



DECCA AUSTIN INSULATORS

**THE EFFECTIVE INSULATION OF
MASTS AND TOWERS FOR AM
BROADCASTING**

WESTERN ASSOCIATION OF BROADCASTERS

ENGINEERING SECTION

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TITLE

THE EFFECTIVE INSULATION OF
MASTS AND TOWERS FOR AM
BROADCASTING

AUTHORS

L.J. Dennett & E.E. Thompson
Decca Austin Insulators
71 Selby Road, Brampton, Ontario

THE EFFECTIVE INSULATION OF MASTS AND TOWERS

FOR AM BROADCASTING

L.J. DENNETT - E.E. THOMPSON
Austin Insulator Division
Decca Radar Canada (1967) Limited

INTRODUCTION

During the first three decades of radio broadcasting, a great deal of attention was given to problems associated with practical antenna design. Antenna insulators were quite widely advertised and many technical papers dealing with antennas and insulation were published and read. During the past three decades very little seems to have been published in this field and one might gain the impression that everything has been said or done.

This is far from being fact. If not in North America, certainly in other parts of the world the powers used for broadcasting are increasing to the point where one or two million watt stations are becoming almost common and there are a great number using powers between 100 KW and 1 MW. There has also been a renewed interest in the LF and VLF bands for communication purposes and for long range navigational aids and again powers of several MWs are involved. All this activity has reawakened interest in insulation.

Problems are not restricted to high power operation, in fact many exist at all power levels. Unfortunately the broadcast industry with a few exceptions has lost sight of some of the solutions which were understood in the earlier days and now has a tendency to think that any ill effects of poor insulation are a natural phenomena and cannot be overcome.

Returning to our particular field of interest, Radio Broadcasting in the MF band, we can and should still be maintaining an interest in antenna insulation. The antenna is the last link in the chain over which the station engineer has any control. So often it is the case that a great deal of consideration is given to the choice of studio equipment and transmitter and the antenna system is then considered solely from the point of view of achieving the pattern which the station license dictates should be used. The mast supplier or manufacturer is frequently left to choose the insulators that will support the antenna structure and is usually given little or no guidance in the specification presented to him. Since he is likely to be bidding competitively, he may select the least expensive insulators that he considers he can use. To offer better insulators may result in an increased cost and leave him non-competitive though he may be offering more value for money than his successful competitor.

This is not intended to be a criticism of mast suppliers. They are experts in their field but from our experience many do not profess to be experts in the field of electrical insulation and would prefer that the specification given to them left no doubt as to the type, quantity and quality of insulators to be supplied.

The performance of any station is dependent, among other things, on the power usefully radiated. Every watt of power fed to the antenna has cost many dollars to produce and it is surprising how little consideration is frequently given to what happens to it after it is launched down the feeder line to the antenna. Ideally an antenna structure would not require any insulators. Insulators are only used because it is impractical to install an effective antenna system without them. They are a necessary evil and will be with us for a long time.

In the time available for this paper, we can not go into insulator design or usage in detail but hopefully, in reviewing the state of the art, provoke a fresh interest in the subject.

HISTORICAL

The growth of the radio insulator industry paralleled that of the power frequency industry and was intimately tied to the development of porcelain. Around the turn of the century, glass insulators were in common usage in line telephone and telegraph circuits and glass insulators were also used in the early days of power distribution. As insulators became larger, glass lost its attractiveness as it was hard to fabricate in large shapes. Industries specializing in insulators for power frequencies grew up in areas where the porcelain industry was already established primarily for tableware, bathroom fittings etc.

As voltages on power transmission lines increased, the power industry became aware they had problems and soon realized it was not simply a

case of increasing the size of an insulator but rather that there were many years of development necessary to produce insulators with a long trouble free service life, that could operate through wide extremes of environmental conditions, operate at sustained high voltage and withstand fault transients and lightning discharges. Much of the technology that was developed in the power industry usefully served the growing radio industry but it was found that insulators which were satisfactory for power frequency use would frequently not operate satisfactorily at higher radio frequencies.

A.O. Austin started his insulator career in 1906 (Figure 1) and joined the Ohio Brass Company in Barberton, Ohio in 1909. He became a Director and their Chief Engineer, retiring in 1935. He devoted his life to the development and production of insulators and following his retirement from Ohio Brass in 1935 he formed and operated his own company in Barberton where until his death in the mid '60s he developed and manufactured insulators for the radio industry. He was a contemporary of others who grew up in North America in the insulator business, Lapp, Lock and Goddard to name only a few. Lapp, as you probably know, are still very active in the insulator business and over the years have had some quite different views, on insulator design, than those held by Mr. Austin. Two power insulator companies in Canada are Ohio Brass at Niagara Falls, founded in 1922 as a Canadian subsidiary of Ohio Brass of Barberton where Mr. Austin spent so many years and Canadian Porcelain at Hamilton started by Mr. Goddard in 1912 with the backing of Locke and others. The Austin Insulator business moved to Canada in 1970 when the company was purchased by Decca.

INSULATOR LOADING

Let us now look at the electrical and mechanical loads or stresses an insulator might be expected to carry and do this as it relates to North American medium frequency AM broadcasting.

Electrical - Discounting older type installations and some unusual antenna configurations, the most commonly used transmitting antenna structure is a steel mast with insulated guys and supported at its base by an insulator. This is the classical vertical radiator and the height, unless there are some constraints imposed due to its locality, will be at least $1/4$ of a wave length and commonly $1/2$ or $5/8$ of a wave length. The height and thus weight to be supported depends on the frequency of the station but we are usually concerned with structures up to 500'. The impedance of the antenna and the amount of power fed to it determines the RF voltages which have to be withstood by the base insulator and guy insulators. The base insulator sees a RF voltage which is the product of the base impedance and the base current. The $1/4$ wave radiator has a relatively low base impedance and the $1/2$ wave radiator a high impedance. The highest RF voltage to be withstood by an insulator in the system will most likely be the guy insulator adjacent to the mast and at the highest point in the structure. This is true whatever the electrical height of the radiator may be. Because of the varying current/impedance relationship at different heights on the structure the guy insulators at levels between top and bottom of the mast will be required to withstand a range of voltages. On the $1/2$ wave structure the voltage at the guy attachment points will drop from a maximum at the top to a minimum at the centre and back to a slightly

lower maximum at the base. On the 1/4 wave radiator the voltage at the guy attachment points will fall progressively from top to base. It is important to remember that as far as insulation is concerned we should consider peak voltages. If the unmodulated carrier of the transmitter results in, say, 1,000 volts across the base insulator or one of the guy insulators this will usually relate to its RMS value. The peak value will be 1.4 times this or 1,400 volts and with 100% modulation the voltage will double to 2,800 volts. It is this 2,800 volts we should be thinking about and if we are using 120% positive modulation on peaks we had better think of a bit more than 3,000 volts as being the working voltage required of the insulator. Typically the range of voltages encountered at the base of broadcast radiators is 1 KV to 30 KV (Figure 2). If we were only concerned with these voltages under dry conditions and without such phenomena as dry blowing snow, blowing dust and electrical storms the problem would not be too great.

Unfortunately, we have to contend with pollution deposits on the insulator surface, wetting due to precipitation, salt spray in coastal regions, in many parts of Canada high induced potentials due to blowing snow and dust, the ever present danger of high induced potentials due to electrical storm activity and also the direct strikes of lightning.

It is relatively easy to argue, by ignoring the environment, that a piece of earthenware drain pipe for a base insulator and two or three egg insulators in the guy is sufficient insulation. It is when the environment is not kindly disposed that the benefits of good electrical insulation are felt. The best insulator is the one which has the least effect on the wanted behavior and performance of the antenna. This requires that leakage be a minimum, the electrical capacity be as low as possible, the dielectric losses be a minimum, breakdown does not

occur in the presence of unwanted induced voltage stresses, the insulator if it does arc over is not damaged, the arc path is long enough that the transmitter does not sustain a power arc following flashover, that the insulator requires a minimum of maintenance and that it never fails. To varying degrees, insulators available to the broadcast industry meet some or most of these criteria but none of them are perfect and you as an engineer are free to make your choice from the varieties available to you. The important thing is to consider your requirements and make your choice and not leave it to the mast supplier who is not likely to have the information and knowledge you have and may well not make the best choice for you.

Mechanical - We have found that misunderstandings can arise between station engineering staff, mast manufacturers, consultants and the insulator supplier when it comes to specifying and choosing a guy strain or base insulator to handle mechanical loads on a particular system.

Masts are required to withstand wind and frequently ice loads. Structural strength is then dictated by the maximum loads likely to be encountered.

In still air with no ice loading, the tensile load on a guy wire and its associated insulators is generally only a small fraction of the maximum working load and of the ultimate strength of the guy wire and of the insulators. For example, the tension on a particular guy in still air with no ice on the structure could be 2,000 lbs. This will often be marked on the drawings of the antenna system with a note indicating it is the initial tension. The designer will have made

calculations which show what the maximum load on this guy can be under the worst loading conditions that have been specified to him. This may be 6,000 lbs. A factor of safety will have been specified or used for design purposes and this is generally a factor of 3, so the ultimate strength required of the guy and insulators is 18,000 lbs. Perhaps 1/2" wire rope with a breaking strength of approximately 25,000 lbs. will be called up for this particular guy. We now can see where confusion can arise. The choice of the insulator must be based either on the maximum working load for the guy times the safety factor or the insulator matched to the ultimate strength of the guy wire actually used. The figure quoted for initial tension is of no concern in the choice of the insulator.

