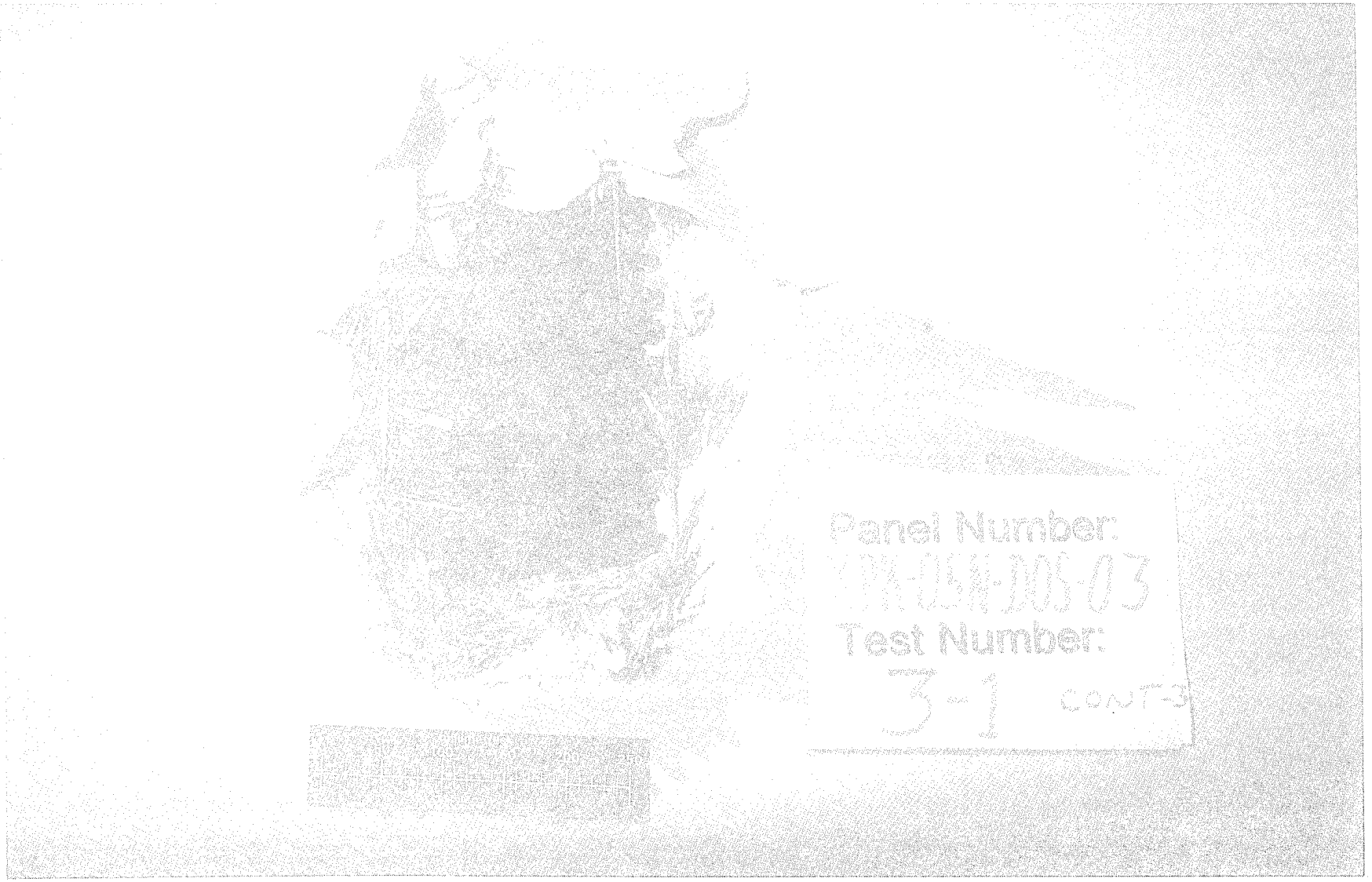


Figure 54. Protect side of panel XPK-05N-DOS-03 after the third assault phase of test 3-1

