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Preliminary Study of Ground Handling Characteristics of Buoyant Quad Rotor (BQR) Vehicles

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Goodyear Aerospace Corporation

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Prepared for
Ames Research Center
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Space Administration

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FOREWORD

The development of facilities and capabilities at modal transfer points is fundamental to any transportation mode. In most cases, the utility of the mode is more sensitive to terminal operations than in-transit performance. Historically, ground handling has been a severe problem for lighter-than-air (LTA) vehicles due to their inherent lack of low-speed controllability. Although the BQR vehicle will exhibit a substantial increase in control power availability, ground handling remains a concern.

Recent developments in LTA suggest that BQR vehicles will be in production in this decade. This is supported by the number of past studies that have been favorable with respect to this concept. It will be the overall operational effectiveness of this airship system, however, that will ultimately define its role in the market place.

The objective of this study is to define several ground handling systems appropriate for BQR vehicles and assess their impact in vehicle design and mooring operations. This report represents the culmination of this study performed under NASA-Ames Contract No. NAS2-10448 by Goodyear Aerospace Corporation.

Dr. Mark D. Ardema was the NASA Technical Monitor. Within Goodyear Aerospace, Mr. Dale E. Williams, LTA Program Manager, and Mr. Donald B. Block, Chief LTA Engineer, provided overall program guidance. Mr. Ronald G. E. Browning was the Project Engineer. Prime contributors were Mr. F.Bloetscher, Mr. W. Trumpold, Mr. A. Ahart, and Mr. L. Cermak.

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1. EARLY APPROACHES

a. General

The evolution of ground handling systems has, by necessity, paralleled the advancement of airship design and operational capabilities. Early craft, due to their limited size, were easily ground handled to and from mooring sheds by small groups of men. However, as envelope size increased, the requirements for more effective and efficient ground support were necessary.

b. Floating Hangar

Not unexpectedly, Von Zeppelin extended his innovative skills to airship mooring. The use of a floating hangar on Lake Constance was the culmination of his assessment of how to satisfy three main requirements for airship mooring operations:

1. Provide a flat surface
2. Provide unobstructed approaches
3. Enable the airship always to carry out docking procedures in line with the prevailing wind direction.

This also marked the inception of mechanical handling systems through the use of small boats acting as tugs.

The downfall of this approach was its sensitivity to stormy weather. Due to this, the concept was eventually abandoned and a return to land facilities was implemented. An early example is shown in Figure 1-1.

c. Manpower

For several years, no attempt was made to change the operation of walking an airship to and from its protective hangar. Since most airship flights during this period (World War I) were conducted by the military, a sufficiently large contingent of personnel was always available for ground handling. This system remained, however, closely dependent on wind conditions. Numerous flights either were cancelled or extended due to incompatible winds at the scheduled undocking or docking times, respectively.

d. Docking Rails and Trolleys

In keeping with the philosophy of providing hangar space for an airship when it was not in flight, early attempts at ground handling were aimed

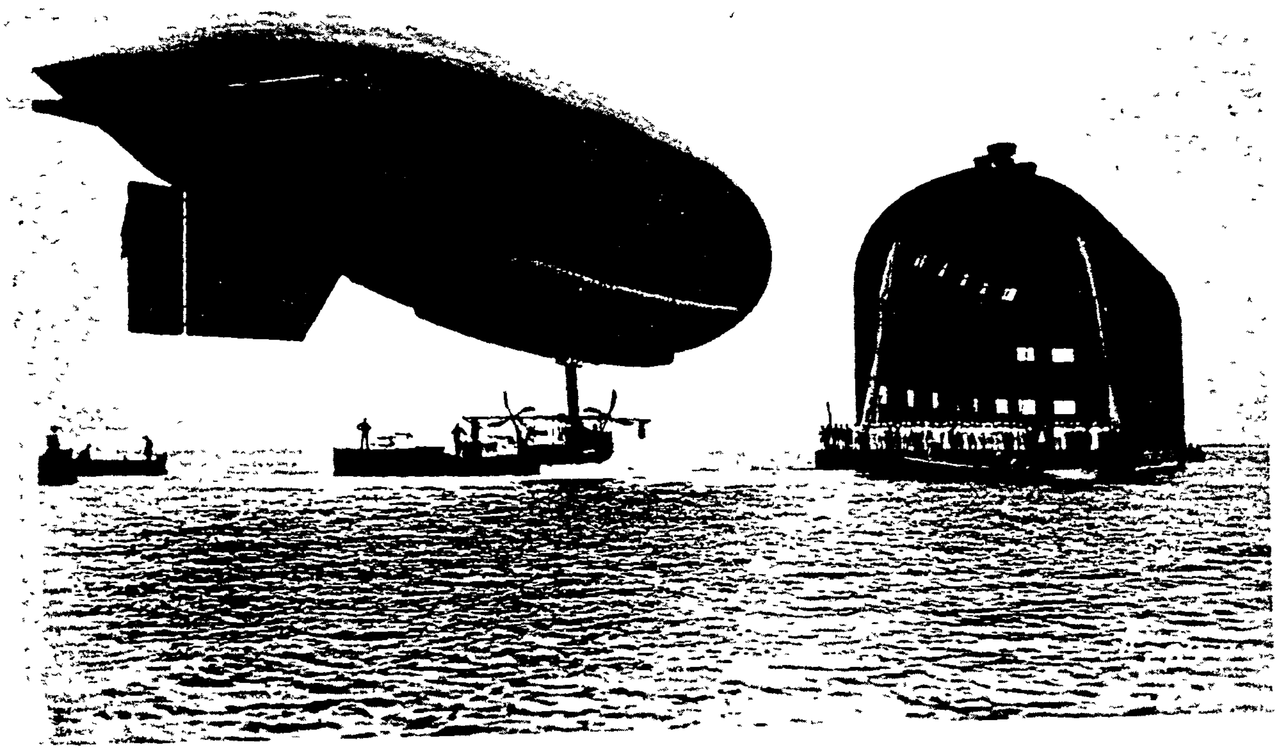


Figure 1-1 - Floating Airdock (1917)

at improving the efficiency of moving the airship to and from the hangar, rather than providing an exterior mooring system. The result was the development of docking rails and trolleys (see Figures 1-2 and 1-3). Initial design and use of this equipment was undertaken by the Germans and Italians. System refinements were instituted at a later date in both the United States and England.

Docking rails were built along the inside of each hangar wall and extended some distance out onto the airfield (see Figure 1-4). These rails provided a rigid base along which mobile trolleys could run, thereby establishing a control system for the critical portion of the airship undocking/docking sequence.

A typical docking operation utilizing the rail/trolley system is:

1. The airship lands and is walked to the external rail end by the ground crew.
2. A rope tackle is attached from the left and right trolleys to bow mooring points on the airship.
3. The airship is walked forward until trolleys can be attached in the same manner to stern mooring points.
4. The airship, now secured fore and aft, is walked into the hangar.

Eight crewmen were used on each trolley. The remaining available personnel were assigned to the bow hauling rope to ease the airship forward and underneath the car to keep it from contacting the ground.

e. Ground Cable Landing System

Another early attempt at minimizing ground crew personnel requirements was the ground cable landing. The end points of a long cable were secured, through springs, to ground anchor points. The airship's objective was to engage the cable with a suspended grappling hook while flying overhead. The results of this experiment were unsuccessful.

f. Mooring-by-Wire

Several variations of a mooring by wire system were suggested and tried (see Figure 1-5). Although experiences with these systems were not totally unsatisfactory, some significant drawbacks made them impractical.