A similar problem exists as far as the base insulator is concerned. The down load or vertical load imposed by a mast in still air with no ice, that is the dead weight of the mast and guys carried on the insulator, is not the figure the insulator supplier needs. He needs to know what the design specification calls for in terms of a maximum down load under the worse conditions of loading due to wind and/or ice. This figure provides the working load requirements for the insulator and multiplied by the factor of safety determines the ultimate strength the insulator must have. With base insulators there is a further consideration and this relates to the shear load or horizontal load applied to the insulator. Shear load is a horizontal load generally resulting from wind forces and the insulator supplier needs to know the maximum shear load and down load that will be applied simultaneously. In still air with no ice, if the mast is a true vertical the shear load is zero.

The self supporting tower with either 3 or 4 legs requires the base insulator loading to be specified in a different manner than for guyed masts. A self supporting tower in still air conditions has its weight distributed more or less evenly among the 3 or 4 legs, when the wind blows conditions can change quite dramatically and on one or more of the legs the down load lessens (windward side) and the load is transferred to the leg or legs on the leeward side. In addition to the weight of the tower which is transferred, additional loading is imposed due to component of the wind force. Insulators for the legs of self supporting towers must be designed to not only take a down load or compression load but an uplift or load in tension. From our experience an insulator under maximum wind loading conditions can experience an uplift of about 3/4 of the normal down load. In addition to these loads in compression and tension the insulator must withstand shear or horizontal loading -- thus a specification for a tower leg insulator must specify maximum working down load, maximum working uplift, shear load at maximum working uplift and the required factor of safety.

We have prepared a specification sheet which is available to anyone who would care to make use of it and which calls for the minimum information necessary for the supplier to do a good job of insulator selection.

INSULATOR DESIGN

Insulator design is at best a compromise between conflicting mechanical and electrical requirements. Porcelain is favored as an insulation because it is relatively inexpensive, has great compressive strength,

is virtually impervious to its environment and has acceptable electrical qualities. At the higher radio frequencies porcelain loses some of its attractiveness as far as electrical characteristics are concerned but fortunately other ceramics such as steatite and some of the alumina bodies can take over the job, though at a higher cost (Figure 3). Typical characteristics of porcelain at 1 MHz are:

compressive strength	50,000 psi
tensile strength	6,000 psi
power factor	0.015
dielectric constant	6
loss factor	0.090

The tensile strength of porcelain is not high. This combined with its brittle nature precludes its use under a tensile load except for light loads and where reliability is not of first importance. Its losses are acceptable at all but the higher frequencies above a few megacycles.

Steatite is stronger than porcelain and has lower losses particularly at the higher radio frequencies, typically:

compressive strength	90,000 psi
tensile strength	10,000 psi
power factor	.002
dielectric constant	6
loss factor	.012

There are literally dozens of other materials but some of the new alumina products are particularly interesting and a typical one has the following characteristics:

compressive strength	400,000 psi
tensile strength	25,000 psi
power factor	.001
dielectric constant	9
loss factor	.009

You will note that the alumina has very high compressive strength typically 8 times that of porcelain. Its losses are very much lower over a broad frequency range. It costs, volume for volume, about 10 times that of porcelain.

Remembering the poor tensile strength of porcelain, one can then examine some of the insulator configurations in use today. Figure 4 shows a typical small strain insulator in which the ceramic (steatite) is in tension. It would only be used in antenna structures where the loss would not be serious if it broke. The "egg" insulator, Figures 5 and 6, illustrates the manner in which the insulating properties of porcelain can be used in a guy wire but with the porcelain loaded in compression rather than in tension. Unfortunately this requirement, to take the mechanical load on the porcelain as a compressive load, results in a configuration that leaves much to be desired from an electrical point of view. It is difficult to get sufficient surface leakage path and arcing distance to withstand anything but a moderate voltage. Frequently it is necessary to insert a string of eggs in a guy where it attaches to the mast, in an attempt to carry the operating

voltage without flashover or excessive leakage. This is not always successful (Figure 7) as the voltage division across a string depends on a number of stray capacities:

- (a) The capacity of one insulated segment of guy wire to the adjacent segments.
- (b) The capacity of each insulated guy segment to the mast.
- (c) The capacity of each insulated guy segment to ground.

Figure 8 is typical of another solution. This type insulator, of which there are several variations made in different countries, is an improvement on the egg type and can be designed to carry greater loads. The design still presents a problem in that it is difficult to achieve a reasonably large surface leakage path and the necessary clearance to prevent arc over. Again these have to be strung in series to withstand high or moderately high voltages.

All the foregoing designs are typical of one school of thought and one approach to the use of ceramic in a guy strain insulator.

Figure 9 shows a typical Austin Guy Strain Insulator which is manufactured in sizes ranging from a 2 ton working load capability to over 100 tons working load. We feel, as did Austin, that this insulator overcomes most of the shortcomings of the more conventional types and it has proven to be as reliable in service as any of the so called fail safe types. To briefly describe the Austin design (Figures 10 and 11) the tension load imposed by the guy is carried through metal end attachments to a filament wound fibreglass link, which is then immersed in transformer oil and contained within a porcelain sleeve

which forms the body of the insulator. Through this design we can now increase the surface leakage path to cope with much higher voltages and the ceramic is not a load bearing member in the assembly but rather protects the insulating link from the environment and acts as a container for the oil.

Achieving the necessary mechanical strength in the metallic fittings of an insulator is not a difficult engineering problem. The filament wound fibreglass core assembly has high tensile strength typically 65,000 lbs. per square inch. It is bonded with an epoxy resin and has excellent electrical characteristics typically:

dielectric constant	6
power factor	0.003
loss factor	0.018

With the apparently desirable electrical and mechanical properties of fibreglass you might well ask -- why bother with the porcelain housing and the oil. If the insulator was not exposed to the environment, the bonded fibreglass alone would probably prove adequate. We do, however, require that our insulator function through all environmental conditions peculiar to our site and for long periods of time, perhaps 10 - 20 years or longer without attention. Fibreglass can not be counted on to maintain its mechanical and electrical properties under these conditions. Radiation from the sun adversely effects its properties, weather erodes the bonding agents and the material can be tracked, that is carbonized, if subjected to sufficient heat such as would occur if a power arc went across its surface or a heavy lightning discharge occurred on its surface or close by. In the Austin design

the fibreglass is protected from the environment, from the effects of solar radiation and because of the presence of the insulating oil and the external electrical controls any power arc or arc due to lightning is forced into a path external to the insulator. We are thus able to build an insulator with a long surface leakage path, the surface path occurs on a porcelain which will not track and has a high resistance to erosion. We can achieve a long physical isolation and thus arc path between the metal fittings.

We have been discussing the design characteristics of guy strain insulators. Base insulator design follows a similar philosophy with modifications to take into account the following important design criteria:

- (a) High shear loads may occur.
- (b) High compressive loads exist in normal use.
- (c) In the leg of a self-supported tower an insulator may also experience high tensile loads.

Typical base insulators are shown in Figures 12 and 13.

INSULATOR TESTS

In the power transmission industry an important parameter in an insulator specification is its 60 Hz wet flashover rating. In technical literature of the power industry, a dry or wet flashover rating is usually quoted. The practice has spread, without much justification, into the radio insulator field.

A wet flashover test is performed under specified test conditions which include the conductivity of the water, the direction from which water spray strikes the insulator, the equivalent rate at which the water flows, the wave form of the test voltage and the rate at which the test voltage is raised to the point where the insulator flashes over. This test, performed at 60 Hz, tells us something about the probable performance of the insulator at radio frequencies but it can be misleading if not properly interpreted. An insulator can have an objectionably high loss factor at radio frequencies and still have an acceptable 60 Hz flashover rating.

A 60 Hz flashover test does not give us an overall figure of merit for the insulator and many power frequency insulators, which are excellent for their intended purpose, make very poor radio insulators. At power frequencies cemented joints may perform acceptably whereas some cemented joints are very lossy at radio frequencies. Insulators that are satisfactory at 60 Hz can develop hot spots when they are used at radio frequencies. Power frequency insulators are generally not designed to have what we would consider to be a low capacity and a capacity which is acceptable at 60 Hz may become significant as a shunt capacity in an antenna circuit.

There is a relationship between the 60 Hz flashover rating and the probable flashover behavior of the same insulator at radio frequencies. As a fairly reliable rule of thumb if one starts with the 60 Hz dry flashover rating, the wet 60 Hz flashover will be of the order of 60% of this value and the radio frequency wet flashover about 60% of the 60 Hz wet flashover. We are talking about 60% of 60%, so if an insulator

is stated to have a 60 Hz dry flashover rating of 100 KV, it's wet radio frequency flashover will be of the order of 36 KV. This tells us nothing about the performance of the insulator at radio frequencies except it's probable flashover rating.

The tests which can and should be applied to a radio insulator involve 60 Hz flashover tests, DC impulse tests and radio frequency tests.

The 60 Hz flashover test is useful because it gives us a first approximation to the radio frequency flashover rating. It enables one to determine where and when corona or an arc is likely to occur. It is desirable that electrical discharges take place well clear of the ceramic insulating surface (Figure 14).

DC impulse tests simulate the steep wave front of lightning and also enable us to determine if any resulting flashover will occur well clear of the ceramic material (Figure 15).

The behavior of the insulator may well be different when results of an impulse test and a 60 Hz or radio frequency flashover test are compared and both tests are necessary. Apart from determining by means of these tests where the discharges occur and the probable flashover voltage they do not in themselves establish whether the insulator is a good one for radio use. A radio frequency test (Figure 16) during which the insulator is maintained for an appreciable time at its maximum rated working voltage will allow one to determine its loss characteristics. Losses always produce heat and any undue overall or localized temperature rise indicates a loss condition and a design change may be necessary.