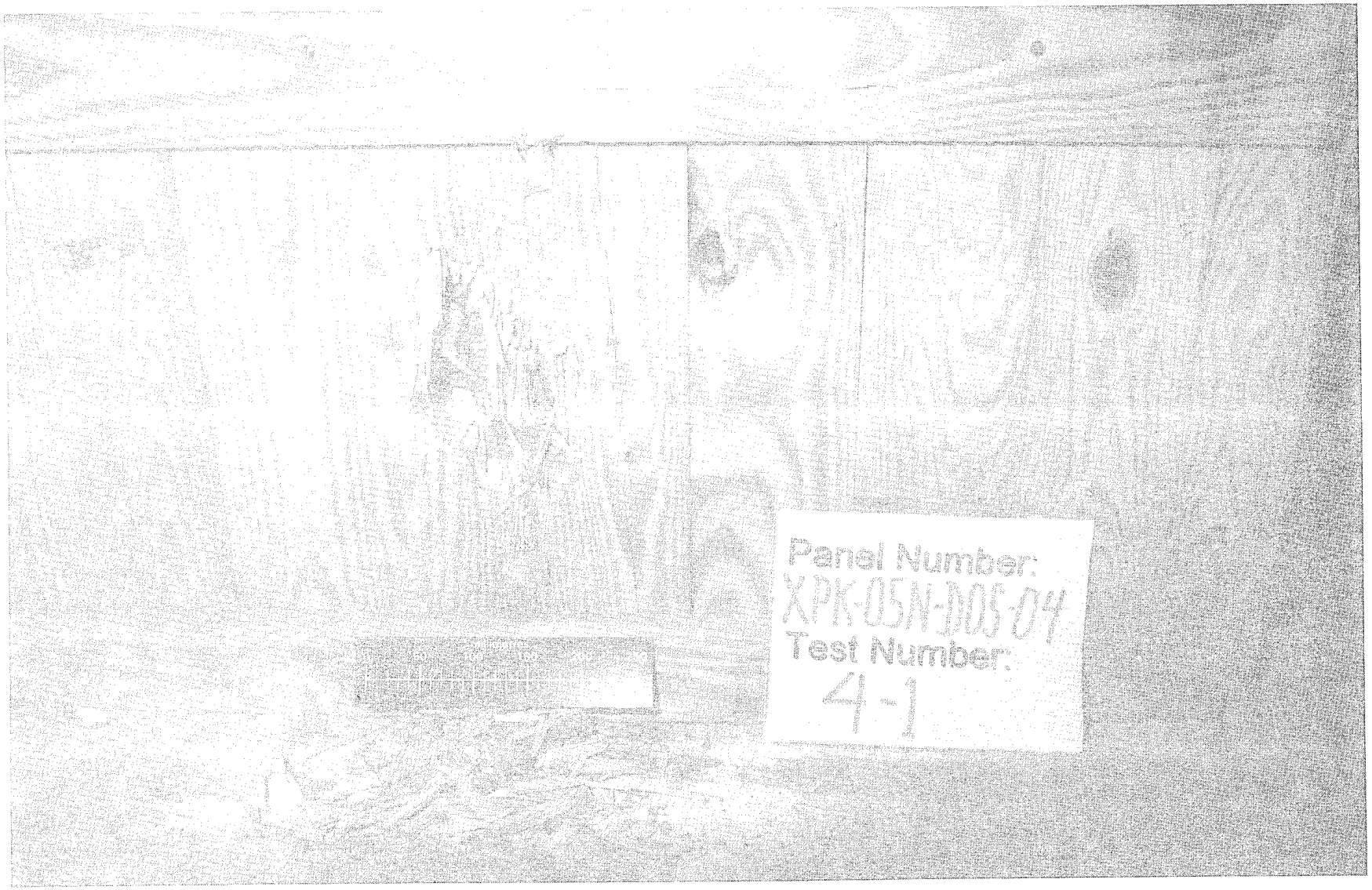


Figure 55. Assault side of panel XPK-05N-DOS-04 after test 4-1

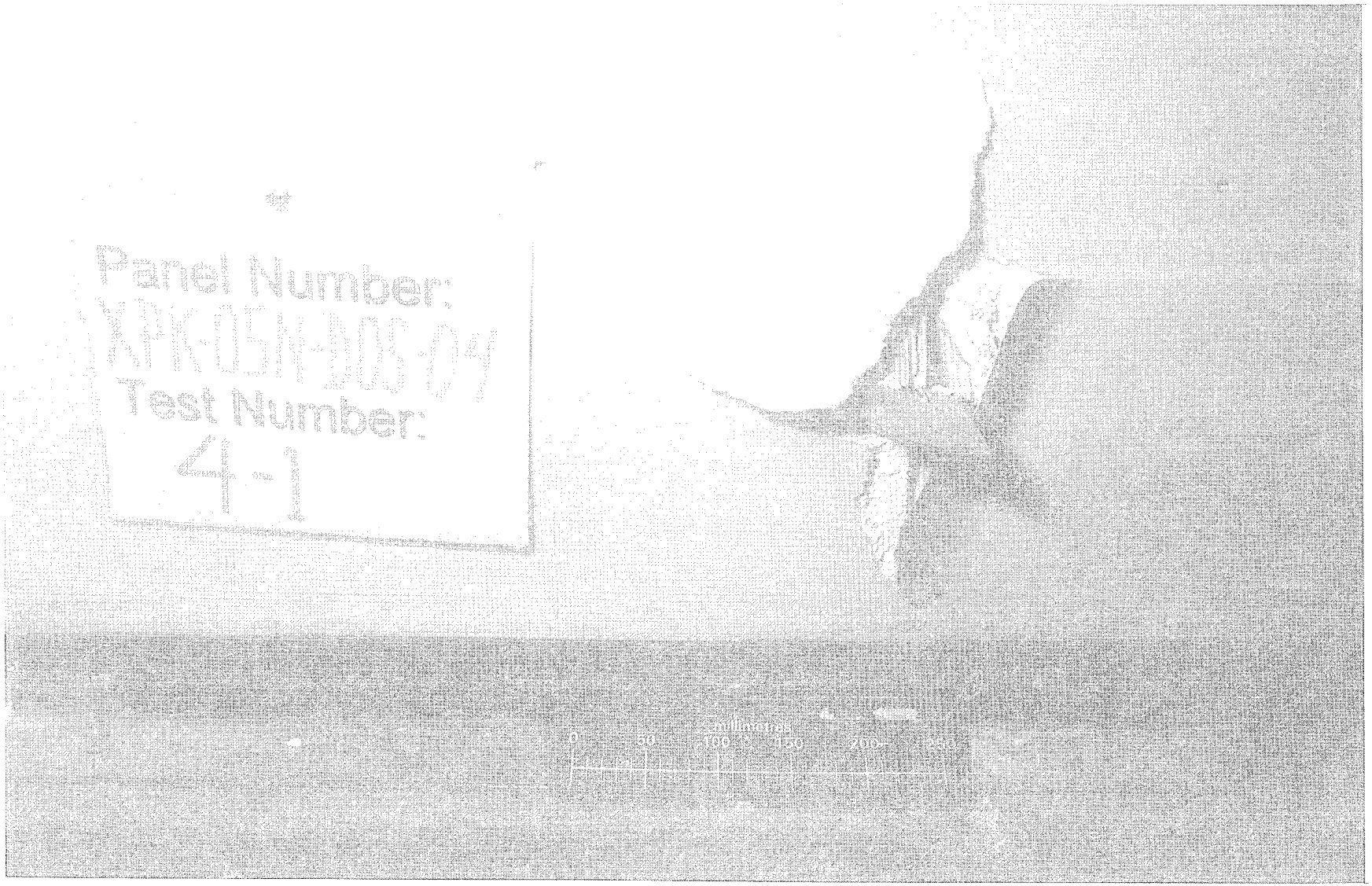


Figure 56. Protect side of panel XPK-05N-DOS-04 after test 4-1

Figure 57. Assault side of panel XPK-05N-DOS-05 after test 5-1

Figure 58. Protect side of panel XPK-05N-DOS-05 after test 5-1

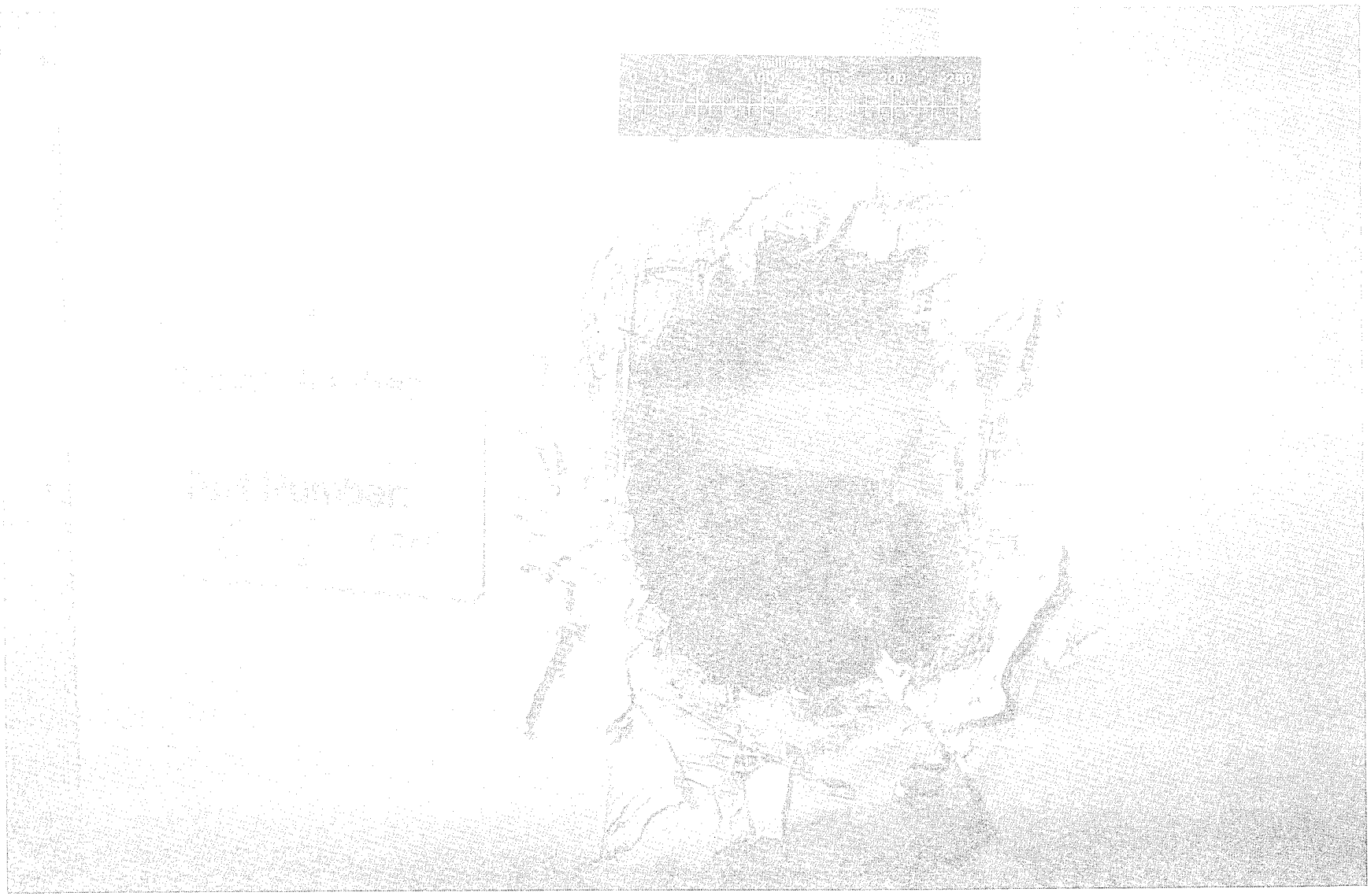


Figure 59. Assault side of panel XPK-05N-DOS-06 after test 6-1

Figure 60. Protect side of panel XPK-05N-DOS-06 after test 6-1

Table 1
Wall Panel Construction Summary

Panel Number	Primary Structural Element	Assult Side Appliques	Protest Side Appliques
XPK-05N-DOS-01	2" x 6" wood studs @ 8" on center, studs attached to top and bottom plate with four types of connectors	1" x 6" wood boards (one layer), 3/8" gypsum board (one layer)	1" x 6" wood boards (one layer), 3/8" gypsum board (one layer)
