July 4, 1933. E. R. SCHAEFFER 1,916,335

SYSTEM FOR PREVENTING ELECTRICAL IGNITION OF RESERVOIR STORED INFLAMMABLES

Filed Jan. 17, 1927 3 Sheets-Sheet 1

Fig.1

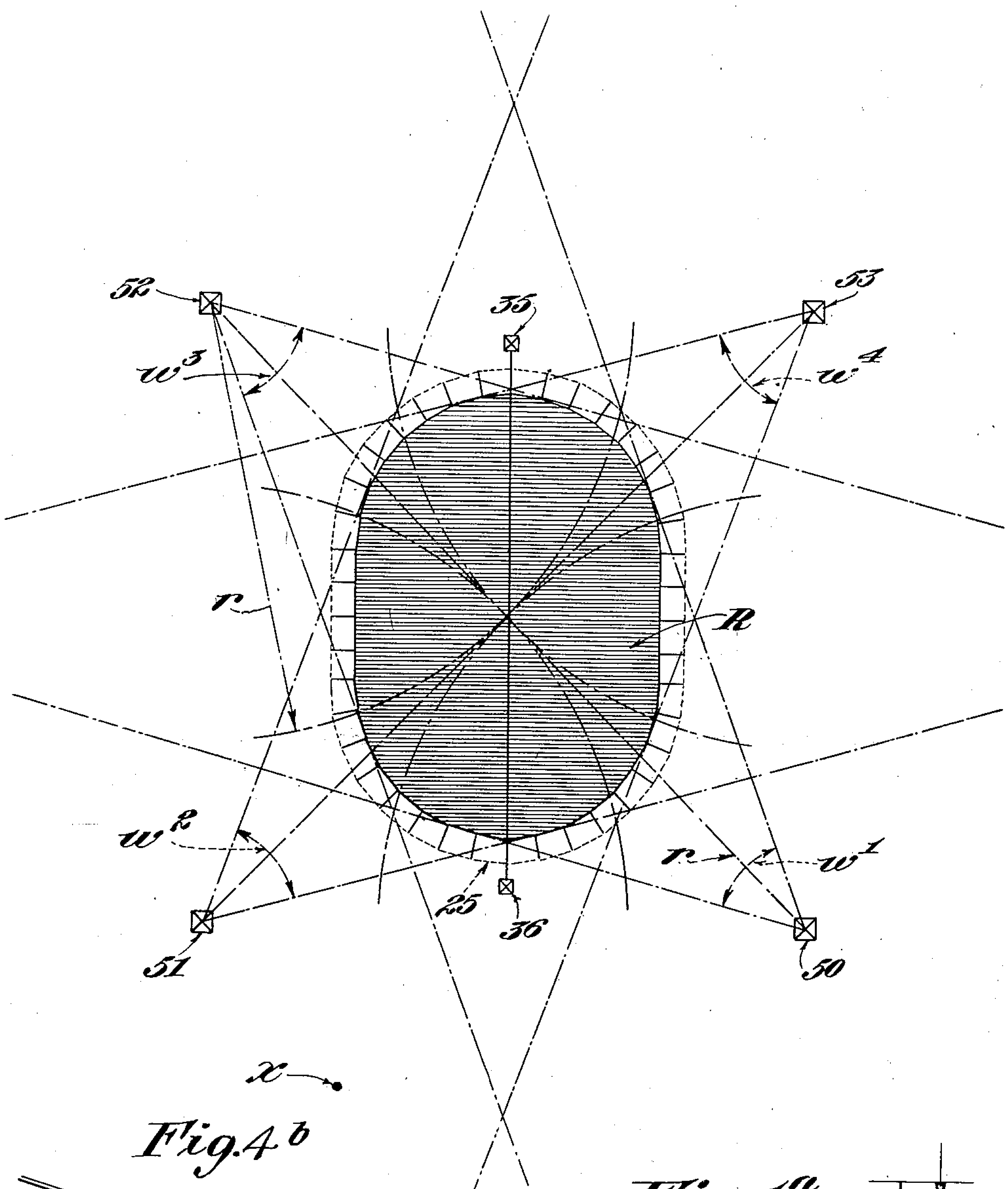


Fig.4b

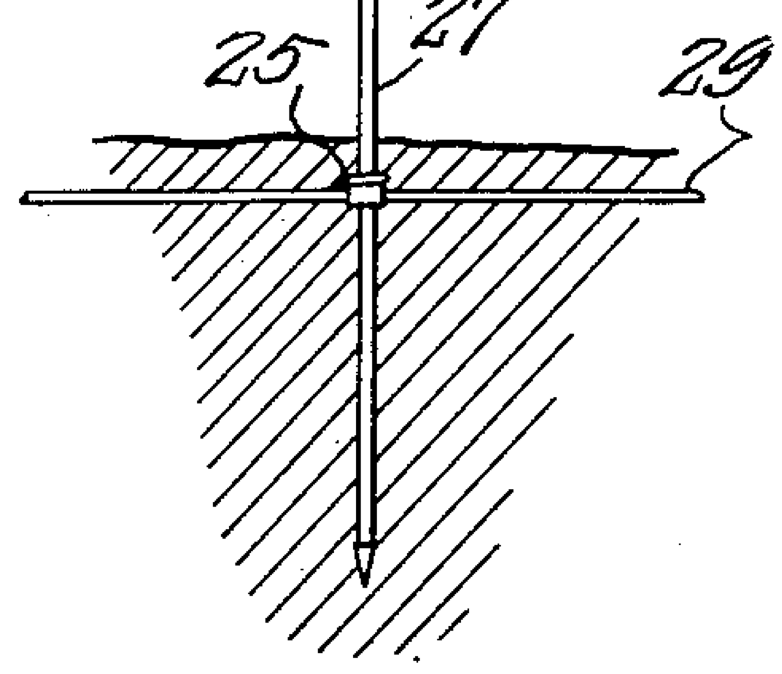
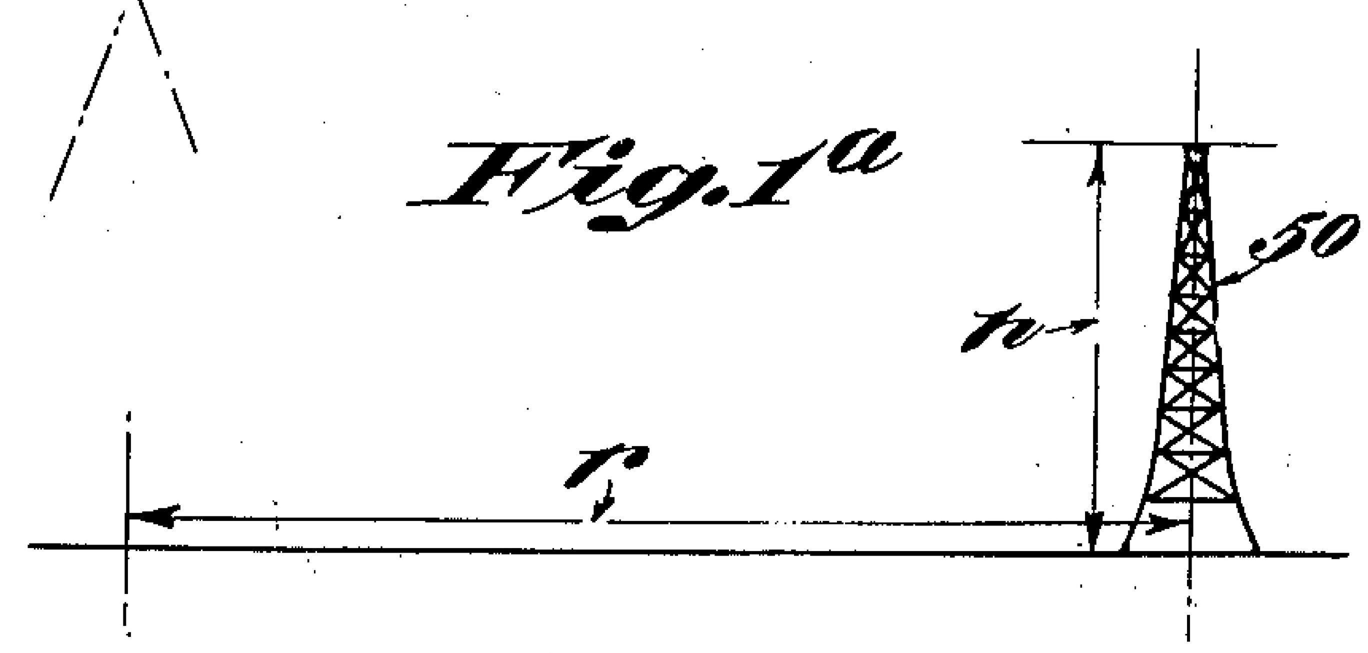


