# Shielded Enclosure Floor Load Study

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## INTRODUCTION

Historically, the primary purpose of a shielded enclosure was to provide a sterile electromagnetic environment, free from the radio frequency contamination caused by electromagnetic signals. Enclosures providing such sterile electromagnetic environments were used as test chambers to measure the electromagnetic characteristics of equipment under test.

The concept of developing a sterile electromagnetic environment was expanded from a *test bed* usage to an *operational* usage, where equipment and systems were placed in shielded enclosures to protect them from interference from signals emanating from commercial industrial communications equipment. Computers or sensitive electronics were placed in shielded enclosures for protection against interfering signals. A secondary purpose of a shielded enclosure was to contain the electromagnetic energy being radiated by a device within the boundaries of the enclosure, so that the electromagnetic radiation from the device would not adversely affect equipment outside the shielded enclosure.

The concept that the interior of a shielded enclosure could effectively contain the electromagnetic energy generated within the enclosure developed into the requirement to prohibit the unauthorized recovery of electromagnetic energy emitted by equipment located inside the shielded enclosure.

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Service records of shielded enclosures show that with time, most enclosures lose some of their RF shielding integrity. Many enclosures develop RF leaks significant enough to render the enclosures ineffective in performing the task for which they were designed.

Many RF leaks associated with shielded enclosures have been traced to devices that penetrate the RF barrier, such as power line filter feed-thru pipes, A/C feed and drain pipes, communication line feed-thru pipes, and fiber optic waveguide penetrations. In addition to these penetrations, it was found that the screws securing the hat-and-flat channels that hold the shielding panels together are also a source of RF leaks. Field tests have shown that screws loosened by as little as one-quarter of one turn will cause an RF energy leak large enough to be detected by a sensor placed 1 to 2 feet away from the source of the RF leak.

In many cases, the low-level RF signals detected are not considered a threat and, therefore, are not corrected. In a few instances, severe RF leaks have been traced to loose fitting hat-and-flat channels.

## FLOOR LOAD CONSIDERATIONS

In an operational scenario, a typical shielded enclosure is erected over a pedestal system (on 4-foot centers) that elevates the floor of the enclosure from 3 to 9 inches above the parent-room floor for inspection purposes. As new hardware that improves the quality and efficiency of communications is developed, the users will add this new equipment to the complement of hardware already located within the shielded enclosure. The added weight of this new equipment will be significant, and the question has been raised, "How much weight can the floor of an overall shielded enclosure with a pedestal system withstand before the stress at the panel seams causes the seams to leak RF energy?"

## THEORETICAL ANALYSIS

A preliminary theoretical stress analysis was performed in an effort to answer questions concerning floor loading and floor deflection. The number of estimates and best guesses regarding the input data rendered the results inconclusive. Therefore, theoretical analysis yielded an unacceptable margin of error in calculating the safe load limit of a pedestal-supported shielded enclosure. An empirical test was required in order to observe and quantify the phenomenon of floor loading. Prior to any testing, theoretical calculations were made to determine the load at each of 16 points located directly over the plastic block pedestals (Figure 1). The calculations were made for a number of point loads.

## TEST DESCRIPTION

A test program was implemented to determine the maximum load that can be placed on the enclosure floor before the floor panel seams flex enough to cause an RF leak that is detectable by an RF-detection system (Figure 2).

### PLATFORM SYSTEM

A shielded enclosure was erected on a rigid platform. The pedestal system consisted of a series of 4" x 4" x 20"-long "I" beam legs (25 each) with a 1/4"-thick, flat-steel top plate. A 2"-thick wood platform was bolted to the 25 "I" beam legs (Figures 3, 4, and 5).

The raised platform allowed working access to the bottom of the shielded enclosure. Access into the bottom of the enclosure was made by cutting a 5-inch diameter hole in the platform and the 3/4-inch particle board that the enclosure rested on.

The surface of the platform served as the parent-room floor. The 20-inch platform space allowed technicians to expertly mount the strain gauges and the dial indicators. The dial indicators were mounted from the parent-room floor and extended up through the holes cut away in the wood floorings so that the dial indicator arm rested on the bottom surface of the enclosure (Figure 3).

