The Effect Of An Atomic Blast On Electric Facilities

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Electricity has become an essential commodity in the life and economy of the American people. In the home, it is used for illumination, refrigeration, cooking, cleaning, water heating, washing, ironing, for entertainment, and to an ever increasing degree for cooling and heating. Even more important is the indispensable part it plays in turning the wheels of industry and in supplying the power required for our national defense. Yes in industry—such as the oil and allied industry that means so much to the economy of our nation, as well as playing an important part in our national defense. The industry that you gentlemen represent.

Historically, the investor-owned, free enterprise utilities have taken great pride in the reliability of their service, reflecting good management, sound engineering, and the efforts of conscientious employees. They have also taken pride in their good record for restoring service following storms and disasters—just as you take pride in your operations in your industry.

The electric industry, manufacturers and business-managed service companies, working together as a team, have constantly striven to improve equipment and facilities for better, more dependable and more economical services. This industry has devoted and continues to devote study and planning to methods, organization, and equipment for the fast restoration of service.

We shall discuss a new phase of this study and planning today. A phase that has become important because of the age in which we are living—the Atomic Age, of which we are reminded practically every day.

The electric utilities recognize the desirability of obtaining information on the effects of an atomic explosion on the electric power facilities. While there is a limited amount of information available on the effect of World War II atomic explosions on the electric power facilities of Japan, there was no known published information on the effect of such an explosion on electric facilities of the United States, which are generally different in construction. Cognizant of this fact, the investor-owned, business-managed electric utility companies, through their nationwide assoication, the Edison Electric Institute, undertook to test electric power facilities at the 1955 Nevada Atomic Test.

The Edison Electric Institute test was the first organized for the express purpose of obtaining direct and definite information, under specified conditions, on the absolute and relative effects of an atomic explosion on an electric power system typical of those in use in the United States. From the test the electric utilities expected to learn:

