Department of Energy
Oak Ridge Operations
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DOCKET NUMBER PROPOSED RULE PR-50 (4)
(45 FR 36082)

June 11, 1980

Secretary of the Commission
U. S. Nuclear Regulatory Commission
ATTN: Docketing and Service Branch
Washington, D. C. 20555

Gentlemen:

I wish to comment regarding proposed rules, 10 CFR Part 50, "Fire Protection Program for Nuclear Power Plants Operating Prior to January 1, 1979," dated Thursday, May 29, 1980.

Section III. Specific Requirements, Part A. Fire Water Distribution System - A policy statement recommending the use of water extinguishing systems over energized electrical equipment is established. I support this concept based on past events and experience. However, this policy is very controversial where personnel safety is involved. The amount of research available which substantiates the effects of fixed water spray discharge over energized electrical equipment is rather limited. General Services Administration did conduct limited testing in 1979 on this subject (report enclosed).

It is recommended that NRC support further detailed testing to thoroughly examine all controversial aspects of this proposal. The effects of water impurities, distance from nozzle discharge, water densities, on-off type sprinklers, shielding configuations, drainage, etc., should be examined and documented for design guidance.

Sincerely,

Jim Hutton
James R. Hutton
Safety & Fire Protection Branch
Safety & Environmental Control Division

Enclosure

Acknowledged by card. 6/20/80 mdv

ABSTRACT

This report covers a series of transformer room fire tests conducted by the General Services Administration (GSA). The tests were set up to demonstrate what shock hazard might be present when automatic sprinklers operated over energized electrical equipment. The test room was 25 feet long, 12 feet wide and 8 feet high. Fire protection was provided by standard one-half inch pendent automatic sprinklers temperature rated at 135°F and installed to give approximately 150 square feet per head coverage. A 480 volt dry transformer was used in the room to provide a 3-phase, 4-wire distribution system, which is typical of the electrical systems found in GSA buildings. The tests showed that the induced currents in the test room during the various tests were relatively small and posed no appreciable personnel shock hazard.

Detailed descriptions of the various tests, together with the results and conclusions, are contained in the body of the report.

ACKNOWLEDGEMENT

This project was accomplished due to the hard work of the craftsmen and technicians of both the Anacostia and the Central Support Field Offices who aided in the design, construction, coordination and testing.

Special thanks to Mr. Warren Hayes of the National Bureau of Standards for his help and suggestions in the test design.

We thank Grinnell who was so kind to donate the sprinkler heads for these tests.

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INTRODUCTION

This report covers a series of transformer room fire tests conducted in a room configuration which is typical of the electrical distribution systems found throughout GSA buildings.

1.1 BACKGROUND

There has been much concern expressed about the shock hazards that might result to personnel if automatic sprinklers were to discharge in areas where there was energized electrical equipment, especially transformers and/or switchgear. GSA had established firesafety criteria which called for sprinkler protection in typical electrical closets, telephone rooms and other rooms where electrical equipment would be located. Although the firesafety design criteria has been in effect for several years, designers and trade unions have voiced strong opposition to installing sprinklers in such areas.

It is typical in GSA-owned and leased space that electrical distribution rooms are used for combustible storage. The danger of a fire starting in the combustible storage and spreading to electrical equipment or vice versa is a real one. Without sprinkler protection, a small fire can spread and become a potentially large one that is difficult to manually extinguish.

1.2 OBJECTIVE

The objective of this project was to determine what shock hazard to personnel might be present if water from automatic sprinklers was discharged over energized electrical equipment in a typical GSA electrical installation.

1.3 SCOPE

The scope of this project was designed for a series of three tests. Results from these series of tests would be used to either reinforce or modify the firesafety criteria with respect to sprinkler installations in areas with energized electrical equipment.