### TEST ENCLOSURE

Following the construction of the platform, a 12' x 12' x 8',

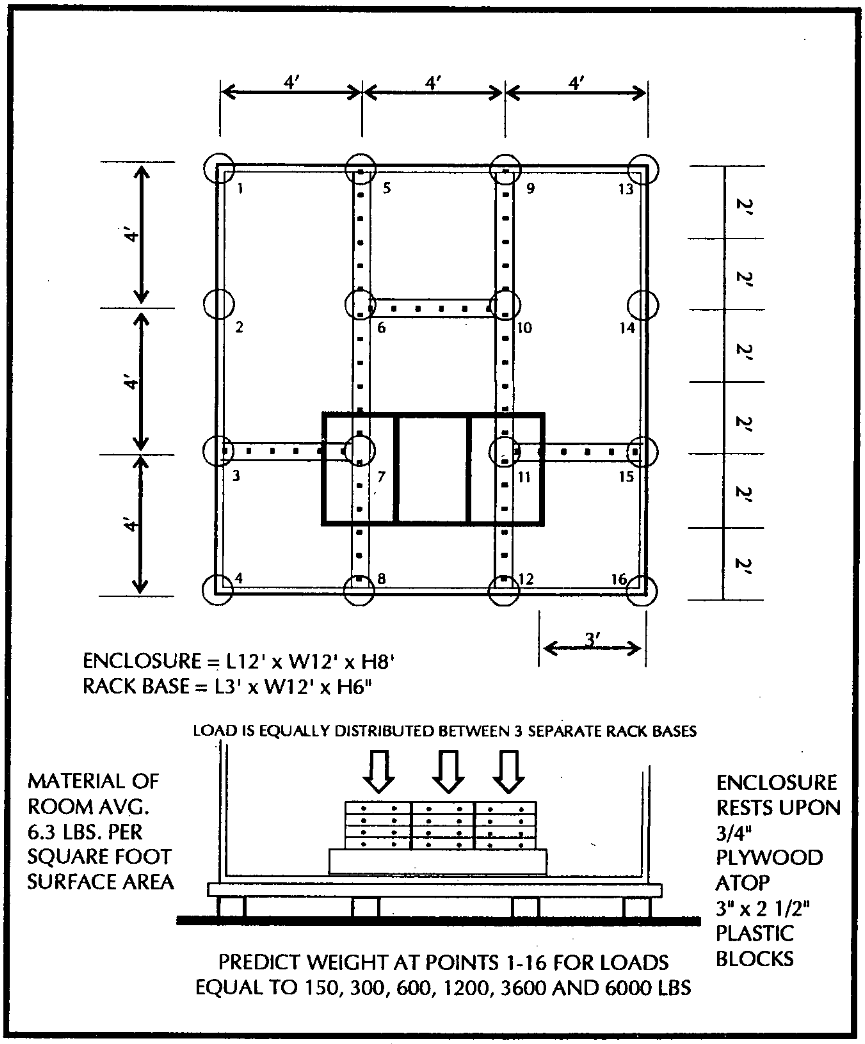


***FIGURE 1.*** *Theoretical Calculations of Floor Loading.*

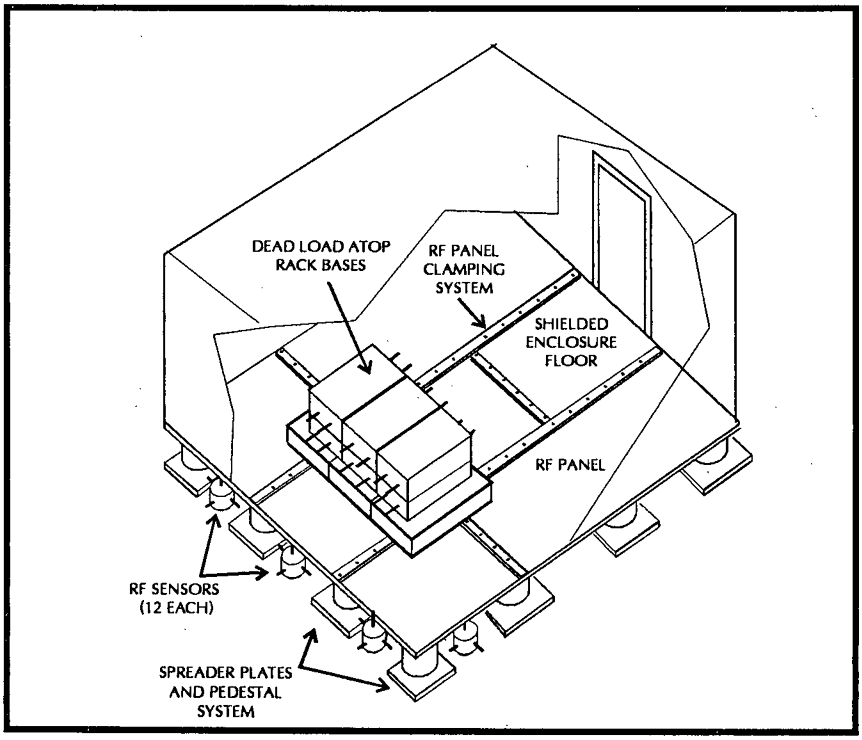


***FIGURE 2.*** *Test Setup.*

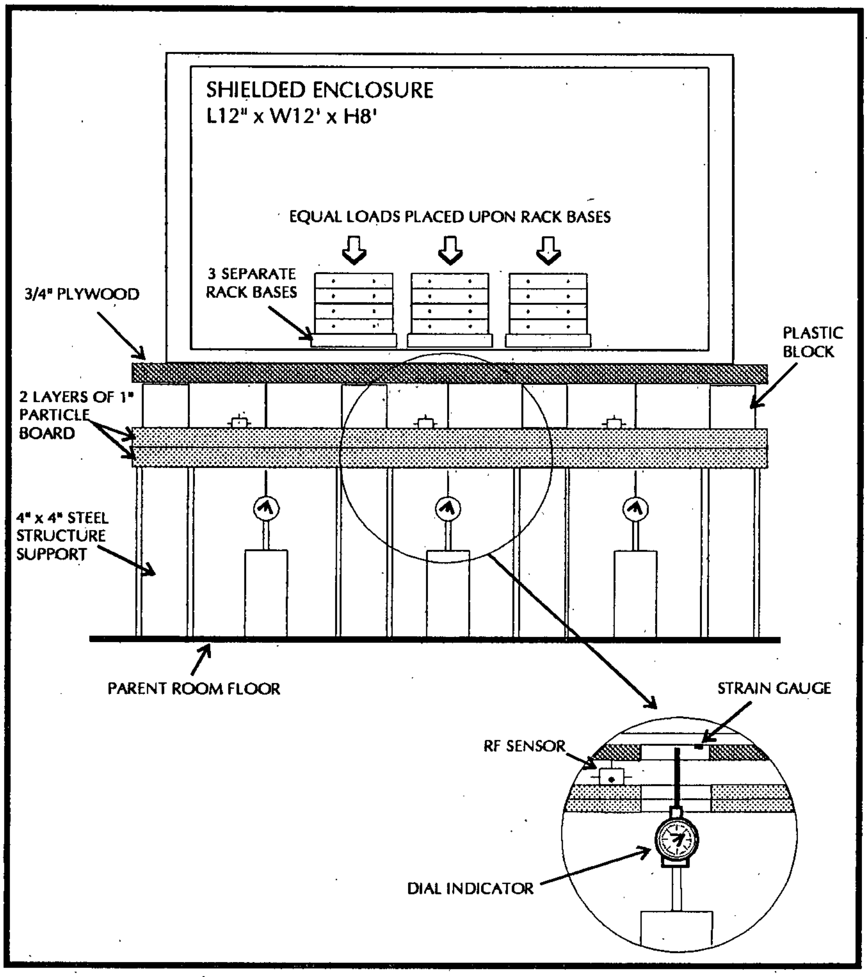


***FIGURE 3.*** *Shielded Enclosure Structural System.*

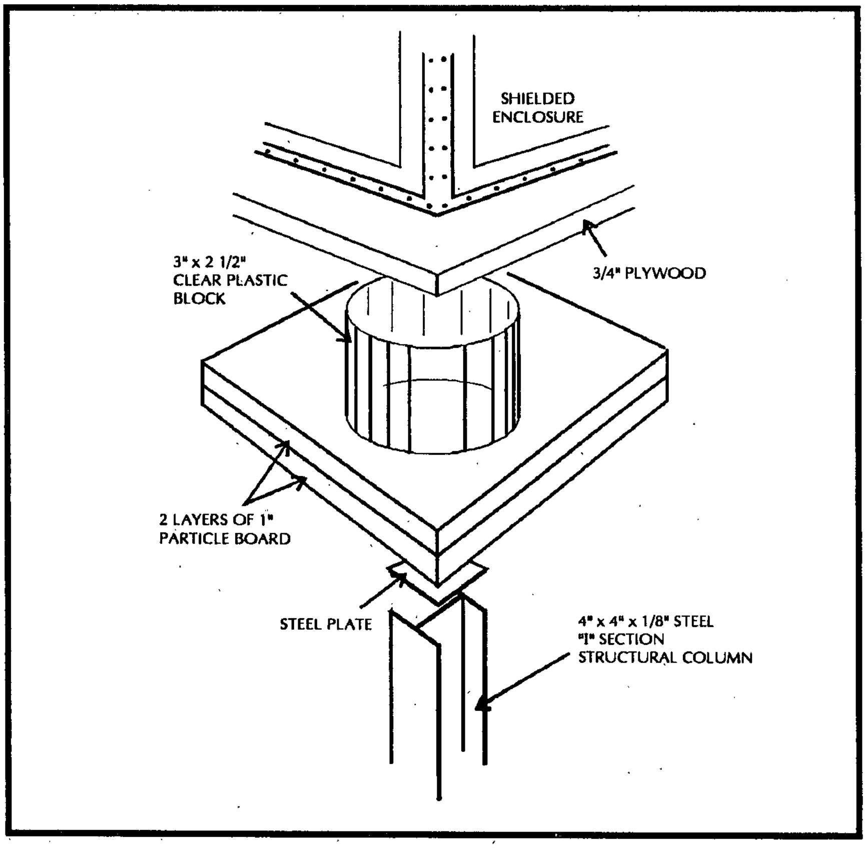


***FIGURE 4.*** *Detail of Plastic Block and Column Supports.*

3/4"-thick, sandwich-design shielded enclosure was erected on top of the rigid platform. All enclosure fasteners were repeatedly tightened over a 24-hour period to ensure RF integrity. A preliminary RF test was performed on the enclosure using test gear that is employed in the field to perform NSA 65-6 tests. The frequencies covered were 400 MHz, 1 GHz and 8 GHz.

After the enclosure was erected and tested for RF tightness, it was instrumented and measurements were conducted for one week to establish a test procedure that described the location of the RF sensors, the dial indicators, the strain gauges and the load points. After the test procedure was established, measurements of RF energy detected by each sensor, floor deflection measured by the dial indicators, and strain gauge readings were recorded for each increment of load.