Quite apart from the desirability of having insulators with a minimum of loss the heat produced can make the insulator vulnerable to mechanical failure. Ceramic materials are poor conductors of heat and many a radio insulator has broken under a mechanical load which it should have been able to stand were it not for stress introduced by the steep temperature gradient due to internal heating.

NATURAL ELECTRICAL PHENOMENA

Static Electricity - Some radio stations in Canada experience a phenomena which to others is relatively unknown. We refer to a voltage built up on an antenna system due to blowing dust or blowing snow, which when it impinges on metallic parts of the antenna, transfers an electrical charge. During intense dry blowing snow or blowing dust activity, the potential across an insulator can build up to the point where the air breaks down and a discharge occurs. This is the same phenomena experienced by aircraft which have a tendency to build up high charges on their structure and also the same basic phenomena that occurs when you walk down a carpeted corridor and reach out to touch a metallic door knob only to have a fat blue spark jump a short gap as your hand approaches the knob. Many station engineers have commented to us on this phenomena and some have described machine-gun like discharges across insulators in their antenna system.

The problem that these discharges cause is primarily due to their completing a ground path from the antenna structure causing the transmitter to trip off the air or at least activating the protective device. Several alternatives have been offered by other insulator

suppliers, one involves semi-conductive glaze on the insulators. This is used with some success in the power industry and the technique is to build into the insulator a controlled leakage path. Another solution that has been used is to bridge the insulator with a resistor to provide the static drain.

These systems involve the introduction of a deliberate loss in the insulator and tend to spoil an otherwise good insulator. A successful remedy is to isolate the guy system from the antenna with an insulator that has an adequate voltage capability such that induced potential on the guy system can not reach the level necessary to cause an arc to occur between the guy structure and the mast. The break up insulators in the lower part of the guy may arc over periodically but this will not be followed by a power arc fed by the transmitter and the effect is relatively harmless and not likely to seriously interfere with station operation.

There has been a theory for many years that Austin oil filled insulators in some way provided a static drain. Considering that these insulators are filled with high quality transformer oil, and though we do not discount this theory entirely, we believe the successful use of Austin insulators results from their high flashover capability rather than any leakage phenomena.

Lightning - The effects of electrical storms are felt more in some parts of the country than in others and equally are a more serious problem in some parts of the world than they are in Canada.

There is little one can do about lightning beyond observing a few conventional design practices which are well known. The high voltages involved and the tremendous amount of energy released during a lightning stroke makes it difficult to predict the behavior or effect of the direct involvement of an electrical storm and an antenna system.

The earth normally has a small negative charge and a cloud drifting over the earth is usually polarized with a negative charge at its base and a positive charge at the top (Figure 17). The voltage gradient between the cloud and ground in settled weather is low and about 1 volt per centimetre. As the cloud moves towards the station the concentration of positive charge on the earth below the cloud drifts with it.

During a thunder storm the voltage gradient between the base of the cloud and ground increases several hundredfold and with the cloud over the station we have the classical situation where the antenna system acts as a "point on a plane" and an ideal setup for a stroke to occur between the cloud and the antenna system. If a direct stroke does not occur the concentration of charge on the antenna system can still result in visible corona and some discharge activity over guy insulators if they have a low voltage withstand capability such as that of an egg insulator. If a stroke does occur it will usually be preceded by leaders reaching down from the cloud and up from the antenna system. It is when these meet and a path of ionized gas is opened between the two charge concentrations that a direct stroke occurs.

The amount of current flowing in a stroke can be several thousand

amperes and power dissipated in the order of megawatts. Hopefully if a direct stroke does occur the current will flow to ground through the protective gap across the base insulator. It does not always do this and frequently enters the tuning hut and wrecks havoc in there. Despite the presence of a protective gap at the base of the mast the discharge may cascade to ground across the guy insulators. Again, if you have adequate insulation between the top of the guy and the mast, even if the lightning flashes over this insulator the path will be too long to have the arc sustained by the transmitter.

Lightning can not be counted on to hit the top of the mast. It frequently hits one of the guy wires near the top and again will flashover all the break up insulators in its route to ground but with adequate insulation at the top of the guy it may not arc over to the mast at all.

Returning to our earlier statement, little preventative action can be taken. The obvious precautions are to ensure that there is a protective gap across the base insulator and to provide the best possible insulation between the top end of all the guys and the mast. Though we are not an authority on the subject, we suggest a small amount of inductance be inserted in the feeder between the mast and the feed-through insulator on the tuning hut to try and discourage the discharge from taking that path. During a lightning stroke one is involved with a very steep voltage rise in the order of a micro second or a fraction of a micro second. A lightning discharge results in an impulse voltage being applied to the system and the route taken by the discharge, particularly the initial high current surge will be along a path where there is the minimum impedance.

CONCLUSION

It is hoped that this presentation, which has looked at some of the highlights of insulator design, will stimulate broadcast engineers to take a renewed interest in their antenna system.

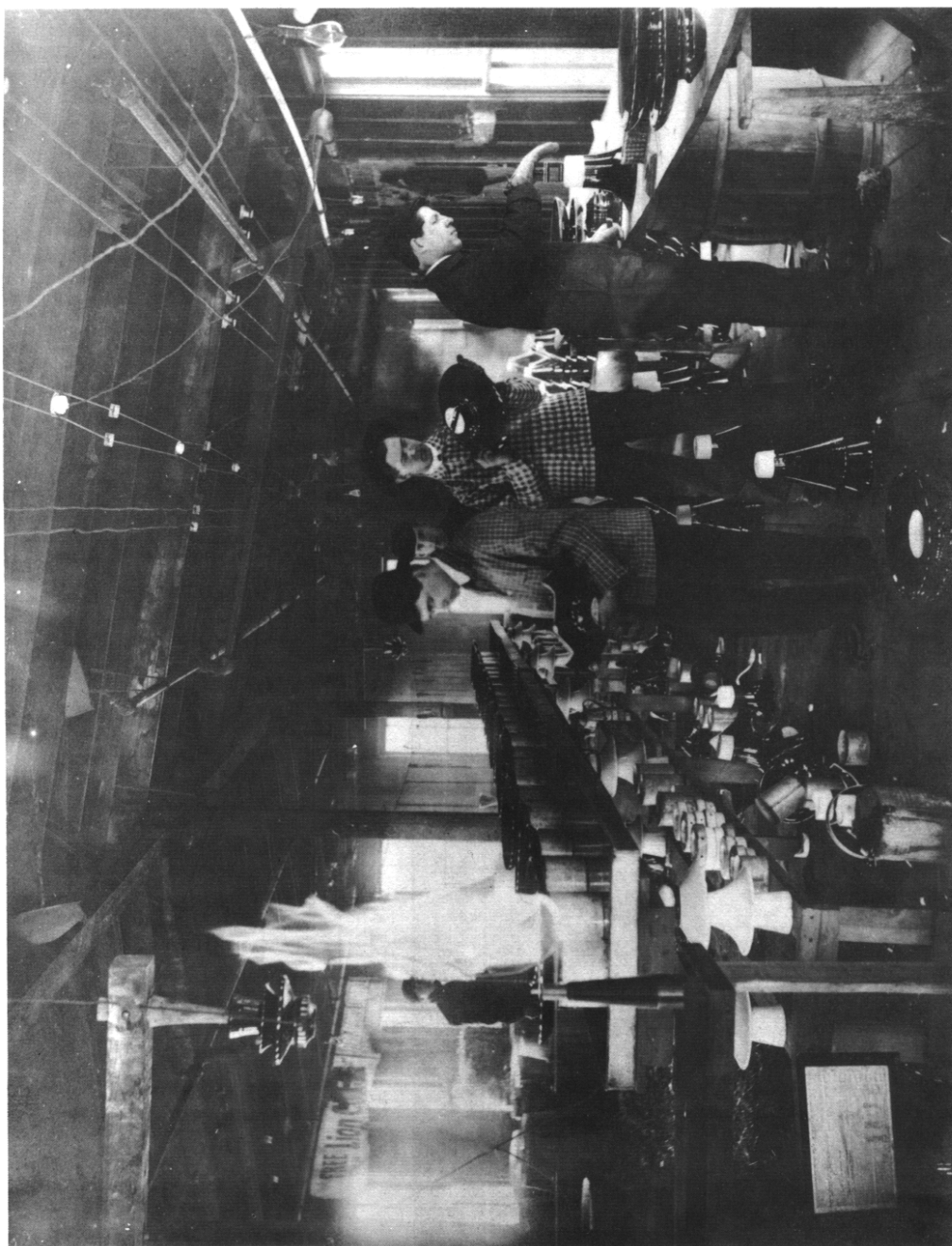


FIGURE 1. THOMAS INSULATOR PLANT - OHIO - 1906. A.O. AUSTIN
(centre foreground) INSPECTING INSULATORS FOR THE
PACIFIC GAS AND ELECTRIC COMPANY.

