MOORING AND GROUND HANDLING RIGID AIRSHIPS

Hepburn Walker, Jr.

ABSTRACT: This paper will deal with the problems of Mooring and Ground Handling Rigid Airships. A brief history of Mooring and Ground Handling Rigid Airships from July 2, 1900 through September 1, 1939 is included. Also a brief history of ground handling developments with large U. S. Navy non-rigid airships between September 1, 1939 and August 31, 1962 is included wherein developed equipment and techniques appear applicable to future large rigid airships. Finally recommendations are made pertaining to equipment and procedures which appear desirable and feasible for future rigid airship programs.

Today proposals for construction and operation of very large rigid airships for both COMMERCIAL and GOVERNMENTAL purposes are actively being considered. These plans envision conventionally configured rigid airships dependent on static lift ranging in volumes up to 100,000,000 cubic feet displacement. These huge specialized cargo rigids would have a length of some 1,800 feet, and a maximum diameter of 300 feet.

Mooring and ground handling these very large airships presents problems, but none of the problems are insurmountable. During the first rigid airship era, which spanned some forty years from July 2, 1900 through September 1, 1939 and the outbreak of WWII, great strides were made in developing mechanical equipment and ground handling techniques. During this forty year period approximately 160 rigid airships were built and operated in Germany, Great Britain, France, Italy and the United States of America. Rigid airships increased in displaced volume during this time span from about 400,000 cubic feet to over 7,000,000 cubic feet. As these volumes increased obviously the mooring and ground handling problems increased also, but fortunately linear dimensions and surface areas of airships do not increase at the same ratio as volumes increase. In fact with the eighteen fold increase in volume from the 400,000 cu. ft. LZ-1 of 1900

to the 7,000,000 cu. ft. volumes of LZ-129 and LZ-130 we find the length had merely doubles from a little over 400 feet to 804 feet. Diameters rose from 38'6" for LZ-1 to 135'1" for LZ-129 and LZ-130.

During the first nine years of rigid airship flight operations from July 2, 1900 to October 27, 1909 Count Zeppelin concentrated construction activity and flight operations of the Bodensee, or Lake Constance, at Mansell on the shoreline at the western outskirts of Friedrichshafen. LZ-1 made her first flight from the floating construction shed on the Lake on July 2, 1900. The ship was secured to a float inside the hangar and towed out on the lake by small boats acting as tugs. The LZ-1 then made her takeoff from the deck of the float and a short time later landed on the surface of the lake on her two cars which were designed to float on water. She was then spotted on her barge and towed back inside the hangar, or rather maneuvered into the hangar, by the launches. The term ground handling is an obvious misnomer during this period as it was strictly water handling. The significant point is that by using the boats as tugs mechanical handling was first used for undocking and docking rigid airships.

Count Zeppelin had decided on water based operations for two reasons;
1. He felt that takeoffs and landings could be accomplished more easily and safely from and to the surface of the lake.
2. He was of the opinion that a floating hangar moored at one end and free to weathervane would solve any problems with cross hangar winds.

The water takeoffs and landings created no problems in themselves. In fact water landings by rigid airships continued infrequently through the Arctic flight by the Graf Zeppelin in 1931. It is felt that water landings and moorings are perfectly feasible for any future airship program on the surfaces of large protected bodies of water such as bays, lakes and wide rivers. Loading and off-loading cargo to boats and barges can be accomplished easily, and water landings are ideal from the standpoint of ease in ballasting airships as unlimited amounts of water ballast are immediately available.

The problems Count Zeppelin faced with his Lake Constance construction and operation efforts were due to the two floating hangars, and the original floating hangar relocated on pilings on the shoreline at Manzell. On one occasion a severe winter storm damaged the second floating hangar and badly damaged the airship housed inside. Another time a storm tore the hangar from its moorings and drove it ashore. On top of all this it proved extremely difficult to tow the airships back into the hangars in any real wind, and on one occasion a ship was severely damaged redocking. In 1908 Count Zeppelin decided that his operation should be relocated on a flying field on land. A site at Friedrichshafen was obtained on a long term lease and in 1909 he transferred his construction and flight activities to this base.

On March 16, 1909 the first deliberate landing on land was made by LZ-3 on the field at Friedrichshafen. May 9, 1909 LZ-3 was first

docked in the temporary tent hangar, and on October 27, 1909 LZ-6 made the final flight from the floating hangar at Manzell. All construction and flight operations by the Zeppelins subsequent that date were from land based hangars.

