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CONTRIBUTION TO THE TECHNIQUE OF LANDING LARGE AIRSHIPS

By O. Krell

PART II

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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By O. Krell.

PART II.*

The development of the mooring mast in England and America has come to be of great importance for airship traffic, and this is the best proof that the German patent examiner was wrong in denying this idea the protection of a patent. The Siemens-Schuckert airship was well adapted for mooring to a mast, in that it was the first airship to be provided with a bow-mooring attachment (Figure 58). Two braided cotton mooring lines, several hundred meters long, were divided three times into two strands and the ends of these strands were attached to a circular patch on the bow of the airship, the resistance to tear of this patch being as great as the combined strength of the two mooring lines. The doubts in some quarters regarding the strength of this "tailoring" led the Siemens-Schuckert Works to make very strenuous and daring tests which, however, were so much the more assuring to the constructors.

Realizing that the most unfavorable stresses could be produced by the freeing of kinetic energy, the ends of the two

*"Ein Beitrag zur Landetechnik grosser Luftschiffe," from Zeitschrift für Flugtechnik und Motorluftschiffahrt, Sept. 28, 1928, pp. 421-438. (For translation of Part I, see N.A.C.A. Technical Memorandum No. 512.)

mooring lines were fastened inside the shed and the ropes left as slack as possible and then the airship started backward, so that the inertia of the airship, weighing about 15 tons, would produce a certain stress on the mooring lines. A test was made with the anchoring point near the airship, to see if the bow mooring would hold against an oblique pull (Figure 59).

Had it not been for the opposition of the patent examiner in Germany to the idea of the mooring mast, perhaps, even during the war, there might have been some such development as that which has later taken place in England and America. Perhaps, however, some such experiment would have been made as the one shown in Figure 60, which is incorrectly ascribed to the Americans in a Swiss publication. The picture bears the inscription, "How the Americans Protect Their Airships against Storms," and illustrates nearly every mistake that could be made in this simple matter. Instead of the shortest possible mooring line (to nip every formation of kinetic energy in the bud), the bow is secured by a long rope, apparently in remembrance of the practice of paying out long anchor chains from surface vessels in order to let the anchor grip securely and to allow for the absolutely necessary movements of the airship with the motion of the water. The vertical anchorage of the airship by two heavy groups of sandbags would undoubtedly result in snapping the lines if they were suddenly stressed by a vertical upward movement of the airship. In short, it is again the lack of appre-

citation of kinetic energy that speaks from every detail of this picture.

The fundamental requirements for a mooring mast are:

(1) Sufficient height to prevent the airship from touching anything on the ground (as a result of vertical movement); (2) A very short and unyielding attachment at the bow, to prevent the development of kinetic energy; (3) Entire freedom of the airship in its horizontal and rolling movements, so that the yielding of the airship to every stress may be obstructed as little as possible.

The type of mast erected at Pulham, a simple pole with guy wires, does not satisfy these requirements, because this type of mast would certainly have a certain amount of elastic yielding, which would lead to oscillatory increases in the load on the mooring point. In contrast with this mast the enormous structure at Cardington, with its great rigidity, is entirely satisfactory. It is not improbable that this seemingly excessive rigidity is a result of the unfavorable experience with the guyed mast at Pulham. Figures 61 and 62 show the small mast at Pulham and the big mast at Cardington in their correct relative sizes. Figure 63 shows the R.101 on the mast at Cardington and a comparison of its size with that of the R.33. It is obvious that a special method must be invented and developed for mooring an airship to a mast without injury to the former. The most important requirements are that the airship should not take on/ yawing motions. Figure

64 shows the guy lines running to the left and right to prevent this, as well as the main mooring line from the bow of the airship to the tip of the mooring mast. The excellent photograph (Figure 65) shows the LOS ANGELES at the Ford mooring mast in Detroit. Figure 66 shows the LOS ANGELES at the mooring mast of the PATOKA. Here the guy wires, leading to the ends of the yaw booms, prevent the yawing of the airship while it is being moored to the mast.

Figure 67 better illustrates the maneuver of mooring to the PATOKA. In particular, it shows the lines running from the airship to the ends of the yaw booms. The discovery was soon made that the mast mooring exerts enormous stresses on the bow of the airship, so that several airships have torn away from the mast. The most noteworthy incident of this nature was the breaking away of the R-33. However, after a stormy flight, it reached its harbor safely again. Figure 68 shows the attaching of the repaired bow to the airship. This picture also shows the mooring spindle on the airship's bow and how it is connected to the latticed girders. The picture of the return of the R-33 from its stormy flight (Figure 69), which appeared in all the newspapers at the time, is given here again, because it shows how the handling lines are manned. The long lines of men on the single handling lines would be of absolutely no use in an emergency for, if the airship were suddenly lifted by a gust, they would be compelled to let go of the rope, one after the

other, in order not to be carried up with it. The branched handling lines are much better, but there should be more of them and they should have more branches, as they do on German airships.

Since the above-mentioned breakaway of the R-33, the question of the safe mooring of airships to masts, so that there can be no danger of their breaking away under any circumstances, has occupied the minds of many constructors. This is apparent from the many English and American patents that have been taken out on such inventions.

Naturally, an effort was made to reduce the enormous local load on the mooring point by introducing some elastic device, usually in the form of springs. However, one cannot be too strongly warned against the use of springs in this manner, since, when under load, they always represent stored-up energy which, when released, can produce very undesirable accelerations. The most complicated devices in the form of caps for shielding the bow have also been proposed, as well as apparatus to turn the course of the wind into line with the axis of the airship, in order to stabilize its position at the mast.

It has even been proposed to make the mooring so that, in a wind of given force, the airship would be automatically released. This proposal is based on the assumption that, in a storm, an airship would be safest in its own element, the air. This indicates an incomprehensible and lamentable lack of understanding of the technique of handling airships and strengthens

the impression already existing that the crew of an airship moored to a mast must have their nerves weakened, instead of being able to rest. The demoralizing effect of being moored to a mast on the nerves of the crew of Nobile's ship could be seen, even though they did not have to face the continual possibility of the automatic functioning of a releasing device.

It seems to me that the correct diagnosis of the problem has not yet been made, and I am convinced that there are technical means for safely preventing a breakaway, excepting in the case of a veritable whirlwind or tornado, which neither tower, airship nor shed could withstand.

The above-mentioned strength tests of the bow mooring of the Siemens-Schuckert airship warrant the conclusion that this airship, with this type of mooring, could have weathered a storm at the mooring mast. Its great safety lay in the fact that the forces concentrated in the mooring lines were not only distributed very evenly over the circular patch by the branches of the two mooring lines, but also especially in the fact that the plastic yielding of the three-ply balloon fabric provided a further even distribution of the pull over the whole envelope. Here the nonrigid rather than the rigid airship has the advantage. Apparently the constructors of rigid airships have not yet been able to bring themselves to the adoption of the envelope mooring, or else they have not learned of the experiments made by Siemens-Schuckert with this type of mooring. Even if

the bow-mooring load is distributed by numerous wires or cables to attachment fittings on a rigid airship, on account of the hard elasticity of the steel, the same automatic and uniform distribution of the load cannot be obtained as on the nonrigid airship through the envelope fabric.

I would be glad to have my idea for a bow mooring (Figure 70) tried out on a rigid airship, as I myself am firmly convinced of its practicability. The figure shows the mooring eye, g, secured to the metal bow cap C, which is only laid on the airship frame and not fastened to it. The fabric ring B, is fastened to the bow cap at the points d, by means of the eyelets O, shown more plainly in the catenary band at the right. In this catenary band steel wires distribute the concentrated forces on the eyelets evenly to the fabric ring B. The bow cap must be large enough so that, when it is forced sidewise, it cannot lift away from its supports. The other edge of the fabric ring has another catenary band. The row of eyelets is fastened to the points k by means of short coil springs of hard wire f. This second catenary band may be carried aft on the airship's hull until the load is sufficiently small on each attachment point. My great faith in this fabric ring attachment of the mooring eye will be understood when one remembers the hard landing of the Siemens-Schuckert airship (Figure 22) and the unexpectedly favorable experience with the strength of ordinary balloon fabric. By this mooring, bending loads in any

part of the frame are prevented.

In spite of the low cost of mooring masts as compared with sheds, it is not always possible to erect them in every locality in which the temporary stay of an airship is expected, and consequently other/^{cheap} methods of mooring have been devised, which would also answer the purpose in an emergency. Since, however, the main object is always to provide the airship with a more or less stationary point in the air, a simple mooring cable, with which one would have to count on a yawing of the airship in the wind, would not suffice even for temporary moorings. For such purposes the so-called "three-point mooring" has often been used, which consists in mooring the airship, with sufficient excess buoyancy, on at least three cables. Great care must be taken that none of the cables can become slack, so that there will be no danger of breaking the cable or damaging the airship as a result of surging.

With the increasing size of rigid airships, the fear of bringing them into dangerous contact with hard objects on the ground is only too well founded. For this reason Count Zeppelin was the first to use a water surface for alighting. The natural result of this situation was the floating shed. How little the great advantages of this method of landing were realized at the time, is shown by the fact that it was still thought that, after landing for servicing, the airship must be secured to a float to bring it into the airship shed, which was not allowed to swing

in the direction of the wind, but anchored at both ends to prevent it from turning. Today it is hard to understand why no one at that time thought of turning the floating shed in the direction of the wind. At one time there was even danger that, because of heavy cross winds, the pontoons on the lee side of the shed would fill with water - a thing which could never happen with a shed that turned automatically in the direction of the wind. Figure 71 shows the first Zeppelin airship on the float, ready to enter the floating shed.