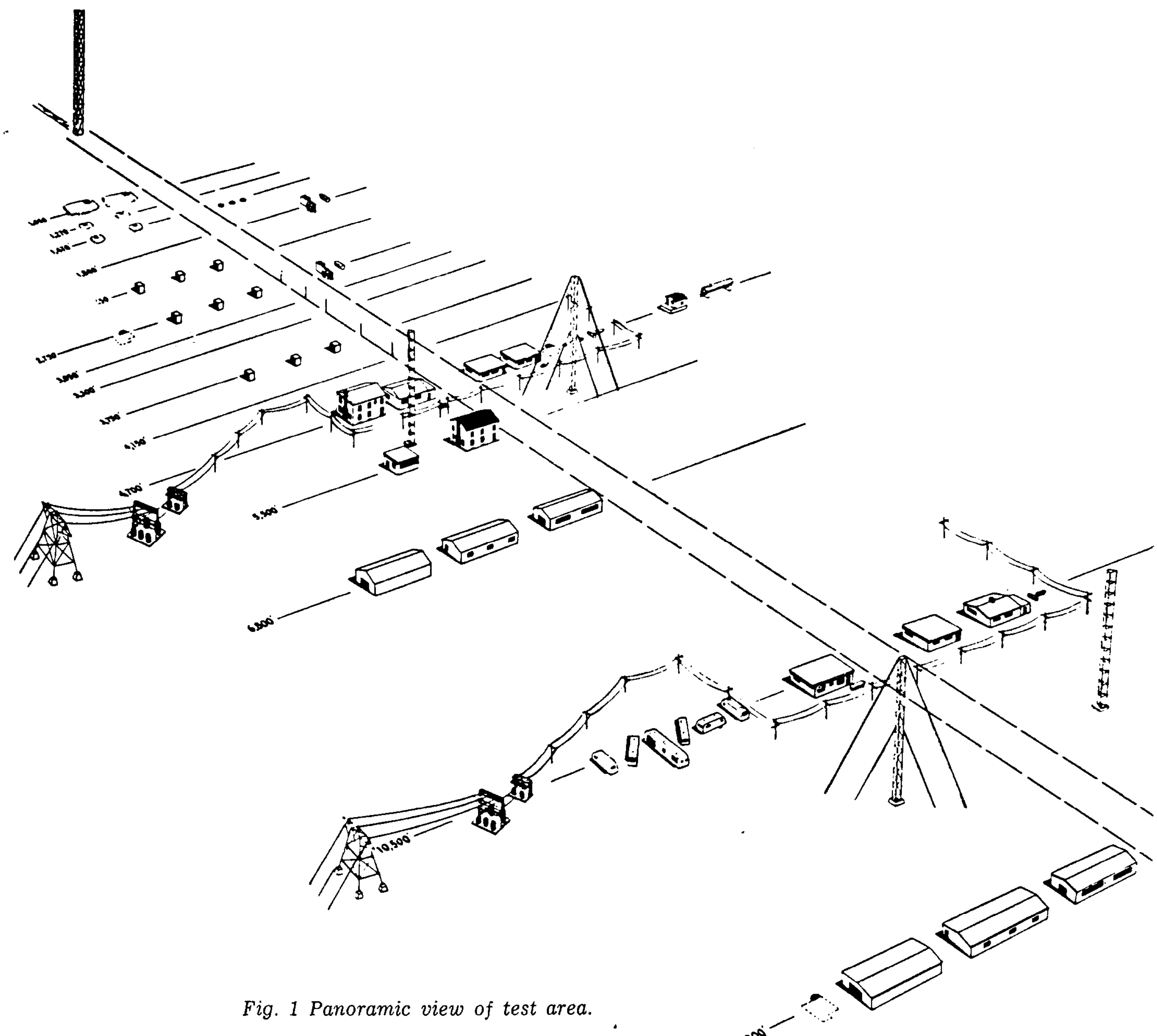

Fig. 1 Panoramic view of test area.

1. The effect of an atomic explosion on a typical electric power system.

2. The nature of the problem of rapidly restoring electric service to affected survival areas in the event of an atomic attack.

3. The relative ability of electric power facilities to withstand the effects of an atomic explosion in comparison with the structures they serve.

Bechtel Corporation was retained by EEI to work with the project officers and committee in preparing detail plans and specifications for the test installations. This group also handled the purchase and transportation of material and equipment to the site and supervised construction of the test installations.

The Test Installations

In determining the type and layout of the equipment to be tested, it was agreed that the test installations should be typical of those which serve urban communities and industrial facilities.

It was decided that two identical installations at different distances from the blast should be constructed in order to determine the approximate survival range of the equipment. Members of the Atomic Energy Commission, having knowledge of expected force of the blast, indicated pressures at various distances from ground zero, or point of explosion. The specific location of the electric installations were then determined by the project officers and approved by the AEC.

The actual locations of the electric power facilities were 4700 feet and 10,500 feet from ground zero. Each installation was located in an area where test houses of various types were constructed; certain of the houses were connected to the system.

Planning, preparation, and construction of the installation required 13 months.

A panoramic view of the test area is shown in Fig. 1. Here we see the actual locations of the electric power facilities, 4700 feet and 10,500 feet from ground zero. The 500 foot tower that contained the Atomic device is in the upper left hand corner of the view. Basically the test installation consisted of a 69-kv transmission line, an outdoor substation, 11-kv and 4-kv distribution circuits. The 69-kv transmission line at each location is shown at the left in the drawing. The electric circuits can be traced through the high voltage side of the substations, low voltage side of the substations, and distribution systems, consisting of about one-half mile each of typical wood-pole type construction and oriented both radially and transversely to the lines of the blast. This view also shows the relative locations of various residential units, industrial units and radio transmission towers tested by the Federal Civil Defense Administration.

We mentioned that identical electric facilities were installed 4700 feet and 10,500 feet from the point of detonation. The pictures we shall see are of the installation in the 4700 foot area. There was no damage in the 10,500 foot area; therefore, using the pictures of the duplicate facilities in this area would serve no purpose.

The actual work of installing the complete electric test installation was performed by the Silas Mason Company, the construction agent for the AEC at the Nevada test site, and one of its subcontractors, the Reynolds Electric Company.

Even though the AEC contractors performed the work, this test on the effect of an Atomic blast on an electric installation was not at the taxpayers expense. Payment by the Edison Electric Institute for the work of these organizations was made to the U. S. Government, which, in turn, reimbursed the contractors through its agent, the Atomic Energy Commission.