From May 9, 1909 until May 16, 1911 Zeppelins routinely docked and undocked from their new hangars on land using manpower alone without serious incidents. On May 16, 1911 LZ-8, the commercial "Deutschland II", was undocked at Dusseldorf in a strong cross hangar wind with a ground crew of about 300 men. The wind carried the ship away from the ground crew and stranded her on top of the wind screen, damaging the ship so severely that she had to be dismantled.

Dr. Hugo Eckener took the accident to LZ-8 to heart and he quickly developed a system of docking rails and docking trolleys for the hangar at Baden-Oos in the summer of 1911. These proved so successful that they were soon installed at all German airship bases, and were later copied in Great Britain, France, Italy and the United States for their rigid airship bases.

The docking rails and trolleys were the first mechanical aids devised for docking and undocking the land based rigid airships. They marked a vast improvement in maneuvering the ships in and out of their hangars. The ships were secured by lines, port and starboard abreast the ships for much of their lengths, to the trolleys which ran on small wheels or rollers in two tracks recessed in concrete extending from inside the hangars several hundred feet out on the field. After undocking, the aft cables would be slacked off and disconnected and the ship would be held by the ground crew until takeoff. The reverse procedure was used after landing into the hands of a ground crew for docking. Docking rails and trolleys continued in use in Germany until flight operations ceased September 1, 1939.

For any future rigid airship program the docking rails and trolleys should probably continue to be considered as an alternate docking aid, particularly at construction hangars where docking and undocking would be a very infrequent occurrence. The reason for this is that the trolley-rail system is a relatively inexpensive system as compared to the more sophisticated docking and undocking equipment which will be discussed later in this paper.

Between August 1, 1914 and the Armistice on November 11, 1918 Germany completed some 106 rigid airships, while the British completed 8 rigids. It seems almost incredible that with all the technical skill and ingenuity of the Germans that they were unable to devise any system to moor their ships out, either on the ground or in the air. They had only two alternatives; fly them or dock them. Their ships were frequently hangar bound by high winds when they were needed for scouting or bombing missions. Often on returning from long flights of 24 hours or more high winds were encountered at their bases that prevented the ships from being docked.

Very large ground crews were required to handle the German army and navy airships. In 1916 large 2,000,000 cu. ft. ships were introduced, five times the volume of LZ-1. In 1917 ships as large as 2,400,000 cu. ft. were completed, six times the volume of the earliest ships. While the smaller pre-war passenger ships of the DELAG, all well under 1,000,000 cu. ft., were operated only in fair weather, the much larger military airships of WWI operated in extremely unfavorable weather. It was not unusual for ground crews of as many as 700 men being used to land and dock one of the larger ships in adverse weather, and using the docking trolleys to assist in getting the ship into the hangar. At the height of WWI North Sea operations the number of men assigned to the ground crews at the two largest bases were 1,293 men at Nordholz, and 1,299 at Ahlhorn.

The German navy did make one very expensive attempt to solve the ground handling problem. In 1914 a revolving double hangar was completed at Nordholz to lick the problem of cross hangar winds. This hangar, later lengthened to accommodate larger ships, remained in service until November, 1918, but it could house only two ships of the 26 operational. High costs, plus the problem of revolving the hangar with snow on the ground, precluded other revolving hangars from being completed.

Great Britain, although she only operated 8 rigid airships during WWI, grasped the need for some method to moor the airships outside their hangars. In April, 1917 rigid #9 was accepted and operated at Howden testing sea anchors, and operated at Howden and Pulham testing the "three-wire system" for mooring out through October, 1917. A triangle some 550 feet on each side with ground anchors at each corner and tied together with three wires of greater length forming a bridle to the airship at her mooring point midway between the nose and control car was the essence of the system. The R-9, ballasted light, rode at a fairly safe altitude above the ground. The 3-wire system was never a satisfactory solution to the mooring problem, but at least it was an attempt to find an answer.

In 1919 R-26 experimented further with this system. R-34 used the 3-wire arrangement at Mineola during her American stay in July, 1919, but it gave considerable trouble. The 3-wire system was last used at Howden in January, 1921 when R-34 rode out to it and was so badly damaged on the field that she had to be dismantled. It does not appear that the 3-wire mooring out system has anything to offer for future rigid airship programs, with the possible exception that a variation of this arrangement might prove practical for mooring on the surface of protected bodies of water.