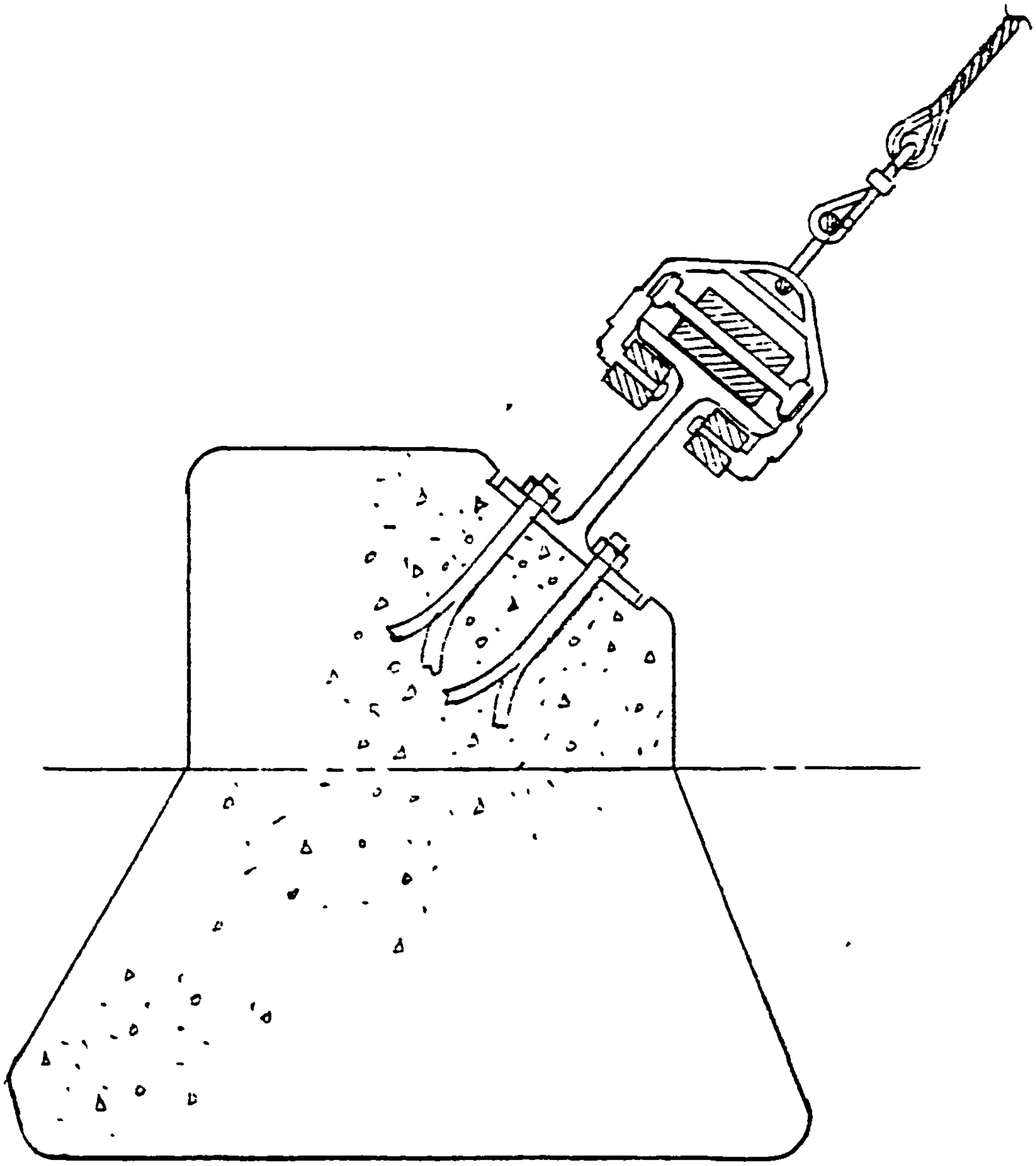
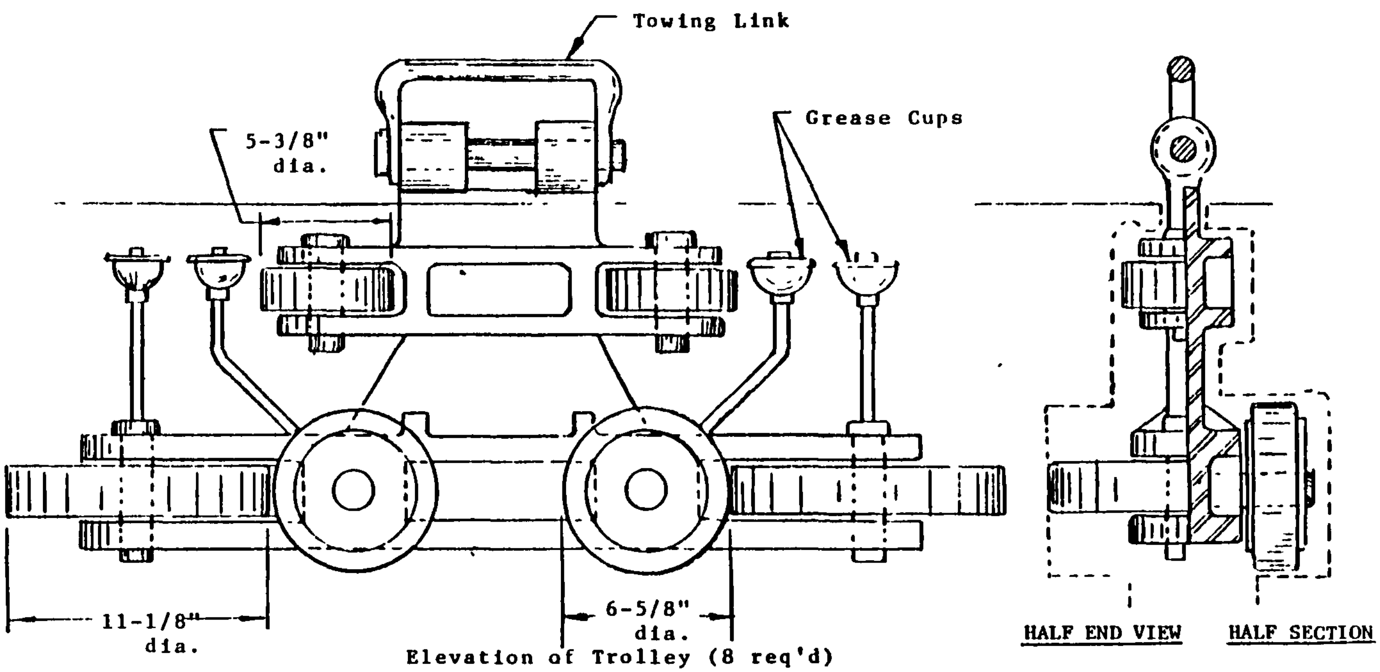


Figure 1-2 - Italian Docking Rail and Trolley (1923)



All Wheels must have Hyatt Roller Bearings or equivalent.

Figure 1-3 - Docking Rail Trolley (1923)