TEST METHOD AND SETUP

2.1 TEST SITE

The tests were setup and conducted at the Temporary Building A, B, C complex at Second and S Streets, S.W., Washington, D.C. These two story wood frame buildings were built in the early 1940's and were scheduled to be torn down.

A test room was constructed on the first floor in Wing 6 of Temporary Building B. The room was 25 feet long x 12 feet wide x 8 feet high. The walls and ceilings were constructed of two layers of one-half inch gypsum board on steel studs. The room was built on a 31 feet x 15 feet reinforced concrete pad which was equipped with a center floor drain. Both the drain and the 15 mil wire reinforcing grid were grounded.

Two 135°F pendent sprinklers on one inch pipe were supplied by the building sprinkler system. The deflectors were five inches below the smooth ceiling. The static water pressure was 55 psi.

The room contained a manually controlled 3000 cfm electric fan which was used to exhaust the room after each test.

2.2 TEST SETUPS AND METHOD

The test room (see Figure 1) was setup to represent a typical distribution transformer room. Copper isolated conductors were attached to the walls of the room with insulators. These conductors simulated people. The current from these conductors to ground was monitored with high speed recording ammeters. Two 475 ohm and one 450 ohm surge limiting resistors were installed in series with the ammeters.

Charles F. Dalziel of the University of California reported in his paper "Electric Shock Hazard", that the average current at which a women would involuntarily grasp any object within her fingertips and not let go was about 11 milliamperes. For a man it was about 16 milliamperes. He further stated that 500 ohms is the commonly used value for the minimum resistance between extremities of the human body with regard to estimating shock currents with wet or liquid contacts during industrial accidents. Therefore, it was decided to evaluate the potential shock hazard to personnel by making measurements in the room between any two points likely to be touched during emergency egress and monitoring to see whether or not hazardous current levels would be noted through a 500 ohm resistance. The lesser ohm resistors were used due to availability. A value of 10 milliamperes was selected as the maximum current acceptable to be considered to offer no appreciable personnel shock hazard.

The copper conductors (simulated persons) were 1/64 inch thick, four inches wide and 852 inches long. The conductors were stacked on the wall, i.e., the bottom person conductor was run around the inside perimeter of the room one foot above the floor with the middle person conductor three feet above the floor and the top person conductor six feet above the floor. Each of the copper conductors was insulated from the wall by a space of 7/8 inches provided by several wood spacers attached to the wall.

These conductors were three feet from the grounded case of the transformer. The top person conductor was one foot from the unshielded section of the voltage supply conductor.

To obtain the voltage for the test transformer and to simulate a typical 3-phase, 4-wire distribution system, the existing 120/208 wye voltage had to be modified.

The voltage source started with a 13,200 volt wye grounded voltage source from the local public utility. The 13,200 volts was reduced to 125/216 wye then fed into a Delta Star transformer further reducing the voltage to 65 volts phase to ground. This voltage was stepped up to 210 volts phase to ground, 375 volts phase to phase. This voltage (375 v) was used in all tests. The different transformers were used to obtain a 3-phase, 4-wire distribution system. This type of system is typical of the electrical systems found in GSA buildings. The current to the test site was limited by 400 amp, 16,000 amp peak let-through, fuses. See Figure 2 for equipment arrangement.

2.3 TEST PROGRAM

To measure the effects of potential shock hazard, three tests were scheduled. In case 1, the objective was to ignite combustible storage in the test room near an energized transformer and monitor the current flow to various copper conductors adhered to the room walls at various heights above the floor. The sprinkler discharge over the energized transformer would be observed. The shock potential of the water over the wall and floor surfaces would be measured by electrical instrumentation.

In case 2, electrical current flows were to be monitored during a phase to phase or an arcing control fault in the transformer while sprinklers were discharging.

In case 3, a phase to phase, bolted fault was to be setup in the transformer and electrical current was to be monitored while the sprinklers were discharging.