Fig.1a



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SYSTEM FOR PREVENTING ELECTRICAL IGNITION OF RESERVOIR STORED INFLAMMABLES

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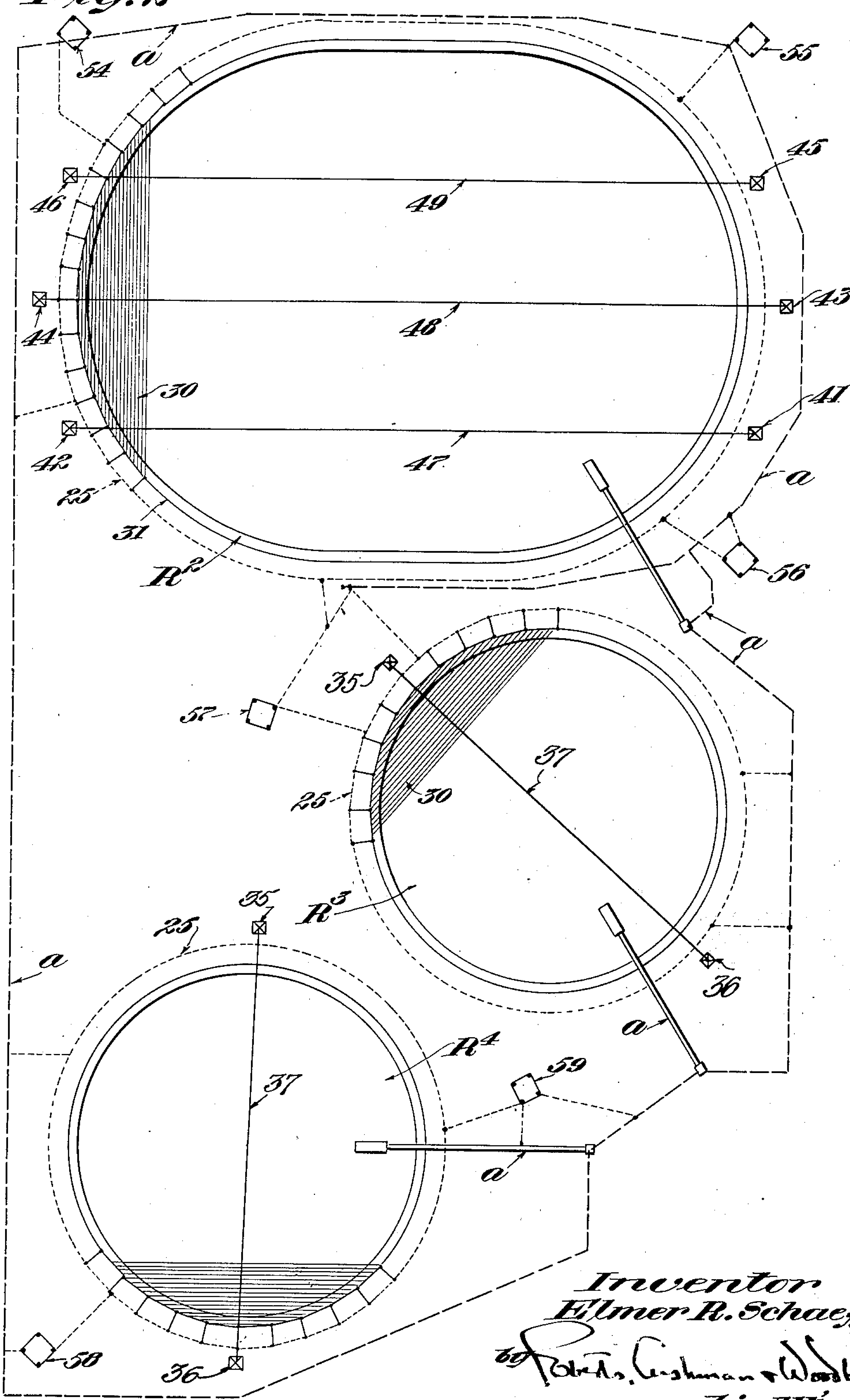
Fig. 2