## RF DETECTION SYSTEM

The tests were conducted by instrumenting the pedestal-supported shielded enclosure with an RF-detection system. The antenna sensors of the detection system were concentrated on the underside of the shielded enclosure and positioned at the panel seams. The RF sensors were distributed over the entire underside of the floor, so that the RF integrity of the entire floor area could be examined as a function of floor loading. The basic detection instrumentation was a spectrum analyzer and a pre-amplifier.

The RF data was collected by reading the amplitude of the detected signal on the spectrum analyzer. The input of the analyzer was connected to a coaxial switch which was used to sample the outputs of 10 RF sensors placed below the floor of the enclosure and two RF sensors placed on the walls of the enclosure. Sensor readings were recorded each time data was taken.

### DIAL INDICATORS

A series of 10 dial indicators were placed under the shielded enclosure floor between the underside of the enclosure and the parent-room floor. The indicators were graduated in increments of 0.001 inch and were used to record the deflection of the floor as the floor load was increased (Figure 3).

### STRAIN GAUGE INSTRUMENTATION

Stress applied by the test load to the enclosure floor structure was measured with 10 strain gauges. The strain gauges were of the polyamide-encapsulated, constanton type. The gauges were bonded to the floor structure with a bonding adhesive.

The surface area preparation consisted of cleaning the bonding area with a degreaser and then applying a bonding conditioner to the floor structure. After the strain gauges were firmly bonded to the structure, they were lavishly covered with a protective coating of acrylic.

As the test load was increased and applied to the floor of the shielded enclosure under test, the reading from each strain gauge was recorded on a data sheet. Each increment of load was applied for 24 hours before the load was increased again.

The 10 strain gauge elements were bonded in close proximity to the RF sensors and the dial indicators. Dial indicator readings and strain gauge readings were taken simultaneously in pairs.

The output of each of the strain gauges was connected to a 10-channel switcher/balancer specially calibrated for strain gauge inputs. The output of the switcher/balancer was connected to an indicator having a four-place digital readout.