But the British deserve full credit for developing the high mooring mast for rigid airships, a solution to the mooring out problem that was extremely successful, if not quite the ultimate answer. In 1911 they had tried a floating mast at Barrow with the "Mayfly", but that particular approach, while of historical interest, was not made in

England for a high mooring mast for rigid airships. In March, 1918 an 120' high mast was ordered from Vickers. In May, 1919 the mast was completed at Pulham and on July 11, 1919 R-24 was moored to the high mast for the first time. She remained moored for nearly three weeks. From Sept. 1, 1919 until Oct. 15, 1919 she again rode out on this mast. Her final mooring out was from Nov. 7th to about the middle of December, 1919. In late December, 1919 R-24 was dismantled at Pulham as she was obsolete. A satisfactory solution to the mooring out problem had been developed. Now rigid airships finally had three alternatives; they could fly, they could remain in their hangars, or they could ride out for extended periods on the high mast.

The original procedure with R-24 at Pulham was first to walk the ship to the vicinity of the mast from the hangar, or after landing to a ground crew, connect the mooring wire from the ship to a wire from the mast head, allow the ship to rise statically, and then have the mast winch pull the ship into the mast connection. Later in 1919 the ship was able to make flying moors to the high mast using a ground crew of only half dozen men to connect the wires and operate the winch. Static takeoffs from the mast could be made with even fewer men. Riding out to the mast only one man was needed to operate the ballast pump, and two men aboard to attend the elevator and ballast the ship.

In February, 1921 high mast mooring experiments resumed with R-33. On February 7, 1921 she made her first static takeoff from the high mast and on the same date she made her first flying moor to the mast. She continued to use the Pulham high mast until July or August when she was decommissioned. From April to June, 1921 R-36 also used the mast. During this period yaw guys were added to the equipment to control lateral movement of the nose and to prevent the airship from overiding the mast while being pulled into the cup. British experiments were suspended Sept. 20, 1921 when R-80 arrived at Pulham to be decommissioned.

While the temporary close down of the British airship program was unfortunate, the U. S. Navy has been very favorably impressed with the high mast experiments by R-24 in 1919 and with R-33 and R-36 in 1921 at Pulham. The U. S. Navy had bow mooring provisions included in the design of ZR-1 and insisted that the LZ-126 design by the Zeppelin Co. include a strengthened bow for nose mooring, a nose spindle and a nose cone.

The ZR-1, or USS Shenandoah, between Sept. 4, 1923 and Sept. 3, 1925 made 26 high mast moorings, plus 7 to the mast on the airship tender "Patoka".

The procedure for a high mast flying moor follows. The airship approaches the mast slowly headed into the wind at an altitude of about 200'. The mooring wire from the mast has previously been laid out on the ground some 500' to leeward from the mast. As the nose of the airship reaches a point above this mast wire she lowers her main

wire to the ground where it is connected with a special coupling to the mast wire. The airship is allowed to rise statically taking the slack out of the mooring wire. The two yaw guy wires are then sent down to the mast head on messenger blocks and connected by couplings to the two yaw winch wires which have already been led from the winches at the base of the mast to fairlead snatch blocks located about 60 degrees to each side of the mast on a 500' radius circle. One of these fairlead block anchorages is located every 7 1/2 degrees around this 500' circle so that the ship can moor headed into a wind coming from any direction. The slack is taken out of the yaw lines and all three winches controlled remotely from the mast head pull the airship slowly into the mast until the airship cone is locked in the mast cup. This procedure is an easy one and can be accomplished with a ground and mast crew of less than a dozen men. The ship can remain moored to the high mast for any desired length of time.

Aside from the very high costs for the permanent type high masts there are other disadvantages. The fact that an airship must continually be literally "flown" while moored to a high mast is the main disadvantage. A complete section of the flight crew must remain aboard at all times to man the elevator and rudder controls and keep the ship properly ballasted. Also they must be prepared to slip the mast in an emergency and fly the ship. Suitable tail drags to prevent the airship from kiting were a problem and the crew had to be alert that sudden rain or snow would not cause the tail to contact the ground.

The ZR-3 was delivered in October, 1924 and between that date and her final high mast mooring in October, 1929 she made 47 high mast moorings. She also made 44 moorings to the mast on the "Patoka" during her career. On August 25, 1927 the Los Angeles made her famous nose stand on the Lakehurst high mast when a cool sea breeze swept in from the Atlantic. The ship had tremendous superheat when suddenly immersed in the cool air. The ship kited to almost a vertical position with the 180 degree shift in wind coupled with the sudden drop in air temperature. She soon regained her normal horizontal attitude and suffered no damage, other than to her dignity. But officers at Lakehurst were convinced that a better method of mooring had to be devised, and in fact they were already at work on this project. This was the low, or stub, mast.