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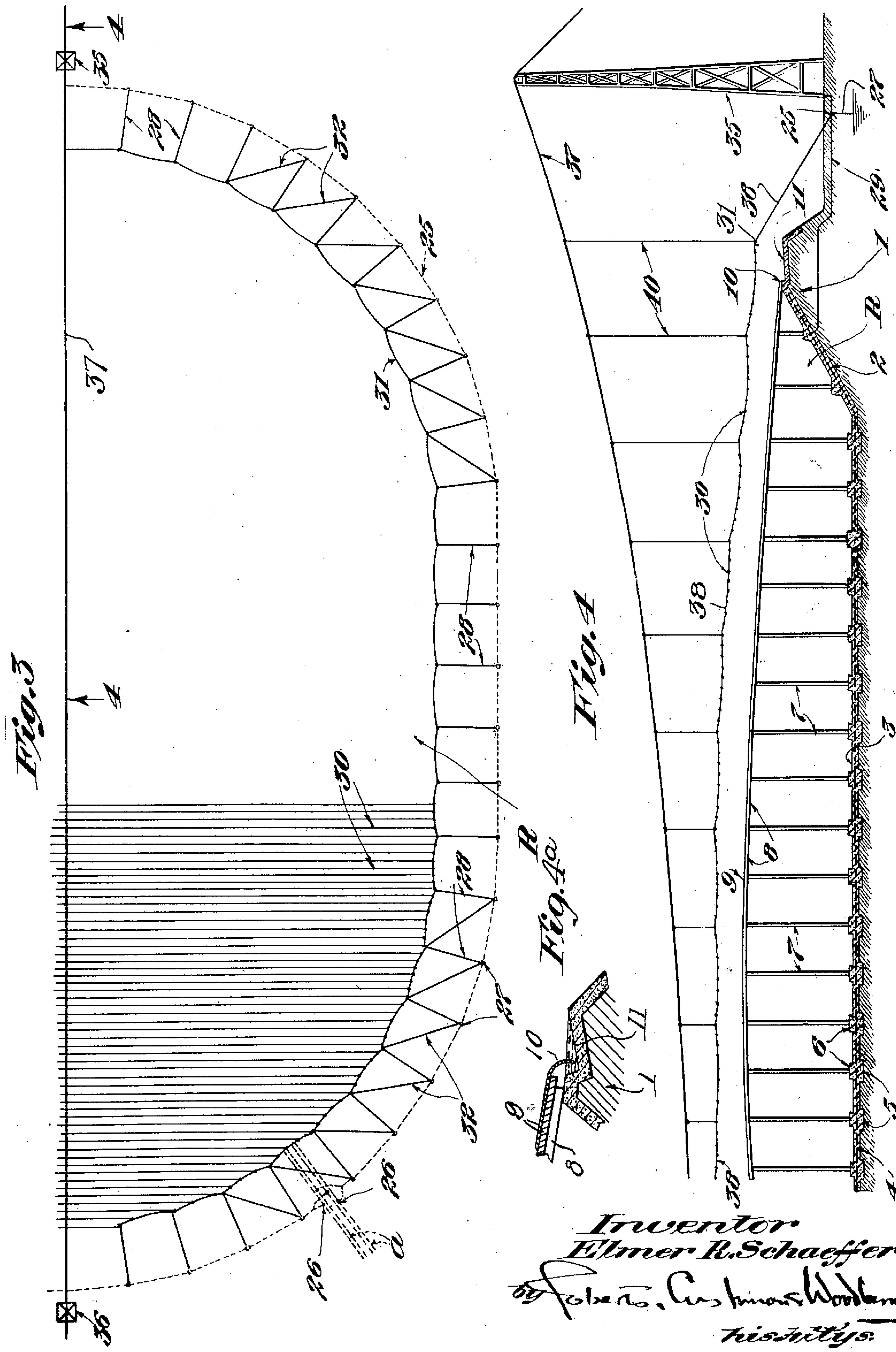
Filed Jan. 17, 1927 3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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SYSTEM FOR PREVENTING ELECTRICAL IGNITION OF RESERVOIR STORED INFLAMMABLES

Application filed January 17, 1927. Serial No. 161,623.

This invention is concerned with the prevention of fire and explosion risks from electrical ignition of stored inflammables such as crude oil or petroleum products.

The great rate of production of petroleum in active oil fields has necessitated the use of storage structures or containers which may be pools or reservoirs partly excavated or surrounded by earth embankments. These storage structures are sometimes very large, of the order of 500 to 600 feet in diameter if circular, and of greater major length if oval. Naturally these reservoirs are placed where the surface contour enables the retaining embankment to be constructed of earth excavated for the pool or basin proper. Prevention of evaporation losses dictates a roof or cover of some kind for these great pools of oil.