The data output from each of the 10 strain gauges was recorded for each point load variation. Signal levels from the RF sensor dial indicator readings and strain gauge readings were recorded on a single data sheet (Table 1). The strain gauge measurements served as a backup for comparison to the dial indicator readings to ensure measurement consistency and accuracy of data.

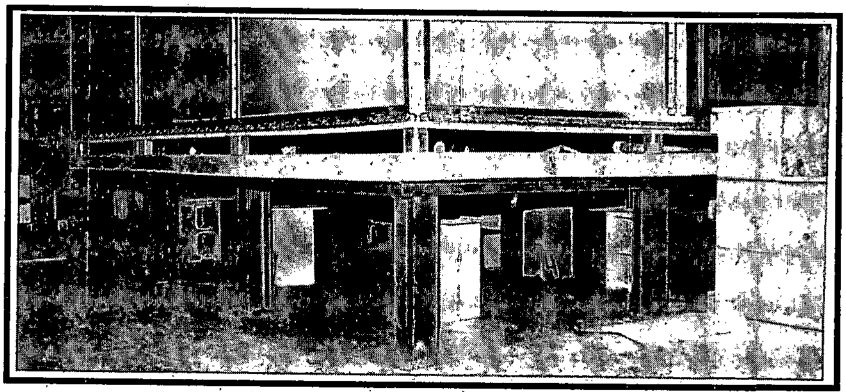

***FIGURE 5.*** *Floor Load Platform.*

| T.P. | RF SENSORS SIGNAL LEVELS (dBm) | | | DIAL INDICATORS (inches) | | | STRAIN GAUGE READINGS | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | A-B | A | B | B-A | A | B | B-A |
| 1 | 75 | 6 | 69 | .000 | 0 | 0 | 0000 | 0032 | 0032 |
| 2 | 85 | 6 | 79 | .093 | .152 | .059 | 0000 | 0076 | 0076 |
| 3 | 85 | 0 | 85 | .099 | .138 | .039 | 0000 | 0155 | 0155 |
| 4 | 90 | 16 | 74 | .000 | .273 | .273 | 0000 | 0178 | 0178 |
| 5 | 92 | 0 | 92 | .004 | .118 | .114 | 0000 | 0137 | 0137 |
| 6 | 88 | 0 | 88 | .000 | .591 | .591 | 0000 | 0172 | 0172 |
| 7 | 82 | 0 | 82 | .000 | .211 | .211 | 0000 | 0131 | 0131 |
| 8 | 100 | 0 | 100 | .007 | .009 | .002 | 0000 | 0137 | 0137 |
| 9 | 92 | 0 | 92 | .007 | .058 | .051 | 0000 | 0526 | 0526 |
| 10 | 85 | 0 | 85 | .002 | .024 | .022 | 0000 | 0310 | 0310 |
| 11 | 65 | 0 | 65 | | | | | | |
| 12 | 65 | 0 | 65 | | | | | | |

T.P. = Test Point
A = Ref Level
B = Instrument Reading
A-B = Measured Level

**DATE:** Day 27 5-15-90 **TIME:** 9:30 AM **WEIGHT (lbs.): 6280**

***TABLE 1.*** *Strain Gauge Data.*

At the end of a 30-day test period, it was concluded that the floor of a properly erected shielded enclosure will not flex to the point where the seams will leak RF energy when loaded with a 6,000-pound weight.

## FLOOR LOAD DESIGN

The design of the load consisted of 15 poured concrete slabs having a 3' x 2' base dimension and a height dimension varying from one to 6 inches. Two lengths of 3/4" reinforcing bars were imbedded through the middle of the concrete. A 6-inch section of each bar pro-