XPK-05N-DOS-02	2" x 6" wood studs @ 16" on center, studs attached to top and bottom plate with four types of connectors	3/4" plywood (one layer), 3/8" gypsum board (one layer)	3/4" plywood (one layer), 3/8" gypsum board (one layer)
XPK-05N-DOS-03	4" hollow CMU, type "S" mortar	3/4" plywood (two layers), 3/8" gypsum board (one layer)	3/4" plywood (one layer), 3/8" gypsum board (one layer)
XPK-05N-DOS-04	4" hollow CMU, type "S" mortar	1" x 6" wood boards (two layers), 3/8" gypsum board (one layer)	1" x 6" wood boards (one layer), 3/8" gypsum board (one layer)
XPK-05N-DOS-05 (modification of XPK-05N-DOS-04)	4" hollow CMU, type "S" mortar	1" x 6" wood boards (one layer), 3/8" gypsum board (one layer)	1" x 6" wood boards (one layer), 3/8" gypsum board (one layer)
XPK-05N-DOS-06 (modification of XPK-05N-DOS-03)	4" hollow CMU, type "S" mortar	3/4" plywood (one layer), 3/8" gypsum board (one layer)	3/4" plywood (one layer), 3/8" gypsum board (one layer)

Table 2
Test Team Members

Name	Function	Organization	Phone Number
James M. Watt, Jr.	Test Director	CEWES-SS-R	(601) 634-3537
Charles R. Malone	Deputy Test Director	CEWES-SS-E	(601) 634-2997
John Leimanis	DOS Representative	A/FBO/PE/BDE/ESB	(703) 875-6195
Andy Remson	DOS Representative	A/FBO/PE/BDE/ESB	(703) 875-6206
Victor Ratermanis	DOS Representative	DS/PSP/PSD	(703) 875-6546
Joe Jeffers	Assault Team Member	DEL-JEN (WES general construction contractor)	(601) 634-8828
Zach Howard	Assault Team Member	DEL-JEN (WES general construction contractor)	(601) 634-8828
Robert Wayne	Technician, Alternate Assault Team Member	CEWES-SV-J	(601) 634-3993
David E. Ray	Photographer	CEWES-IM-MV-P	(601) 634-2541
Gary E. Dill	Photographer	CEWES-IM-MV-P	(601 634-2783

Table 3
Forced Entry Tools

Tool	Description	Quantity Allowed
Sledgehammer	10 lb, 30 in. long	2
Carpenter Hammer	3 lb	2
Carpenter Hammer	1 lb	2
Ram	120 lb, 2-man, 4- x 4-in. impact area	1
Crowbar/Ripping Bar	48 in.	1
Wood Splitting Wedge[1]	9 x 2.5 in.	2
Keyhole Saw[2]	12-in. wood cutting blade	1
End Nippers	14 in.	1
Cold Chisel[1]	1 in.	1
Cold Chisel[1]	0.75 in.	1
Masonry Chisel[1]	2.25 in.	1
Channel Lock Pliers	10 in.	1
Vice Grip Pliers	12 in.	1
Push Broom	wooden	1

[1] Sharp edged tools could not be resharpened during the test.
[2] The keyhole saw could be used only during the test-to-failure phase.