Although Count Zeppelin's idea of using the surface of Lake Constance to assure his first extremely fragile airships a soft landing place, was an ingenious one, it was not realized at that time that even water can become a hard, unyielding body if struck at sufficient speed. Landing on water could also give rise to undesirably large forces, since the cars had been given shapes too much like that of an ordinary boat and the displacement increased too rapidly as the car was immersed. In one of the first Zeppelin flights the two forward gas cells were accidentally deflated, so that the very nose-heavy airship descended rapidly, and the impact of the forward car on the water was so violent that the struts of the car were broken, and its occupants saved themselves from injury by the descending hull of the airship only by lying on the floor of the car.

In order to assure a gradual increase in the displacement by the parts of the airship which strike the water first, these

must be wedge-shaped, water-tight bodies, as shown at the left in Figure 72. On the depth a of this wedge or keel, as compared with the width of the car, depends the lightness of the impact which the displacement of the water makes on the airship. Therefore, it is not correct to give these cars the form of ordinary boats in which the full force of the impact on the water would develop during the short distance b (Figure 72, right). In fact, our fastest ships, which plow the ocean with the speed of the wind, have no keel at all in their midship section (Figure 72, c). To replace the "landing keel" a by a boat form would be a great mistake. A boat must have carrying capacity and great stability. The sharp keel reduces the carrying capacity, and its stability is meaningless, because it could take effect only while rigidly attached to the structure of the airship. We have in the history of airship construction one case in which the car was given the form of a regular sea-going motor-boat, on the airship SUCHARD (Figure 74). In case of necessity, it was intended that the envelope should be freed from the car and the voyage be continued by water. The deep keel shown in the picture serves only the purpose of a protecting skeg for the water propeller, and therefore has the form of a simple rectangle and not that of a wedge. This deep keel might have been very dangerous, however, if the car had had to be detached during oblique flight of the airship. The dropping test pictured in Figure 73 shows very clearly, by the manner in which the displacement waves

have broken into foam, how hard the impact on the water was. In any boat for which stability and seaworthiness are required, this impact with the water cannot be other than hard. A properly constructed landing keel, if separated from the airship structure and dropped like the the Suchard boat, would immediately capsize.

The operation of the landing keel can best be illustrated by imagining an airship of early Zeppelin type as floating with the usual cars. Should the sea become rough, the airship would be broken up, because the cars, like boats, would rise and fall with the waves. If, however, the airship should rest on floats having deep wedge-shaped keels, the waves would run along the floats and exert only very slight forces on the airship. That is the important difference between a boat and a landing keel.

When at rest and the dynamic forces do not have to be taken into consideration, the displacement of a few gallons of water is sufficient to make the airship float. Indeed, the displacement of the bottom of the bumping bag intended only to ease the shock of landing on the ground, may be quite sufficient to balance the airship which the lift of the gas has deprived of most of its weight but none of its mass.

The inconvenience of such a deep keel must be taken into the bargain, if one wishes assurance of an easy landing on the water, and the importance of the safety of expensive airships is certainly great enough to warrant putting up with necessary

inconveniences. Only because I ascribe future practical importance to the landing keel, have I discussed the matter here at such length.

Figure 75 shows the descent of a large airship over water, in which no provision is made for outside help. Only the anchoring buoy B, needs to be installed in advance. The airship is received on the water by the large landing keel T. The tail, lightened by dumping or shifting ballast, rises. After the crew has placed the anchoring foot c, in the buoy and secured it there, the ballast bucket chain K, shown in detail in Figure 76, is let down into the water and the spherical buckets, immersed by the lead weight B, quickly fill with water, which enters through the flap valves F, in the bottom of the buckets. When all of the buckets are filled, the tail of the airship is drawn down to the horizontal position, by hauling in part of the bucket chain, which will be when it has taken on as much weight in chain and water as it had previously thrown off in ballast to acquire a slanting position. Under these conditions the bucket chain acts as a vertical stabilizer, for, by drawing up a few of the buckets, a heavy load can be put on the after part of the airship, while lowering the chain will have the effect of releasing ballast.

The resistance of the chain being dragged through the water by the sidewise motion of the airship does not need to be considered where only a very slow rate of turn is involved. How-

ever, if this is feared, it is not necessary to use the bucket chain, in which case one must do without its damping effect on vertical movements. The chain may be drawn up by a line, as shown by S in Figure 76, whereby the buckets, caught from underneath and upset, will be emptied until the tail of the airship starts to leave its horizontal position and rise up when, by hauling in the remaining full buckets, the ballast which had been dropped may be regained.

Quite frequently the proposal is made to moor the airship to a low floating mooring mast where the floating platform that carries the mast can also furnish a storage place for gas flasks, etc. (Figure 77). In order to withstand the very considerable pull that would be exerted on the top of such a mast, under some conditions, by an airship lying in the wind, such a floating body would have to possess a high degree of stability. As a result, the slightest roughness of the water would give rise to large rolling moments which would of necessity be felt at the mooring point and load that point with continually changing positive and negative pressures.

If it is considered necessary to have a platform around the mooring point, the disadvantages of the floating mast may be avoided by putting the floating platform around the buoy shown in Figure 75, and connecting the platform and buoy by springs, as shown in Figure 78. This float is almost entirely independent of the buoy in its movements, especially if care is taken that

the pivoting axis of the mooring point of the airship on the buoy is also the center of gyration of the platform. From such a platform as this, a bucket chain like the one previously described could easily be picked up by an airship and it would not be necessary for the airship to carry one.

The airship tender, PATOKA, mentioned above, must also be considered as a floating mast. Those who have had anything to do with this ship know that in a seaway, with which the ship moves in sympathy, the use of the mast by an airship is impossible, and that it is advisable, if an airship is already moored to the mast, for it to take off when a heavy seaway begins. The fact that these problems have not yet been discussed in public, should not be taken as evidence that they have not been encountered.

Another proposal for the use of water for airship stations was made by Engineer Simon of Hamburg. The idea is to provide the airship with a car having the shape of a boat and almost the same length as the gas-filled envelope above it. Means are provided underneath for scooping up enough water during the landing of the airship not merely to offset the lift of the airship but also to cause the car to sink far enough into the water to give it the desired stability. Before the take-off, which is supposed to resemble that of a seaplane, the ballast tanks are emptied of water by air pressure. The inventor's not altogether impracticable design is reproduced in Figure 79.

Another airship mooring problem which is expected to be solved in the near future, concerns the possibility of mooring airships on the ice. Polar expeditions have created much interest in the possibilities of using airships for establishing, and later returning to observation stations in otherwise inaccessible regions near the poles. The practicability of using airships in polar regions will depend on the solution of the problem of mooring to ice. In the absence of other proposals, I have thought of the use of an electrically heated plate-shaped anchor, which could be let down from the airship, allowed to melt into the ice and then the current turned off so that it would be frozen in. This would be constructed so that its adhesion would be increased by grooves cut in its surface. The anchor cable could then be used to transfer men and material up and down. When desired to weigh anchor, it would only be necessary to turn on the electric current in the anchor, which would then be thawed out again. As shown in Figure 80, the airship in this instance is not supposed to be moored by the bow, but after the manner of mooring kite balloons.

All these proposed methods for mooring airships in the open are more or less makeshift in character and are dictated chiefly by the desire for economy. When repairs are required (which will be after every long nonstop flight in the case of most airships), the airship must be brought into a shed. It may be either a revolving or a stationary shed, but safe docking and the opportu-

nity for undisturbed work must be assured. In consideration of the latter necessity alone, the floorless, revolving shed mentioned above as being under construction by the army during the war, can be eliminated, because it would be impossible with every turn of the wind to move everything on the ground (trestles, ladders, cranes, etc.), in order to move the shed. In case of snow, the walls of the shed would have to be raised above the level of the ground, otherwise they would operate as snow plows and soon be blocked by the snow. So there would be nothing to do but to let the snow into the shed. The saving in cost which it was hoped would accrue from leaving out the floor is illusory, because it would be offset by the much heavier girder construction necessitated by the absence of the stiffening effect of the floor. Not even a smooth, unimpeded ground space would be available, because the circular tracks shown in Figures 81 and 82, with lateral guide wheels, present very inconvenient obstacles to movement in the shed, in comparison with which the single theoretical disadvantage of the ramp in a revolving shed with a floor is of no consequence. No airship crew that ever used the Biesdorf shed, found the ramp troublesome. For the drawings I am indebted to the Maschinenfabrik Augsburg-Nurnberg, which, however, is in no way responsible for the floorless system.

Here I must also call attention to an article by A. Kauer-
mann in Zeitschrift für Flugtechnik und Motorluftschiffahrt,
Nos. 22 and 23, of the year 1913, entitled "Luftschiffhallen und
Luftschiffhafen." It describes several projects very carefully

developed by the Deutsche Maschinenfabrik A-G, of Duisburg, in cooperation with Heinrich Lehmann & Company, bridge builders of Düsseldorf. The project of a double shed with a central column and without floor, naturally has the same fundamental weakness as all projects founded on this vicious idea, for which, however, the above-mentioned firm, as I said before, must not be held responsible. Even the double shed with central columns and with a floor, cannot be considered practicable today, after the experience with the revolving shed at Nordholz.