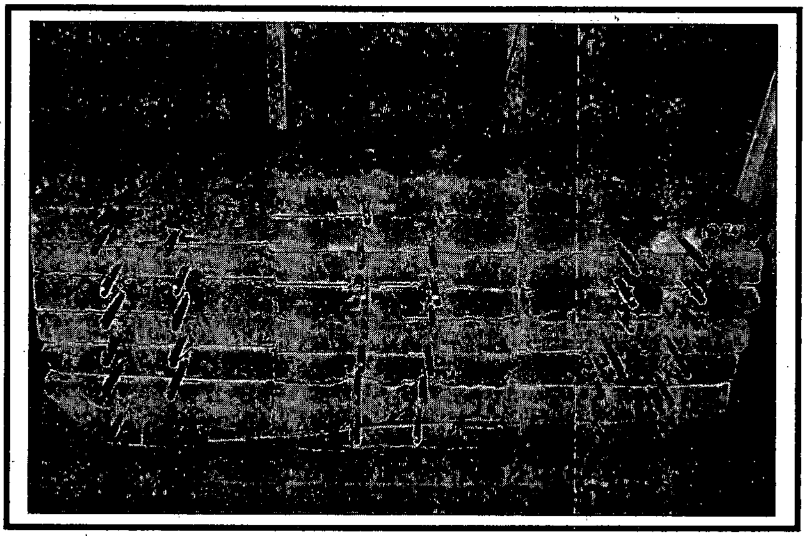

**FIGURE 6.** *Load Study Weights.*

truded from the ends of the blocks. The 6-inch sections of reinforcing bar were used to maneuver the concrete load blocks (Figure 6).

The load was changed in 1,000-pound increments up to 6,000 pounds or when an RF leak was detected, whichever came first.

As soon as an RF leak was detected, the load was reduced and reloaded with a combination of 500-, 200- and 100-pound concrete slabs, so that the weight of the load that caused the detectable RF leak was determined to the nearest 100 pounds.

The tests were performed over a period of 30 days to see if the structural integrity of the panel seams deteriorated over a period of time after a load had been added.

## INCREMENTAL LOADS

After the erection of the shielded enclosure, the test team began applying incremental loads to the floor of the enclosure. The schedule of weights that were applied were as follows:

| Wt. Application No. | Weight (lbs) |
|---|---|
| 1 | 495 |
| 2 | 776 |
| 3 | 1490 |
| 4 | 2297 |
| 5 | 3072 |
| 6 | 3848 |
| 7 | 4637 |
| 8 | 5423 |
| 9 | 6480 |

After each weight was applied, the load was allowed to rest for approximately one hour, and then readings were recorded. The next load was applied until the weight was increased to the maximum 6,480 pounds. After all weights were applied, the data was plotted on a graph in an effort to evaluate any trends that may have developed.

## MAXIMUM LOAD TEST

The maximum load test was a test performed over a 30-day period with 6,480 pounds of weight applied to the floor of the enclosure. This weight was placed on the interior floor of the enclosure in the exact locations proposed for the new equipment. Readings from the dial indicators, RF sensors and strain gauges were taken three times a day (morning, noon and afternoon), excluding weekends. All data was then graphed to study the trends that occurred over the 30-day period (Figure 7).

## LIVE LOAD TEST

The maximum load phase was augmented by a random live load that was produced by personnel walking in and out of the enclosure throughout the test period. This test was used to produce the stress experienced by an enclosure floor during daily use in the field.

## NO-LOAD TEST

The no-load test was the final phase of the floor load study. All weights were removed from within the enclosure, and all readings were taken and recorded. The enclosure sat for a one-week period with no load and another reading was taken. This allowed the floor of the enclosure to settle back in order to fully gauge the elasticity of the floor panels.

## SUPPLEMENTAL TEST

In a supplemental test, an RF *sniffer* was used in an attempt to detect RF leaks. The RF leak detector consisted of a transmitter and a receiver. The transmitter was connected to the opposite corners of the enclosure exterior and transmitted a low-frequency current across the exterior metallic surface of the enclosure. The AC currents at the frequency do not penetrate into the surface of the metal, so that these currents may be detected inside the enclosure with the receiver only at the points where the enclosure has openings or impedance discontinuities. The RF leak detector was used to check only for RF leaks in the panel seams. This test data was supplemental and was added to the data bank.

## SPECIAL TEST (LOOSE SCREWS)

To simulate a modicum of structural deterioration that would be caused by normal usage, three floor screws were loosened 1/4 of a turn. The concrete loads were applied for the next 30 days.