But before going into the low mast development, let us put the high mast to bed. In 1925 and 1926 the R-33 was put back in commission for mooring experiments to the old mast at Pulham and the new permanent 200' mast completed in 1926 at Cardington for R-100 and R-101. The R-100 used the Cardington mast and the one at Montreal for flying moors on all her flights, and R-101 made all her flights from and to the very expensive Cardington high mast. It does not appear that the high mast has any real future for a rigid airship program based primarily on the excessive cost of permanent type high masts.

On October 5, 1927 history was made at Lakehurst when the Los Angeles was first moored to an experimental 60' high stub mast. This mast was a pole braced by wire cables and proved entirely successful. A taxi-wheel carriage was clamped on #1 power car so that the stern of the ship was free to roll in azimuth around the mast on a 10' wide smooth path on a circle with a radius of 438'. The ship was ballasted heavy on the taxi-wheel to prevent kiting.

This mast was shipped to Panama early in 1928 and the Los Angeles moored to it at France Field, Canal Zone February 28, 1928. The stub mast became so popular with the commanding officers of the Los Angeles that only four more moorings were made to high masts after 1-1-28, and none after October, 1929. The Los Angeles moored to a low mast at the 1929 Cleveland National Air Races. In early 1930 a low mast was erected at Parris Island, South Carolina as a regular advance or alternate base. The Los Angeles moored at Parris Island on numerous occasions throughout 1930 and 1931. Another stub mast was erected for the Los Angeles at Guantanamo, Cuba early in 1931. Between February 4, 1931 and March 2, 1931 the Los Angeles was away from her Lakehurst hangar for a month for operations with the fleet at Panama. She operated from the mast at Guantanamo Bay as well as from the mast on the tender Patoka, mooring at Parris Island also during her return to Lakehurst.
Between October 5, 1927 and her decommissioning for reasons of economy on June 30, 1932 the Los Angeles made a total of 185 moorings to various low masts, and 26 moorings to the Patoka. The stub mast had been a complete success and high masts were no longer used by U. S. Navy airships, except for the mast on the airship tender Patoka.

Static takeoffs from the stub masts were routine for the Los Angeles from October, 1927 on, but moorings were another matter. For the first year or so the Los Angeles would make a conventional trailrope landing to the regular ground crew and the crew would "walk" the Los Angeles to the mast where the main mooring wire winch would slowly pull the nose cone into the mast cup. In July, 1928 a railroad track on a 438' radius from the center of the mast was installed at mooring out circle #1 at Lakehurst. On this track a rideout flat car was provided equipped with rail clamps, but no brakes, upon which #1 power car was secured. This marked an improvement over the taxi-wheel on a path system as, between the ballast on the rideout car and the hold-down clamps on the track, the ship was positively prevented from kiting, even in the severest gust and superheat conditions.

In addition to the rideout car, two yaw guys cars equipped with hold-down clamps and brakes also ran on the same track. While the first flying moors to the stub mast were made with the ground crew handling the yaw lines with the main winch pulling the nose into the cup, the addition of the track and yaw guy cars made mechanical flying moors to the stub mast a reality.

As any future rigid airship program will almost certainly involve some

type of low mast mooring, a detailed description of the procedure seems appropriate. The mooring mast is located in the exact center of the riding out circle. At Lakehurst two tracks were provided at circle #1, one on a 438' radius for the Los Angeles and her rideout car and yaw guy cars, and a second track on a 643' radius for the Akron and Macon. Making a flying moor to a low mast is a relatively easy maneuver. The main wire is laid out on the ground 500' to leeward from the mast cup with the coupling eye located at the landing flag. The two yaw guy anchor cars are spotted forty degrees to right and left of the landing flag, or about sixty degrees right and left from the mast cup on the railroad track.

The two yaw lines are led from the winches at the mast to the fairlead blocks on the two yaw guy cars anchored on the circle, and back to the landing flag. The landing flag is kept directly downward from the mast cup with a smoke candle leeward from the flag. The yaw guy cars and gear are shifted relative to any shift in the wind as indicated by the flag. The airship slowly approaches the mast at an altitude of around 200 feet. When the nose of the airship is over the landing flag the port and starboard trailropes are dropped and the two yaw lines are coupled to the two trailropes, and slack is taken out of the lines quickly in order to control the ship without delay. As soon as the yaw guys have tension the main wire is lowered and coupled to the main mast wire and slack taken out. Four forces are now involved; the positive buoyancy of the airship acting upwards, the main mooring winch pulling the nose cone towards the cup, and the two yaw guy winches supplying lateral control as well as preventing the ship from overiding the mast. Once the nose cone is locked in the cup the water ballast line is hooked up and the stern of the airship is pulled down and secured to the rideout car on the track.