On the other hand, it is very regrettable that the construction of an airship shed according to the plans worked out by the two above-mentioned firms, at the suggestion of the naval architect, Busch, was not undertaken instead of the "floorless" construction. This arrangement is shown in principle in Figure 83. The airship was to be first received in a revolving shed S, situated at a safe distance from the disturbing effects of the stationary sheds H. The revolving shed stands on a movable platform, which can be run into position in front of the stationary sheds H, (position B), so that the transfer of the airship to the stationary shed can be accomplished. In case the field is more suitable for the installation of a radial group of sheds, a choice may be made of the arrangements shown as 5 and 7. The arrangement of the sheds in rows was suggested by Busch, while the radial arrangement is mine. Because of the similarity, in principle, of the two arrangements, I have shown

both in one sketch.

In view of the altogether unobjectionable "Busch system," it must always be regretted that the fundamentally erroneous construction of the floorless revolving shed was helped to accomplishment. How many accidents and losses, even of men's lives, might have been spared, and what valuable experience, which we are still lacking, might have been acquired, if structures worthy of the then existing advanced technique had been developed instead of the useless floorless sheds.

Since that time the dimensions of airships have grown to formidable proportions. The representation of airship types, showing their comparative sizes, by Dr. Roeser in his article, "The History of German Rigid Airships" (ZFM 14-7-1925) has been extended by me and is here presented as Figure 85. The enormous growth of the types, especially in diameter, is shown. The following table is from the same article, with the addition of the Siemens-Schuckert airship, LZ-126, R-101, and the proposed SL-120 types, in order to make it complete.

Builder or Designation	Year	Length m	Max. diam. m	Volume m ³	Propul- sion	HP.	Speed m/s
Giffard	1855	70	10.00	3500	Steam engine	4	3
Hänlein	1872	50	9.20	2400	Int. comb. engine	3.5	5
Renard & Krebs	1884	50	8.40	1865	Elec. motor	9	6
Schwarz	1897	48	13.5	1250	Int. comb. engine	12	5
Santos Dumont 6	1900	33	6.0	620	Int. comb. engine	16	8
Lebaudy	1902	52	9.8	2960	Int. comb. engine	50	11
Zeppelin LZ-2	1905	128	11.65	11300	Int. comb. eng. (2)	170	11
Parseval	1906	50	8.9	2300	Int. comb. engine	90	10
Zeppelin Z-1	1906	136	11.65	12200	Int. comb. eng. (2)	200	13.5
Siemens-Schuckert	Jan. 1911	118	13.2	13000	Int. comb. eng. (4)	480	19.8*
Schütte-Lanz 1	Oct. 1911	131	18.40	20500	Int. comb. eng. (2)	480	19.8
Zeppelin LZ-126	1923	200	27.24	70000	Int. comb. eng. (5)	2000	35.0
R-101	1928	220	40.26	142000	Int. comb. eng. (6)	4800	37.0
Schütte-Lanz 127, Project	1926	283	35.3	170000	Int. comb. eng. (10)	4000	36.0

*The Siemens-Schuckert Airship had, for 3/4 of a year, a speed 6.3 m/s greater than the fastest previous airship, the Z-1.

With such rapid growth in size, it is obvious that the further development of airship navigation is very questionable, unless the important technical problems of landing airships is solved. It is a fundamental error to allow these problems to lag behind the building of airships. Another suggestion for increasing the usefulness of stationary sheds is to make them wider near the entrance, as shown in Figure 86. The inventor believes that, with the wind in the direction shown by the arrow, the conditions for entering the shed against the direction of the wind would be very favorable at the entrance of the shed. Photographs have been made of the currents prevailing in the case illustrated in upper left-hand corner of Figure 86; also for the empty shed (Figure 87); with the ship entering the shed (Figure 88); and with the ship half inside the shed (Figure 89). But even with the wind in the direction of the longitudinal axis of the shed, entering the shed would not be without danger, as can readily be seen, because of the great eddy at the entrance.

The impracticability of such a shed arrangement as is shown in Figure 86 is demonstrated by the flow photographs (Figures 32-47, Part I, Technical Memorandum No. 512), so that I need not repeat the discussion of the idea. It is noteworthy that this patent dates from the year 1919 with all the experience of the war behind it, and that it was presented by a firm with a very good reputation.

In a newspaper article on the mooring of the ZR-3 after her

35-hour flight over Germany, in September, 1924, appears the following: "A giant caterpillar tractor having a special device, with the help of which it is possible to fasten the control car rigidly to the tractor, stands ready to drag the air giant into the shed, in order to avoid the possibility of the enormous hull being struck by a gust and thrown against the shed." What results were obtained with this movable anchorage have not as yet been learned. If, however, the attempt is ever made to fasten an airship of about 70 tons weight rigidly to such a heavy vehicle as a caterpillar tractor, it would certainly lead to the breaking of some connecting part, for the irregular, jerky movements of the tractor on uneven ground would develop accelerating and retarding forces on the fastenings that no airship construction and no material could withstand. To avoid this result, it is fundamentally necessary for the mooring point of the airship to be motionless, so that there may be no motion of the airship relative to it by which it may gather kinetic energy. If such a rigid mooring is not possible, then at least elastic members must be provided between the airship and the mooring point which, however, must not consist of springs of any sort.

During the preparation of this article it has been learned that it is the intention of the Americans to use a low movable mooring mast of about 90 tons weight, to bring airships into the Lakehurst shed. The three supports of the mast are to rest on caterpillar tractors. This proposal is open to the same objec-

tions as those noted above, but in even greater degree, because the height of the mast will increase the swaying of the tractors. Even the intentional provision of a certain amount of elasticity would not help matters. Under these conditions the accumulated forces due to springs might give rise to a whipping motion. The movable mast could only be moved on very carefully laid tracks, which would reduce the swaying of the mast top to a minimum. Regarding this intention to drag the airship into the shed by means of a low mast, it appeared desirable to make a more detailed investigation of the wind conditions caused by such an enormous obstruction to the wind as the Lakehurst shed presents.

On account of the short time since the appearance of the above-mentioned newspaper article, it was not possible to have photographs made of the air flow to be considered, and so we will have to be content with the schematic diagram (Figure 84) representing the air flow past the shed. This is based on flow photographs (Figures 16, 17 (Part I, T.M. 512), and 90). The arrows show that the airship on its way to the shed, hanging to the mast, must pass through currents flowing in direct opposition to one another, which, if the airship is fastened only to the top of the mast, would turn the airship 180° . Besides, with a gusty wind, these eddies shift back and forth, so that under certain conditions an airship would be subjected, in a short space of time, to gusts differing 180° in direction, without change in the direction of the main wind which strikes the shed.

It is the fundamental disadvantage of stationary sheds that with them one is obliged to take up the fight with the wind and hold the airship by force against local changes in direction of the wind or against cross winds. A fairly strong wind will always have the upper hand on account of the great resistance offered by the enormous bulk of modern airships. It is a struggle with unequal weapons. The wind seizes the ship (pushing on one side of the gigantic surface and sucking on the other) and exerts its force much more effectively than men can whose force must be more or less concentrated at diverse points, even though many, on the ship's hull.

It is sought to offset the inconveniences of not being able to enter a stationary shed in a cross wind without great risk by erecting a mooring mast at a safe distance from the shed, to which an arriving airship may be moored and await a lessening of the wind or a change in its direction to one parallel with the axis of the shed, when it can be taken in. The latter maneuver is always uncertain and requires a large crew of men. Only a small part of the necessary repairs can be made at a mast of 70-90 meters height. Bigger jobs must wait for the more convenient mooring in the shed. Under these conditions there can be no thought of keeping to a regular schedule. All this is incompatible with the proper requirements of a modern commercial enterprise. The great desirability of getting away from the high mast is evidenced by the construction used in the Ford mooring

mast, in which it is possible to bring the airship to the ground by a vertical rail. However, even the revolving shed, in its present form, is not altogether dependable under all wind conditions, as it is maintained that airships entering the shed could be caught by downward gusts and forced to the ground. This possibility cannot be denied, though nothing of the sort was ever experienced during the $4\frac{1}{2}$ years of operation in and out of the Biesdorf shed. However, this disadvantage can be obviated by the use of a combined revolving shed and mooring mast as shown in Figure 91.

If a mooring mast is erected ^{of} over the entrance to a revolving shed, /at least such a height that an airship could be safely moored to it without danger of touching the ground, one would then only have to provide direct means of preventing perpendicular movements, in order to control the landing and take-off of the airship. For this purpose the tail of the airship is first made light by discharging ballast, after which the light end of a ballast chain, which greatly increases in weight toward the other end, is picked up, thereby bringing the airship to a horizontal position again. We then have exactly the same conditions as described in the case of stabilization by means of a bucket chain (Figure 76). If the bow of the airship is then brought down the mast until it is about in the middle of the entrance, on a movable section prolonging the rail of the mast, while at the same time the stern has been hauled down at the same rate by

the chain at the tail, the movement is entirely stabilized. The movable section T in the shed entrance, is so arranged that it can be moved inside the shed, drawing the bow of the airship with it. If it is desired not to drag the heavy ballast chain on the ground, it may be carried behind the airship on a specially constructed tractor. As regards reliability and speed, the operation just described, in the light of the present status of the technique, is the most efficient for landing airships.