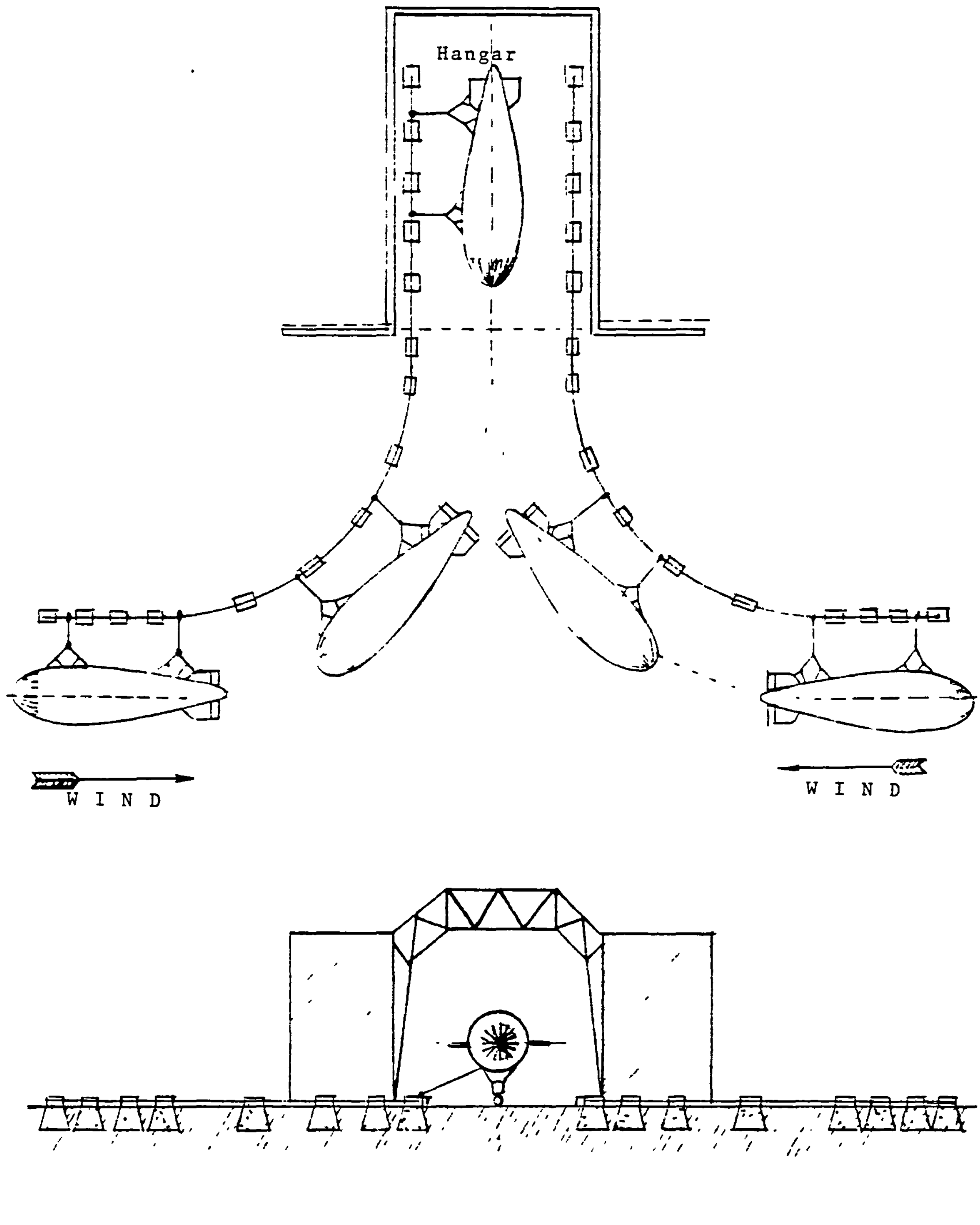


Figure 1-4 - Italian Single Rail and Trolley (1923)

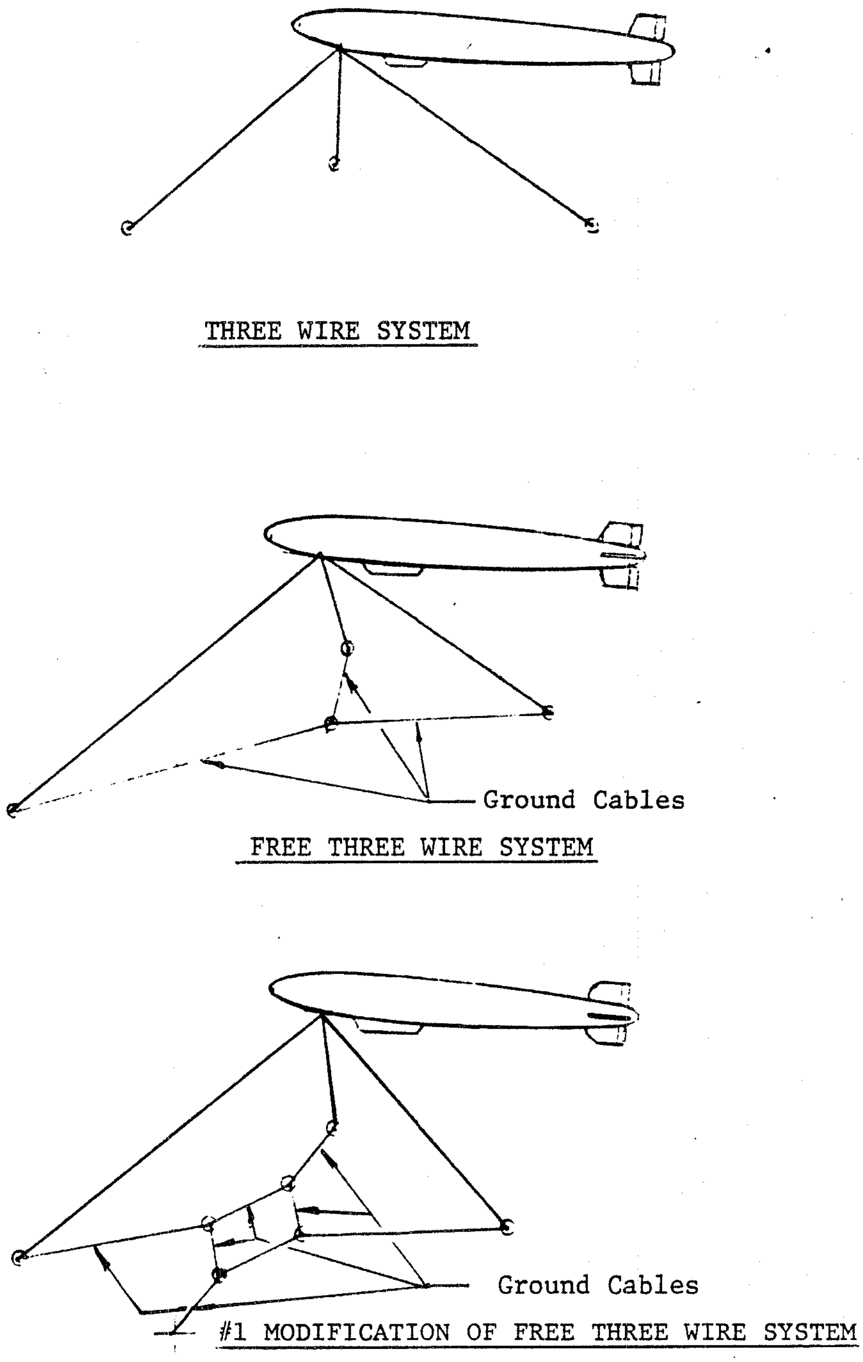


Figure 1-5 - Three-Wire Mooring System

Four variations were attempted:

1. The Usborne system consisted of two vertical wires attached to the car. This proved to be unstable in high winds.
2. The basic three-wire system utilized wires attached at one point on the airship to form an equilateral pyramid. This configuration was used to bring the rigid airships to their mooring masts even through the system itself proved to be too unstable for mooring out.
3. The free-three-wire system enables the three cables to feed from the apex of the equilateral pyramid through sheave blocks anchored to the ground and attached to a free-moving central ring. This concept eliminated the rigidity of the fixed cable system. As a result, the free-three-wire system provided the airship with more stable riding out characteristics.
4. A four-wire system had one additional wire from the ring (described above) to a ground anchor point. This, in effect, formed the ring into a parallelogram. Although this system was tested, it was not successful.

Conclusions resulting from experiences with mooring-by-wire systems were:

1. For maximum stability, an airship would have to be trimmed four to five degrees down by the tail and held a similar amount off wind.
2. Since heating and cooling causes rapid change in the airship static condition, a rapid ballasting system would have had to be developed.
3. To keep tension on the wires, the airship would have to be maintained in a light static condition.
4. Ballasting and fueling an airship moored in this manner would be very difficult.
5. A crew would have to remain on board at all times. Crew changes would be very difficult.
6. The mooring area would be large.

The mooring by wire system was proven to be too unstable and cumbersome to be practical, except possibly as an alternative emergency mooring system.

g. Vickers Masterman Mast

The Vickers mast was an early development by the English for non-rigid airships. Its unique design enabled the airship to be cradled in a yoke rather than be constrained at a single attachment point (see Figure 1-6). Two pads were fastened to the envelope several feet behind the nose to reinforce the contact areas between the airship and the end points of the yoke.

To initiate the mooring procedure, the ground crew, with handling guys, would walk the airship upwind toward the mast. At the yoke, a man would be stationed at a winch in each yoke. Once the airship was properly positioned in the yoke, cables would be attached to the envelope and reeled in such a manner that the airship was securely attached to the mast.

While the Vickers mast saw limited use for several years, deficiencies in the following areas accounted for its final demise:

1. The mooring patches were cumbersome and had sufficient weight to cause the airship to become nose heavy
2. The patches were difficult to attach
3. The mooring operation was extremely sensitive to high, gusty winds and therefore required an excessive number of ground personnel
4. There was insufficient positive maneuvering action during mooring
5. The positioning of two men on the yoke of the mast was hazardous

h. Nose Mooring Systems

(a) General

The expansion of military airship programs stimulated the search for acceptable mooring systems. Hangars were operationally effective but prohibitive in cost. Thus, development of an outside mooring technique was mandatory. The nose mooring system appeared to be the most suitable.

Consistent with this approach was the development of nose battens in non-rigid airships. While early airships were slow enough to obviate this need, newer and faster craft required nose stiffening to prevent in-flight fabric deformation. Similarly, a nose mooring approach necessitated the development of a system to distribute the mooring loads. A fabric-covered metal nose cone structure satisfied both these needs.