Table 4
Summary of Test Results

Test Number	Date	Wall Panel Number	Assault Location	Tools Used	Start Time, 24-hour clock	Stop Time, 24-hour clock	Penetration Criterion Met?	Total Assault Time, MM:SS
1-1	31 May 95	XPN-05N-DOS-01	Lower left	Sledgehammers	09:35:00	09:39:56	yes	04:56
1-2	31 May 95	XPK-05N-DOS-01	Lower right	Sledgehammers	10:30:00	10:33:11	yes	03:11
1-3	31 May 95	XPK-05N-DOS-01	Center	Sledgehammers, ram	10:55:00	10:58:35	yes	03:35
1-4	31 May 95	XPK-05N-DOS-01	Upper left	Sledgehammers	11:30:00	11:32:45	yes	02:45
2-1	31 May 95	XPK-05N-DOS-02	Lower left	Sledgehammers, crowbar, wood splitting wedge	13:40:00	13:45:00	no	05:00
2-2	31 May 95	XPK-05N-DOS-02	Center	Sledgehammers	14:10:00	14:12:50	yes	02:50
2-3	31 May 95	XPK-05N-DOS-02	Lower right	Sledgehammers	14:45:00	14:49:50	yes	04:50
2-4	1 June 95	XPK-05N-DOS-02	Upper left	Sledgehammers, 3-pound hammer	08:15:00	08:20:00	no	05:12
					08:35:00	08:35:12	yes	
2-5	1 June 95	XPK-05N-DOS-02	Upper right	Sledgehammers, 3-pound hammer	09:10:00	09:15:00	no	05:49
					09:35:00	09:35:49	yes	
3-1	1 June 95	XPK-05N-DOS-03	Upper left	Sledgehammers, crowbar, wood splitting wedges	10:40:00	10:45:00	no	14:31
					11:10:00	11:15:00	no	
					11:35:00	11:39:31	yes	
4-1	1 June 95	XPK-05N-DOS-04	Lower right	Sledgehammers, crowbar, wood splitting wedge	13:40:00	13:45:00	no	05:00
5-1	1 June 95	XPK-05N-DOS-05	Lower left	Sledgehammers, crowbar	14:35:00	14:38:01	yes	03:01
6-1	1 June 95	XPK-05N-DOS-06	Lower right	Sledgehammers, crowbar, ram	15:15:00	15:19:38	no	04:48
					15:39:00	15:39:10	yes	

Table 5
Summary of Test 1-1

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
02:26	Assault side appliques penetrated. Stud totally shattered. Began penetrating protect side appliques.
04:17	Began jabbing protect side appliques with sledgehammers.
04:42	Began attempting to pass metal box through opening.
04:56	Box passed completely through opening. Test halted.

Table 6
Summary of Test 1-2

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
01:30	Assault side appliques penetrated. Stud totally shattered. Began penetrating protect side appliques.
02:12	Began jabbing protect side appliques with sledgehammers.
02:32	Resumed swinging motion with sledgehammers.
02:49	Began attempting to pass metal box through opening.
03:00	Began enlarging opening slightly with sledgehammer.
03:11	Box passed completely through opening. Test halted.

Table 7
Summary of Test 1-3

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
01:07	Assault side appliques penetrated. Stud totally shattered. Began penetrating protect side appliques.
01:37	Began jabbing protect side appliques with sledgehammers.
01:52	Resumed swinging sledgehammers.
02:32	Began using ram to penetrate protect side appliques.
02:48	Began attempting to pass metal box through opening.
03:07	Began enlarging opening with sledgehammer.
03:35	Box passed completely through opening. Test halted.

Table 8
Summary of Test 1-4

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
02:08	Assault side appliques penetrated. Stud totally shattered. Began penetrating protect side appliques.
02:15	Began jabbing protect side appliques with sledgehammers.
02:40	Began attempting to pass metal box through opening.
02:45	Box passed completely through opening. Test halted.