While a mooring mast separate from the stationary shed (e.g., Lakehurst), affords no control over the time of mooring and so does not permit of establishing a definite flying schedule, with the combination mooring mast-revolving shed, on the other hand, one-half to three-fourths hour after arrival of the airship, it can be safely housed in the shed and undergoing necessary repairs, preparation for which has perhaps been ordered by radio, so that even if the changing of engines or whole engine cars must be undertaken, the time for a fresh start may be definitely determined in advance. The trimming and balancing of the airship can also be accomplished with greatest ease and safety in the shed. They present real difficulties at the mast. There is the further advantage that the commander of an arriving airship can tell, from the lay of the shed, in what direction the wind is blowing on the ground and can maneuver so as to head into the wind in landing. This is very important for very often, even at low altitudes, there is a different wind direction from that next to the ground.

Above all, it must not be forgotten that the mooring mast itself may present dangers of collision, as was proved by the experience of Nobile at the mooring mast in Vadso, where the bow of the ITALIA suffered considerable damage from the mast. This is most liable to happen when there is no wind or very little wind. For this reason it is best (even when there is a wind), as soon as the main mooring line has been hauled in and fastened, to start the propellers of the airship astern, in order to allow the airship to be drawn slowly toward the mast. The tendency to yaw will thus be decreased. The increased pull on the mooring line is no great disadvantage compared with the much greater stability and safety of the entire operation. The movable sheds shown in Figures 83 and 86 should be provided with such an arrangement of the mooring mast over the entrance to the shed.

The disadvantage of the revolving shed, that it possesses its typical advantages only when housing but one airship, can be overcome by other means than the use of movable sheds. If it is considered that only a close fit of the shed entrance to the airship section and the assurance of a narrow air stream over the airship, provides a stable, dependable introduction of the airship, then it will be seen that the type of shed shown in Figure 92 which, in spite of its streamline form, can house several airships, has the typical advantage of the revolving shed. In this case, the mast installed over the entrance may serve to moor the airship which lies just within and blocking the entrance

until one of the other two ships within leaves the shed. This last airship cannot take off from the mast. The use of the mast in this way is not impracticable because, until it reaches the entrance, the ship has its bow fastened to the perpendicular rail and cannot make the slightest sidewise movement with the fore part of the ship. In bad, gusty weather, if necessary, the ballast chain can again be used in taking airships out of the shed to suppress the vertical movements of the ship in the same way as was done in landing.

If the shed has two openings, in order to be able to house still another airship in it, then these openings must be furnished with wind-tight doors, because one of the openings will always be to windward. The streamlined shed with only one entrance needs no wind-tight doors, because the entrance is always on the lee side. The shed in Biesdorf, for example, had only a curtain in front of the entrance, the chief object of which was to help keep the shed warm in winter. Figures 93-97 show the streamline shed with only one opening. It is obvious from Figure 93, that the wind currents are just as favorable as around the prismatic shed for only one ship. The precarious air-flow conditions shown in Figure 98 will never be found behind the tapered entrance of the streamline shed. Figure 94 shows the shed with the airship half-way in. Here the air currents are especially favorable, because the form of the ship completes the streamline form of the shed. Figures 95 to 97 are elevations and speak

for themselves. In particular, Figure 97 shows very plainly that no adverse currents are formed either by the mooring mast or by the airship temporarily moored to it, which would interfere with an airship leaving the shed:

The dimensions of such sheds will naturally be very great to correspond with the size of modern airships. For example, the streamline shed with only one opening would have to have a length of at least 300 meters, a maximum width of 100 meters, and a height of 50 meters. A better conception of the meaning of these dimensions can be obtained by remembering that the shed at Lakehurst is 64 meters high by 106 meters wide. However, the engineer does not need to quail before these dimensions. Of course, they present new problems to be solved, but modern science offers trustworthy means for attaining even these giant dimensions.

In the revolving sheds which have hitherto been built, the turning was effected by having the wheels of the supporting trucks driven by electricity. The same method of operation with the numerous trucks of these giant sheds would lead to unnecessary complications and increase in cost. The idea of pulling the shed around by a large ring connected with its floor, around which ring steel cables are laid, offers a very simple solution of the problem. These details also offer a fruitful field for study to the constructor, but cannot be gone into any further here.

By the foregoing discussion, I hope to have shown the necessity for developing the technique of landing large airships in accordance with modern technical knowledge. Unfavorable conditions have held back this work in Germany far too long. We can no longer close our eyes to the fact that traffic with large airships cannot be successfully carried on without correspondingly complete and consequently costly mooring and docking equipment, just as it would be impossible to maintain regular ocean traffic with our large ocean-going steamships without suitable harbors and docks. If the whole development of large airships is not to be jeopardized, makeshift accommodations will have to be done away with. The profitableness of a commercial undertaking depends first of all upon the safety of its operation, and if a correctly constructed and properly located revolving shed should save but one airship from a catastrophe, it would largely pay for itself.

During the war there was no other recourse than to master the landing problem by a corresponding massing of man power. It is possible, however, for modern engineering, especially with the easily divisible and controllable power of electricity at its command, to coordinate mechanically the operation and landing of an airship, so that a single commander with a crew of not more than twenty men would be able to land and house the largest airship in safety.

Translation by Mrs. Elizabeth T. Cedergren,
Bureau of Aeronautics,
Navy Department.

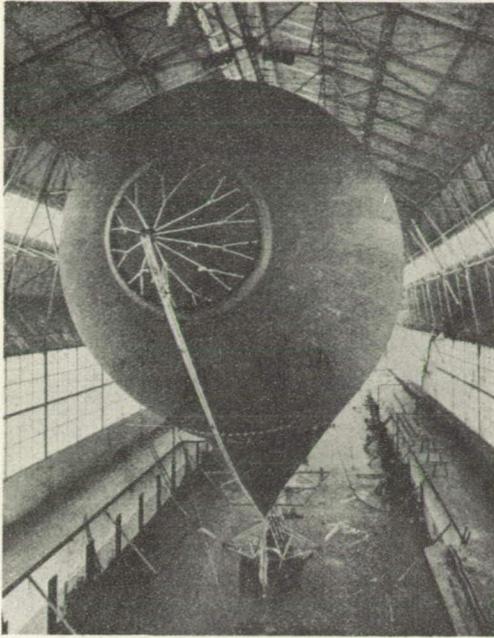


Fig.58 Nose of Siemens-Schuckert airship with bow-mooring attachment.

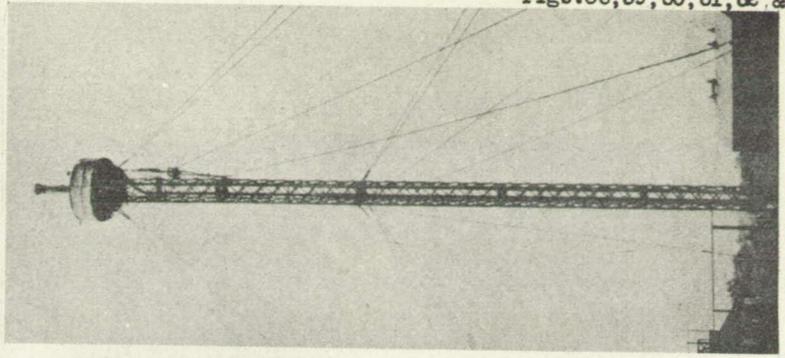


Fig.61 Mooring mast at Fulham.

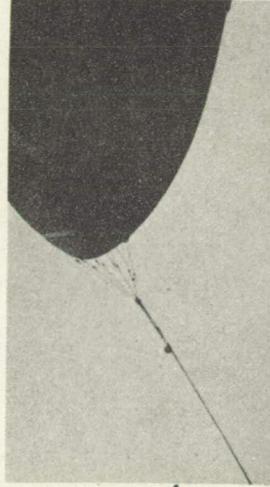


Fig.59 Anchorage test of Siemens-Schuckert airship.

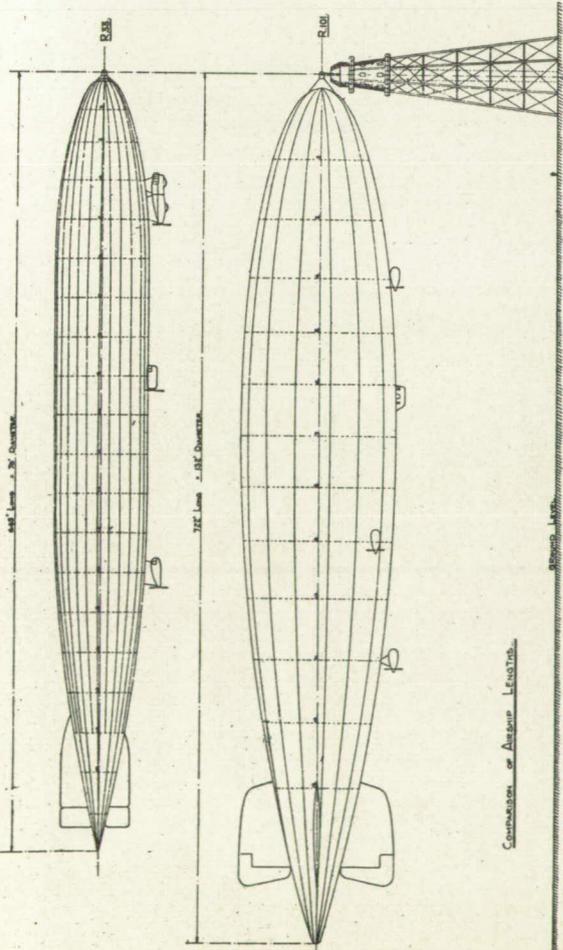


Fig.63 "R-33" and "R-101" (on Cardington mooring mast.)