Low masts were used by six rigid airships between October, 1927 and Sept. 1, 1939. The U.S. Navy rigid airships Los Angeles, Akron and Macon used both the fixed stub masts and the mobile low masts developed for mechanical docking. The German commercial airship Graf Zeppelin used the fixed stub masts regularly during her seven years of service between Germany and Brazil, and also used mobile masts for docking at bases with hangars. The Hindenburg and Graf Zeppelin II used the mobile type of low mast only, but Hindenburg rode out at circle #1 at Lakehurst regularly in 1936 with the mobile mast anchored and dogged down, so in effect it served as a fixed mast for most of her flights to Lakehurst. It is to be noted that of all 160 rigid airships built to date, but six of them had the great operational advantage of being able to operate from either stub masts, or from the mobile masts.

After the tremendous success with low mast mooring in October, 1927 at Lakehurst bids were asked for a mobile mast at Lakehurst in November, 1927. This first mobile mast for rigid airships was completed in the summer of 1929 and revolutionized rigid airships ground handling. This mast had a triangular base and was mounted on

crawler treads. It was towed by a heavy duty tractor. The mast had a minimum height of 60', but the top was telescopic so that ships larger than the Los Angeles could also moor. The procedure for mooring to the mobile mast was identical with that for a fixed low mast.

In September, 1929 the Los Angeles made her first static takeoff from the mobile mast. Also in September, 1929 the Los Angeles made history by using the mobile mast for the first time for docking in the Lakehurst hangar. By using the mast to handle the bow of the ship and for towing into the hangar, the ground crew was substantially reduced as manpower was only needed to handle the stern of the airship in docking and undocking maneuvers. In November, 1929 the Los Angeles made her first flying moor to the mobile mast. Finally in January, 1930 the Los Angeles first docked with the mobile mast in conjunction with four docking trolleys on each side of the ship connected to one another and a taxi-wheel under the aft car. A system, presumably with bridles, was used whereby the trolleys were towed by the airship, while the tractor towed the mast, airship and trolleys. The ground crew for docking the Los Angeles was now reduced to 60 men, where previously several hundred were required to dock and undock the ship in moderate winds. Two larger railroad mobile masts on square bases were built in 1931 and 1933 respectively for the Akron and Macon. Also a large telescopic railroad mast was constructed at Sunnyvale for the Macon.

The first mobile railroad mast was completed at Lakehurst in 1931 for use by the Akron of 6,500,000 cu. ft. volume, nearly 3 times that of Los Angeles. The railroad mast was heavier, ran more smoothly on the tracks and was towed by a railroad locomotive. The larger telescopic RR mast completed in 1933 had a self contained power plant and was almost identical with the Sunnyvale mobile RR mast.

In 1930 officers at Lakehurst had devised a heavy stern beam to handle the tails of the Akron and Macon for docking and undocking at the class A bases, Lakehurst and Sunnyvale. It was assumed that the side load on the Akron would be on the order of 63,000 lbs. in docking and undocking in a cross wind. The stern beam was designed to run in and out of the hangar on the two existing 64 1/2 ft. gage railroad tracks. The stern beam built by Wellman Engineering Co. for Lakehurst weighed around 178,000 lbs. The length was 186'6". Traveling in and out of the hangar the beam rolled on two four-wheeled trucks towards each end of the beam on the existing tracks. For traveling on the circular hauling up track in front of the hangar the beam was supported by one truck at each end of the beam. The trucks for the circle are jacked down eight inches lifting the hangar track trucks 4" above the track.

Originally the Akron was towed in and out of the Lakehurst hangar by the mast with the ship towing the beam along under the lower fin. This was felt to be risky and early in 1932 a spreader gear arrangement between the railroad mast and beam was adopted so that the

mast towed the stern beam, and there were no compression forces, or tension forces, acting on the airship.

For hauling the beam and ship against the wind on the circular hauling up track a special locomotive was built 266,000 lbs. in weight and with a drawbar pull of 63,000 lbs.

Sunnyvale and Lakehurst each had hangars, mobile masts, spreader gear, yaw guy cars and rideout cars. At Sunnyvale the two mooring out circles at each end of the hangar served a dual purpose, they were both mooring out circles and hauling up circles.

