Feb. 15, 1927. L. A. BALDWIN ET AL 1,617,788

DEVICE FOR PREVENTING ELECTRICAL IGNITION OF STORED INFLAMMABLE FLUIDS

Filed May 25, 1925 4 Sheets-Sheet 1

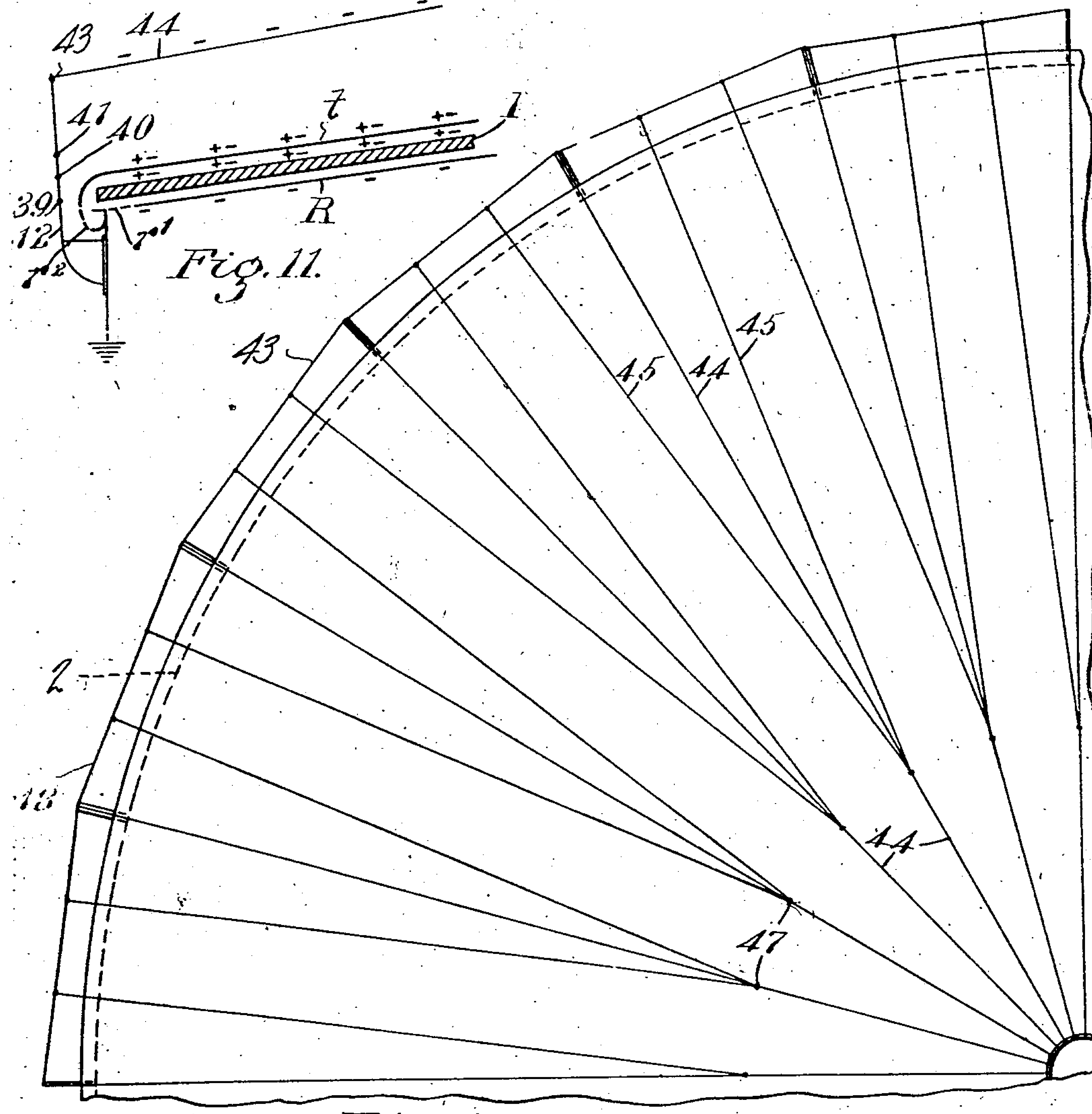

Fig. 11.