It was not possible to expose a large generating station to the test. Furthermore, with cities and industrial loads served by a utility having transmission lines interconnecting several generating stations, electric power could be transmitted to a stricken area from distant points if local generating facilities were destroyed or seriously damaged.

Since there was no outside source of electric power at the test site, it was necessary to use a temporary engine-driven portable generator to energize a portion of the system secondaries at the 4700 foot installations during the explosion.

Substation

A view of the 69-kv transmission line dead-end tower and the substation is shown in Fig. 2.

For the purpose of analysis, the high and low voltage substation equipment were considered separately.

The high-voltage portion of the substation included the following equipment:

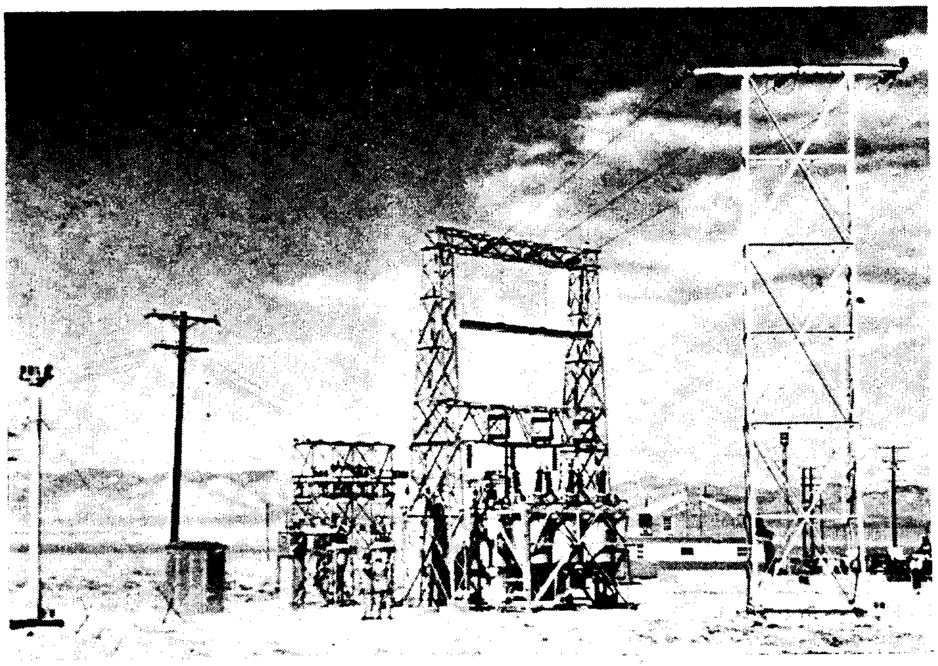

Fig. 2 69-KV transmission line dead-end tower and substation. Guyed steel pole on left supports AEC camera.