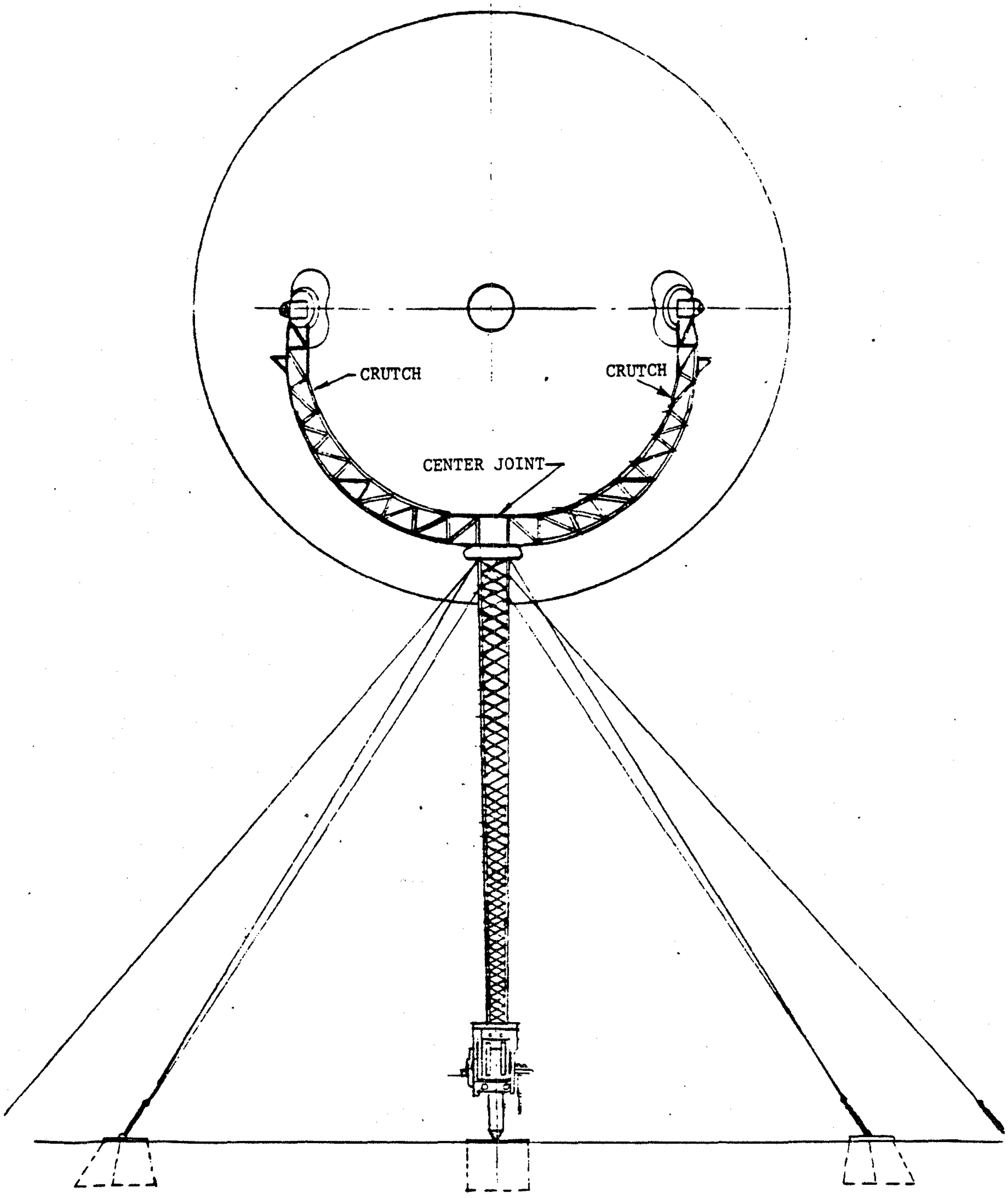


Figure 1-6 - Vickers Mooring Mast (1923)

This led to new airships with a grooved, bearing-mounted spindle installed in the nose cone and a flexible steel pull-in cable secured to the spindle. Battens were attached to the base of the nose cone to distribute the mooring loads evenly over the envelope surface. Initially, these battens were made of wood but were eventually replaced by stronger and lighter aluminum battens. The spindle in the nose cone was mated to a device atop a mooring mast. These early masts were simply variations of guyed built-up steel structures with a hand winch at the bottom and a buffer at the top against which the airship would be drawn. As airships increased in size, more efficient and stronger masts were produced.

(b) Terry Mast (for Non-Rigid Airships)

One type of mast developed early by the military was known as the terry mast (see Figure 1-7). This mast consisted of a structural steel center pole supported by eight guys anchored in the ground. On top of the mast a 13-foot-diameter cone-shaped buffer was mounted. The buffer ring had felt pads secured around the lip to reduce envelope wear at the contact points. The buffer was attached to an arm of a circular casting that rotated on bearings on top of the mast. Counterweights were attached to another casting arm opposite to the buffer.

A pull-in line was attached to two nose patches and run through a sheave on the mast head, down through the mast, and out through another sheave at the bottom, finally to a winch. Once the hookup was made, the winch reeled in the airship until the envelope nose was snug inside the buffer cone. Tension was kept on the pull-in line, and the winch was locked.

While this configuration had merit in terms of minimizing ground crew requirements, it had several drawbacks:

1. The cone and counterweight were heavy and exhibited a flywheel characteristic in shifting winds.
2. Load distribution was unsatisfactory. The buffer cone should have been extended by four to six feet and contoured to the envelope's shape.
3. The nose patches were unable to sustain the pull-in cable load.
4. Considerable stresses built up in the envelope immediately aft of the buffer ring. In actual recorded cases, battens were broken and envelope fabric torn due to these stresses.

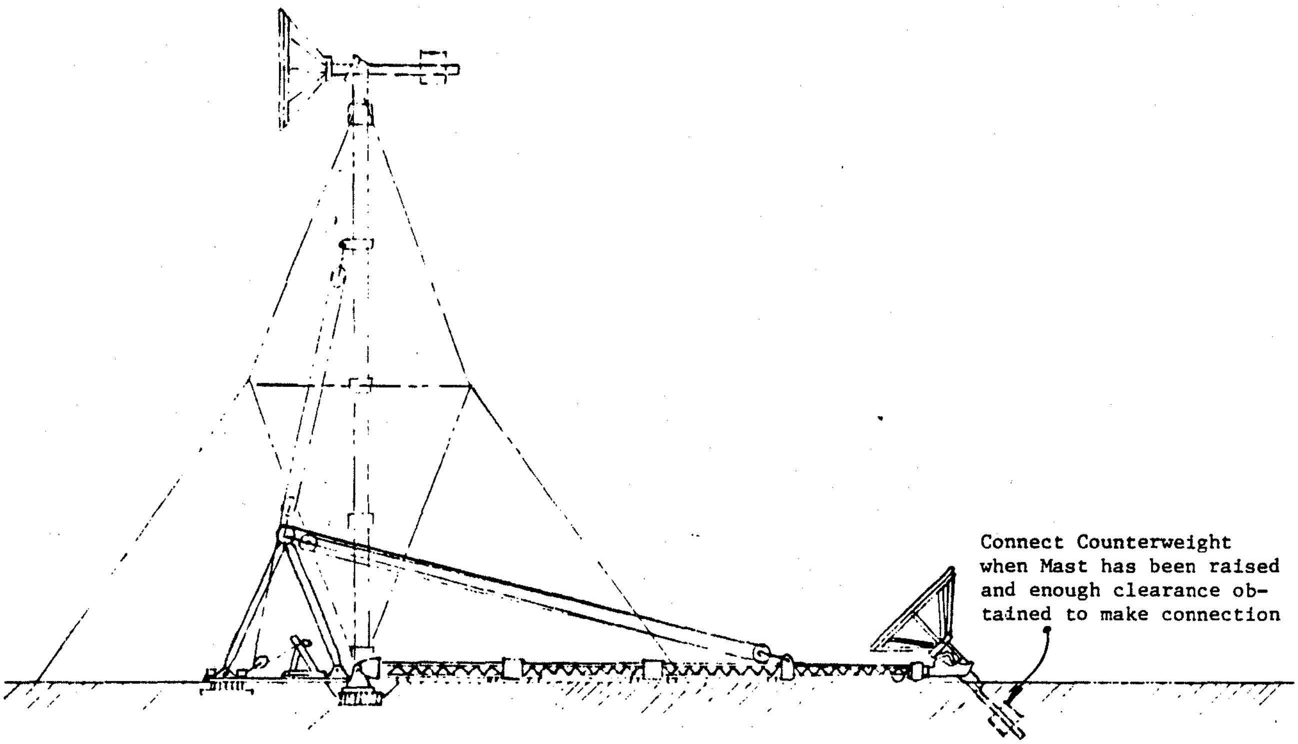


Figure 1-7 - Terry-Type Mooring Mast (1923)

5. Forward and aft shocks around the buffer ring were experienced during mooring operations in gusty winds.

(c) High Mast

Coincident with the rapid development of rigid airships for intercontinental travel in the 1920's was the design of a high mast. This system resulted in the elimination of a hangar as a necessity for airship operations, thereby providing a solution for more efficient (both operationally and economically) mooring hardware that could be made available at several terminal locations (see Figure 1-8). This approach, however, was not devoid of drawbacks. A moored airship was, in fact, always being flown at the mast. Consequently, an on-board flight crew was a continuous requirement. In addition, undesirable air currents were occasionally encountered at the mooring height, thus causing extreme airship attitudes.