Fig.60 From a Swiss publication. "How Americans protect their airships against storms."



Fig.62 Mooring mast at Cardington.

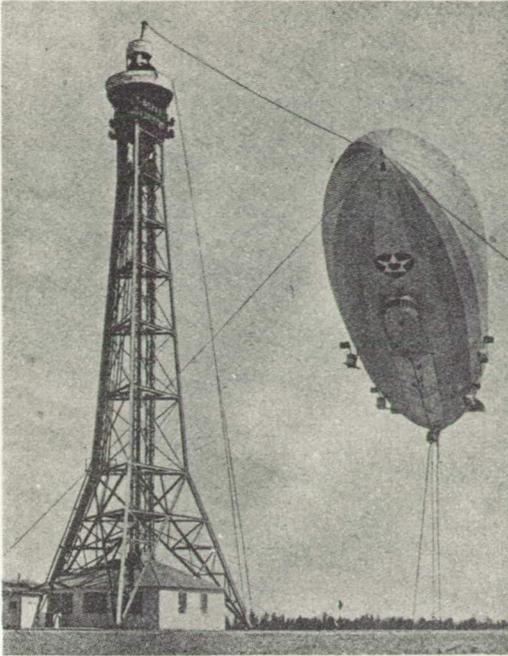


Fig.64 Mooring the Los Angeles at Lakehurst.

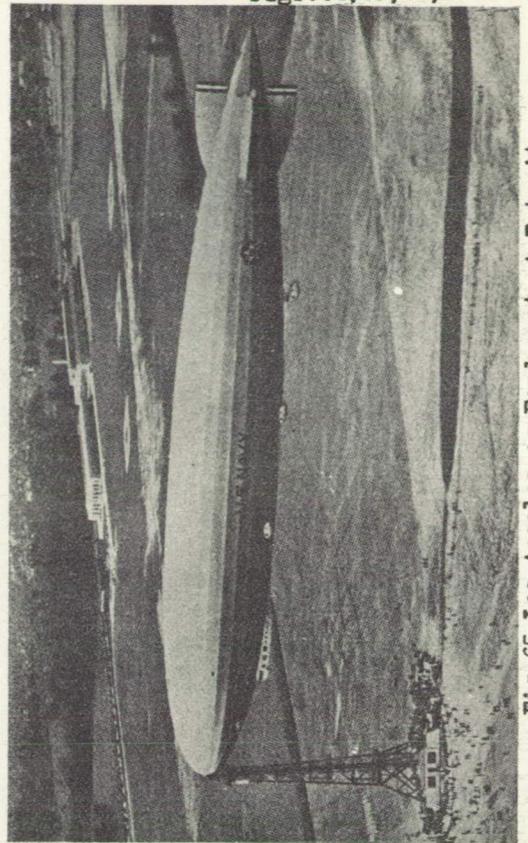


Fig.65 Los Angeles on Ford mast at Detroit.

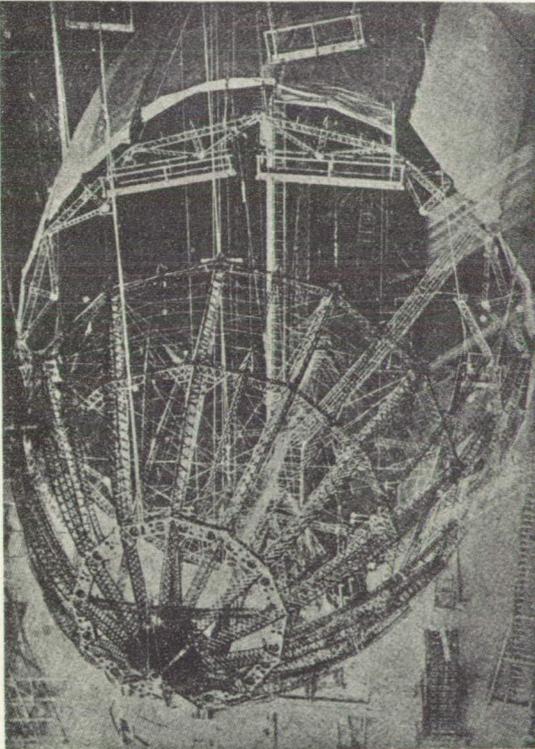


Fig.68 Repairing R-33.

Fig.67 Los Angeles mooring to the Patoka.

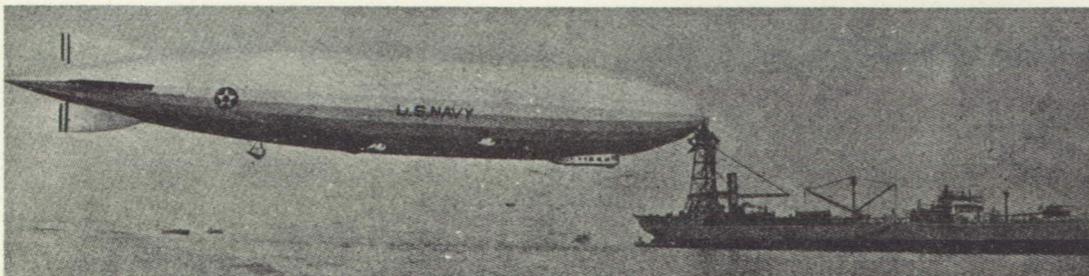
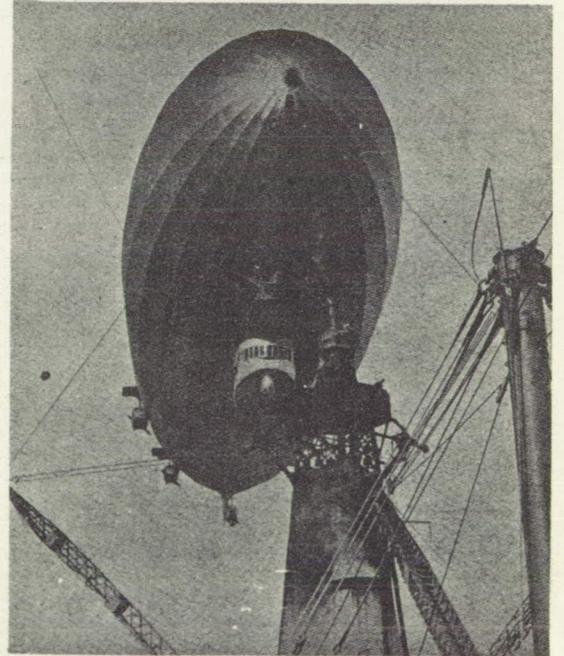


Fig.66 Los Angeles on mooring mast of the Patoka.

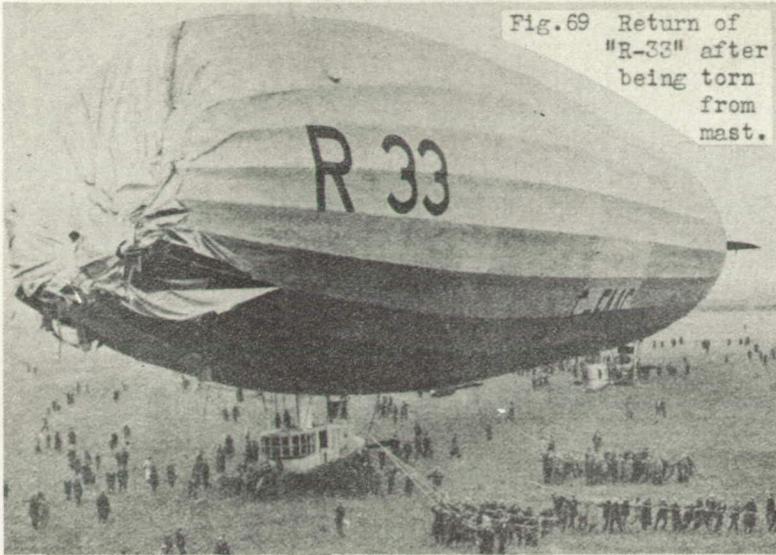


Fig.69 Return of "R-33" after being torn from mast.

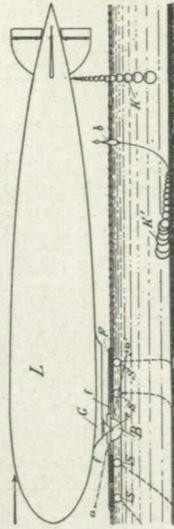


Fig.78 Airship on buoy.