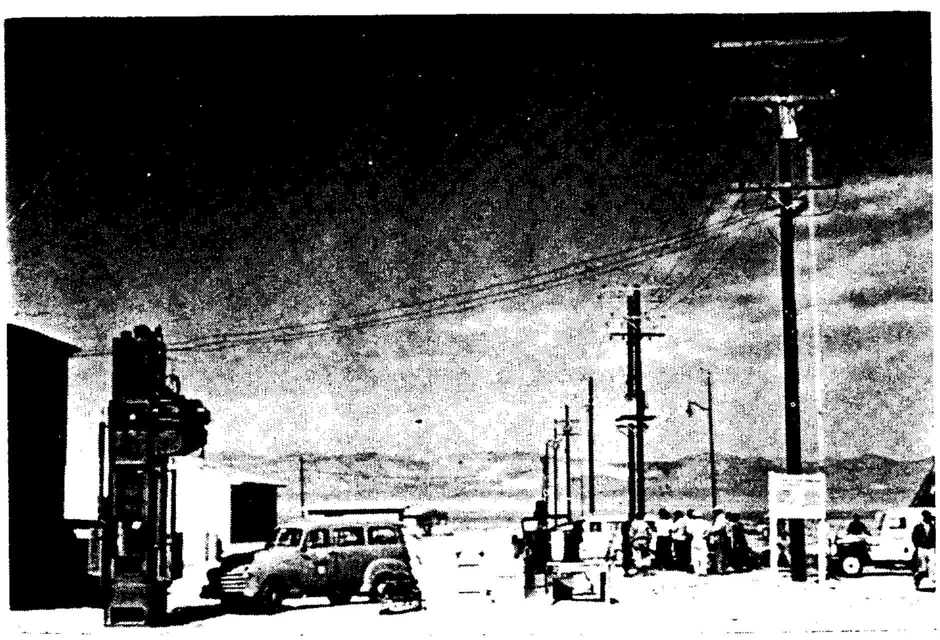

Fig. 3 Distribution line in 4700-foot area.

A single-bay, steel-lattice, dead-end structure complete with 69-kv disconnects, insulators, and buses.

A 73-kv, 400-amp oil circuit breaker.

Two 1500-kva, 69/11-kv single-phase, oil-filled, watercooled transformers.

The low-voltage substation equipment consisted of the following:

A steel rack with two 4-kv positions supporting two sets of 7.5-kv, 400-amp disconnect switches and associated buses.

Two 7.5-kv, 800-amp oil circuit breakers.

Two 4-kv, 200-amp induction voltage regulators.

Three 4-kv lightning arresters.

Three switchboard panels complete with indicating, recording, and integrating instruments, and relays, including a 12-cell, lead-acid battery, all enclosed in a three-compartment metal cubicle.

Distribution Circuit

Part of the distribution line is shown in Fig. 3.

The poles used in the line were 45-foot, class-4, full-length creosote-treated douglas fir poles, set 6 feet in the ground. The poles were framed with crossarms to carry three of the following four types of circuits: an 11-kv, 3-phase, No. 2/0 ACSR circuit; a 4-kv, 4-wire, No. 4/0 copper circuit; No. 4 bare copper secondaries for a portion of the distance, with the remaining secondaries consisting of No. 2 aluminum weatherproof conductors installed on racks; and a street light circuit consisting of No. 6 bare copper. In addition, a part of the 4-kv circuit was made up of a 4-kv, 3-conductor, No. 2/0 copper pre-spun aerial cable with a 1/2 inch copper-clad messenger.

In each of the two distribution circuits, one at 4700 feet and one at 10,500 feet, there were three 50-kva, 2400/220-volt single-phase transformers, platform mounted, and two 15-kva and four 10-kva, 2400/230--115-volt single-phase transformers, all pole mounted.

Street lights on mast arms were mounted on two poles and were supplied by a pole-mounted constant- current transformer. Two types of street light construction included two steel and two concrete street light standards. (A steel street light standard is shown in the right background).

There was an aluminum service drop to one house. There were copper service drops to two houses in which there were small loads connected. (The service drop to the two-story brick house is shown in the foreground).

The secondary and service drops were energized from a portable generator located in a pit behind one of the houses.

General

Three of the four houses located in the 4700 foot area are shown in Fig. 4. The house on the right is a one-story wood-frame house of standard construction. A reinforced concrete block house is shown in the center. The house on the left is of pre-cast concrete construction. A steel tower housing cameras is shown in the right foreground. This is an AEC installation. A radio transmission tower can be seen in the center background.

The fourth house in the 4700 foot area is shown in Fig. 5 This is a two-story brick house of standard construction. The piece of machinery behind the house is in its test position, simulating a location behind a factory wall.

The Blast

The Atomic device was mounted on a 500 foot steel tower in order to provide an air burst at a fixed distance from the test installations. The preliminary yield figure was of the order of 30 kilotons with damage reaching out for about three miles. One kiloton equals 1,000 tons (TNT equivalent). By comparison, the bombs that leveled Hiroshima and Nagasaki were 20 kilotons.