The test program was unstructured to the point that modified tests could be arranged if equipment was damaged during the tests or if results dictated a needed change in the test method. This proved to be the case for this test program. Tests were conducted July 9-11, 1979.

2.4 MEASUREMENTS

Both voltage and current readings were taken on each of the three copper (simulated people) conductors for each test. Voltage was measured on the main bus duct and ground current was monitored for the main room ground, transformer and main drain line.

2.5 INSTRUMENTATION

The following were used in the measurement of test results:

1. Bus Voltmeter by Weston Instrument Company

2. Three-Rustrak high speed recording ammeters by Gulton Industries, Model P4116 range 0 to 1 amperes. Recording speed 1500 inches/hour.

3. Recorder A-C Ammeter by Westinghouse Type PM-44 Style WG-13924-1. Recording speed 3 inches/hour.

4. Oscilliscope - Sony Model 335

5. Tripplet volt-ohm meters.

2.6 MISCELLANEOUS

After the first test in which the sprinklers were to operate by being fused by the heat of the fire, the sprinkler discharge was to be controlled by operating the manual shut off valve on the sprinkler feed line outside the test room. Therefore, all tests after No. 1 would be simulating an accidental sprinkler discharge followed by some type of fault on one of the electrical components in the room. This latter type of simulation was chosen to most closely duplicate that condition which was of concern to electricians working in rooms which contained electrical distribution equipment.

The sprinkler flow was approximately 64 gallon per minute (32 gpm per sprinkler) or providing a density of 0.21 gpm/ft2.

2.7 EVALUATION CRITERIA

The maximum let-go current for wet contact in the electrical distribution room was established at 10 milliamperes. It was judged that 10 milliamperes and below would offer no appreciable shock hazard to personnel.

TEST NO. 1

In this test, approximately 50 pounds of combustibles (cardboard, wood pallets, and scrap paper) were stored one foot from the transformer. The combustibles were ignited and burned for two minutes and thirty seconds before the first sprinkler (one nearest door) actuated. The second sprinkler actuated 17 seconds later. The transformer was energized with a 100 amp load and maintained a voltage of 365 volts during the test. Ground amps measured 0.5 amps with the top person yielding 4.21 milliamps, the middle person 8.42 milliamps and the bottom person 1.0 milliamps. The readings on the copper wall strips were taken on the voltmeter/recorders and on the oscilliscope. The recording equipment was very difficult to stabilize and raised doubts about the accuracy of the data.

TEST NO. 2

As a result of Test No. 1 it was decided to duplicate Test No. 1 controlling the water discharge manually through open sprinklers. This time the Tripplet mini volt-amp meters were used to monitor the voltage drop across the three conductors. The power to the room was energized and the sprinkler system was actuated manually. The sprinklers discharged a total of approximately 64 gallons per minute. The water was permitted to flow ten minutes and there was no measurable recordings on the mini volt-amp meters.

TEST NO. 3

Using the mini volt-amp meters again to monitor the voltage drop, this test was run with the manual disconnect switch panel left wide open. The object was to see what affect sprinkler water would have on the exposed switch and how this might affect the shock potential to room occupants. The power to the room was turned on, the open sprinklers were operated and left to run two minutes. During this time the inside of the switch panel was thoroughly wet down. No readings were measured on the upper two conductors and a reading of 1 milliamp was recorded on the bottom conductor. The reading for the total current to ground for the drain, transformer and disconnects was 0.5 amps.

TEST NO. 4

The objective in this test was to have a phase to phase fault in the transformer while sprinklers were operating. This would simulate what would happen if sprinklers accidently operated and a transformer fault occurred. The transformer cover was removed and a ten inch long piece of No. 12 copper wire was connected between phase A and C. The cover was replaced and the sprinklers were turned on for ten seconds before the power was actuated. A bright arc was noted at the base of the transformer with ensuing smoke. The circuit breakers tripped in two seconds. No current flows were measured on any of the meters.