As each increment of load was added, the readings of the 10

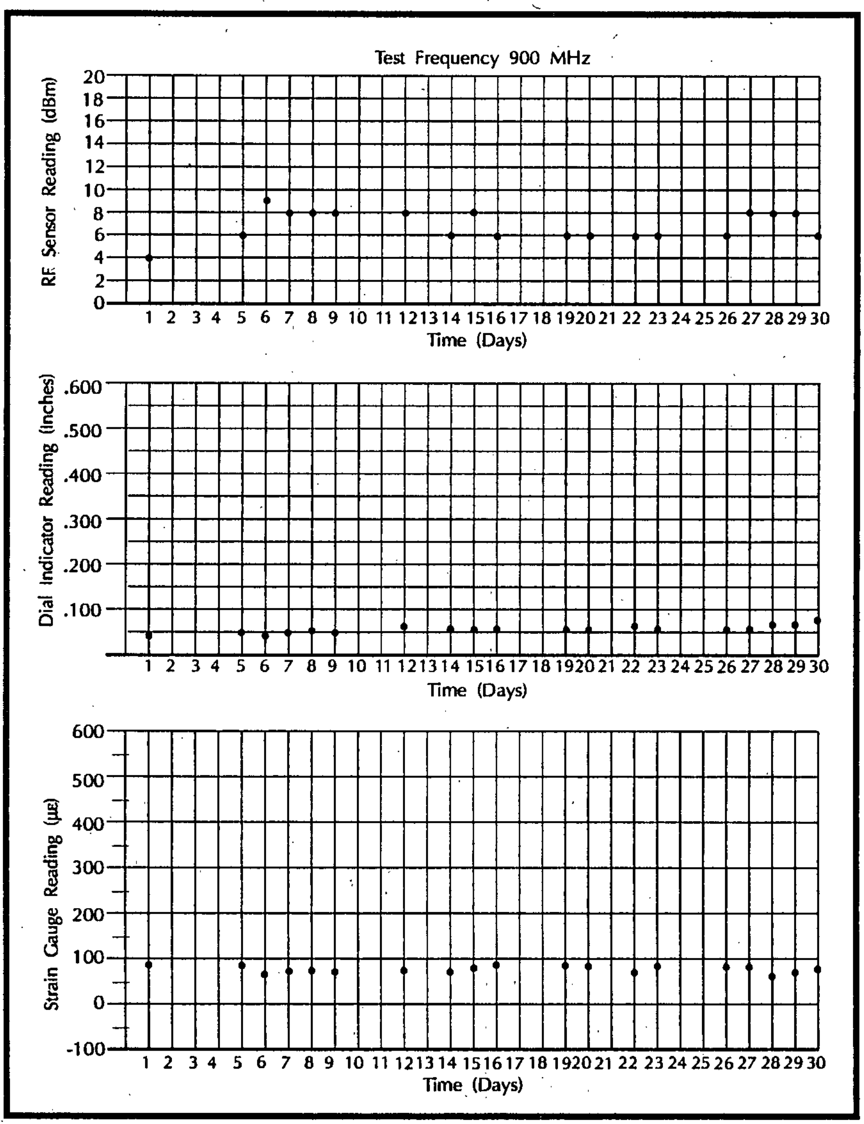


***FIGURE 7.** Maximum Load Test.*

RF detector sensors, the 10 dial indicators and the 10 strain gauges were recorded.

The data showed immediately that as the load was increased, the signal detected by the RF detection system increased in direct proportion to the added floor load. The detected signal increased above acceptable limits. It should be noted that this increase in detected signal with increased load was recorded only for the condition where three floor screws were loosened by a 1/4 turn. No increase in RF signal was detected as the load was increased when the enclosure was first erected and completely RF tight.

The test team then studied the increase of the RF signal detected over the entire maximum load phase period (30 days).

## SUMMARY

The objective of this program was to measure the RF integrity of the enclosure under a variety of loads and to record the level of the detected RF test signal as loads were applied to the enclosure floor. The data collection was performed three times a day. The original schedule was to perform these measurements for a period of 30 days. However, due to changing data, the period was extended by 14 days in order for the test team to fully evaluate the effects of direct loading on the shielded enclosure floor.

It was concluded that adding floor weights of up to 6,500 pounds to the normal complement of equipment in a 12' x 12' x 8' enclosure will not cause any deflection of the floor and an RF leak will not result due to added floor load. The foregoing applied to a newly constructed enclosure certified as RF tight after it had been erected for 24 hours or more.

Adding floor weights to an RF enclosure that has been in use for a year or more will probably result in an RF leak that is above an acceptable limit.

## RECOMMENDATIONS

1. RF testing of an enclosure should be required 24 hours after the entire enclosure has been erected.

2. The pedestal system that supports the enclosure floor away from the parent-room floor should be designed so that the supports are on a 2' by 2' grid. This will ensure adequate support of the enclosure floor structure and prevent any bending or flexing of the floor structure.

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