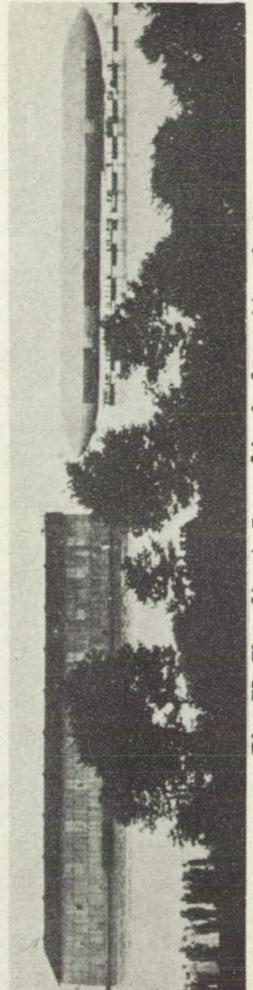


Fig.71 The first Zeppelin before its shed.

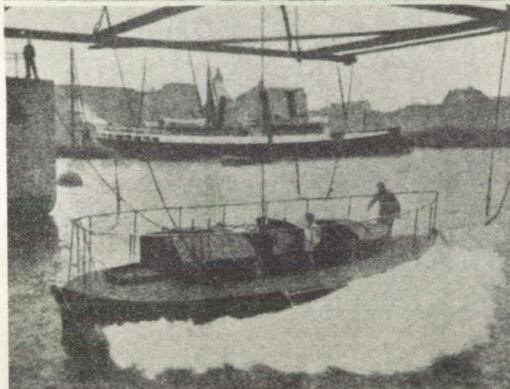


Fig.73 Dropping test with Suchard car.



Fig.74 Car of Suchard airship constructed as a sea-going motor boat.

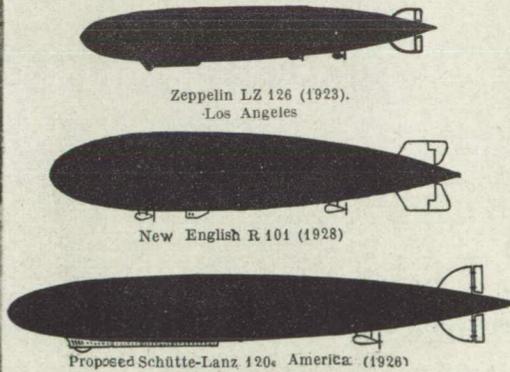


Fig.85 Comparative sizes of airships

Fig.76 Ballast bucket chain.

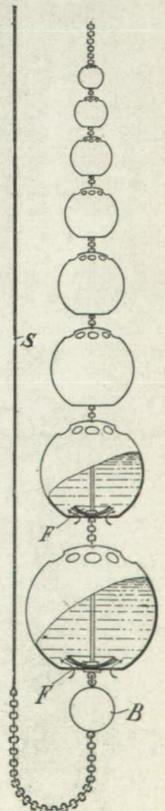


Fig.87 Flow about shed with widened entrance

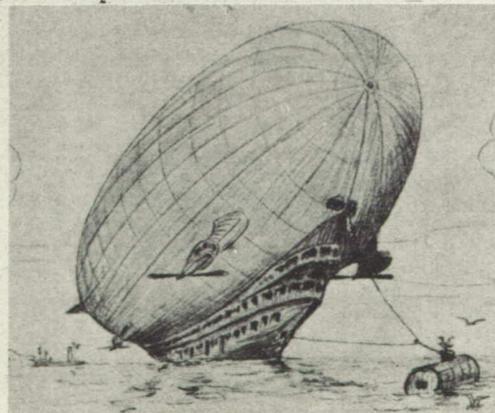


Fig.79 Airship proposed by Simon.

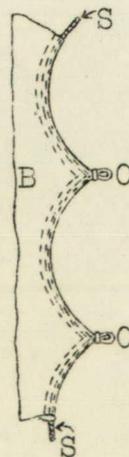
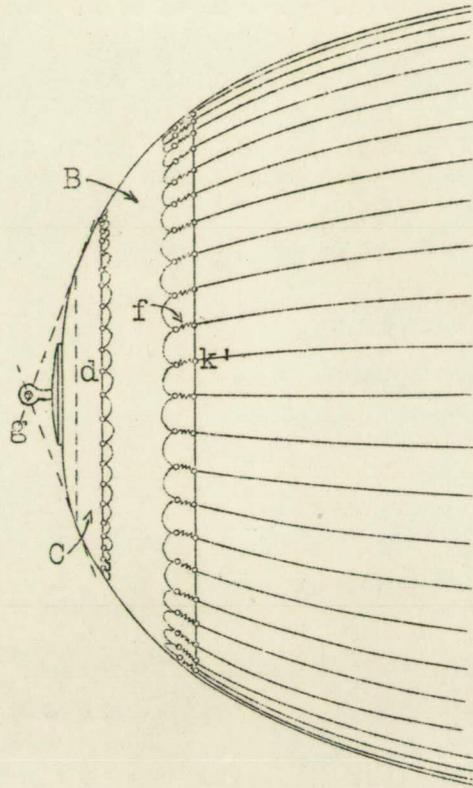


Fig.70 Proposal of writer for mooring bow of rigid airship.

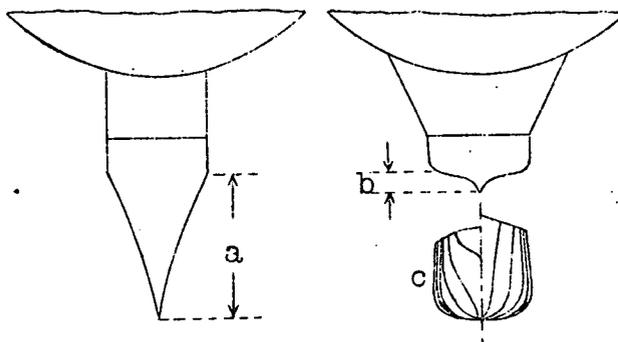


Fig.72 Keel shapes.

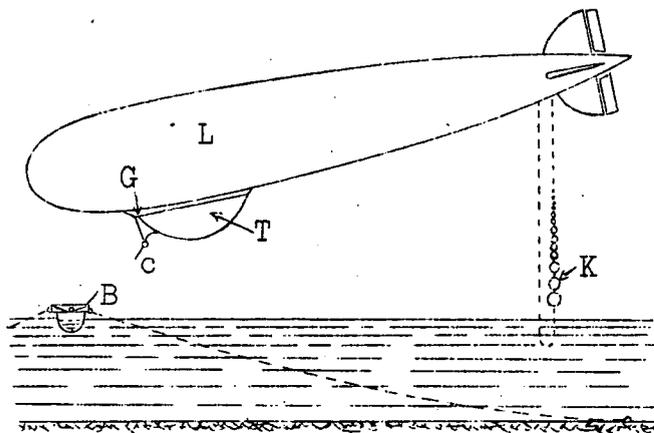


Fig.75 Descent of airship over water.

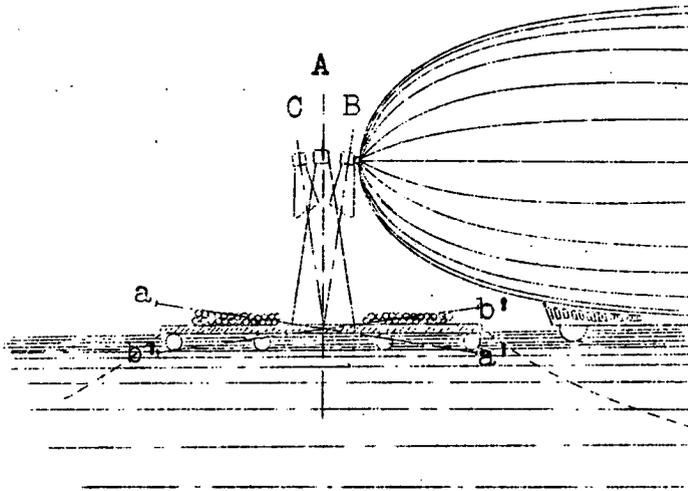


Fig.77 Airship on floating mast.

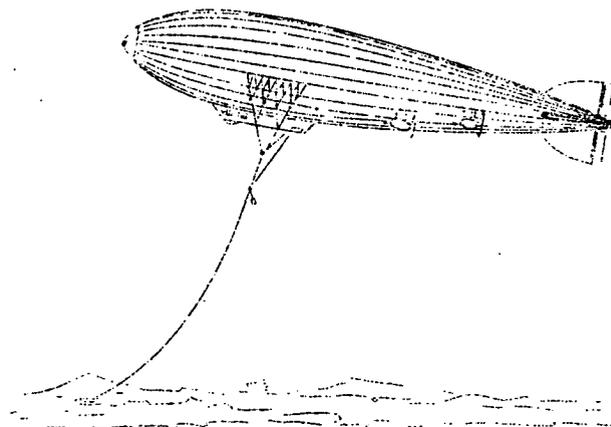


Fig.80 Writer's proposal for mooring to ice.