TEST NO. 5

In this test a solid copper bar eight inches long by three inches wide by 1/8 inch thick was clamped to A phase of the transformer and brought within 1/32 inch from B phase. A small piece of aluminum tag wire was placed between B phase and the copper bar. The objective here was to have a longer controlled fault. Again the open sprinklers were turned on for ten seconds then the power was started. There was a small flash of fire at the bottom of the transformer but no propagation. The only current measurable was that on the bottom person. It read 1 milliamp. The voltage of the transformer held at 365 volts with a load of 100 amps. The reading for the total current to ground for the drain, transformer and disconnects was 0.5 amps. However, with a 40 to 1 current transformer ratio, there were 20 amperes flowing through the transformer case, floor and drain grounds.

TEST NO. 6

This test was a duplicate of Test No. 5 except the gap between the edge of the copper bar and B phase was only several mils. Again a small piece of aluminum tag wire was placed between the bar and B phase. With sprinklers running for ten seconds, the power was applied and a flash of fire followed by molten metal sparks came from beneath the transformer. No measurable currents were recorded mainly due to the fuses in the system blowing. The voltage on the transformer dropped from 365 to 80 volts due to the blown fuses.

TEST NO. 7

This test was to determine what affect a fault on the bus coming into the room would have as far as personnel shock hazard. A 12 inch piece of No. 6 copper wire was wrapped between A phase and ground. Sprinklers were turned on for ten seconds, the electrical system was energized but no noticeable sparking or fire resulted. The voltage of the transformer held at 365 volts. There was a slight current flow in each of the person conductors. The top conductor measured 25.3 microamps, the middle conductor measured 26.3 microamps, and the bottom conductor measured 26.6 microamps.

TEST NO. 8

This test was a repeat of No. 7 with the exception that the No. 6 copper wire was wrapped loosely between A phase and ground so as to permit more intermittent arcing. With sprinklers operating the top conductor measured 5.26 milliamps, the middle conductor 5.26 milliamps, and the bottom conductor yielding 5.55 milliamps.

TEST NO. 9

This test involved the faulting of the transformer by using a piece of No. 6 copper wire between the A phase and the ground. With the sprinklers flowing for ten seconds, the power was turned on and there was an arcing at the transformer. For this test, the transformer was under no load. The circuitry held for approximately one minute, then there was a flash in the supply transformer located in the instrument reading room. At this point the power was shut down to protect those conducting the test. The current readings for the conductors were as follows:

top	=	10 milliamps
middle	=	10 milliamps
bottom	=	100 milliamps

Ground current for the transformer, floor, drain and disconnects was recorded at 5.0 amps which multiplied by the 40 to 1 ratio yields a current flow of 200 amperes.

See Figure 3 for a summary of all the test result measurements.

CONCLUSIONS

1. An accidental sprinkler discharge in a typical GSA electrical distribution room poses minimal shock potential to personnel within the room.

2. An accidental sprinkler discharge in conjunction with various electrical faults in the electrical equipment poses minimal shock potential to personnel within the room.

3. A phase to ground fault in a transformer will induce large current flows to ground which in themselves will be dangerous to personnel coming in contact with it irregardless of a sprinkler discharge.

4. The fire protection criteria of chapter 5 of PBS P 5920.9, Building Firesafety Criteria, for providing sprinklers in electrical rooms was valid. The criteria will be modified to provide specific design details for sprinkler installations. (See recommendations.)

V

RECOMMENDATIONS

1. Automatic sprinkler protection shall be provided in electrical distribution rooms. To preclude accidental operation of sprinklers in electrical distribution rooms, pendent sprinklers of the on-off type having both a rated fusible element and a temperature sensitive mechanism on each sprinkler to control the water flow (Central Sprinkler Corporation On-Off Automatic Sprinkler or equivalent) and shall be equipped with a sprinkler guard to provide extra protection.