Experience has shown that these reservoirs are almost as vulnerable to risk from fire by electrical ignition as the above ground metallic-wall oil tanks, which are notoriously prone to fire from this cause.

One object of this invention is to provide a system of protection adapted to minimize the risk of occurrence of an inflaming electrical spark in the vapor spaces above the oil and beneath the roof or cover of the storage container or around the eaves of the roof or cover.

It will be understood that the risks from atmospheric electrical phenomena are not confined to actual lightning strokes on the reservoirs or their roofs. Most of the fires which have destroyed great quantities of oil stored in these reservoirs have occurred during lightning storm conditions, it is true, but in nearly all cases the actual ignition could not be traced to lightning bolts striking at or near the pool or reservoir destroyed. Lightning discharges as far away as a mile or several hundred yards have generally been coincident with the appearance of fire at the pool. When this specification mentions lightning or atmospheric electrical phenomena of the sort dangerous to inflammables, it will therefore be understood that conditions other than direct strokes of lightning are included in the class of phenomena referred to.

In the accompanying drawings, the invention is shown by way of example as applied to the protection of an oil storage container of the earth reservoir type as illustrative of some of the forms in which the invention may be expressed.

Fig. 1 is a plan view of a large reservoir and the surrounding territory, serving in the nature of an explanatory diagram of the effect of and reason for certain preventive electical devices;

Fig. 1[a] is a corresponding detail elevation;

Fig. 2 is a similar plan illustrating a multiple group of three reservoirs and an arrangement of protective devices for these reservoirs;

Fig. 3 is a fragmentary enlarged plan of an oval reservoir showing on a larger scale parts of the protective devices;

Fig. 4 is a corresponding vertical section on a still larger scale, **for example on the** line 4—4 of Fig. 3 and

Fig. 4[a] is an enlarged detail of devices shown in Fig. 4;

Fig. 4[b] is an enlarged detail of certain anchorage and grounding posts shown in Fig. 4.

Referring now to Fig. 4, a good and usual construction of one of these reservoirs or pools, typical of many now in existence, comprises a surrounding embankment at 1 having interior slopes 2 defining a level bottom 3, the slopes 2 and bottom 3 having a masonry lining, usually of reinforced concrete, serving as an oil-proof container to hold the pool of oil. The reinforcement may be for example a 6 in. x 6 in. wire or bar welded mesh 4 laid continuously through the sheet masonry 2 and 3; for strength, rigidity and economy of materials the wide sheets of concrete may be reinforced at intervals as by integral ribs at 5; there may be series of these crossing each other, for example, at right angles. The intersections at 5 may be provided with elevated bases 6, 6 for a system of vertical struts 7 adapted to support the usually wooden rafters 8 of a roof 9. The roof 9 usually comprises planking covered with tin or saturated felt, or asbestos, or some other prepared roofing.

The roof 9 may end in eaves or eaves attachments at 10 dipping into a surrounding water gutter trough at 11 for a more or less effective vapor seal.

Referring now to Fig. 2, such reservoirs are naturally and necessarily the terminal points of considerable systems of metallic piping. These pipe systems may carry water for drainage from the roof structure; they may be provided for fire extinguishing purposes; they may comprise the inlet and outlet pipes for filling and emptying the reservoirs. Such a piping system for reservoirs R^2, R^3, R^4 is indicated generally at *a* in Fig. 2. For the purposes of the present description, what these pipes serve to carry is of no importance; they are an inevitable accompaniment of the reservoirs or tanks, and in the present aspect they constitute a system of electrical conductors in haphazard directions terminating at the pools or reservoirs and, so far as they there find and are connected purposely or incidentally to conducting structures in or about the metallic reinforcements of the concrete, the water gutters at 11 or the roof at 9 of the typical structure shown in Fig. 4, they are conductors ending in a large area having high electrostatic capacity. It is true that in thoroughly wet weather the pipe lines leading to such a tank or reservoir are relatively well-grounded throughout their length to earth, and there is then no preferential area for the development of high-potential electric charges, for example on the roof of a reservoir at the end of a pipe system 1, but it is a commonplace that tanks or reservoirs of the kind here in question are in most instances in arid or semi-arid regions, where the moisture content of the ground is always relatively low and sometimes practically nonexistent. When the earth is dry, it will be observed that the reservoirs are termini of electrical conductive systems along the pipes leading to them, and are almost ideally adapted to receive the high terminal potentials of charge resulting from electrical surges along the pipes. Whether or not the reservoir roof is the terminus of a surge, difference of potential from one part to another part of the roof or between the roof and the surrounding earth may readily develop from other causes operative whether the earth is dry or wet.