Fig. 1

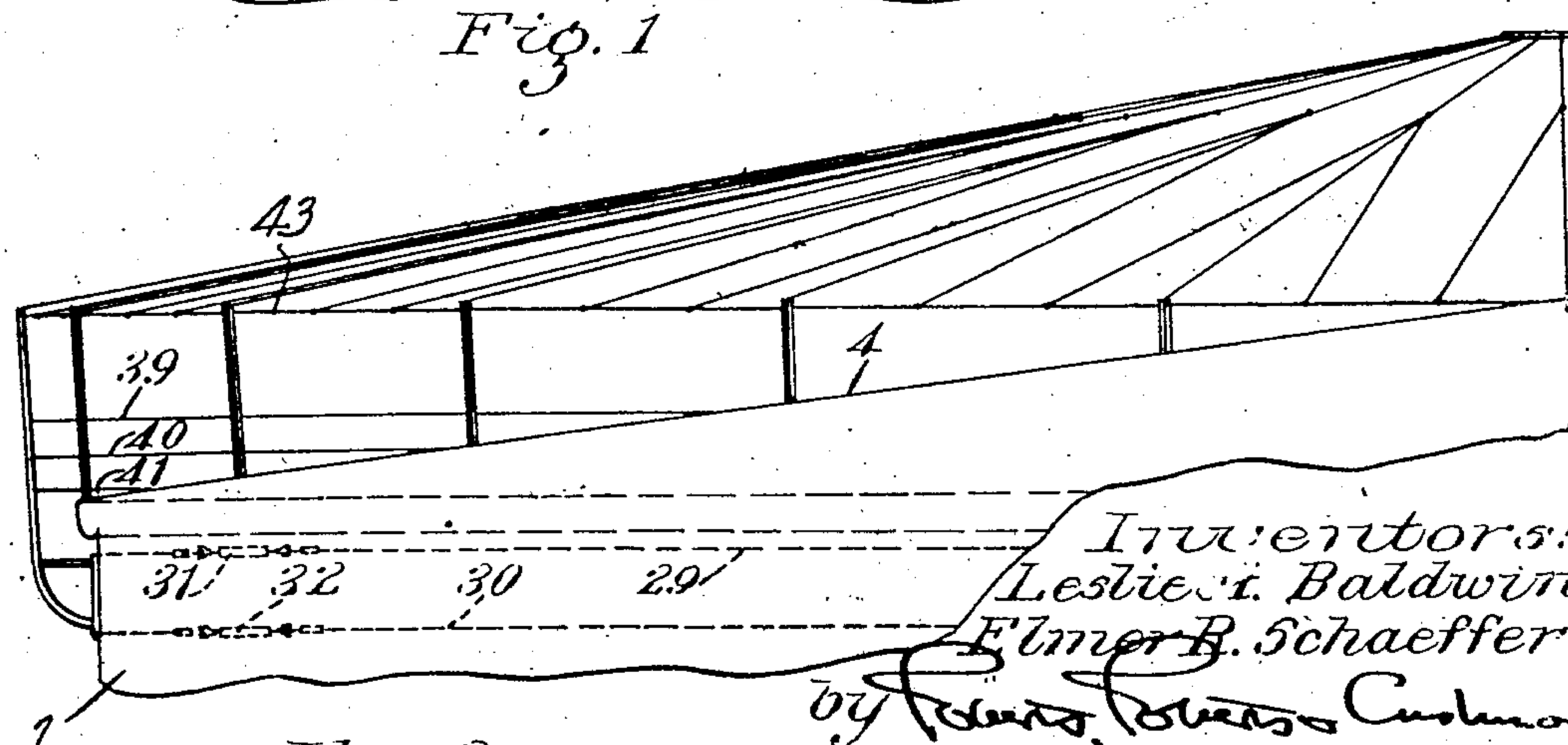

Fig. 2.

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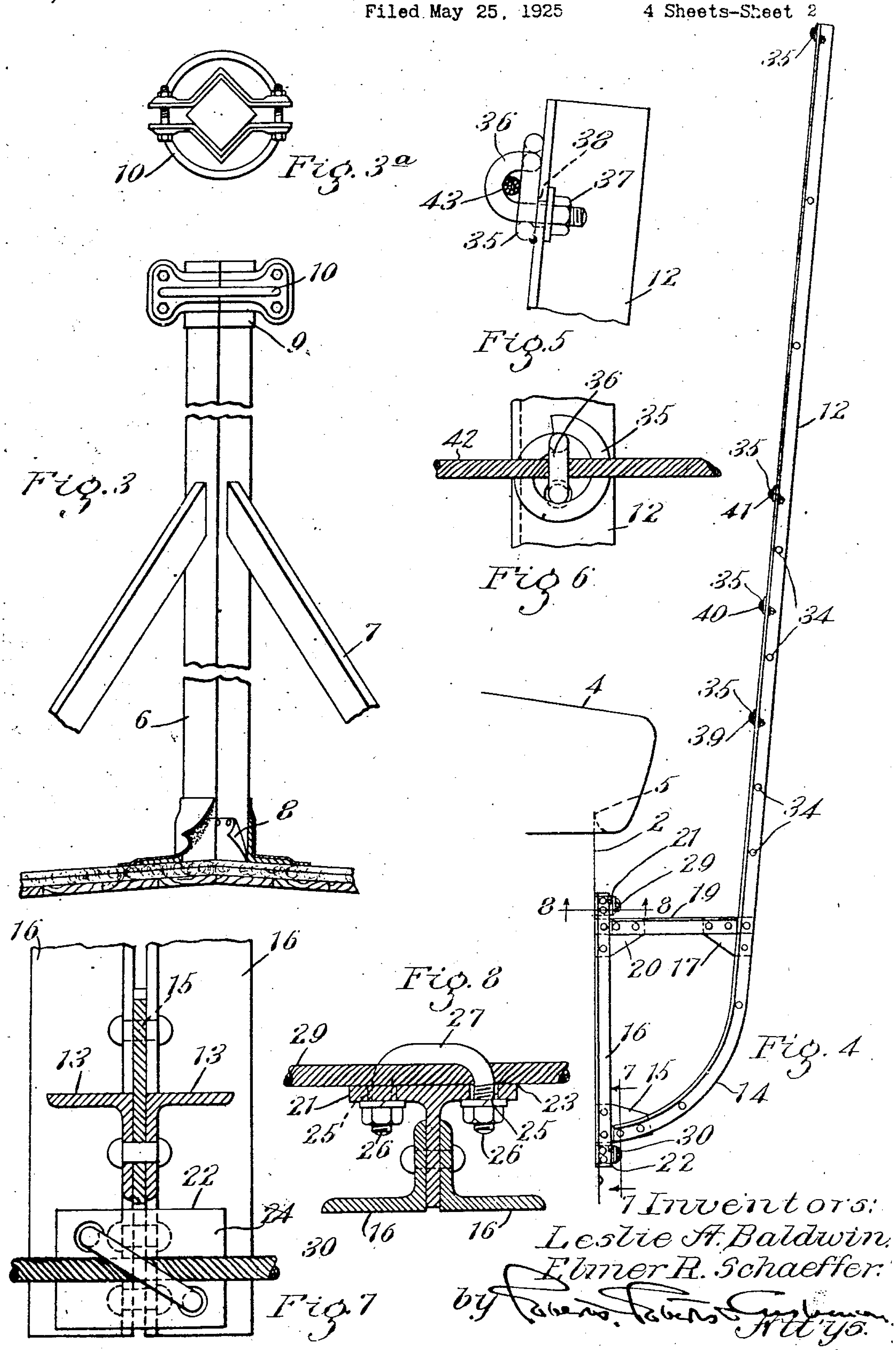