Safety instructions were given to the test observers to insure that no injuries would result from looking at the blast with unprotected eyes. Specially treated dark glasses were distributed to those who desired to look directly at the shot as it was fired. Persons not wearing glasses were cautioned to look 180 degrees away from the blast, then turn around slowly after it had been fired. When the bomb was detonated, the sky was lighted with a brightness many times that of the sun and heat from the explosion was felt immediately by observers seven miles away. The brilliant light quickly diminished in intensity and the test observers not

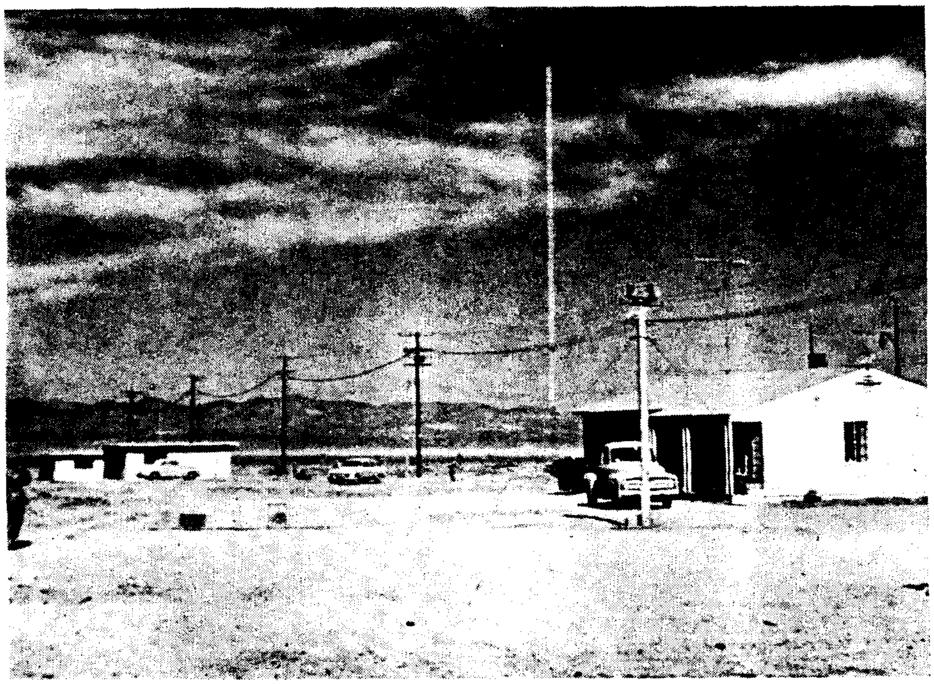

Fig. 4 View of three of the houses, distribution line, radio transmission tower, and AEC camera installations in the 4700-foot area.

Fig. 5 The two-story conventionally built house located in the 4700-foot area. Service drops to the house can be seen at the upper right.

wearing glasses turned around slowly to see the after-effect of the blast. As the last vestiges of the fireball disappeared a few seconds after the explosion, the familiar mushroom-shaped cloud formed, colored first in brilliant purple, then gray and capped in white by the formation of ice crystals.

As the test observers became intent in watching the awesome beauty of the explosion, many failed to remember that the blast had some noise associated with it. The whip-like crack of the explosion, accompanied by the shock wave, thundered past as a sharp reminder. It arrived about half a minute after the fireball died out. At seven miles the shock wave was still raising dust on the desert.

From the observer area, it was not possible to see what damages had occurred to the electric installations located some five and six miles away, respectively. This was due not only to the distance involved, but also to the tremendous dust clouds that had engulfed the area.

Results of The Test

The first team of industry representatives, dressed in protective clothing, went into the 4700 foot area less than three hours after the shot to make an initial survey of the damages to the equipment. This followed the physical damage and radio-logical surveys.

From a radiation hazard point of view, the test area at 4700 feet from ground zero was found to be safe enough to allow maintenance and repair crews to enter the area at this time and remain for a full day's work.

The damage to the electric system at the 4700 foot line was moderate. The type of damage appeared similar to that caused by severe wind storms and was apparently due to the blast effect rather than the thermal or radiation effect of the explosion. There was no evidence of induced radiation in the electrical structures and equipment.

Substation

The substation survived the blast with nominal damage to the essential components (See Fig. 6). The metal cubical itself, housing the meters and relays, was heavily damaged. The substation was in sufficiently sound condition to permit re-energizing on a non-automatic basis with only a small amount of work by maintenance crews. The two 1500-kva single-phase oil filled transformers were undamaged, and were un-moved on the foundation pad. They withstood a 30-kv high potential test to ground and they meggered the same as pre-shot values. The paint on the transformer tank on the side facing the blast was slightly blistered. The cylindrical oil level gauges were undamaged. The glass on the regulator temperature gauge was broken.