Referring for example to Fig. 1, let us suppose that thunder-storm conditions prevail. In that case a highly charged cloud may pass above the country shown in diagram in Fig. 1, and that point of this cloud which is nearest the earth in an electrical sense, and therefore adapted to become the taking-off spot of a lightning bolt, will travel in respect to the surface illustrated in the figure and may occupy any point on it. Suppose, for example, this discharge point of the overhead cloud is over the point x on Fig. 1. A coordinate result of this condition will be that the equivalent and opposite electrical potential of the earth surface will increase at point x, about to become or possibly to become the terminus of the electrical discharge from earth to cloud, or cloud to earth. Since it is clear that the point x is not at rest so far as motion in the plane of the earth's surface is concerned, in the instance given the point x will be any place of highest potential of the earth in respect to the cloud, and this potential will be attained and maintained to lightning stroke rupture by an electrical flux relative to the point x to or from all directions on the earth's surface. The surface fluxes on the earth are of course complicated by proper motion of the point x as the cloud moves. If the conductivity of the earth's surface may be assumed to be uniform except as it is interrupted by the structures in and about the reservoir R, it may be observed that whatever the position of the point x or whatever its wanderings, there will be electrical flux across the structures in and about the reservoir R and therefore there will be lateral difference of potential due to the flow toward or away from the point x. Assume now that there is disruptive discharge of a lightning stroke to and at the point x; equilibrium of the surface charge of the earth ensues for the moment, but only after an opposite flux across the reservoir R, the flow radiating away from the point x.

The flux on the surface of the earth during a thunder storm is far from a negligible factor in the case of such large structures as the reservoirs above mentioned, and I attribute to such fluxes the destruction of several such reservoirs. At the entirely reasonable figures of 100,000,000 volts for the potential from cloud to earth and a maximum current on lightning discharge of 100,000 amperes, the flow interrupted by the tank protecting structures as shown in Fig. 1 for a discharge relatively to the point x is amply sufficient to account for serious sparking between metal or wet parts of the roof, about the eaves of the roof, between elements of the concrete reinforcement, and especially between any pipe connections or conductor connections to points near the roof of the tank at distances of the point x measureable in miles.

This invention provides for deviating the potential differences which might result in sparking in or about the roof, roof supports, eaves, from one part of the roof to another part of the roof, or from one part of the reinforcements or water layer on the roof or the retaining embankment to another part, on the occasion of either an induced surge in the conductor leading to the reservoir or on the occasion of a lightning stroke. The structures mainly depended upon for these provisions are recommended to comprise a conductor system adapted at the same time to provide a shunt path for surface flows on the surrounding surface of the earth excluding the reservoir roof, and to provide a surge terminus for the pipe-line conductive system and other electrical conductors, if any, not in itself in fire-risk proximity to the oil in the reservoir or the vapors above the oil.

As a part of such a system of conductors a well grounded surrounding or ring conductor, everywhere spaced from the eaves of the roof of the reservoir, may in some cases be wholly relied upon, but in view of the large quantities of surges adapted to flow in the necessary metallic or other conductor systems terminating in the tank roof and for other reasons it is preferred to supplement this ring conductor by an overhead network or grid. There is thus secured the advantage of elevating away from the tank roof the equipotential surface corresponding to the surface of the earth, so that in an electrical sense the reservoir roof and the oil in the reservoir may be regarded as having been placed underground, provision also having been made of an artificial low resistance shunt for earth-surface fluxes quite harmless in respect to producing sparks in vapor bearing spaces in and near the reservoir.

I have jointly with Leslie A. Baldwin in my application for Letters Patent, No. 32,738, filed May 25, 1925, Patent No. 1,617,788, dated February 15, 1927, described and claimed a system of spaced earthed conductors spaced away from the upper surface of an insulating tank roof and concentrated by closer spacing at the regions of maximum potential gradient between the tank top and an elevated charged atmospheric stratum, which system has been found effective for the protection of the tank from direct lightning strokes and for the harmless discharge of accumulated charges of atmospheric electricity; a species of this device is perfectly suitable for the purposes above mentioned.