Table 9
Summary of Test 2-1

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
00:40	Assault side appliques penetrated on either side of stud. Stud still inteact. Began hitting stud.
02:00	Began prying and jabbing stud with crowbar.
02:41	Stud still intact. Resumed hitting stud with sledgehammers.
02:55	Returned to prying and jabbing stud with crowbar.
03:11	Began driving crowbar tip into stud with sledgehammer.
03:34	Stud split slightly in the middle but still largely intact. Resumed hitting stud with sledgehammers.
03:47	Began driving wedge into stud with sledgehammer.
04:03	Wedge completely embedded in stud but stud still argely intact. Resumed hitting stud with sledgehammers.
04:40	Stud broken and moved to the left. Began hitting protect side appliques with sledgehammers.
05:00	Test halted. Assault side appliques penetrated and stud broken. Small opening created in protect side appliques. Penetration criterion not met.

Table 10
Summary of Test 2-2

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
00:54	Assault side appliques penetrated. Began hitting protect side appliques with sledgehammers.
01:48	Began jabbing protect side appliques with sledgehammer.
02:06	Resumed swinging motion with sledgehammers.
02:47	Began attempting to pass metal box through opening.
02:50	Box passed completely through opening. Test halted.

Table 11
Summary of Test 2-3

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
02:13	Assault side appliques penetrated. Stud totally shattered. Began hitting protect side appliques with sledgehammer.
03:13	Began jabbing protect side appliques with sledgehammer.
03:22	Resumed swinging motion with sledgehammers.
04:33	Began attempting to pass metal box through opening.
04:50	Box passed completely through opening. Test halted.

Table 12
Summary of Test 2-4

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
01:37	Assault side appliques penetrated. Stud totally shattered. Began hitting protect side appliques.
03:53	One sledgehammer lost through opening in panel. Retrieval of the sledgehammer not allowed. Began sharing the one remaining sledge-hammer.
04:40	Second sledgehammer lost through opening in panel. Retrieval of sledge-hammer not allowed.
04:45	Began attempting to pass metal box through opening.
04:56	Began using 3-pound hammer to enlarge opening.
05:00	Initial assault phase of test halted. Penetration criterion not met. After a 15-minute break, sledgehammers given back to forced entry team and second assault phase began. Began using sledgehammer to enlarge opening.
05:12	Box passed completely through opening. Test halted.

Table 13
Summary of Test 2-5

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
02:23	Assault side appliques penetrated. Stud badly broken and pushed to the left. Began hitting protect side appliques.
03:12	Initial hole created in protect side appliques.
04:56	Began attempting to pass metal box through opening.
05:00	Initial assault phase of test halted. Penetration criterion not met. Began second assault phase after 20-minute break. Began using 3-pound hammer to enlarge opening.
05:23	Switched to sledgehammer.
05:46	Began attempting to pass metal box through opening.
05:49	Box passed completely through opening. Test halted.

Table 14
Summary of Test 3-1

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
00:15	Began driving wedge into panel with sledgehammer.
01:20	Wedge completely embedded in panel. Continued hitting panel with sledgehammers.
01:57	Began driving second wedge into panel next to first wedge.
02:20	Unable to get second wedge to bite into panel. Began jabbing and prying assault side appliques with crowbar.
02:45	Small opening created in assault side appliques. Broken pieces of CMU began to fall from hole.
03:34	Switched to sledgehammers.
04:17	Switched to crowbar. Larger peices of CMU began falling out.
05:00	Initial assault phase of test halted. Penetration criterion not met. Opening created in assault side appliques. Wedge penetrated protect side appliques. Began second assault phase after 25-minute break. Began driving second wedge into panel with 3-pound hammer.
05:28	Switched to sledgehammer to drive wedge.
06:40	Wedge completely embedded in panel. Continued hitting panel with sledgehammers.
06:51	Switched to crowbar.
07:41	Switched to sledgehammers.
08:20	Wedge dislodged from panel.
08:56	Began driving wedge into panel with sledgehammer.
10:00	Second assault phase of test halted. Penetration criterion not met. Larger opening created in assault side appliques. More CMU removed. No further damage to protect side appliques. Second wedge half embedded in panel. Began third assault phase after 20-minute break. Continued driving second wedge into panel with sledgehammer.
10:28	Second wedge dislodged from panel. Continued hitting panel with sledgehammers.
11:16	Began removing rubble from hole with hands.
11:36	Began jabbing/prying protect side appliques with crowbar.
12:07	Switched to sledgehammers. Began directing blows primarily against protect side appliques.
14:10	Began jabbing/prying protect side appliques with crowbar.
14:27	Began attempting to pass metal box through opening.
14:31	Box passed completely through opening. Test halted.