In the same decade, the U. S. Navy entered the rigid airship world with the delivery of the ZR-1 Shenandoah in the fall of 1923 and the ZR-3 Los Angeles one year later. Accommodation in the form of a 100-foot high mast was provided at Lakehurst, New Jersey (see Figure 1-9). A sequential description of the airship's operations at this site is as follows:

1. The mast and airship are prepared for the mooring operation.
2. When all is ready, the airship approaches the mast into the wind.
3. When near the 500-foot circle, the main mooring wire is dropped.
4. The ground crew connects the airship and mast wires.
5. The airship then rises until the mooring lines are taut, discharging ballast if necessary to accomplish this.
6. The main winch starts to haul in the airship.
7. After the main hauling line is taut, the left yaw line is let down on a messenger block carrying the end of the line to the mast cup.
8. The same operation is repeated for the right yaw line.
9. When the airship's yaw lines are coupled to the mast yaw lines, they are cast adrift from the mast platform and hauling is begun.

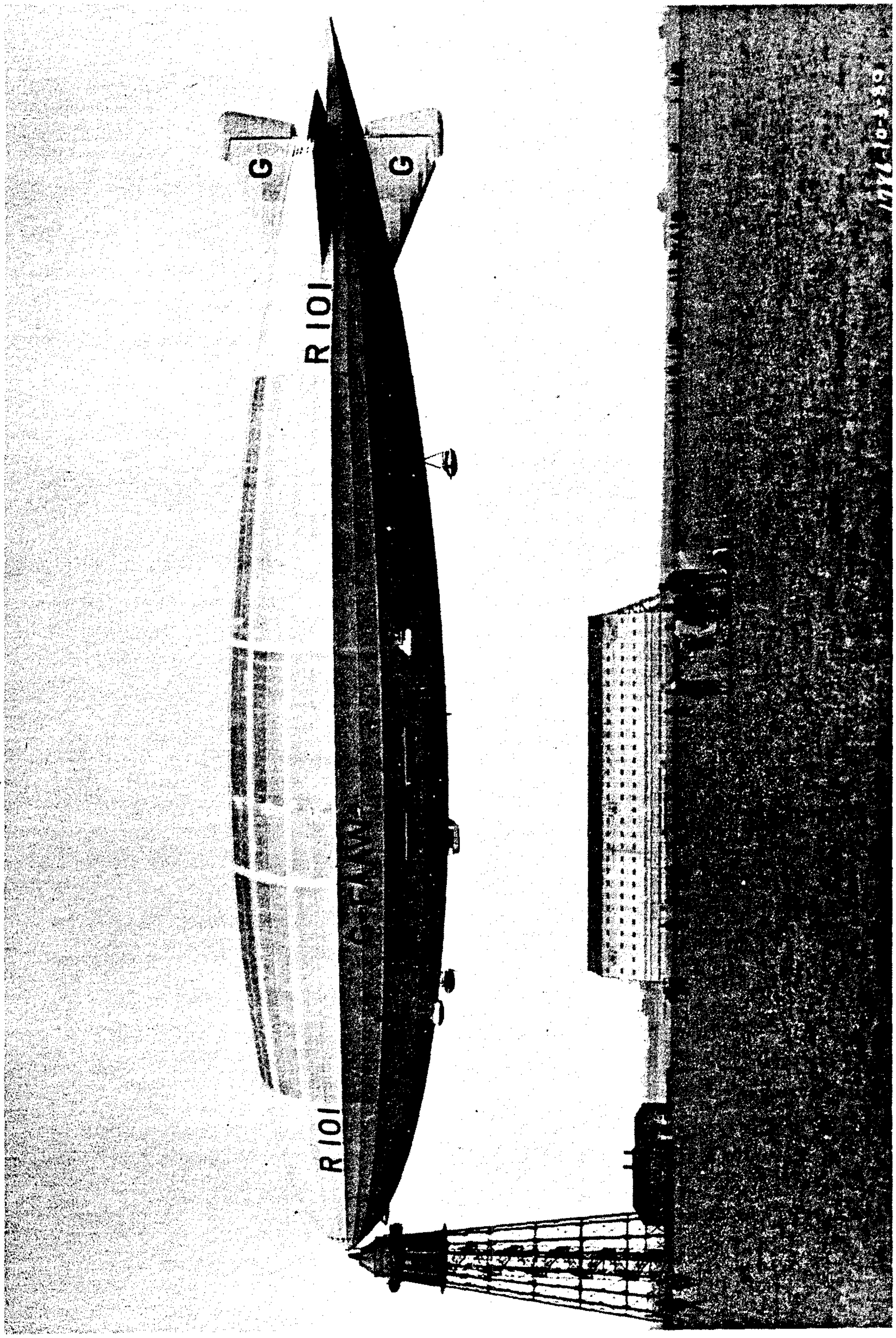


Figure 1-8 - English High Mast (Cardington, England), 1930

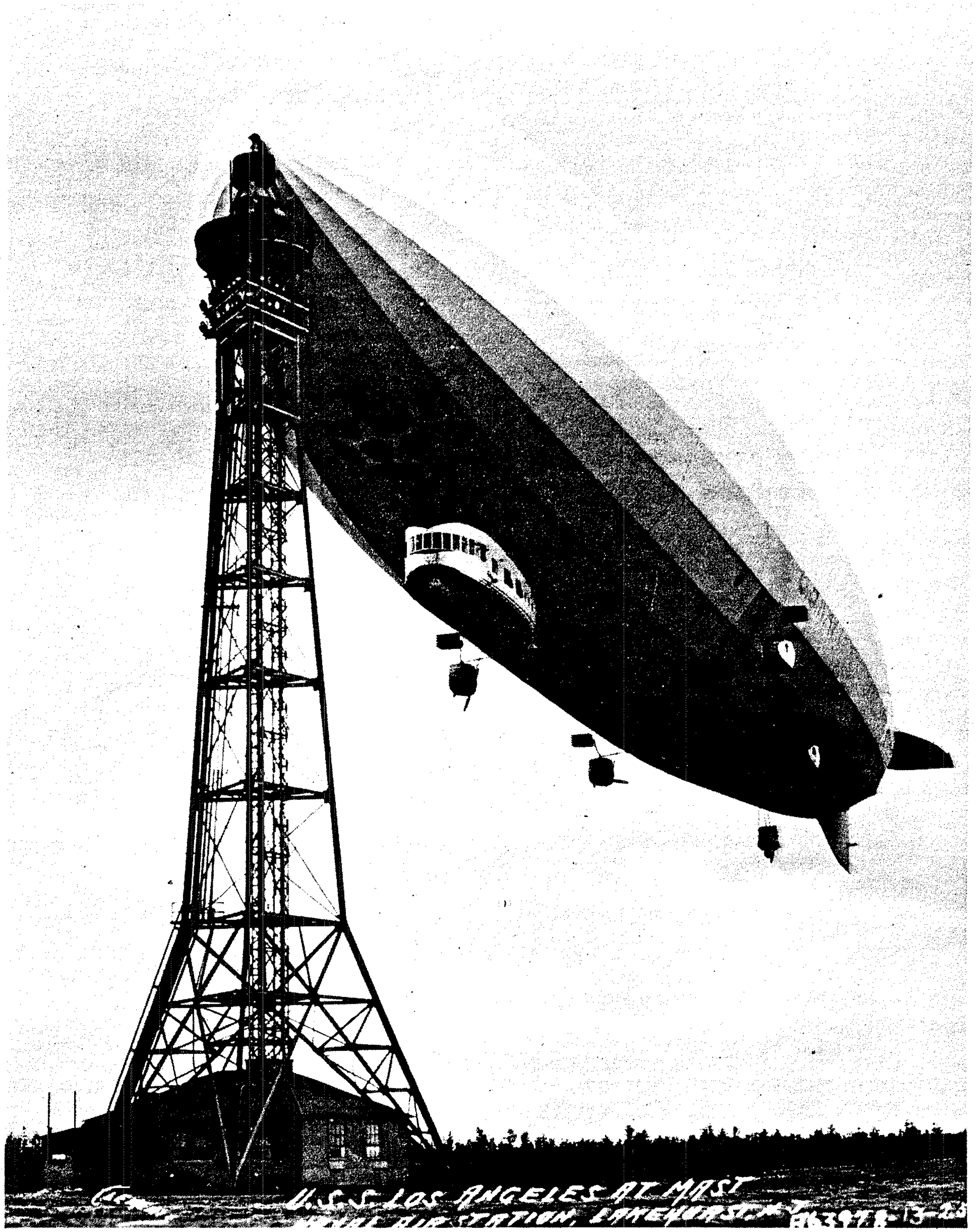


Figure 1-9 - Navy High Mast (Lakehurst, New Jersey), 1925

10. Each mast yaw winch is operated until a predetermined mark on its guy appears at the snatch block anchorage, which indicates that there is just enough line between the snatch blocks and the bow of the airship to allow the airship's cone to be brought down into the mast cup. The mast yaw winches are then stopped and the lines held.
11. When the airship's cone is about 25 feet from the mast cup, the speed is reduced and maintained "dead" slow.
12. The main hauling line continues to draw the airship forward and down until the airship's cone enters the revolving cup on the mast and locks itself into place with the three spring locks.
13. When the airship is secured to the mast, all airship lines are returned to the airship.
14. The airship is immediately readied for flight so that an emergency unmasting could be accomplished if a situation required it.
15. Ballast lines and the tail-drag are hooked up.

The egress operation is as follows:

1. The airship is trimmed and weighed off light so that it will rise immediately after release.
2. The release pendant is slacked off a few inches to allow movement of the cone in the mast cup.
3. The releasing hook is tripped, and the airship rises carrying the releasing pendant out through the ram and cup.
4. The releasing pendant is retrieved and secured in the airship and the tail-drag is dropped.