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DEVICE FOR PREVENTING ELECTRICAL IGNITION OF STORED INFLAMMABLE FLUIDS

Filed May 25, 1925 4 Sheets-Sheet 3

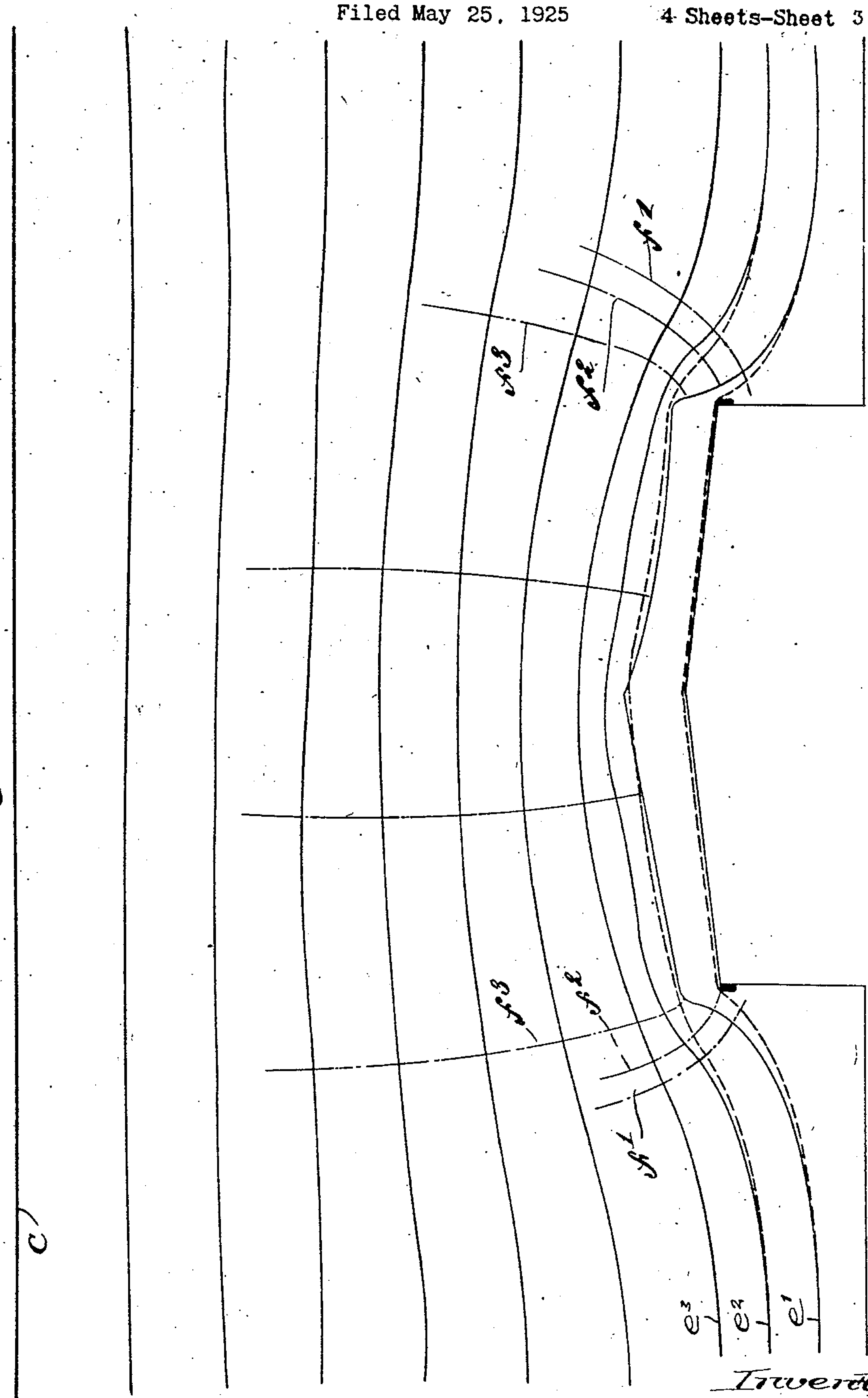

Fig. 9

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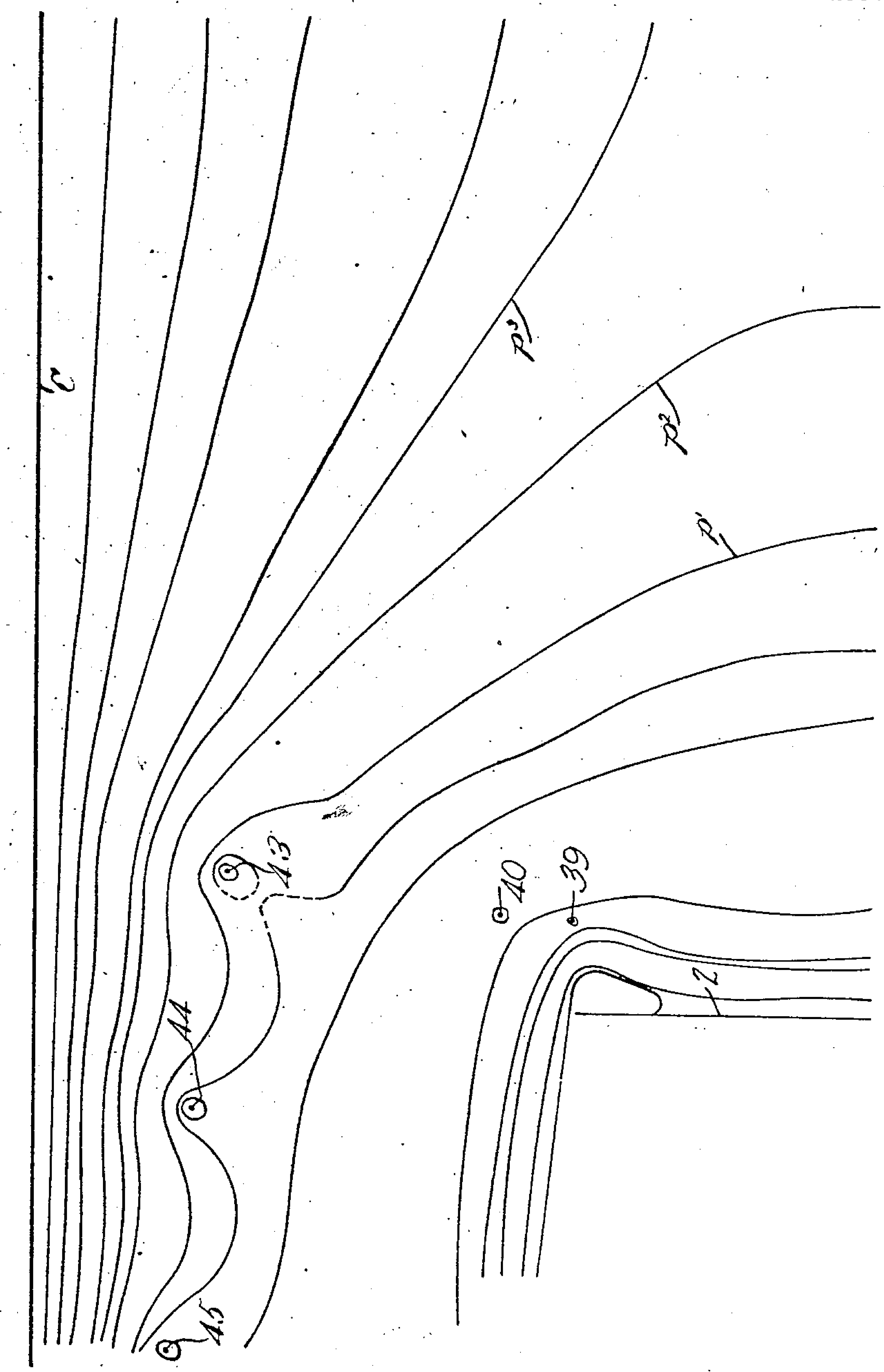
Fig. 10.



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Patented Feb. 15, 1927. 1,617,788

UNITED STATES PATENT OFFICE.

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DEVICE FOR PREVENTING ELECTRICAL IGNITION OF STORED INFLAMMABLE FLUIDS.