FIRE EXPERIENCE IN ELECTRICAL EQUIPMENT ROOMS

Fires do and will continue to start in electrical equipment rooms. The need to keep these rooms free of combustible storage has been repeated many times. The need for automatic sprinkler protection as called for by GSA firesafety criteria has been repeatedly recommended. Since fires will continue to occur, and keeping combustible storage out of electrical equipment rooms is difficult to enforce, sprinklers must be installed.

The following fire experiences are listed to highlight the problems associated with electrical distribution rooms:

1. An electrical fire occurred on July 31, 1979, in an electrical distribution room at a 20 story high rise office building which GSA leased for Federal agencies in New York City. A fault in a connection to an aluminum bus duct in an electrical distribution room on the 17th floor of 1 LeFrak Plaza, caused a fire which ignited the plastic insulation on the electrical wires and which spread to cardboard cartons of filters stored in the room. The building was not equipped with automatic sprinkler protection except in the basement levels. Responding city firemen extinguished the fire with fire extinguishers and hose streams. 1,100 people had to be evacuated.

2. The National Fire Protection Association publication "Fire Journal" highlighted a fire involving electrical distribution equipment in a nine story high rise office building. The July 1979 issue, page 22, noted that a loose connection in a 600 volt switch box caused a short. The arcing ignited polyvinyl chloride covered electrical distribution wiring and telephone wiring circuit boards which were mounted on plywood boards on the concrete block walls of the eight foot by five foot electrical room. The fire department responded to this fifth floor room and used two 1-1/2 inch hoses and two portable fire extinguishers to suppress the fire. Damage was mainly confined to the electrical equipment. Again, in this incident no sprinkler protection was installed.

3. On January 10, 1978, an electrical equipment explosion in the boiler room of a 12 story office building caused a fire in the building's electrical switching equipment. However, the fire was quickly put out by the automatic sprinkler system which had been installed to protect this high voltage equipment. The attached reprint of the story from the Montgomery County Maryland, Journal highlights the benefits of having the sprinkler system for the protection of electrical equipment.

EVACUATED — The photograph of the sign superimposed on the above photograph of the Montgomery Center, 8630 Fenton Street, Silver Spring, was posted last week after 1,400 persons had to evacuate the 12-story office building as a result of an explosion which knocked out the building's power supply. The building is expected to be fully reoccupied on Monday, January 30.

Record photo

Mont. Co. Journal 1/27/78

Explosion Empties Building

By John R. Benedict

All 1,400 employees of the 72 tenants in the Montgomery Center at 8630 Fenton St., Silver Spring, are expected to be able to return to their offices Monday after having been evacuated for a week and a half because of an explosion which left the building powerless on January 10.

The developing problem was discovered by alert building security man Gordon Underwood while making routine rounds at about 9 p.m. on Tuesday of last week. When he arrived at the basement boiler room of the 12-story structure, he noticed water running down the wall on the Fenton St. side. (Heavy rain was falling outside on top of snow from an earlier storm.)

Underwood got to a telephone and called several building engineers and then called for fire department assistance, because he had seen water building up in the boiler room.

After making the telephone calls, Underwood returned to the boiler room, where he found the situation getting worse. Moments after Underwood had made his second exit from the boiler room, which houses the building's electrical switching equipment, there was a terrific explosion which shook the entire building.

Fortunately neither Underwood nor anyone else in the mostly empty building was injured.

The explosion caused a fire but an automatic sprinkler system went into operation and soon put it out. The electrical equipment, valued at $350,000, apparently exploded when the seeping water came in to contact with it.

A spokesman for the Fire Marshal's Office told the Record that that Office has been advocating for some time the use of sprinkler systems to protect equipment which handles high-voltage electricity. The effectiveness of the sprinkler system in the boiler room of the Montgomery Center proved the point, he said.