BASE VOLTAGE: TRANSMITTING POWER/ANTENNA HEIGHT/MODULATION				
TRANSMITTING POWER KW	BASE VOLTAGE KV			
	RMS: NO MODULATION		PEAK : 100% MODULATION	
	ANTENNA HEIGHT		ANTENNA HEIGHT	
	0.25 λ	0.5 λ	0.25 λ	0.5 λ
1	0.4	1.4	1.1	4.0
10	1.3	4.6	3.8	13.2
50	2.8	9.9	8.0	28.0
1,000	12.6	44.3	36.0	125.0

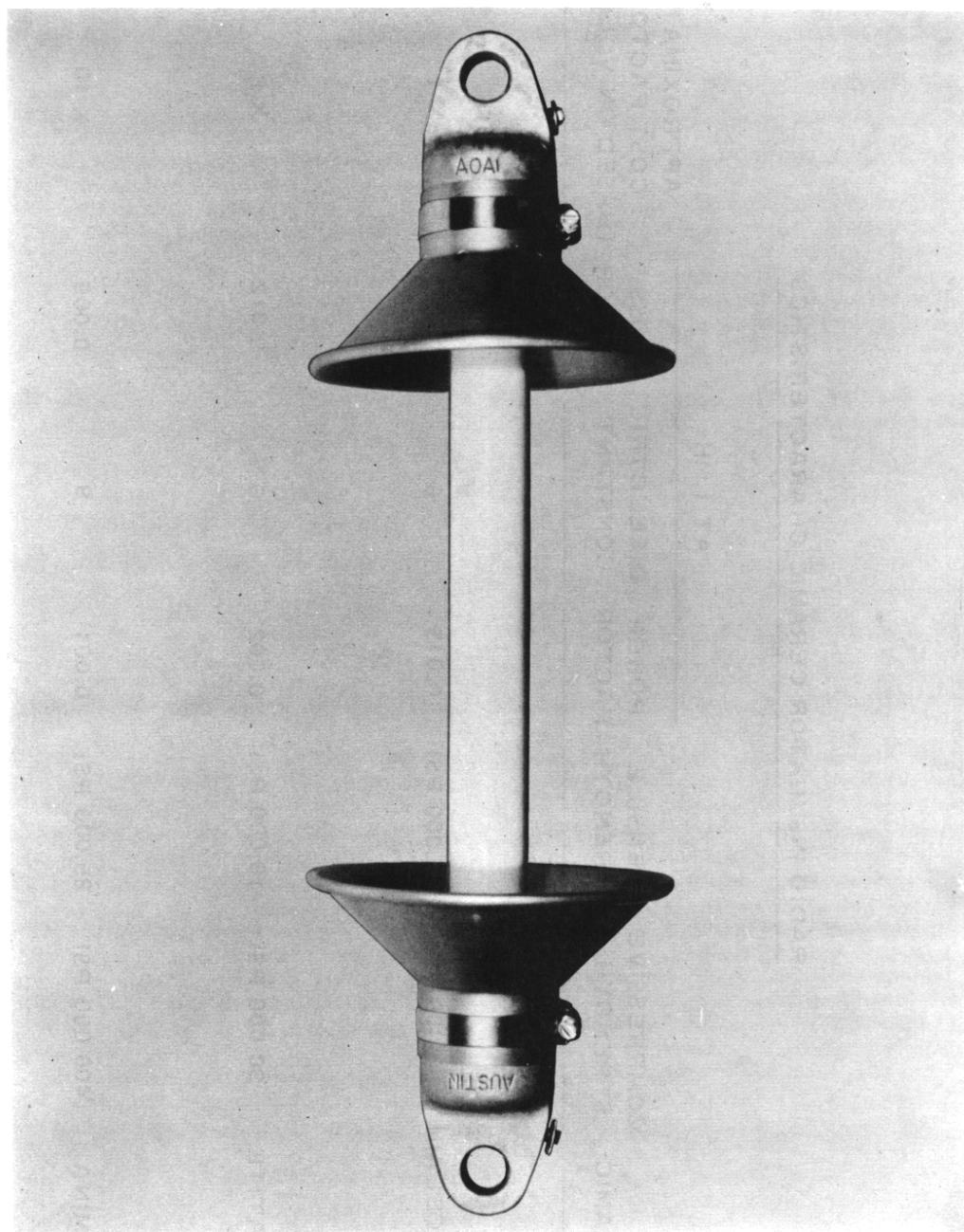
FIGURE 2.

RADIO INSULATOR CERAMIC CHARACTERISTICS

CERAMIC	AT 1 MHz					APPROXIMATE COST FACTOR (BASED ON VOLUME)
	COMPRESSIVE STRENGTH	TENSILE STRENGTH	POWER FACTOR	DIELECTRIC CONSTANT	LOSS FACTOR	
PORCELAIN	50,000 PSI	6,000 PSI	0.015	6	0.090	X 1
STEATITE	90,000 PSI	10,000 PSI	0.002	6	0.012	X 2
ALUMINA	400,000 PSI	25,000 PSI	0.001	9	0.009	X 10

FIGURE 3.

FIGURE 4. AUSTIN STEATITE ROD TYPE STRAIN INSULATOR - WORKING
LOAD 4, 000 POUNDS.



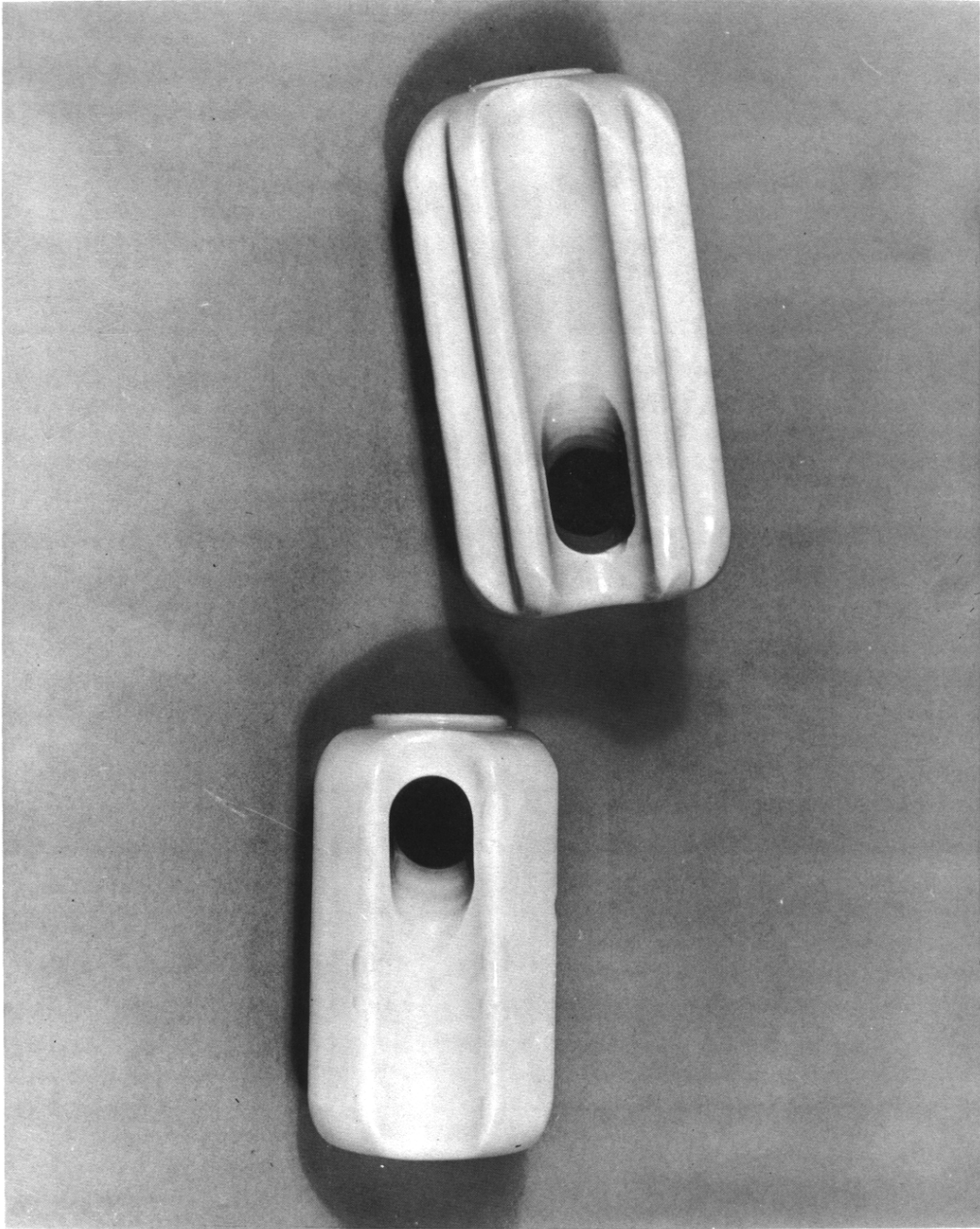


FIGURE 5. PORCELAIN "EGG" TYPE STRAIN INSULATOR - CLOSED ENDS.