Application filed May 25, 1925. Serial No. 32,738.

This invention is concerned with the prevention of preventable fire and explosion risks from electrical ignition of naphthas, oils, hydrocarbon gases and other inflammable fluids in containers or tanks.

Notoriously the necessary peculiarities of construction, location and use of such oil and gas tanks cause or contribute to undue liability to explosions or fires initiated by electrical discharges. Petroleum, its derivatives, vapors and associated gases are good insulators; the tanks used for storage and handling are generally metallic, necessarily open to the atmosphere at one point at least (usually also, at many accidental points); and the structure of these tanks dictated by custom or by intelligent economy does not avoid providing ideal opportunity for electric spark discharges between parts of the structure through combustibles, such as mixed air and vapor or gases. Most of the oil fields are in regions of high probable occurrence of isolated lightning discharges and of thunderstorms, high winds, large diurnal variations of temperature, and other meteorological conditions leading to high surface electrifications as well as to exposure to the vast sudden differences of potential incident to lightning discharges, pre-lightning stroke electrifications, and the induced flows and discharges following near-by lightning flashes.

In modern practice heat insulation of storage tanks by protective coverings is more and more resorted to. In the best practice, such structures are characteristically also of dielectric substances, well adapted to increase the mutual electrostatic capacity of metallic or moisture-film surfaces between which they may intervene. While such insulating coverings are not easily penetrated by spark discharges, they are not wholly immune to puncture by discharges from surface to surface of the Leyden-jar type of condenser which they often constitute, and they do not oppose any adequate obstruction, of course, to discharges, either direct or secondary, of lightning stroke intensities. High static potentials on the outer surfaces of insulating covers, paint or other coatings should be avoided because they connote induced potentials on surfaces at or near which sparking would be disastrous, and indicate the possibility of penetrating sparks or disruptive or sudden discharge, or sudden augmentation, of the exterior charge. It is desirable to prevent, therefore, the building-up to high potentials of electrostatic charges of opposite sign across the insulation covers or fabrics of such tanks. It is desirable to avoid every possible opportunity for a spark discharge through or across spaces likely to contain air and vapor mixtures, as well as to provide, in optimum relation to the containers to be protected, sound metallic conducting paths to earth capable of dealing with current surges of great quantity and high intensity. Provisions to these ends should be of sufficient effective reliability and durability to defy being put into an inoperative state by ignorant handling, but they should not take up undue space or be too costly for general adoption in and about oil-wells, tank farms and refineries.

Since the times of Franklin and Faraday lightning prevention devices have been provided rather as the effect of ingenuous faith than as the result of exact engineering knowledge. Lightning stroke conditions remain in part a mystery of physical science, but nevertheless a sufficient basis of established fact is in hand to indicate and predict success or failure of preventive devices upon exposure to lightning risk and to atmospheric electrification phenomena of normal characters and intensities. This invention seeks to provide optimum protection against normal risks for such exposed objects as oil tanks within a practicable minimum of complexity and cost.

A further object of the invention is to provide by simple structures for neutralization of high static potentials between the exterior surfaces and interior structures of heat-insulated tanks, to avoid differences of potential between internal parts of tanks, and especially to provide lightning protection devices so arranged in respect to the container to be protected as to interpose between the container and exterior sources of electrification, and between the container and the cloud source of a lightning bolt discharge, adequate means effective for harmlessly carrying off induced charges or the heavy discharge currents of lightning stroke character; and operating to distribute the equi-potential areas existing between earth and elevated electrified atmospheric strata in such a way as to exclude the container protected from participation in lightning-inviting exposure to potential gradients abnormally steep in comparison with the potential gradients at nearby objects, buildings and surfaces of the earth or earthed surfaces.

The invention will be explained in connection with typical and recommended constructions illustrative of the various arrangement by which it may be carried out.

In the accompanying drawings of the form shown for purposes of illustration,

Fig. 1 is a diagrammatic plan view of a quadrant of a tank showing a system of conductors;

Fig. 2 is a diagrammatic vertical sectional view on a radius of the tank;

Fig. 3 is a side elevation and Fig. 3a a plan of a central support for certain conductors;

Fig. 4 is a side elevation of one of the peripheral supports in position on the side of a tank;

Figs. 5 and 6 are respectively side elevations and plan views of a holding clamp;

Fig. 7 is a sectional view on the line 7—7 of Fig. 4;

Fig. 8 is a sectional view on the line 8—8 of Fig. 4;

Fig. 9 is a diagram illustrating the distribution of equi-potential surfaces in a typical vertical plane of a tank between earth and an elevated atmospheric layer, such as a cloud;

Fig. 10 is a similar diagram of a detail of Fig. 9 showing equi-potential surfaces between and near the protective system and the tank surfaces; and

Fig. 11 is a diagram in radial section illustrating the distribution of induced static charges between the tank top, a heat-insulating cover, and the protective system.