The spokesman noted that it was fortunate that the sprinkler system put the fire out because it took firemen some time to get into the boiler room after the explosion took place. He also pointed out the good fortune of Underwood's having taken time to call the building engineers before calling for fire department help. Had he called for the firemen first, suggested the spokesman, they could have arrived and been in the boiler room at the time the explosion happened.

The damaged equipment left the building completely without power. The following day and for a number of days thereafter tenants were allowed to sign their way into the building only for the temporary purpose of gathering needed material from their offices. Many of the tenants set up makeshift shops in the Holiday Inn and other locations in the area.

Marcelle Fry, who manages the property for the Carey Winston Company, described the cooperation of the tenants during the emergency as "just great."

By the latter part of last week the water had been pumped out of the Capri Theatre and it was being cleaned up. Earlier this week the Golden Flame Restaurant, located in the basement of the building as is the theatre, was back in business.

Ms. Fry maintained her office in the Montgomery Center throughout the entire emergency period. Someone had to mind the store—even when it was powerless!

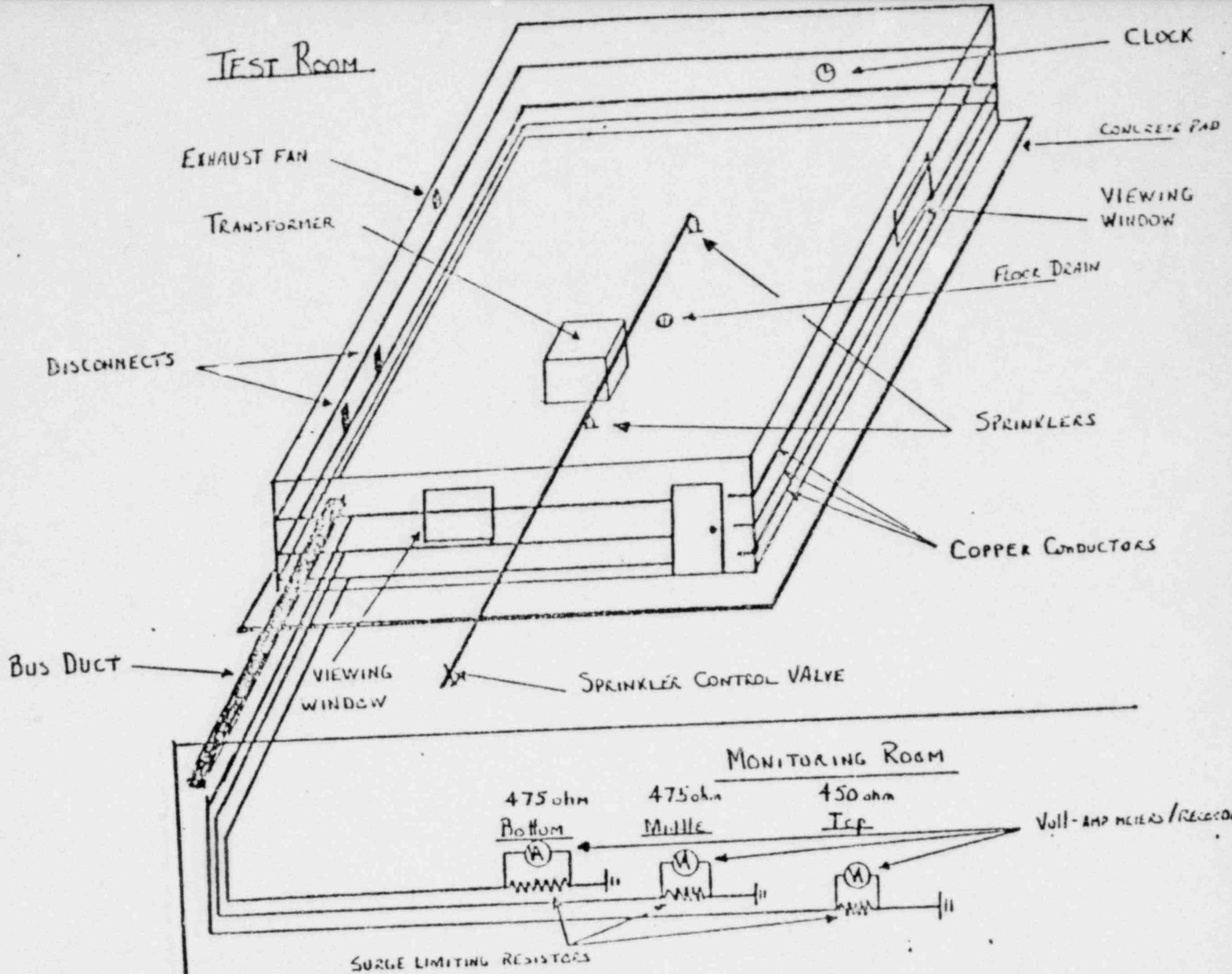
TEST ROOM
CLOCK
CONCRETE PAD
EXHAUST FAN
VIEWING WINDOW
TRANSFORMER
FLOOR DRAIN
DISCONNECTS
SPRINKLERS
COPPER CONDUCTORS
BUS DUCT
VIEWING WINDOW
SPRINKLER CONTROL VALVE
MONITORING ROOM
475 ohm
475 ohm
450 ohm
Bottom
Middle
Top
SURGE LIMITING RESISTORS