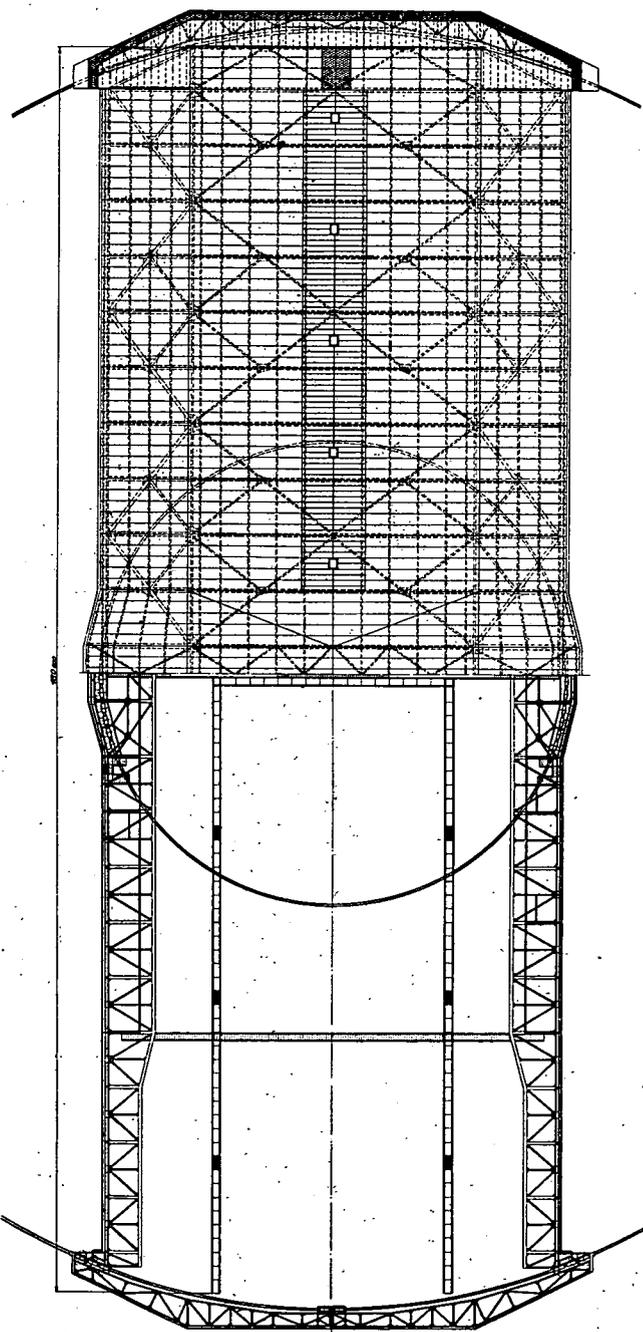
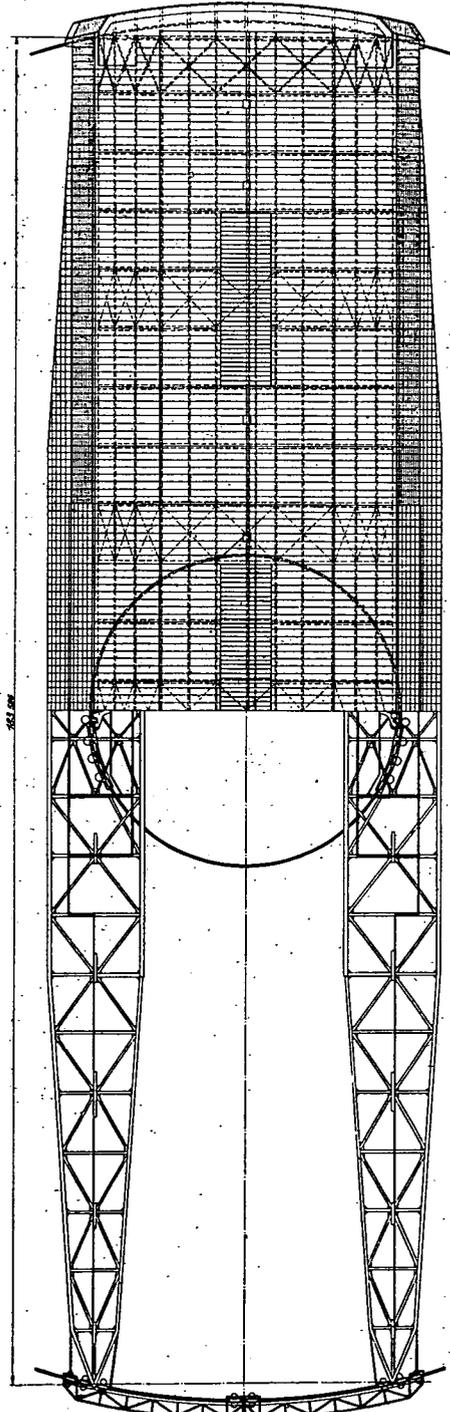
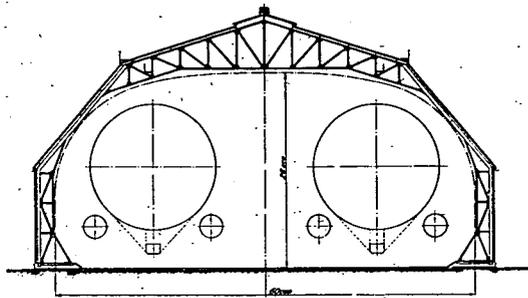
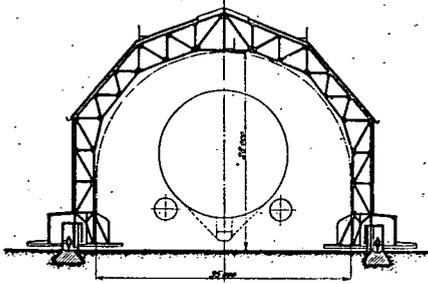


Fig. 81 Floorless shed for one airship.

Fig. 82 Floorless shed for two airships.

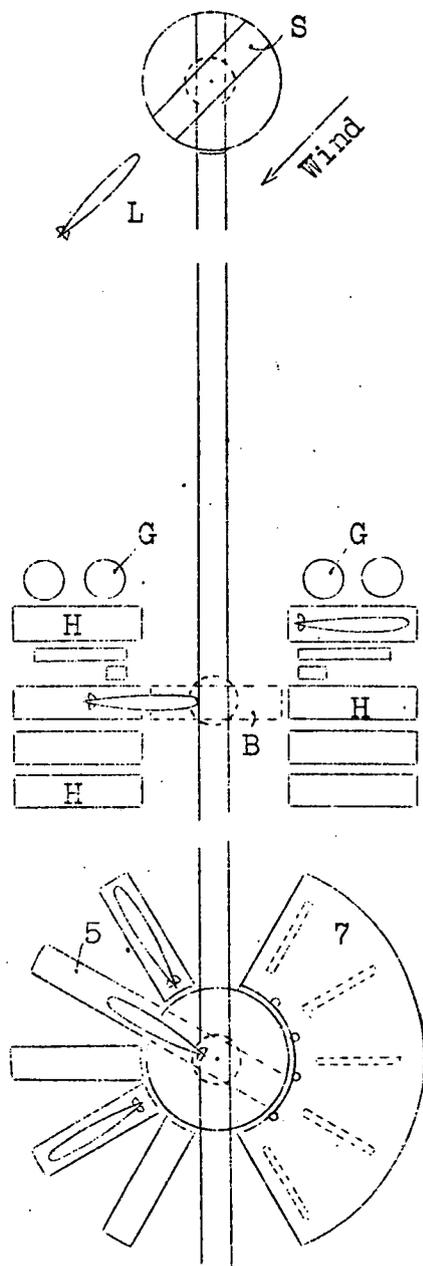


Fig.83 Busch system and Krell system of sheds.

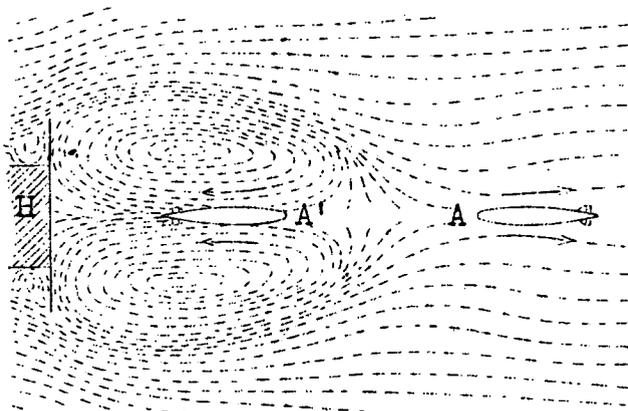


Fig.84 Eddies behind the Lakehurst shed and their effect on an entering airship.

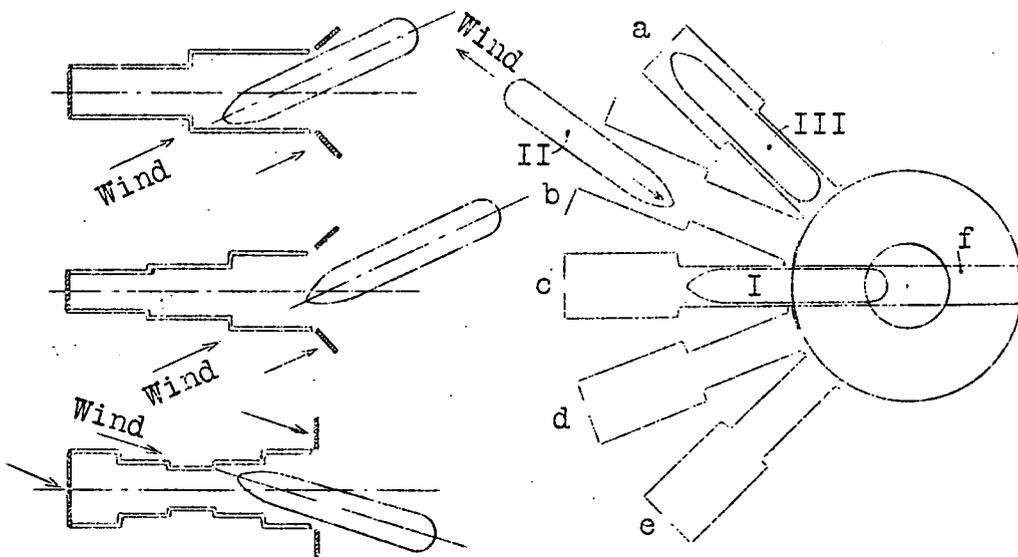


Fig.86 Airship sheds with widened entrances.