Fifteen ground personnel were required for high mast rigid airship mooring operations.

U. S. S. Patoka Ship-Mounted Mast (for Rigid Airships) - A reproduction of the Lakehurst high mooring mast was the ship-mounted mast on the U. S. S. Patoka (see Figure 1-10), the only difference being the yaw-line handling facilities. The Patoka was equipped with two 80-foot steel lattice-work booms. The horizontal angle between each boom and the ship's centerline was 60 degrees from aft. A small boat carried the haul-in line end astern of the Patoka. With the Patoka steaming 45 degrees into the wind, an airship would fly across the

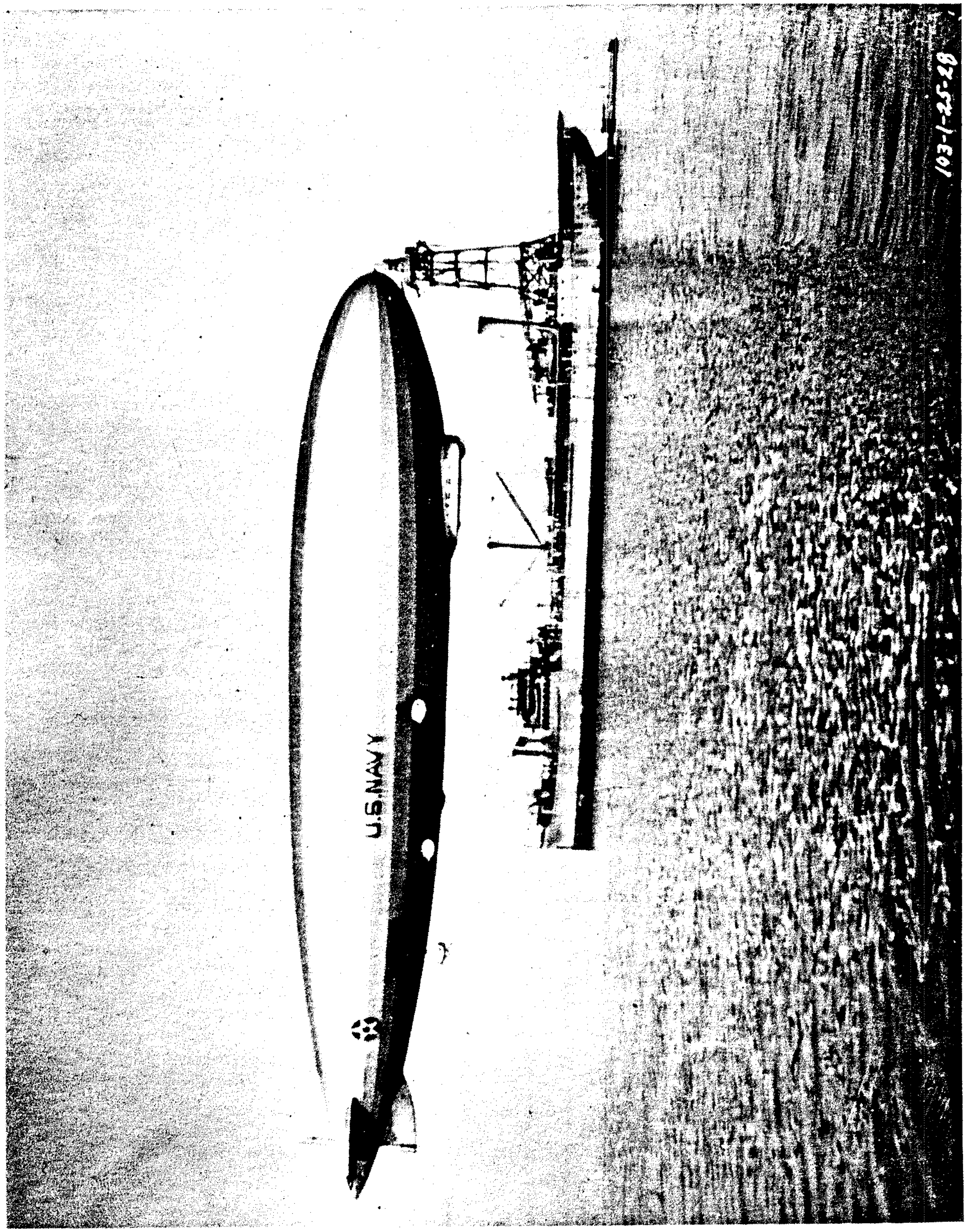


Figure 1-10 - U. S. S. Patoka High Mast (1928) haul-in line. A grappling hook suspended from the airship would snatch the haul-in line, and slack would be taken up. The Patoka would then turn into the wind. The rest of the mooring would proceed in the manner as previously described for land-based high masts. The only airships to use this mast were the Los Angeles, Shenandoah, and Akron.

(d) USN "Stub" or Expeditionary Mast (for Rigid Airships)

In the late 1920's, the U. S. Navy became interested in the stub or expeditionary mast. It had several advantages over the high mast. Since the stub mast was designed for quick assembly and disassembly, it could be made transportable. This made it usable for temporary mooring-out sites (see Figure 1-11). The stub mast's low height meant that the airship would be moored horizontally a few feet above the ground. A detachable castering, pneumatic wheel was designed for attachment to the aft power car. This allowed the airship to swing around the mast without damage. However, some conditions would cause the airship to kite. Various systems were tried to counter this phenomenon such as drag chains, drag wheels, and rail-mounted mooring-out cars. All of these concepts met with limited success.

(e) Self-Propelled Mobile Mooring Mast (for Rigid Airships)

To facilitate ground handling of the large rigid airships, the U. S. Navy experimented with a 100-ton, self-propelled, mobile mooring mast (see Figure 1-12). This pyramid mast was 60 feet on a side and was mounted on crawlers. The wide base and mass of this mast overcame the overturning moment imposed by moderate wind loads on the rigid airships. By mounting each corner of the triangular base on crawlers, and through the use of a self-contained power source, the mast unit was able to traverse the Lakehurst terrain successfully. A similar self-propelled mobile mast was used on the Akron and Macon airships in Akron, Ohio.