The two 4-kv. 200-amp induction regulators were shifted on the foundation pad sufficiently to break electrical connections to the bus. In addition, the square flat-surfaced housing at the top of one regulator was dished-in on all four faces. The dial-type temperature gauge glass was broken. The cy-

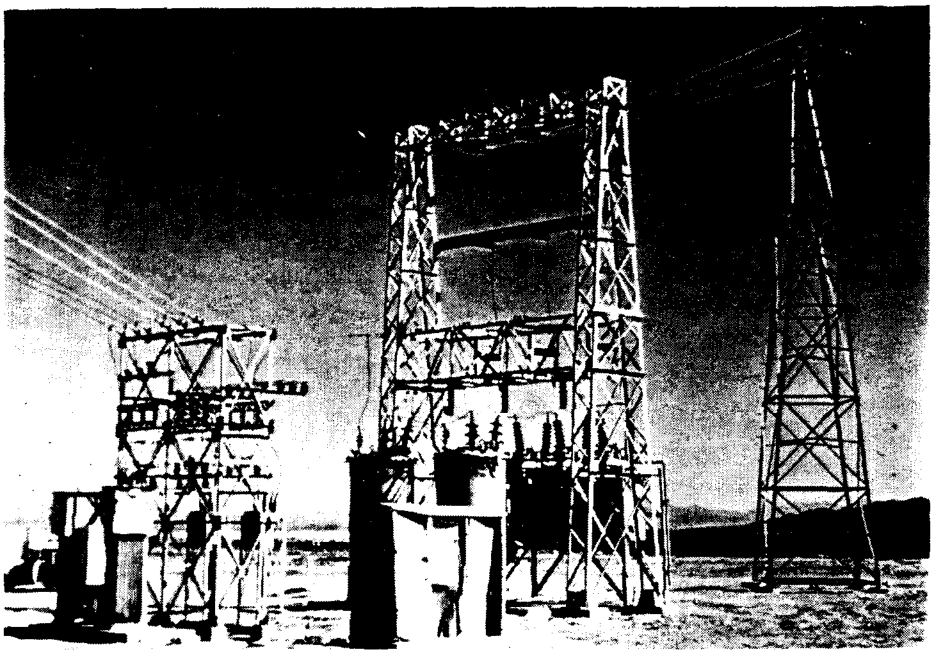

Fig. 6 View of the substation at 4700-foot area after the blast. Note the damaged instrument cubicle.

Fig. 7 One of the legs of the steel dead-end structure that buckled where several unused bolt holes were located.