The six class B bases for the Akron and Macon ideally each had a stub mast with a rideout RR track on a 643' radius, winches, two yaw guy cars and a rideout car. Opa-Locka, Florida; Camp Kearney, Cal.; Ewa, Hawaii; and Guantanamo, Cuba were so equipped. Parris Island had a mast and path only and Fort Lewis was in process when the program ended.

Germany had rail type mobile masts for LZ-127, LZ-129 and LZ-130 at Frankfurt, Lowenthal and Rio. Hauling up circles were at the above bases, but it is not known what mechanical hauling up equipment was used, if any, to secure the ships to docking trolleys. But all three airships used their mobile masts regularly for docking and undocking.

Since September 1, 1939 all significant improvements in airship ground handling have been developed by the U.S. Navy. Mobile masts mounted on balloon tires at each corner of the triangular masts and towed by tractors were built for the L, G, K and M airships during WWII. Stick masts were also used at advance bases. All docking and undocking of the non-rigids was done with a tractor and mobile mast handling the bow and manpower on the stern of the ships.

After WWII 55 new airships were purchased through April, 1960. Sizes of some of these new AEW and ASW non-rigids increased dramatically. Eighteen of these new airships were of 1,000,000 cu. ft. volume, while the largest WWII non-rigid was 725,000 cu. ft. Four of the new airships were huge non-rigids of 1,500,000 cu. ft. with a length of 403'. It became absolutely imperative that new methods and mechanized equipment be developed to help land, moor, dock and undock these large airships.

The largest mobile mast we had during WWII was the KM mast weighing 39,000 lbs. Types weighing from 44,200 lbs. to 55,900 lbs. were produced to handle the 1,000,000 cu.ft. airships. But much larger masts were needed to handle the huge 1,500,000 cu.ft. ZPG-3W AEW airships. The Type V mast with hydraulic controls was developed, and the 1-14-58 Ground Handling Manual listed its weight at 150,000 lbs., but the 1-15-61 Manual revised its weight down to 128,670 lbs. In any event these masts were by far the largest ever built to moor a non-rigid. Jacked and secured at a mooring out circle with a 3W moored a Type V mast was designed for 90 knot winds.

The towing tractors also became heavier and more powerful. The 1-1-54 Manual lists two tractors in use; the Type I-9 Tractor weighing 10,500 lbs. with a drawbar pull of 7,500 lbs. and the Buda HA-120 weighing 16,800 lbs., with a drawbar pull of 12,000 lbs. The I-9 is being phased out at this time. The 1-14-58 Manual lists 3 types of tractors for towing the heavier masts and larger airships. The Buda HA-120 mentioned above is now being phased out in favor of the MC-2 Airship Spotting Tractor weighing 23,500 lbs., with a drawbar pull of 15,000 lbs. The ultimate towing tractor for the program was the Mobile Winch Type MC-3 weighing 30,000 lbs., and with a drawbar pull of 24,000 lbs.

The greatest breakthrough and most significant advance in ground handling airships, since the mobile railroad masts and stern beams for the rigid airships of the 1930s, was the development of the ground handling "mules" in the mid-1950s at Lakehurst. The 1-1-54 Navy ground handling manual makes no reference to mobile ground handling mules, but the 1-14-58 Manual features their use. Obviously at some time between these two dates the mobile winches were developed evaluated and adopted for regular service use. The Mobile Winch Type MC-3 was the first mobile winch developed. This MC-3 mobile winch served several purposes and proved to be invaluable. First of all they were by far the most powerful towing tractors to be used with the large mobile masts. But their other designed uses were far more important, even vital. The MC-3 winches, working in pairs, were used to handle the tails of the airships in undocking and docking maneuvers, while the Type IV and Type V masts, towed by MC-3 tractors, handled the bows. Ground crews were greatly reduced. MC-3 mules held the nose of an airship stationary while the mast was towed close and the winch pulled the nose cone into the mast cup completing the mooring. It was found it was better to bring the mast to the ship than vice versa. A MC-3 tractor towed the mast and ship to a mooring out circle. Pairs of MC-3 mules were used for unmasting the ships, and were also used to launch the airships. With the versatile MC-3 mules at last the ground handling of the largest non-rigids had achieved the ultimate in mechanical ground handling and mooring. Landing a ZPG-3W using a pair of mules was accomplished regularly with a ground crew of only 18 men. Docking was done with a crew of 12. Unmasting and launching with a pair of mules was accomplished with only 12 men.