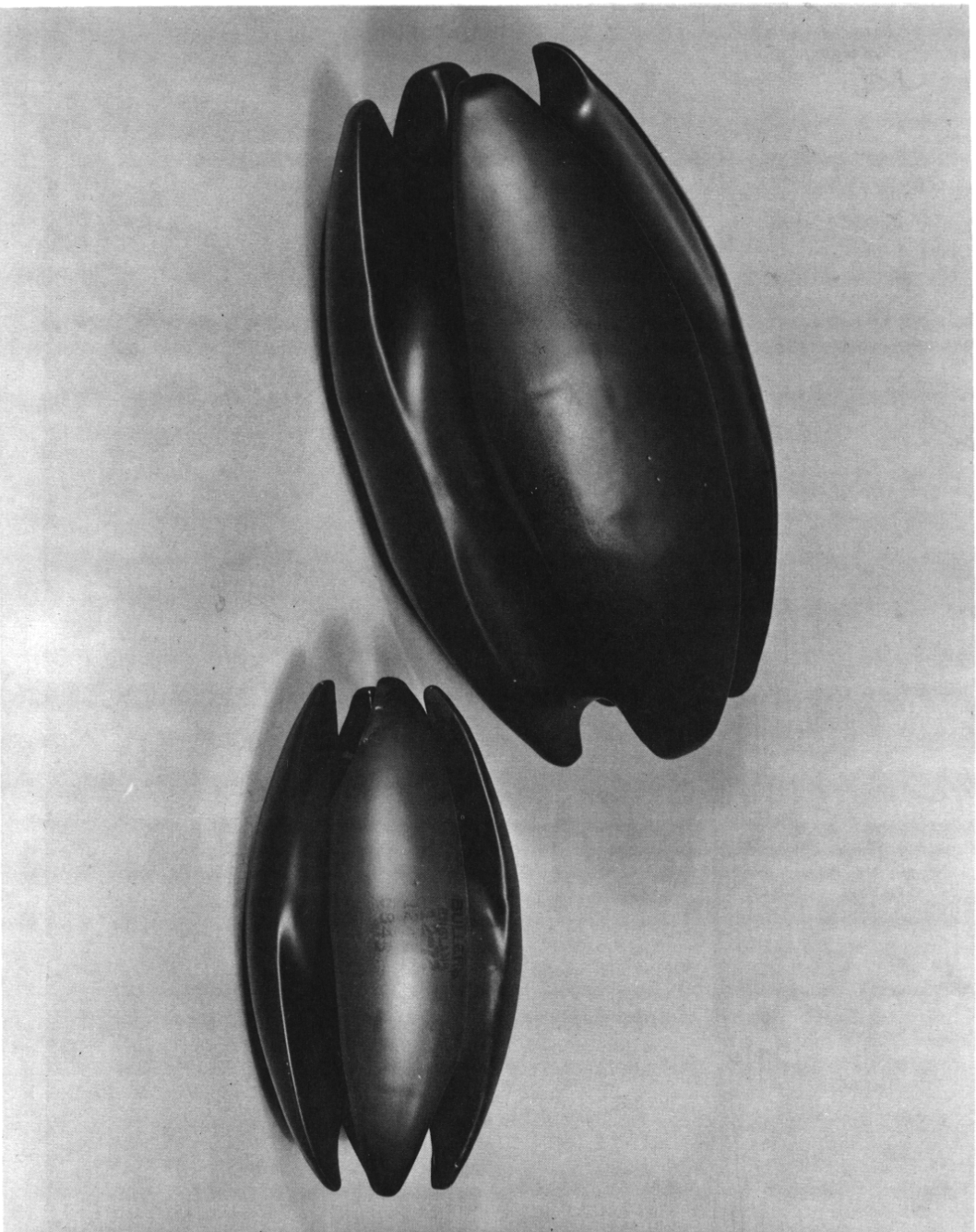


FIGURE 6. PORCELAIN "EGG" TYPE STRAIN INSULATOR - OPEN ENDED.

VOLTAGE DISTRIBUTION ACROSS INSULATOR GROUPS

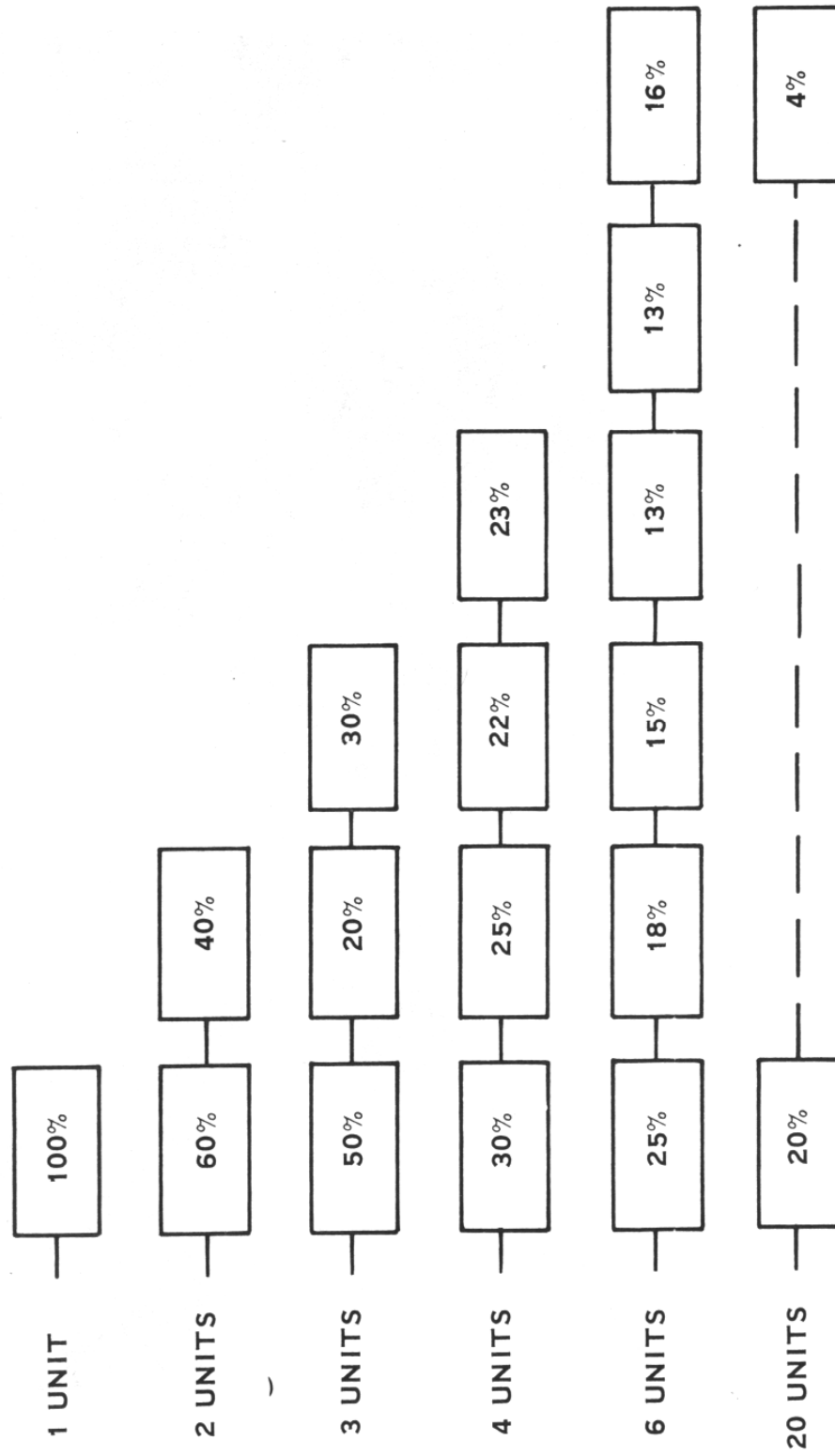


FIGURE 7.