Figure 1.

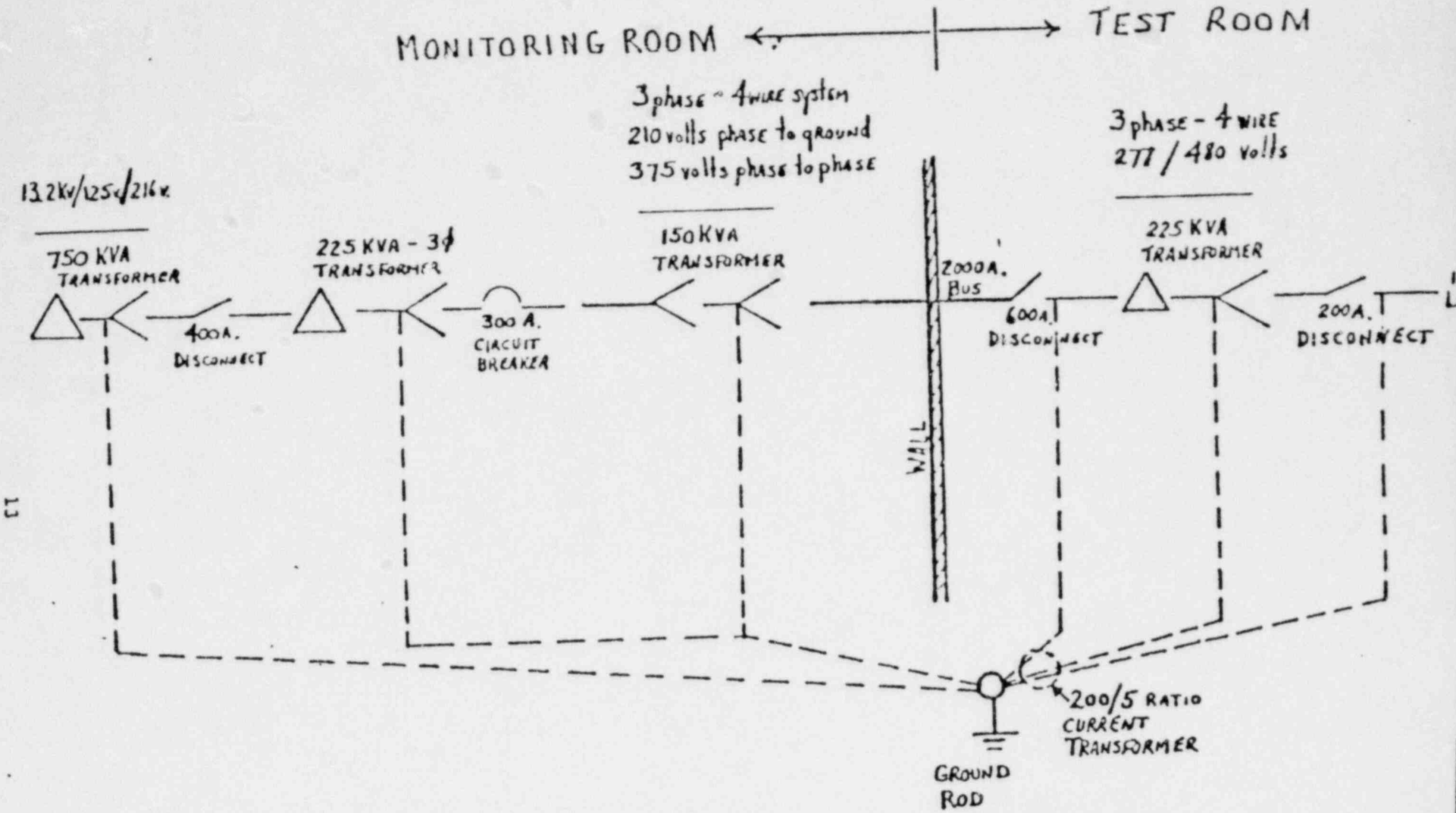
MONITORING ROOM
TEST ROOM
3 phase - 4 wire system
210 volts phase to ground
375 volts phase to phase
3 phase - 4 wire
277 / 480 volts
13.2Kv/125v/216v
750 KVA
TRANSFORMER
400A.
DISCONNECT
225 KVA - 3ϕ
TRANSFORMER
300 A.
CIRCUIT
BREAKER
150 KVA
TRANSFORMER
2000A.
BUS
WALL
600A.
DISCONNECT
225 KVA
TRANSFORMER
200A.
DISCONNECT
200/5 RATIO
CURRENT
TRANSFORMER
GROUND
ROD