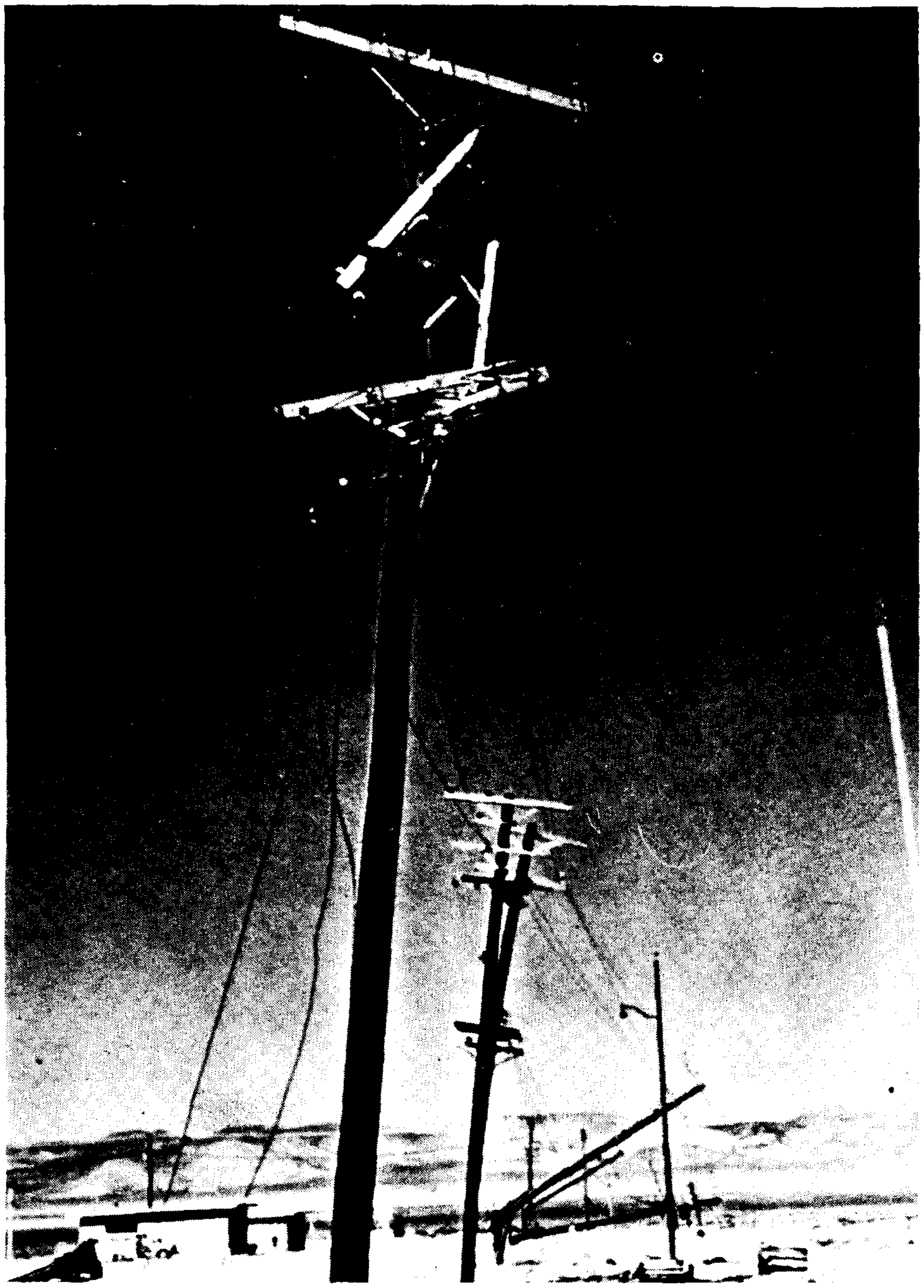

Fig. 8 View of distribution line located perpendicular to the blast line. The downed poles can be seen in the background.

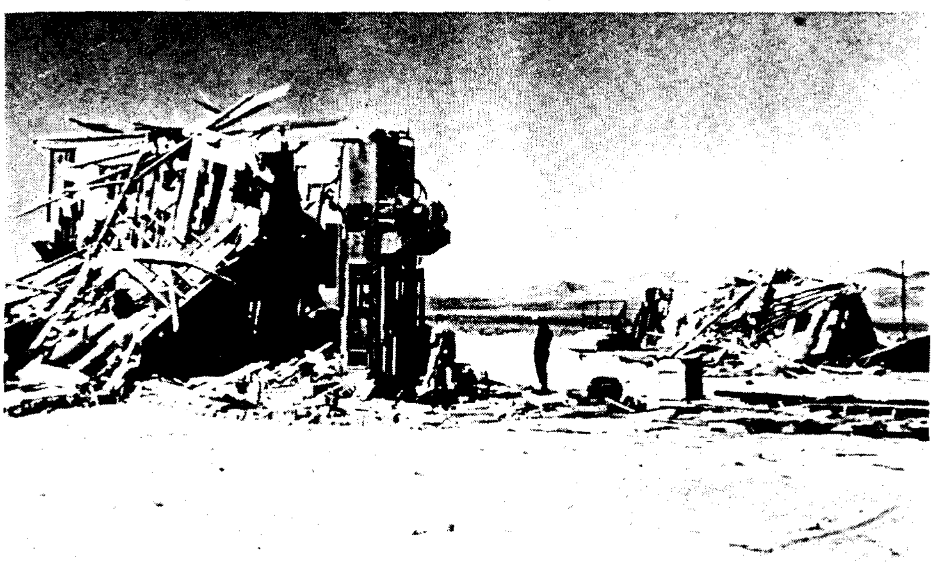

Fig. 9 The brick house and the wood frame house as they appeared after the blast. Compare with Figures 4 and 5.

lindrical oil-level gauge was not broken. The regulators were tested and found to be electrically operative.