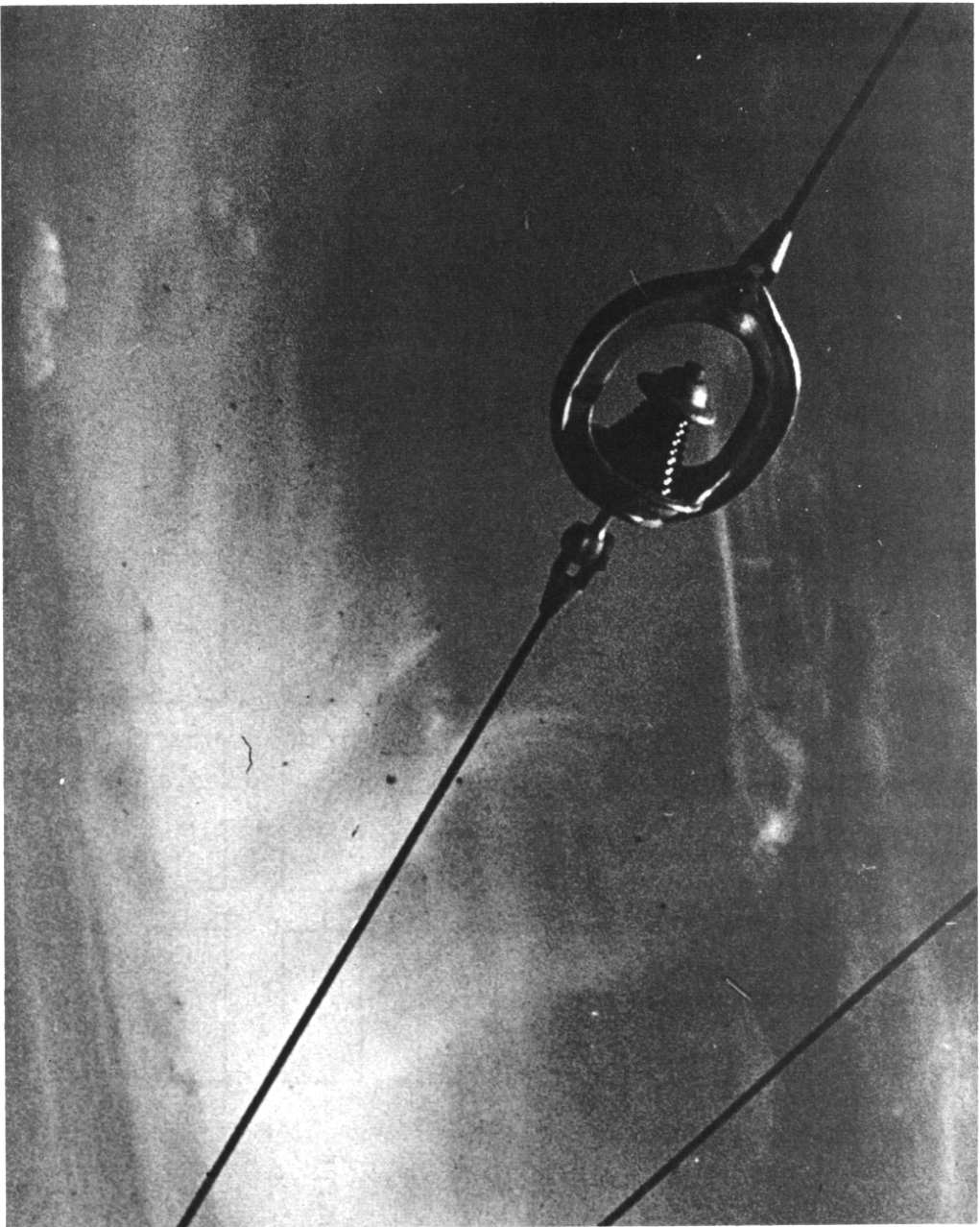
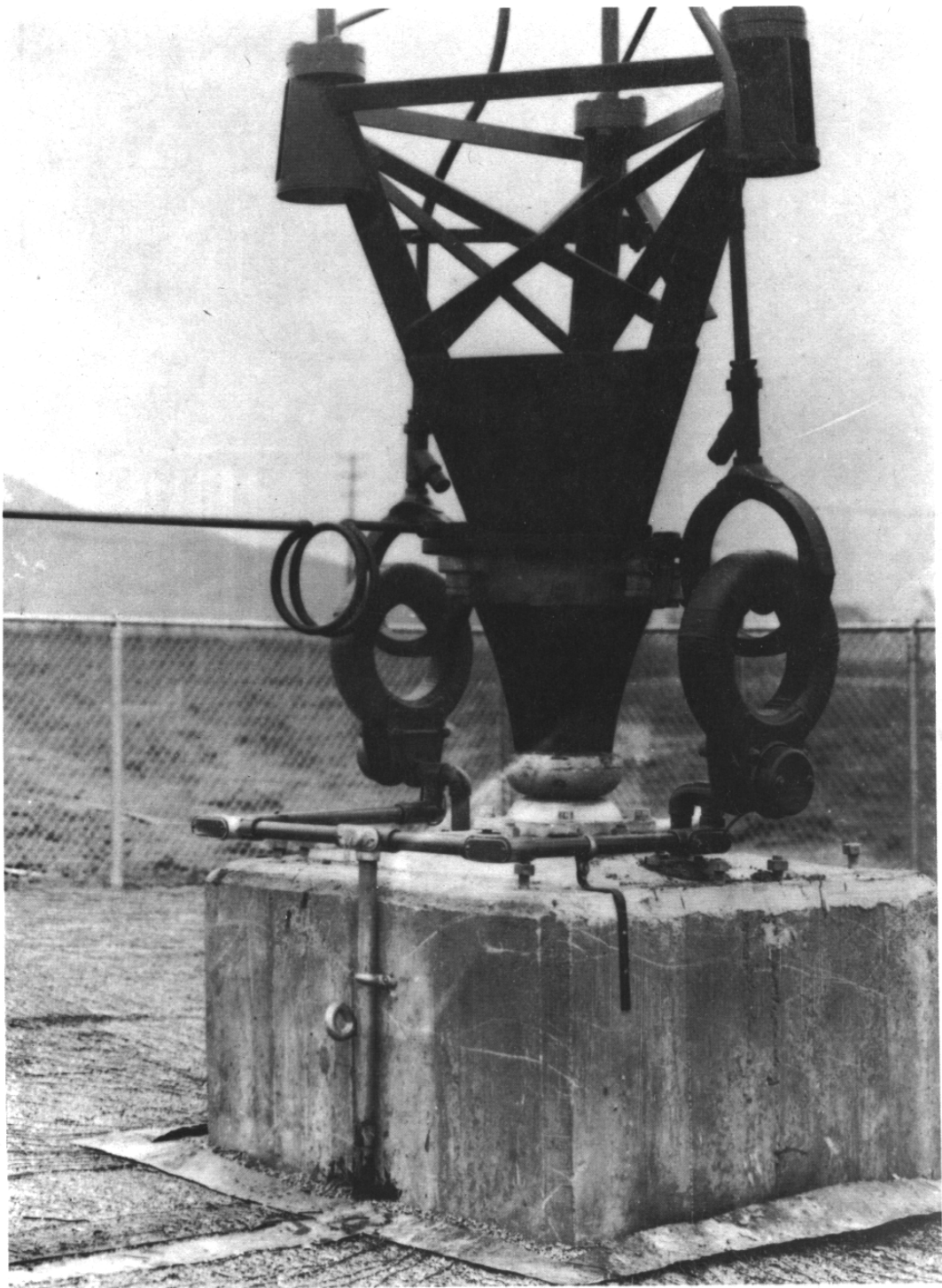


FIGURE 8. GUY STRAIN INSULATOR



FIGURE 9. AUSTIN SAFETY CORE, OIL FILLED, GUY STRAIN INSULATOR
TYPE A-4006 - WORKING LOAD 10, 500 POUNDS.



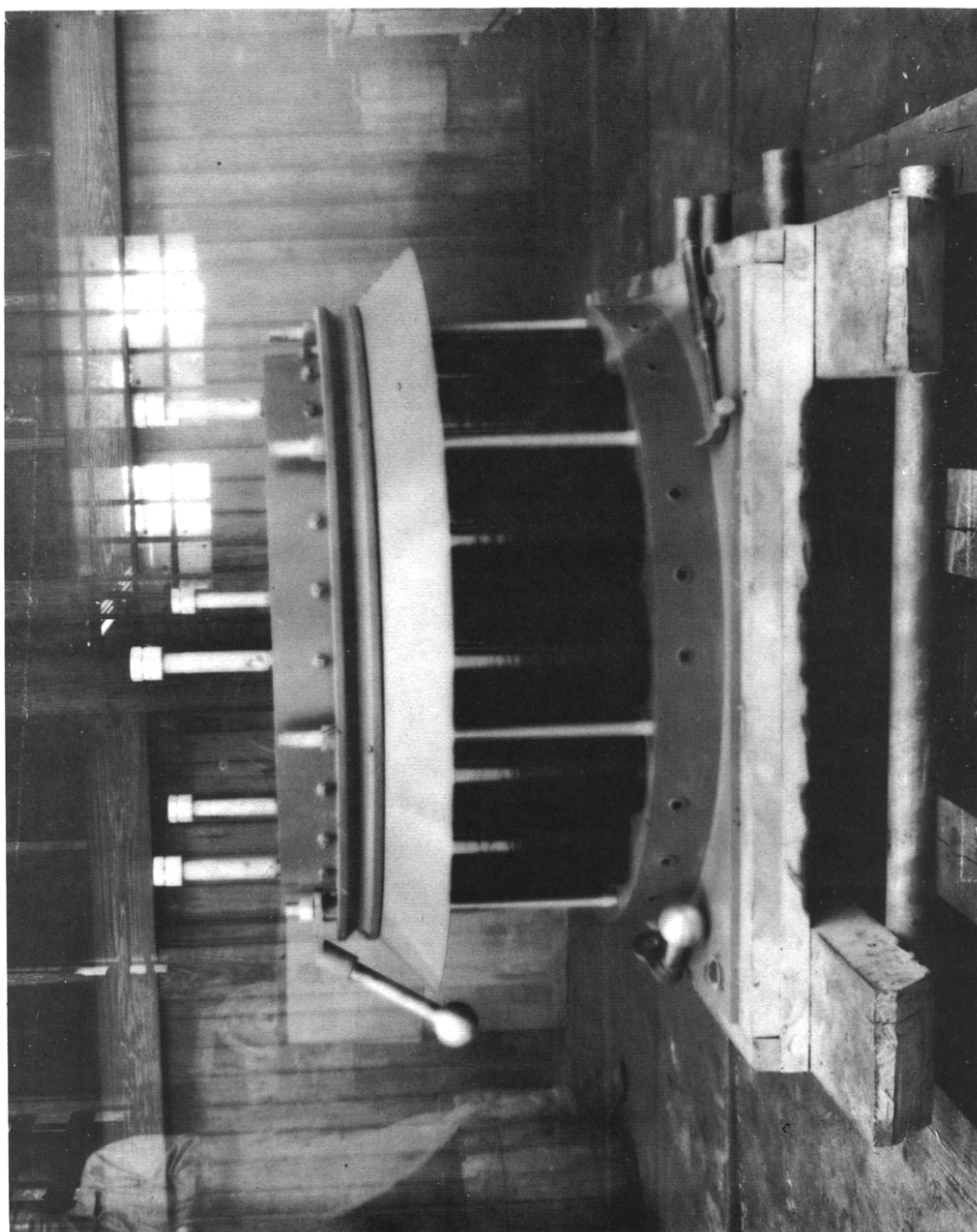


FIGURE 13. TWENTY-ONE ELEMENT OIL FILLED AUSTIN BASE INSULATOR.
WORKING LOAD 2,500,000 POUNDS.