(f) Rail-Type Hauling-Up and Mooring-Out Circles

The U. S. Navy rigid airship program expanded dramatically in the early 1930's with the addition of the ZR-4 Akron and the ZR-5 Macon to the fleet. Ground handling equipment and techniques had improved, but further development was required such as:

1. A method of eliminating the hazardous transfer of an airship from a fixed mooring mast to a mobile mast for docking operations

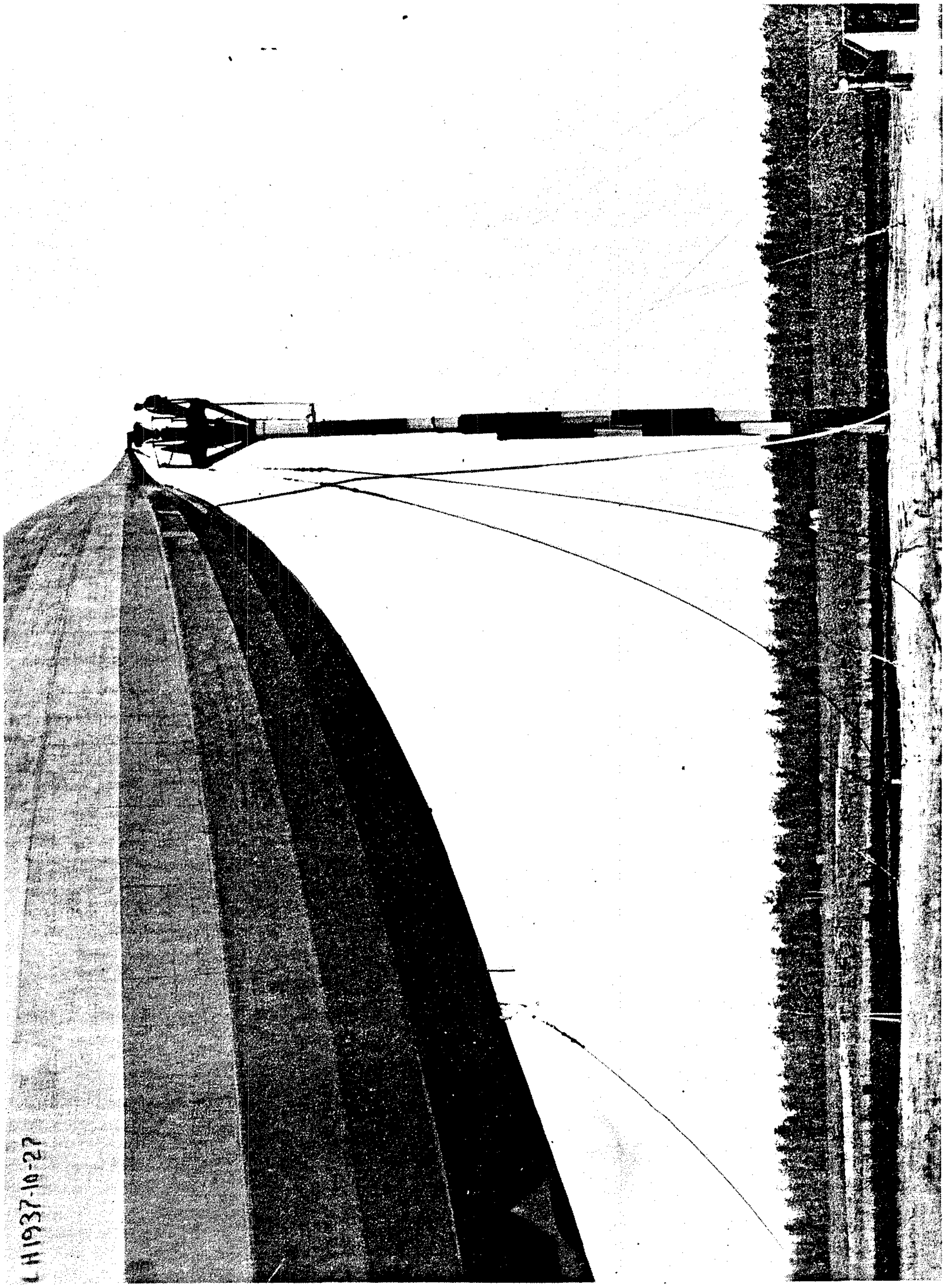


Figure 1-11 - Stub or Expeditionary Mast (1927)

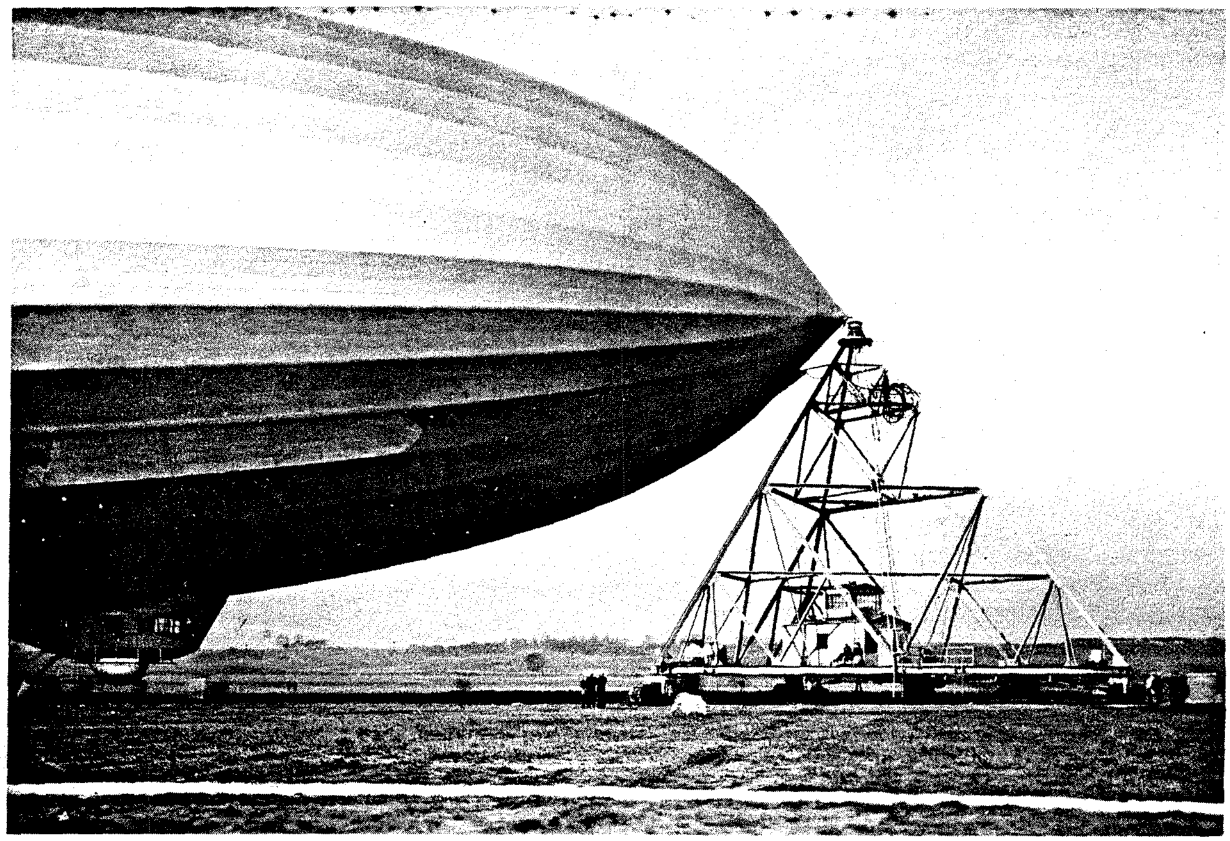


Figure 1-12 - Self-Propelled Mobile Mast (1932)

2. A system that would hold the airship securely during docking operations regardless of the winds
3. Equipment that would reduce the need for large numbers of personnel in the ground handling crews

The final outcome was a docking/undocking, ground handling, and mooring system totally mounted on rails (see Figure 1-13). This system consisted of:

1. Two railroad tracks, $64\frac{1}{2}$ feet apart, running through the hangar and 1200 feet out onto the field.
2. An intersecting 650-foot-radius circular track used for hauling-up operations.
3. Additional track extending out to another circle used for mooring out.