The steel dead-end structure supporting the 69-kv insulators, disconnects and fuses received minor structural damage in that two leg angles, 3 x 4 x 1/4 inch were slightly buckled at a point three feet above the foundation where several unused bolt holes were located. (See Fig. 7).

Distribution Circuits

The distribution system suffered light to moderate damage. (See Fig. 8) It was of the type that could be repaired in a reasonably short time with materials normally carried in stock by electric utility companies. Out of 14 pole positions, five received no damage, three received very slight damage to the extent of broken insulator pins (on the 4-kv only) or insulators, two extensive damage, and four were down. The four downed poles were consecutive poles in a section perpendicular to the blast line. Three of those carried the 3-conductor, No. 2/0 aerial cable in addition to the primary and secondary circuits.

Metal pins supporting the 11-kv insulators all held up. Except for broken poles and four missing insulators, the 11-kv circuit could have been reenergized. There was slight scorching of poles and crossarms. All primary conductors, including the aerial cable, were unbroken. The outer insulation surface of the aerial cable conductor was slightly scorched and charred. All tie wires held and all pole anchors and guys remained intact but were slacked off. Two 10-kva transformers installed on a line crossarm on pole No. 4 were not displaced. Two potheat installations were unharmed. All arresters and fused cutouts were undamaged and firmly in place where crossarms were not broken.

All steel and concrete street light standards were undamaged; however, the luminaires were all broken off and were lying on the ground underneath. The two modern pole-mounted mast-arm type units were undamaged except for a moderate bending of the mast arm. The streamlined elliptical luminaires on these fixtures were in place and undamaged. A steel street light standard is shown on the right.

General

In the general area, damage to structures that would normally be served by power facilities was also experienced. While an official evaluation of this damage has not been published, Fig. 9 shows the typical urban brick and wood frame house after the blast. Compare the "after" appearance of these houses with that shown in Figs. 4 and 5 taken before the blast.

The reinforced concrete block house and the pre-cast concrete house suffered moderate damage. Damage to these houses consisted primarily of the windows and doors being blown out.

Conclusions

In evaluating the results of this test, it should be kept in mind that test conditions which must necessarily form the principal basis of evaluating the effects of nuclear explosions, may differ markedly from those which might be expected if nuclear weapons were used against our population in wartime.

A nuclear detonation produces four major characteristics: blast, heat, immediate nuclear radiation and residual radioactivity. Of these, the first three are essentially instantaneous, while the fourth has a more protracted effect. The phenomena of blast, heat and nuclear radiation from the detonation of a thermo-nuclear bomb are of the same nature as those of earlier and smaller atomic bombs. The nature of the phenomena is, in general terms, standardized whether the bomb be a 300,000 ton (TNT equivalent) atomic weapon or a thermonuclear one of many times that power. The intensity and area of the blast, heat and nuclear radiation increase in relation to the greater energy yield of the explosion. The distance at which a given blast intensity is produced varies as the cube root of the yield of the explosion. For example, a 10 megaton bomb, equivalent to ten million tons of TNT would have an outer damage range of about 16 miles.

The Edison Institute test, to obtain the information just presented, is but another example of the way the electric industry discharges its responsibility to you, the customer. We are fully aware of the importance of continuity of electric service to the convenience, health, and welfare of the respective areas we serve.

We know you are equally interested in the continuity of service on your own systems. We hope this information on the Effect of an Atomic Blast on Electric Power Facilities has been of interest to you and will prove valuable to all of us whose job is to keep electric service available to the point of utilization.

Obviously — should we suffer an atomic attack, there would be no urgency in restoring service to the immediate area suffering the attack. It is restoration of service in the surrounding — or survival area if you please — with which we are concerned and which would be of utmost importance.

A knowledge and understanding of the mechanical and radiation phenomena associated with an atomic explosion are of vital importance. The information may be utilized in the design of structures, and in preparations to deal with emergencies.

We feel valuable information was obtained from this test and wish to assure you that we of the electric industry shall continue to do everything possible to provide you with the best in continuous electric service.