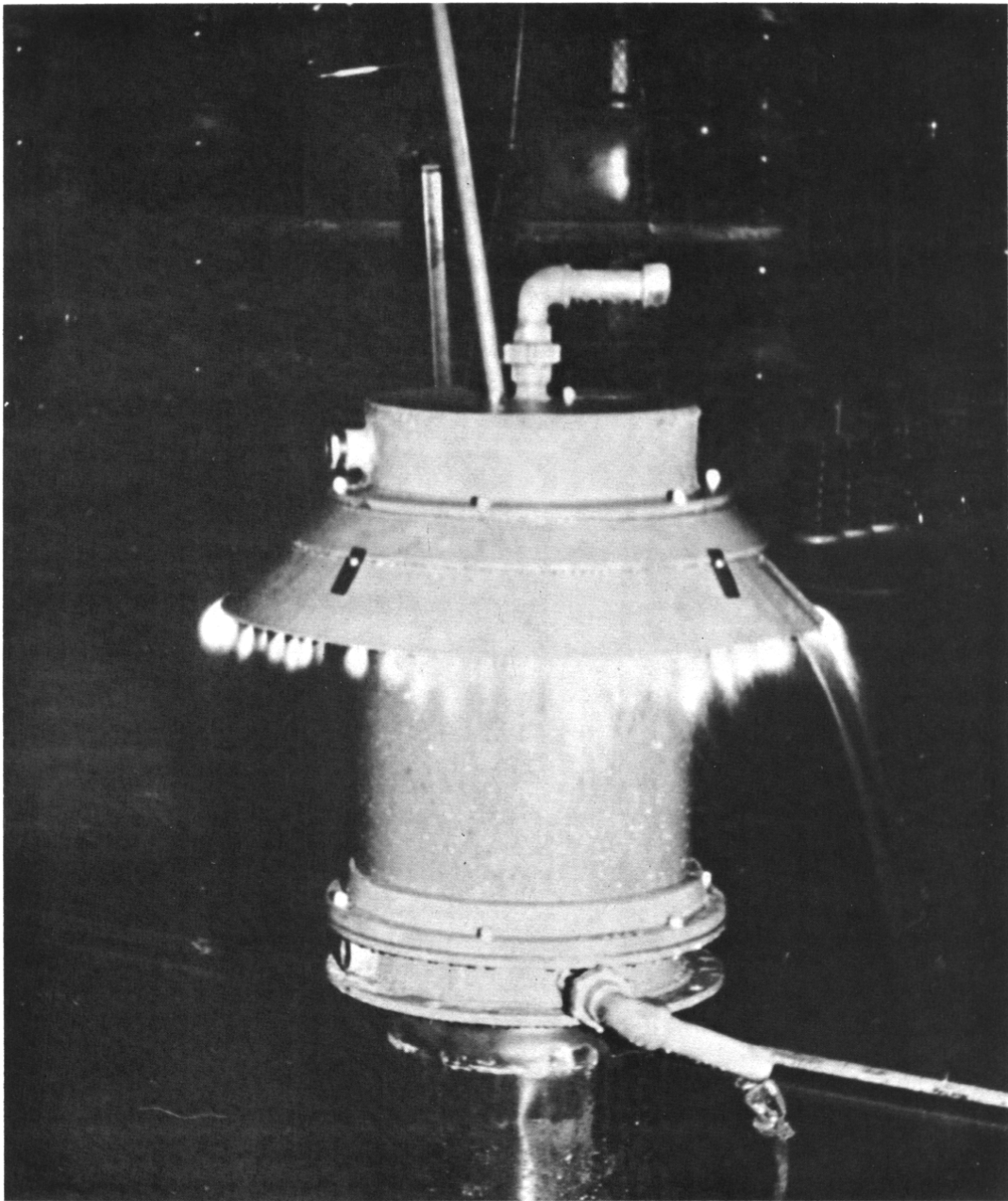


FIGURE 14. WET FLASHOVER TEST AT LOW RADIO FREQUENCY.
DISCHARGE PLUMES PRECEDING ELECTRICAL BREAKDOWN.

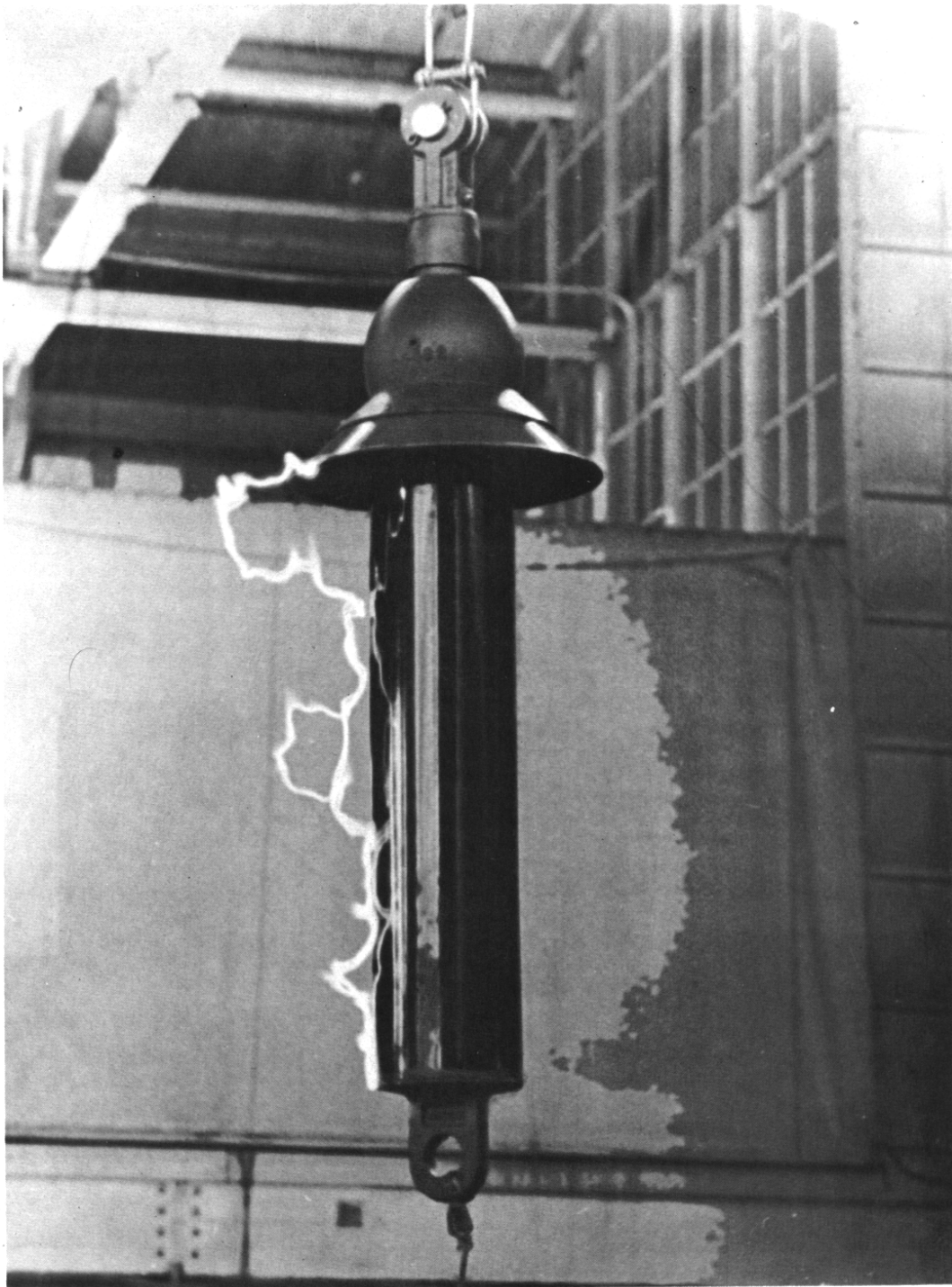


FIGURE 15. FLASHOVER HUGGING CERAMIC SURFACE OF GUY STRAIN INSULATOR. CAUSED BY REMOVAL OF BOTTOM EXTERNAL VOLTAGE CONTROL. (SEE FIGURE 9)