For example, as best shown in Figs. 3 and 4, the entire reservoir may be surrounded by a ring conductor 25 thoroughly grounded as at 26, 26 to any entering pipes, and expediently elsewhere earthed, by driven metal posts, for example, everywhere about the reservoir as indicated at 27, preferably connected to the concrete reinforcement 4 (units of which may be bonded together electrically) as at 29; and this conductor 25 may be systematically connected by radial conductors 28 to an overhead grid or network 30 suspended at a substantially uniform distance everywhere above the roof 9 of the reservoir. Preferably the ring conductor 25 is supplemented by an elevated marginal conductor 31 extending around the reservoir somewhat outside of and above its eaves. The radial conductors 28 may be supplemented, if desired, by conducting guy wires 32, 32 serving electrically and mechanically to connect the ring conductor 25 at posts 27 with the marginal conductor 31. The network 30 may comprise a series of parallel wires stretched across the space enclosed by the conductor 31, and not further apart than the minimum distance of the wires from the roof 9. The conductor 25 may be on the surface of the earth or buried in a shallow trench. While any expedient may be resorted to for supporting the network 30 in the desired relation to the roof 9, a preferred expedient as shown in Figs. 3 and 4 is to provide stout poles or metallic towers 35, 36 at either end of the major axis of the oval reservoir shown in these figures and to suspend from tower to tower a cable 37 in turn supporting a transverse cable or wire 38, the cable 37 having at intervals suspender wires 40 to support the wire 38 in a position substantially parallel with the major diameter of the reservoir roof. It will be understood that the suspenders 40 vary in length with their position and the catenary swept by the cable 37.

The network for the reservoirs may be supported by as many towers and suspension cables as are necessary. Thus in Fig. 2, the support for the network for the reservoir R^2 comprises six towers designated respectively 41, 42, 43, 44, 45 and 46, and three supporting cables 47, 48 and 49, while the supports for the network for the reservoirs R^3 and R^4 comprise the towers 35, 36 and the cables 37 previously described. It will be understood that the parallel wires of the network 30 are in any case recommended to be employed throughout the space within the marginal conductor 31 and within the surrounding ring conductor 25. As shown the towers supporting the suspender cables are preferably connected to the ring conductors 25, whatever the form of the construction.

In addition to the means for suspending the conducting network over the roof of the reservoir for the purpose above mentioned of providing both an elevated conducting path and means for elevating the equipotential plane of the earth's surface above the roof of the reservoir, it is desirable also to provide a structure to control so far as possible the places of culminating potential of the earth's surface in relation to the reservoir or reservoirs and the conductive systems of pipes or wires. One form of such structure comprises erect receiving conductors located in proper relation to the region in which the reservoirs are placed to induce lightning stroke discharge at the places of said conductors. For example, conducting metallic towers 50, 51, 52, 53, Fig. 1, may be placed in such relation to the reservoir R as to induce the expectation that potential rises will culminate upon them and that a lightning stroke will be received by one or the other of these towers rather than directly by the conductive network over the reservoir or a part of the reservoir itself. These towers may be at least of such a height h and such a distance r from the center of the figure of the reservoir R that the assumption that the erect conductor will receive the discharge is valid; in which case, on the assumption that a tower of a particular height protects from stroke a circle whose radius is a definite multiple of the height of the tower, these protected circles will meet or overlap at the center of the reservoir. In general the placing of the towers 50, 51, 52, 53 is recommended to be such as to embrace an angular magnitude of the reservoir R from the tower as a center defining an acute angle such as w^1, w^2, w^3, w^4 of Fig. 1. In respect to surface flux to any of the lightning towers, the territory embraced in one of these angles defines that part of the earth's surface from and to which flux to that tower would embrace and include the reservoir, if the earth's charge were uniformly distributed and the surface homogeneously conductive.

Referring now to Fig. 2, it will be observed that when the reservoirs are crowded together as in the actual instance of practice shown in this figure, stroke receiving towers may be distributed according to the principles above explained in relation to the supply pipe network, the ring conductors 25 surrounding the reservoirs, and the remainder of the conductive network, in such a way as to utilize the service piping and the protective network as shunt flow paths for surges to any one of the towers 54, 55, 56, 57, 58 and 59 from the angular area or areas to the tower as a center subtended by one or more of the reservoirs.

In all cases, the lightning stroke receiving towers are recommended to be thoroughly connected by conductors of relatively low resistance to the piping network a and to adjacent points on the ring conductors 25.