Table 15
Summary of Test 4-1

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
00:36	Began driving wedge into panel with sledgehammer.
02:47	Wedge completely embedded in panel. Continued hitting panel with sledgehammers.
03:13	Began jabbing/prying assault side appliques with crowbar.
03:23	One sheet of gypsum board and one wood board pulled completely off panel by hand. Continued jabbing/prying with crowbar.
03:37	Second wood board removed. Continued jabbing/prying with crowbar.
03:50	Third wood board removed. Continued jabbing/prying with crowbar.
04:00	Switched to sledgehammers.
04:44	Switched to crowbar. Some CMU pieces began falling from opening.
05:00	Test halted. Penetration criterion not met. Small opening created in assault side appliques. Wedge penetrated protect side appliques.

Table 16
Summary of Test 5-1

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
00:05	Began jabbing/prying with crowbar.
01:06	One sheet of gypsum and one wood board pulled completelty off panel by hand. CMU exposed. Continued jabbing/prying with crowbar.
01:21	Second wood board removed. Continued jabbing/prying with crowbar.
01:32	Began hitting exposed CMU with sledgehammer.
02:00	Large opening created in CMU. Began directing blows against protect side appliques.
02:16	Began jabing/prying protect side appliques with crowbar.
02:41	Began jabbing protect side appliques with sledgehammer.
02:47	Began kicking protect side appliques with foot.
03:01	Box passed completely through opening. Test halted.

Table 17
Summary of Test 6-1

Elapsed Time, MM:SS	Progress
00:00	Began test with sledgehammer assault.
00:09	Began jabbing/prying with crowbar.
01:01	Switched to sledgehammers. Peices of CMU began falling from small opening in assault side appliques.
01:27	Switched to crowbar.
01:58	Switched to sledgehammers. Large pieces of CMU began falling from hole in assault side appliques.
02:24	Switched to crowbar.
03:15	Switched to sledgehammer. Blows directed primarily against protect side appliques.
03:37	Switched to crowbar to jab/pry assault side appliques.
04:06	Switched to sledgehammer to enlarge assault side opening.
04:33	Began impacting protect side appliques with ram.
04:38	Protect side appliques completely detached from CMU. Test temporarily halted because of clock failure. After approximately 20-minute delay to reposition clock, test restarted. Upon restart, switched to sledgehammer to enlarge assault side opening.
04:48	Box passed completely through opening. Test halted.

Table 18
Comparison of Wood Connector Performance

Connector Type	Manufacturer's Suggested Load Rating (normal force), pounds	Penetration Time, MM:SS	
		Panel XPN-05N-DOS-01	Panel XPK-05N-DOS-02
THD26	2,430	04:56	>05:00 (no penetration)
LB26	1,380	not tested	05:49
JA5	1,150	02:45	05:12
LUS26	835	03:11	04:50

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13. ABSTRACT ***(Maximum 200 words)***

The U.S. Department of State (DOS), Office of Foreign Building Operations (FBO), has a requirement to design forced entry resistant walls for DOS facilities world-wide. Based primarily on the results of forced entry tests, FBO may certify a given wall design at one of three levels of forced entry protection. The three levels of forced entry protection defined by FBO (5, 15, and 60 minutes) imply a delay time provided against known groups of assault tools and numbers of assault personnel.

In Fiscal Year 1995, FBO tasked the U.S. Army Engineer (USAE) Waterways Experiment Station (WES) to conduct a series of forced entry tests on various wall panels designed by FBO to meet the 5-minute forced entry protection level. Common construction materials, including concrete masonry units, lumber, plywood, and gypsum wallboard, were used to build the wall panels. Each timed assault test involved a two-man team's attempt to create a man-passable opening in a panel using various hand tools (sledgehammer, crowbar, wedge, etc.). Delay times provided by the various panels ranged from less than 3 minutes to nearly 15 minutes.

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