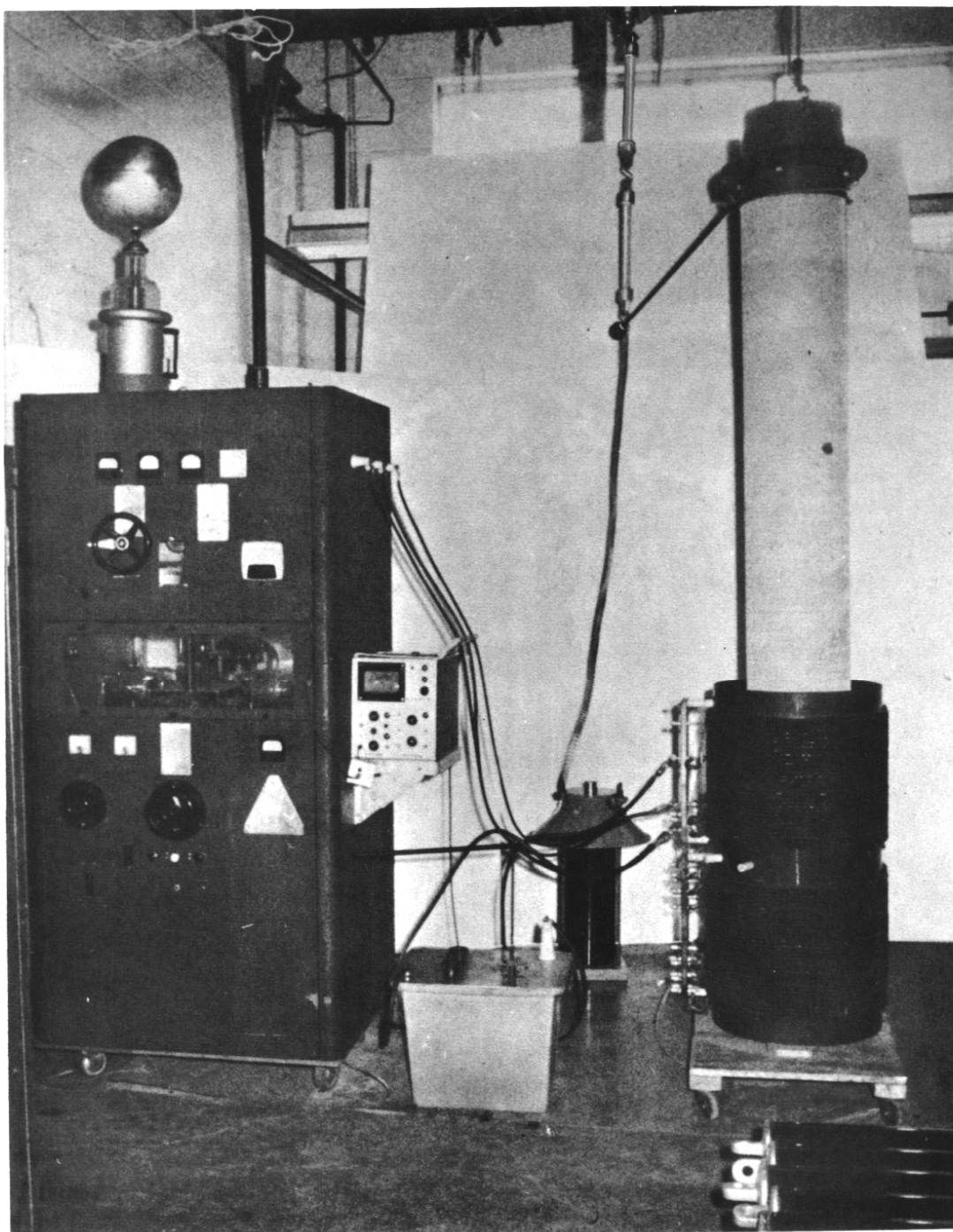


FIGURE 16. RADIO FREQUENCY HIGH VOLTAGE TEST SET. VOLTAGE CAPABILITY APPROXIMATELY 150 KV PEAK.

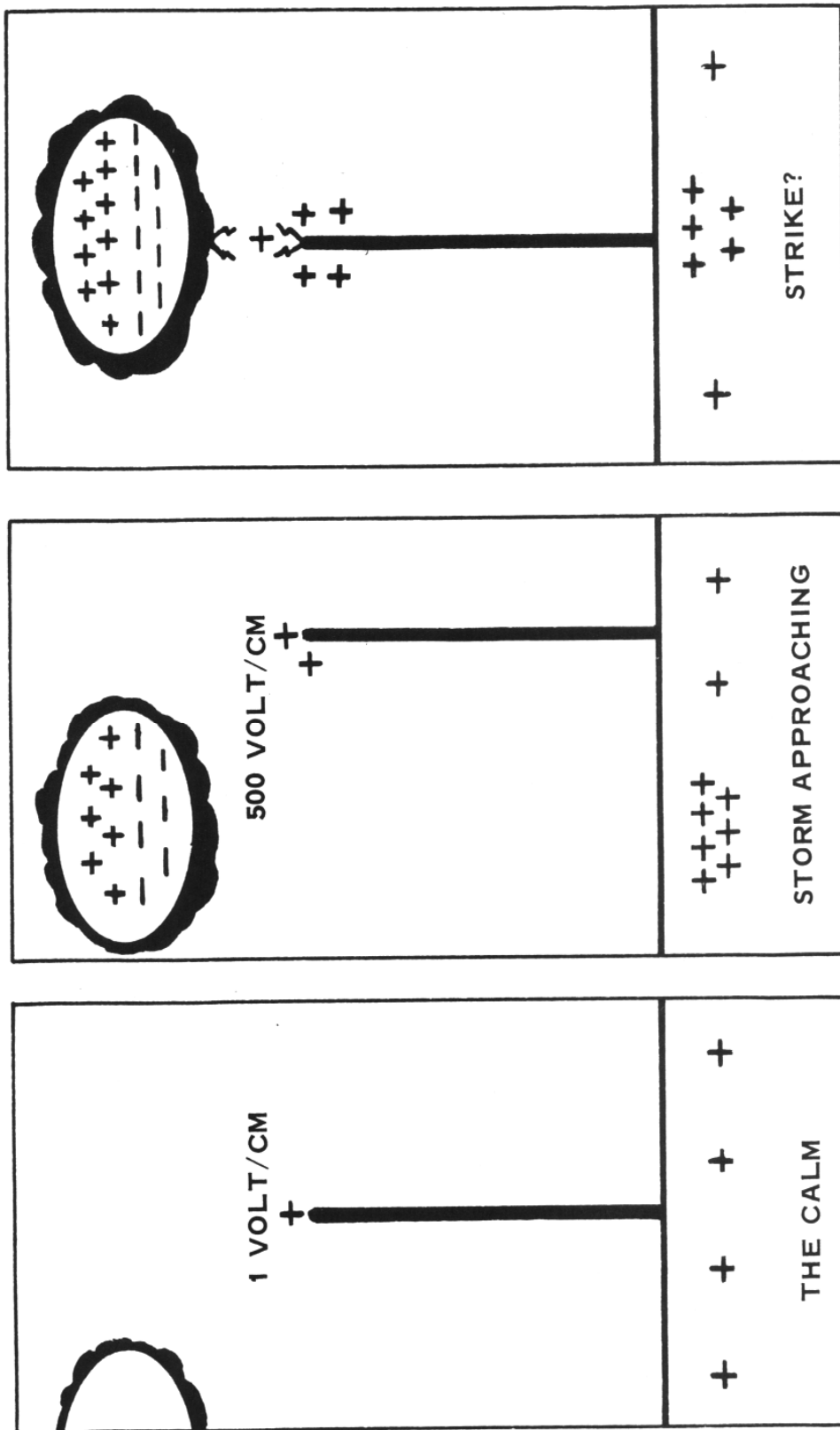


FIGURE 17.

THE USE OF "EGG", "JOHNNY BALL", "WALNUT",
AND SIMILAR SMALL INSULATORS

A SUPPLEMENT TO
"THE EFFECTIVE INSULATION OF MASTS AND TOWERS
FOR AM BROADCASTING"

A paper presented at the May, 1973 W.A.B.E. Conference in
Edmonton by L.J. Dennett & E.E. Thompson of Austin
Insulator Division, Decca Radar Canada (1967) Limited

June, 1973

THE USE OF "EGG" "JOHNNY BALL" "WALNUT"
AND SIMILAR SMALL INSULATORS

In the Paper it was stated that on a string of two or more similar insulators the voltage did not necessarily divide equally among the units in a string.

Figure 7 shows typical distributions along strings of insulators with a variation in the number of units in each string.

Though not stated, it was perhaps implied from the layout of Figure 7 that the left-hand insulator in each string was located adjacent to the mast. If a string of insulators is used in the upper part of a guy close to the mast, the insulator closest to the mast may not be the one most heavily stressed as is implied in Figure 7. Capacitive coupling effects to the mast and to the ground from the short sections of cable joining insulators in a string, largely determines the voltage distribution along a particular string. Either the top insulator or the bottom insulator may be the one most heavily stressed in a particular system.

It will be noted that when more than four to six insulators are used in a series string a further increase in the number of insulators does little to reduce the voltage stress across the insulators at the ends of the string.

The voltage distribution along the string can be made uniform by installing voltage controls at each end of the string (similar in appearance to rain shields or Corona/grading rings) but this increases the complexity and cost of the assembly and still does not achieve the electrical and mechanical performance available from a single properly designed radio guy insulator. About the only advantage gained in making a string of insulators longer than four is that in wet weather the surface leakage path is increased proportionately. The individual insulators are still prone to flash over and on an over-stressed string, when the first insulator flashes over, all the rest will likely follow. If the flash over is caused by natural electrical phenomenon then the longer string is less likely to allow a following power arc to be sustained by the transmitter.

Though "egg" insulators are relatively inexpensive, by the time one has purchased a reasonable number for a string, paid for the rigging necessary to join them together and installed controls to achieve a uniform voltage distribution, the total cost will be comparable with a well designed single insulator and the overall performance will remain inferior.

As stated in the Paper the effective insulation of a radio transmitting antenna is a complex and not a simple problem and depends on many inter-related factors being taken into consideration. Each antenna system has its unique characteristics and although similarities may exist between one system and another the systems are rarely identical. Eggs and other similar insulators having short surface leakage paths and short arcing distances have their place as break-up insulators in many installations and particularly in the field of M. F. Broadcasting in North America where power is limited to 50 KW and electrically short antennas are seldom used. Good insulation is desirable at the points where guys are attached to the mast and particularly so at locations on the mast where the higher system voltages are encountered. Generally speaking these are the upper sets of guys on quarter wave radiators and the upper and lower sets of guys on half wave radiators. An insulator with a long continuous surface leakage path and a long arc gap used at these points will eliminate the possibility of a transmitter power arc following a flash-over initiated by lightning. Such an insulator will also almost entirely eliminate the possibility that any flash over will occur due to natural electrical phenomenon other than a direct lightning strike. The long surface leakage path will ensure a minimum of impedance change during wet weather and improve the overall stability of the system.

With good insulation at the mast attachment points there is still the likelihood that the lower break-up insulators will flash over due to a naturally induced electrical charge, but any discharge will then go down the guy to ground and not to ground via the mast. This, on some antennas and arrays, will still cause sufficient disturbance to the system to result in automatic devices cutting off the transmitter. A further improvement can be made to the system by installing good radio insulators at the bottom of the guys, leaving the egg or similar insulators at the intermediate break-up locations.

Insulation problems should be considered in the earliest planning stages of a new antenna system to ensure that the most cost effective solution to the overall insulation problem is obtained.

June, 1973