Referring now to the drawings, let it be assumed that the structure to be protected is a tank, which has a peripheral wall 2 built up of courses of steel plates and a non-metallic heat-insulating top 4 making a sealed joint at 5, Fig. 4, with the wall 2; for example, of the improved construction described and claimed in the application for patent of Leslie A. Baldwin, Serial No. 675,146, filed November 16, 1923.

As shown, upon the center of the tank roof a suitable support is erected, which may comprise a rectangular wooden post 6, suitably braced by members 7 and making a water-tight joint with the cover 4 with the aid of suitable flashings 8 embedded in a waterproof cement. At its upper end the post 6 is provided with a snugly fitting galvanized metal cap 9 and this is surrounded by and supports a two-part ring member 10 to which the central portions of a protective conductor system may be attached.

At the periphery of the tank there may be arranged a spaced series of erect peripheral conductor and supporting members 12, which members may be made up of a pair of angle-irons 13 of comparatively light section bent, as indicated at 14 in Fig. 4, at their lower ends and fastened together suitably at points 34. At the lower extremities of the members 12 the angle-irons 13 may embrace and be attached to a plate 15 mounted between a pair of vertical angle-irons 16 of slightly heavier section to which the plate 15 may be riveted or otherwise fixed. At a substantial distance above their lower ends the members 12 are secured as by means of rivets and plates 17, to a pair of horizontally extending angle-irons 19 and the latter at their inner ends embrace at opposite sides a plate 20 in turn fastened between the upper ends of the angle-irons 16. The structure so formed is adapted to be attached to the tank 1 in any suitable way providing a good mechanical and electrical contact with the vertical tank wall. For example, at the extreme upper and lower ends of the members 16 T-sections 21 and 22 respectively are arranged, these being riveted to the members 16 to provide relatively flat surfaces 23 and 24 against which tension cables 29, 30 may bear. The members 23 and 24 may be drilled as indicated at 25, Fig. 8, to permit the passage through them of the threaded extremities 26 of U-bolts 27, for example, which provide a fairly close fit for the heavy wire tension cables 29, 30 surrounding the tank, and adapted to be stretched taut by turn buckles 31 and 32, Fig. 2. The bearing surfaces between the parts 16 and the tank wall 1 may be scraped and cleaned before erection and protected by applied paint or cement after erection, in order to preserve dependable areas of actual contact, and any other fastening means for the erect conductors 12 capable of convenient construction and safely holding the conductors 12 against writhing and expansion motions of the tank and maintaining electrical contact may be resorted to. Suitable clamp connections 35, for example having portions forming a loop 36 and provided with tightening nuts 37 are placed in holes 38 in the members 13 at various points in the latter, as shown four of these connections being provided on each of the members 13, the first directly opposite the periphery of the tank cover and the second and third spaced a short distance above, while the fourth is adjacent the top of the members 12. These clamps serve for a series of circumferential wire conductors 39, 40, 41 and 43 of which upper conductor may be a strong wire cable 43 spaced substantially above the top of the tank, for example at a height of about 7 feet, and defining a periphery somewhat greater than that of the tank. Between this member 43 and the ring member 10 there may extend any sufficient number of substantially radial conductor elements 44, the latter at their outer ends engaging the conductor 43. At points 47 approximately one-third of the way from the ring 10 to the member 43 there may be attached to each of the elements 44 a pair of wire conductor elements 45, which are connected to the peripheral conductor 43 at equal distances on opposite sides of the terminal portions of the conductors 44. The wires 45 may be twisted around the wires 44 and the joint may be held by any suitable type of positive clamp. The members 45 may be twisted around the member 43, soldered or clamped; preferably all wiring connections are suitably secured by binding-screw clamps of any suitable construction.

Any suitable material may be employed for the various cables and conductor elements; it is satisfactory to provide galvanized steel cables 29, 30 to hold the members 12 in fixed position upon the tank, and ordinary galvanized iron wire of sufficient size may be used for all the other conductors. The peripheral conductor 43 is desirably a galvanized wire cable. The lower ends of the members 16 may advantageously be allowed to rest against the top edge of the next to the top course of plates in the construction of the tank wall.

The tank wall 2 is, as usual, in reliable electrical contact with the earth. When this is not assured by pipe line connections or standing foundation water, proper earthing conductors are provided. Unnecessary projections above the tank top are recommended to be avoided.

The recommended structure thus comprises a series of peripherally extending conductors defining a diameter greater than the tank, and more closely spaced to each other and the tank at the level of and above the eaves, and a system of radially-extending conductors above and spaced from the upper surfaces of the insulating covers of the tank roof. At any point above the top of the tank the conductors 44, 45 should be closer together than the separation of the plane defined by them from the roof surface. These recommendations flow from the conditions under which the addition of the protective conductor system to the tank results in a redistribution of the equipotential surfaces related to induced charges, for the following reasons:

Assuming an elevated electrified area, such as a charged cloud C, Fig. 9, directly overhead, the normally dielectric air between earth and cloud is in a state of stress between the opposite potentials of earth and cloud. This condition results in a gradient of potential differences, of which equal values will define equipotential surfaces e^1, e^2, e^3, etc., the distribution of which follows in the main the depressions and elevations of the surface of the earth and conductive objects on the earth. Potential gradient intensities of the order of 35,000 to 150,000 volts per foot of elevation are of common occurrence during thunderstorms, and the potential gradient to upper strata may approach a substantial fraction of these values during weather conditions not definitely of the nature of a thunderstorm.