In operation, when high potential differences occur between an elevated stratum and the earth in the neighborhood of a reservoir or reservoirs, it may be assumed that fluxes of the earth's charge in relation to the reservoirs and the respective lightning towers 50 to 59 occur radially in respect to some one of these towers, or to one or more of them in succession. So much of this flow as is intercepted by the position of a reservoir is now taken by the conductor system 25, 30; a negligible proportion of these currents, whether principally a flow in dry weather on the service pipe system or on wet earth after rain, is borne by the roof or other dangerously-close attachment of the reservoir. In the case of surges of such terrestrial currents, the termini of conduction paths for the surges are no longer at the reservoir roof, pipe ends or reservoir walls, but on the network 30 or one or more of the lightning towers 50 to 59. In the case of a lightning discharge, secondary surges in the conduction system are thus shunted away from the gaps between conductors at or near the inflammable vapors.

The effect of the network 30, as more thoroughly explained in said Baldwin and Schaeffer patent, is moreover beneficially exercised to reduce the building up of surface charges on exterior or interior surfaces of the reservoir roof and to lift the equipotential surface corresponding to the potential of the earth's surface away from coincidence with the reservoir roof in respect to any probability of rupture of the dielectric by a direct stroke to the roof or walls of the reservoir instead of to the conduction network, at one of the towers 50 to 59.

I claim:

1. The combination of a structure with a series of other structures, each of the latter in the form of a lightning rod constructed independently of the first structure, each rod spaced from the first structure and extending to a height towering a substantial distance above the first structure to protect the latter against a direct lightning stroke, and a metallic shield for the structure independent of the rods for shielding said first structure against the inductive effect of a lightning discharge and thereby preventing a discharge between two adjacent points in the first structure.

2. Apparatus for protecting the contents of a container of inflammable fluid from atmospheric electrical ignition comprising erect earthed conductors spaced from the container a sufficient distance to insure against side flashes from said conductors to the container, the height of each of said conductors bearing such relation to its distance from the center of figure in plan of said container, as to include said center of figure in the area protected from lightning discharge by preferential path through said erect conductor, the areas so protected by each erect conductor overlapping each other and together covering the whole area of said container to protect the latter against a direct lightning stroke, and a grounded conductor system independent of said erect conductors and exterior to and surrounding the upper part at least of the container for shielding its contents against the inductive effect of a lightning discharge, thereby to prevent a discharge between adjacent points in the container.

3. The combination of a structure with a series of other structures each of the latter in the form of a lightning rod constructed independently of the first structure, each

rod spaced from the first structure and extending to a height towering a substantial distance above the first structure to protect the latter against a direct lightning stroke, and a metallic shield for the structure independent of the rods for shielding said first structure against the inductive effect of a lightning discharge and thereby preventing a discharge between adjacent points in the first structure, the rods being spaced from the structure a distance sufficient to insure against side flashes from the rods to the first structure.

4. The combination of a structure with a series of other structures, each of the latter in the form of a lightning rod constructed independently of the first structure, each rod spaced from the first structure and extending to a height towering a substantial distance above the first structure to protect the latter against a direct lightning stroke, and a metallic shield for the structure independent of the rods for shielding said first structure against the inductive effect of a lightning discharge and thereby preventing a discharge between adjacent points in the first structure, the rods being spaced from the structure a distance sufficient to insure against side flashes from the rods to the first structure, said distance being not less than one half the height of the pole.

5. Apparatus for protecting the contents of a container of inflammable fluid from atmospheric electrical ignition comprising erect earthed towers spaced from the container a sufficient distance to insure against side flashes from said towers to the container, the area protected by each tower being a circle the radius of which is a definite multiple of the height of the tower, and said towers being so located with respect to the container that the distance to each tower from the center of the container is less than said radius and thereby the whole area of the container is covered by said areas protected by the towers, and a grounded conductor system independent of said towers and exterior to and surrounding said container for shielding its contents against the inductive effect of a lightning discharge, thereby to prevent a discharge between adjacent points in the container.

6. Apparatus for protecting the contents of a container of inflammable fluid from atmospheric electrical ignition comprising a ring conductor surrounding and exterior to the container and connected in every direction to the earth, an elevated marginal conductor connected at frequent intervals to said ring conductor, a wire grid above and spaced from the roof connected across the enclosure of said marginal conductor and lightning towers outlying in respect to said marginal conductor having relatively low resistance conductive conections to said ring conductor.

Signed by me at Boston, Massachusetts, this 14th day of January, 1927.

ELMER R. SCHAEFFER.