Later MC-4 mules were introduced. They were lighter and more maneuverable, consequently they were not usually used for handling the tail during docking or undocking, but they were used for landing, masting, unmasting and launching airships where their greater agility came into play.

In ending this paper I should like to make some observations and offer a few opinions.

I feel that future conventionally configured large rigid airships

should operate as true VTOL aircraft. They should make static takeoffs, perhaps aided by vectored thrust, from low type mooring masts.

Large rigid airships should make flying moors to low masts, again making them VTOL vehicles.

Rigid airships should moor out on circles, preferably equipped with railroad track for yaw guy cars and a rideout car.

Nearly 100% of large rigid airship operations should be to and from fixed low mooring masts. Loading and off-loading cargo can be accomplished easily.

Future rigid airships should only need to dock once a year for a few weeks of annual, overhaul. Thus only one maintenance hangar should be required for every dozen or so airships. The maintenance hangar servicing these dozen ships would require a mobile mast, and a stern beam and spreader gear. Ideally the mooring out circle and hauling up circle would be combined as at Moffett Field in the 1930s.

Construction hangars, in my opinion, will always be required for large airships. A mobile mast, docking rails and manpower should suffice at these sites as docking and undocking operations will be few and far between.

Mooring on large protected bodies of water is feasible, and loading and off-loading cargo on barges can be accomplished easily.

A small training rigid airship should be built and operated before going into large rigids. This small ship could be ground handled with mobile masts like the Navy Type V mast, and with ground handling mules similar to the Navy MC-3 Type. This training ship should be from 1,000,000 cu.ft. to 2,000,000 cu.ft. in volume.

The sheer size and length of very large rigid airships, plus the large area landing mat that would be required, plus structural considerations indicate that heavy takeoffs using aerodynamic lift should not be considered for conventional circular cross section rigid airships. For large rigids a static takeoff from a mast is best. Additional payload up to 10% of the gross static lift of the airship can easily be flown aboard by hook-on plane once the airship is at cruising altitude and speed.

Airships larger than 5,000,000 cu.ft., to use an arbitrary figure, should be ground handled with a railroad type mobile mast and beam at maintenance bases.

The metal-clad pressure rigid airships would be moored and ground handled by the same methods and equipment as conventional rigid airships.

For the near future we should only consider rigid airships up to 15,000,000 cu.ft., as that represents the size ship that can be built in our largest existing hanger. After the 15,000,000 cu.ft. ships prove their worth we can go to larger hangars and larger airships.

We have the basic answers for ground handling any size airship, and equipment and techniques will continue to improve with a new airship program.

REFERENCES:

1. RIGID AIRSHIP MANUAL 1927. U.S. Govt. Printing Office 1928.

2. Rosendahl, C. E., The Mooring and Ground Handling of a Rigid Airship, Aeronautical Engineering, (January-March, 1933).

3. Bolster, C. M., Mechanical Equipment for Handling Large Rigid Airships, Aeronautical Engineering, (July-September, 1933).

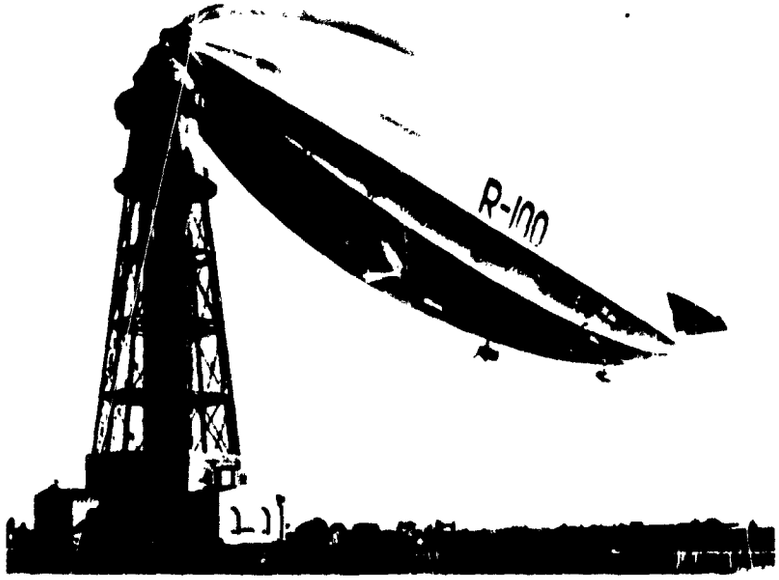
4. Operational Post Mortem, 1935, USS Macon, National Archives. (1962).