Figure 2.

TEST RESULT MEASUREMENTS

TEST NO.	GROUND AMPS	SIMULATED PEOPLE CONDUCTORS TOP (MA)	MIDDLE (MA)	BOTTOM (MA)
1	0.5A = 20A.	4.210	8.420	1.000
2	0	0	0	0
3	0.5A. = 20A.	0	0	1.000
4	0	0	0	0
5	0.5A. = 20A.	0	0	1.000
6	0	0	0	0
7	0	0.0253	0.0263	0.0266
8	0	5.260	5.260	5.550
9	5.0A. = 200A.	10.000	10.000	100.000

Figure 3.

VII

CONCLUDING REMARKS

This project had been contemplated for nearly four years and contracting efforts to conduct shock hazard tests were processed. When the contracting efforts failed it was decided to try to do these tests in-house.

Due to limited finances, many of the sophisticated arrangements for the design and monitoring of the tests had to abandoned. However, we were confident that the design and equipment monitoring arrangements made by the technicians of the two field offices would produce credible results.

We feel that the results obtained from our tests are credible. These results reinforce our position to continue to recommend automatic sprinkler protection in electrical distribution rooms. We are pleased to note that the National Electrical Code will be revised in the near future to advocate the use of automatic extinguishing systems, which include automatic sprinklers, for indoor transformer installations where the transformers are of the type which are insulated with listed less flammable liquids (i.e., a liquid with a fire point not less than 300°C). The revision will note that such protection is required for those installations housed in combustible occupancy areas. Since most electrical distribution rooms in GSA space habitually are converted into quasi-storage areas, we look at this revision as another support to our GSA firesafety criteria for automatic sprinkler protection.

We are hopeful that this testing effort might encourage more research into shock hazard potentials under varying electrical arrangements including higher voltages.