Fig.88
Airship entering shed with widened entrance.



Fig.89
Airship entering shed with widened entrance.

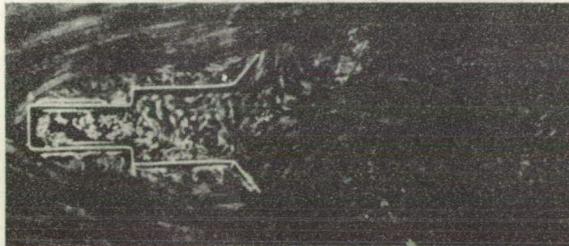


Fig.90 Eddies behind shed when wind is in direction of axis of shed.

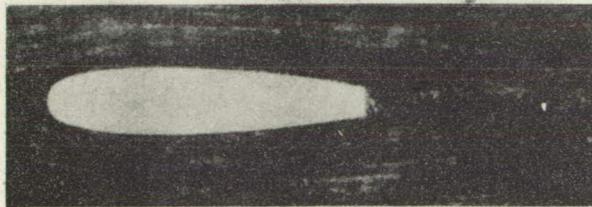


Fig.93 Flow about a streamlined shed.



Fig.94 Flow about a streamlined shed, with entering airship.

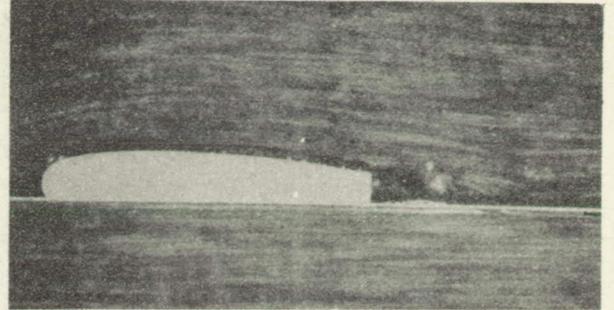


Fig.95 Flow about a streamlined shed (elevation).

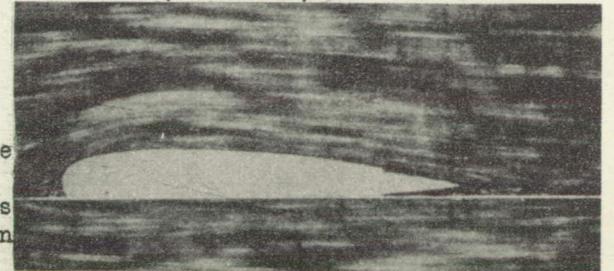


Fig.96 Flow about a streamlined shed, with airship entering (elevation).

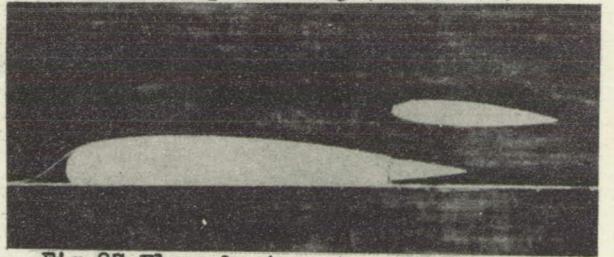


Fig.97 Flow about a streamlined shed, with one airship on mast and one entering.

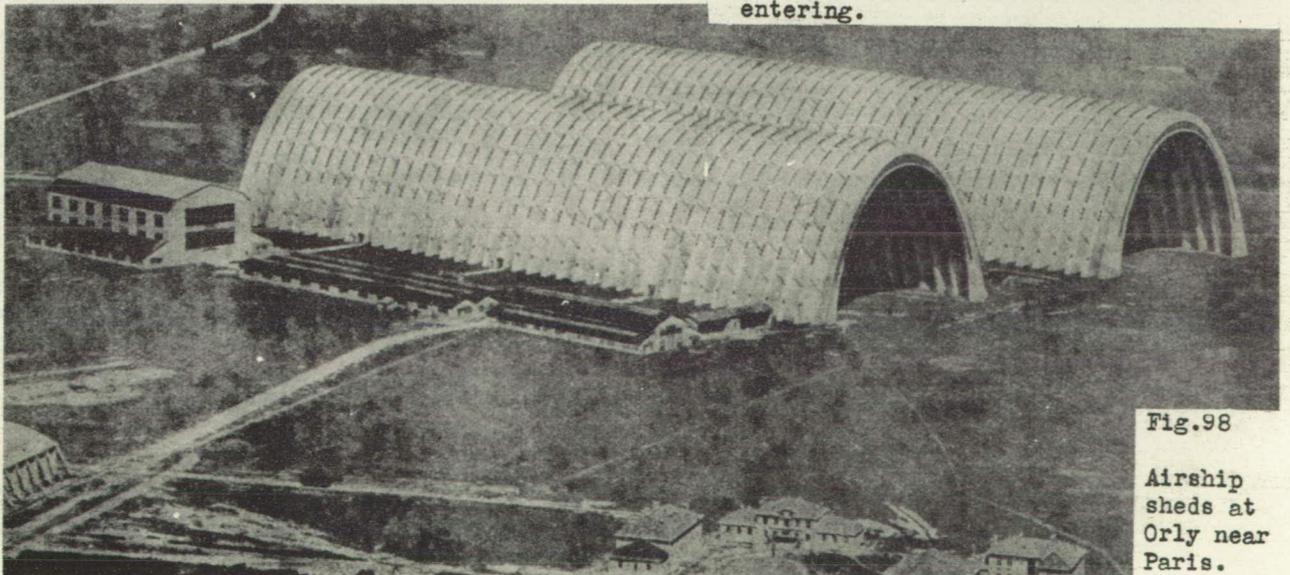


Fig.98
Airship sheds at Orly near Paris.

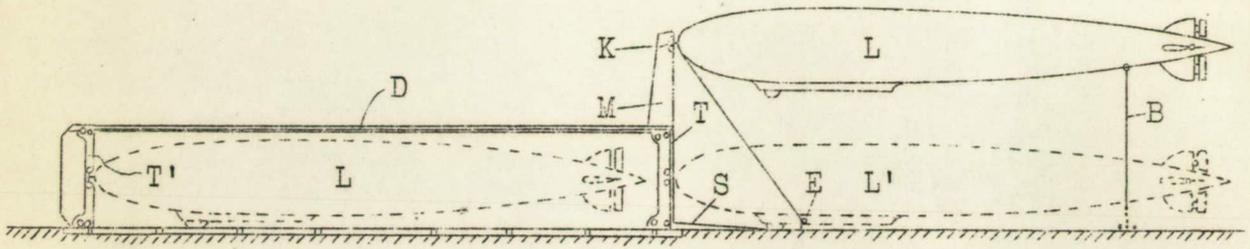


Fig. 91 Combination of revolving shed with mooring mast.

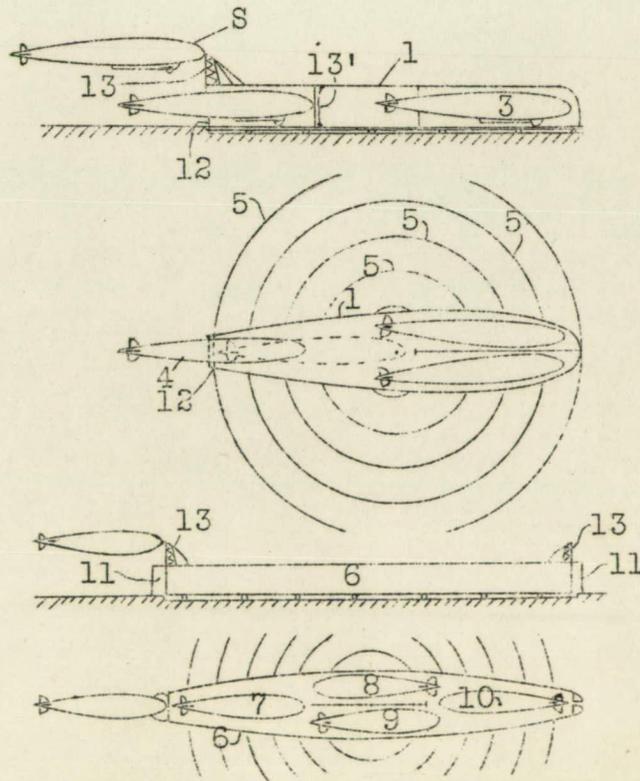


Fig. 92 Revolving shed for several airships with mooring mast and narrowed entrance.