5. Lakehurst NAS, Blue Jacket's Airship Manual 1940.

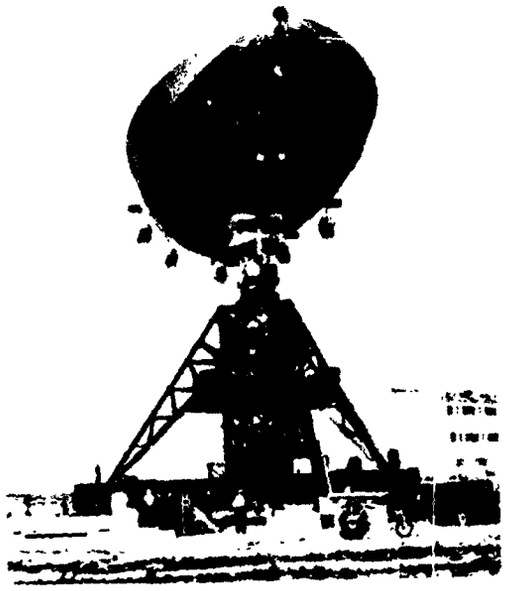
6. Handbook. Airship Ground Handling Instructions. (November 1, 1958).

7. Robinson, Douglas H., Giants in the Sky, GT Foulis & Co. Ltd. Oxfordshire, England (1973).

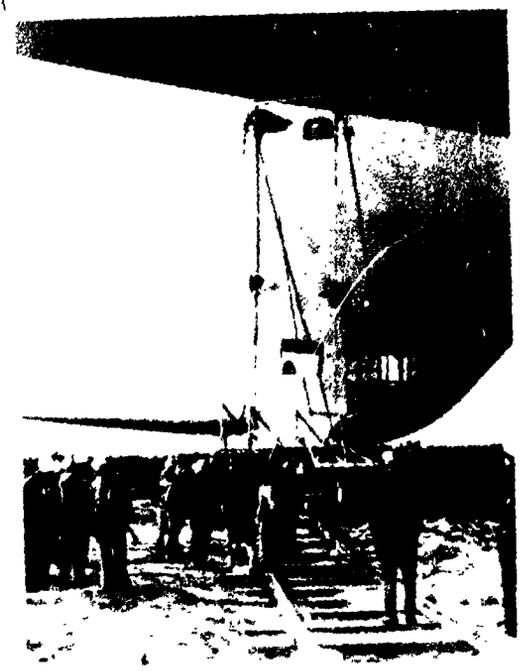
PHOTOGRAPHS:



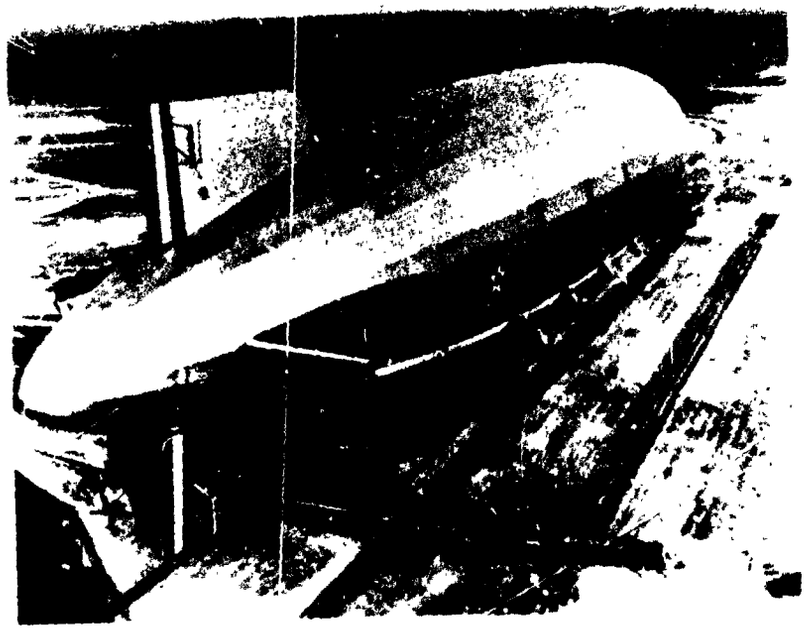
1. R-100 moored to permanent type high mast. Montreal, Canada (1930)



2. USS Los Angeles making a flying moor to mobile mast.Lakehurst(1931)



3. USS Akron lower fin moored at circle with rideout RR carriage and taxi-wheel. Lakehurst(~1932)



4. USS Macon being docked with mobile railroad mast, stern beam and spreader gear. Lakehurst (1933)