In the case of a cloud or charged stratum not overhead, the equipotential surfaces are concave toward the charged elevated stratum, and the gradient intensities may be of any lesser values dependent on the lateral distance of the charged stratum. In either case, the lines of force representing the path of discharge and indicating the normals to the equipotential surfaces are not necessarily vertical. On the contrary, in the case of a sharp terrestial elevation, such as a tree, a building or a tank, there is a compression together of the equipotential surfaces at the tips, edges and projections of these objects; this is merely another way of saying that at these places the potential gradient is steeper, and that the directions of the lines of force are inclined toward the center of figure of the terrestrial projection as indicated at f^1, f^2, f^3 in Fig. 9. When there is normal uniformity of the atmosphere, it may be predicted that a lightning stroke discharge will strike along the steepest gradient and through one of these compressions of the equipotential surfaces. When there is no stroke, the induced electrostatic charges are of greatest intensity at these places.

The lines of force end at any most elevated part, as measured along the direction of the lines of force, of the terrestrial projection, when that part is competently conductive to earth. In the case of a suspended earthed conductor, such as the wires 43, 44, 45 of the described apparatus, the place of compression together of the equipotential surfaces is elevated away from the terrestial projection (the tank in this case) and if of any substantial electrostatic capacity, or if the conductor bears a moving charge or current, will then be the starting point of a series of equipotential surfaces of reversed sign between itself and the neighboring projection (the tank, for example). If the wire and tank, however, are both competent conductors, the potential between them will correspond only to the mutual electrostatic capacity during complete discharge of the virtual air-gap condenser which the wires and the tank together constitute. Flows of current corresponding to static charges induced upon any such system as a whole are localized in the surfaces represented by any intervening earthed conductive network so spaced away from the earthed projecting body.

We have determined by new research the proportional protective effect of the described system of spaced radial and peripheral conductors under high potential gradients. The distribution of equipotential surfaces (altered by the additions to the tank as shown in Fig. 9 in full lines) in one plane is indicated by the traces p^1, p^2, p^3 etc. in Fig. 10, without attempt to indicate the absolute intensities from plotted surface to surface. When the mean lateral spacing from conductor to conductor is equal to or less than the vertical spacing from the tank roof to the conductors, the induced flux of current (a direct measure of the static charge induced by the exciting charged stratum) was found to be proportionally distributed between the tank roof and the conductor system in a proportion between extremes represented by the observed extreme values 3.2 to 96.8 and 1.6 to 98.4. When the number of radial conductors was reduced so that the mean separation of the conductors was greater than their elevation above the tank roof, then the mean values of the proportional charges were as 14.3 is to 85.7. In this case equipotential surfaces between the suspended conductors and the roof intersected the roof at the more separated places between the conductors.

The protective system, in the recommended spacing, carries an average value of the total induced charge of 97.6%. This may be taken as a probable minimum evaluation of the proportion of the current of a lightning bolt discharge likely to be carried by the protective system and the tank roof respectively in case of a stroke to a protected tank. The relatively high conductivity and even distribution of the conductor paths to earth from the protective covering warrants belief that a far greater proportion of a heavy discharge than the induced charge ratio indicates would in that case flow in the protective devices, resulting in a practically complete exclusion of the discharge currents from the tank top and roof proper.

Referring now to Fig. 11, the recommended protective conductor system is also effective to reduce risks from spark discharge from part to part of the tank. The probability of inter-part sparks increases as the potential or intensity of mutually-induced or bound charges is permitted to increase. The heat insulation I of the tank (and to a lesser degree paint or other coatings) will provide exterior surfaces *t* and interior surfaces R which, because conductive or made conductive by condensed moisture, residual sulphuric acid fumes or other thin films, may provide a path for a static charge built up to discharging intensity. Two such surfaces, especially the large roof and top surfaces, separated by a felt, asphalt or paint dielectric I are an ideal Leyden-jar condenser capable of energetic discharges amply able to fire the inflammables. Working joints in the surface R, for example, under expansion or filling writhings of the tank, might, if this surface (and the surface *t* by induction) carried heavy induced charges, permit local sparks from part to part; as illustrated at r^1, sections of the tank, especially the eaves portion, may represent a resistance to ground (due to obstructed joints, openings at the eaves, etc.) and the moisture film at *t* may well be electrically discontinuous or highly resistant, as at r^2.

There is no good way to reach and discharge such isolated surfaces by direct grounding. Conductors within the tank space can not be depended upon to make contact with all charged areas, and are themselves a source of risk during heavy induced rushes of current. There is no probable continuity of a film surface at *t* with which a wholly effective ground contact by any contact wiring system could be made. We therefore prefer to rely for discharge upon the overhead conductor system 12, 44, spaced from the surface *t* by an air-gap dielectric resistance. The overhead conductors complete a system in which the typical assumed charges at *t* preferentially discharge to earth through the conductors 44, 39, 40, 12 and through the resistance r^2, rather than by penetration of I. Such charges at *t*, when that surface is conductive, are of the same sign as the earth; but as indicated, when the surface is not uniformly conductive or is conductive in isolated areas only, these charges may be negative or positive, or negative in one place and positive in another, or in a state of oscillation from one to another relative sign of potential. The discharge of such charges to the overhead conductors is gradual rather than disruptive. Dangerously high potentials therefore do not build up on the isolated surface or surfaces *t*, and by induction on the opposite surface R; and, if and when a dangerous potential is approached, this is discharged without heavy surges of current, generally by ionized-air flow to the conductors 39, 40, 41 or 44. It will be observed that the spacing of the conductors mutually and from the insulated surface of the top of the tank is of optimum functional value when the relations are such as both to discharge surface static charges and to elevate regions of high potential gradient away from this surface.

During times of great meteorological electrical disturbance, the surface-charge discharging effect of the protective conductors is aided by the corona discharge ionization phenomena at the conductors, which then carry heavy currents at great potentials and high oscillating frequencies. When it is borne in mind that the effect of the protective grid is to lessen the charges on the tank proper to only from 1.6 to 3.2 per centum of the quantum otherwise induced by the charged cloud or elevated stratum, it will be perceived that the protective system specified may be relied upon to reduce the probability of induced interior sparking from condenser action of films borne by heat insulating or paint coverings to a minimum, while providing as good probable protection for lightning stroke disaster as it is possible to design.

I claim:

1. The combination with a tank for inflammable fluids exposed to meteorological electrical influences and having an insulating layer above a portion of its extent of a system of earthed conductors spaced from each other and spaced from the surface of said insulating layer by a greater distance than their mean separation from each other.

2. The combination with a tank for inflammable fluids exposed to meteorological electrical influences and having an insulating layer above a portion of its extent of a system of earthed conductors spaced from each other and spaced from the surface of said insulating layer, said conductors being principally concentrated by closer spacing at the regions of maximum potential gradient between the tank top and an elevated charged atmospheric stratum.

3. The combination with a tank for inflammable fluids exposed to meteorological electrical influences of a system of earthed conductors extending beyond the periphery of the tank and spaced from each other and from the top portion of the tank, said conductors being principally concentrated by closer spacing in regions of maximum potential gradient lying about and above the periphery of the tank top and between the tank top and an elevated charged atmospheric stratum.

4. The combination with a tank for inflammable fluids exposed to meteorological electrical influences and having a dielectric layer superimposed upon its top of a system of earthed conductors extending beyond the periphery of the tank and spaced from each other and from the top portion of the tank by erect earthed conductors, said conductors being principally concentrated in the regions of maximum potential gradient between the tank top and an elevated charged atmospheric stratum.

5. The combination with a tank for inflammable fluids exposed to meteorological electrical influences and having an insulating layer above a portion of its extent constituting a dielectric separating outer and inner surfaces, of means for dissipating induced static charges held by mutual attraction at opposite sides of said dielectric comprising a system of earthed conductors spaced by an air-gap from the exterior of the insulating layer.

6. The combination with a tank for inflammable fluids having a vapor and heat insulating top exposed to meteorological electrical influences of an interconnected system of conductors spaced from each other and from the top portion of the tank and comprising a series of erect supporting and conducting members in earthed contact with metallic side walls of the said tank, one or more peripheral conductors connecting said erect members and encircling the region of the eaves of the tank, and a series of conductors extending from the region of the center of the top of the tank to one of said peripheral conductors and supported above the tank top at a distance greater than their mean separation apart.

7. The combination with a tank for inflammable fluids exposed to meteorological electrical influences and having an insulating layer above a portion of its extent constituting a dielectric separating outer and inner surfaces, of means for dissipating induced static charges held by mutual attraction at opposite sides of said dielectric comprising a system of earthed conductors spaced by an air-gap from the exterior of the insulating layer, at a distance at which the air-gap dielectric resistance is not constantly greater at times of atmospheric electric disturbance than the dielectric resistance of the said insulating layer.

8. The combination with a metallic storage tank, and a roof therefor having low electrical conductivity, of a protective system comprising conductors overlying said tank and supporting means therefor including supporting elements projecting beyond and above the periphery of said tank and means for holding the supporting elements in position including flexible members holding their lower ends in mechanical and electrical contact with the walls of said tank below said roof.

9. The combination with a metallic storage tank, and a roof therefor having low electrical conductivity, of a protective sys-

tem comprising a series of connected conductors overlying said tank, and supporting means therefor including a plurality of erect conductive elements projecting upwardly and outwardly from the walls of said tank, and holding means therefor including a plurality of tension elements adapted to hold the said erect conductors in mechanical and electrical contact with the tank walls at a point well below the eaves.

Signed by me at St. Louis, Missouri, this fifteenth day of May 1925.

LESLIE A. BALDWIN.

Signed by me at Boston, Massachusetts, this 22nd day of May, 1925.

ELMER R. SCHAEFFER.