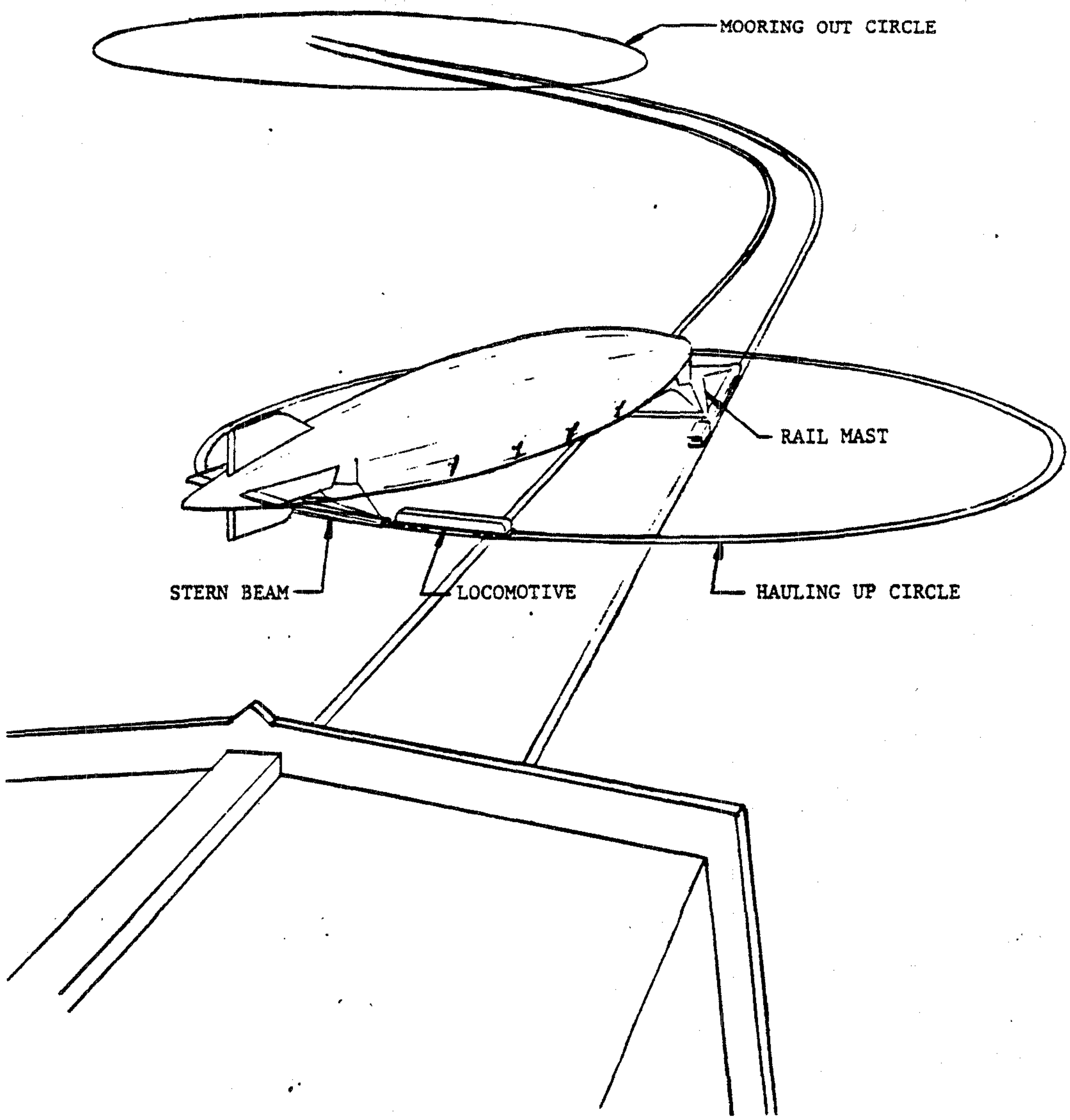


Figure 1-13 - Rail-Type Hauling-Up and Mooring-Out Circles (1930)

4. A rail-mounted, locomotive-powered, mobile mooring mast.
5. A rail-mounted stern handling beam coupled to
6. A second locomotive mounted on the hauling-up circle to swing the stern beam.

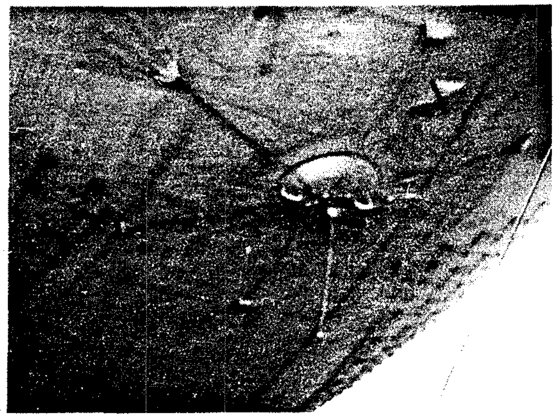
The airship was towed in or out of the hangar secured between the mobile mooring mast at the nose and the 178,000-pound stern handling beam. The mobile mast would be stopped at the center of the hauling-up circle. The stern beam was transferred from the hauling-up circular track to the straight track by means of jacking trucks. The stern locomotive would position the stern beam as required for the docking or undocking operations. If the airship were to be moored out, it would be positioned into the wind and disconnected from the stern beam. A taxi wheel supporting the aft part of the airship was attached, and then the mobile mast would pull the airship out to the mooring circle.

i. Belly Mooring Mast System (Non-Rigid Airships)

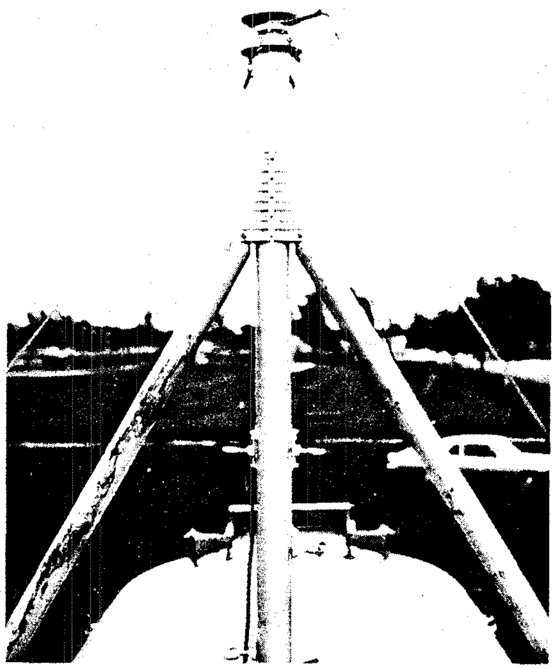
In the late 1920's, The Goodyear Tire & Rubber Company developed a belly mooring system that was unique to its commercial airship fleet. Because of its limited load sustaining ability, it was eventually replaced by an expeditionary mast as the main mooring system. The belly mooring system (see Figure 1-14) consists of a metal disc mounted in the underside of the airship envelope approximately half way between the nose and the front of the car. Several cables attached radiate from the periphery of the disc and have their ends attached to envelope finger patches. A gimbaled spindle is mounted in the center of the disc, with a short pull-in cable attached to it.

A modified bus (see Figure 1-15) was the original mobile ground support vehicle. It contained compartments to carry auxiliary blowers, power supplies, and tools. Facilities to accommodate the crewmen and their luggage were also provided inside the bus. Atop the bus was mounted a short collapsible mast. When erected, it was anchored to the roof of the bus; outrigger wheels on each side of the bus were engaged for lateral stability. A cup and locking device were attached to the top of the mast.

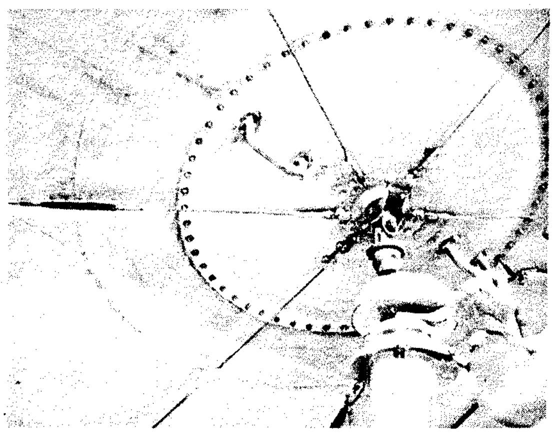
The airship would land to the ground crew and be held in place. One man would pull on the tail lines to raise the belly mooring disc a few feet higher than the top of the bus-mounted mast. Linemen would man two nose lines to keep the nose of the airship steady and into the wind. A mast man was positioned on the mast to direct the spindle into the cup. He would thread



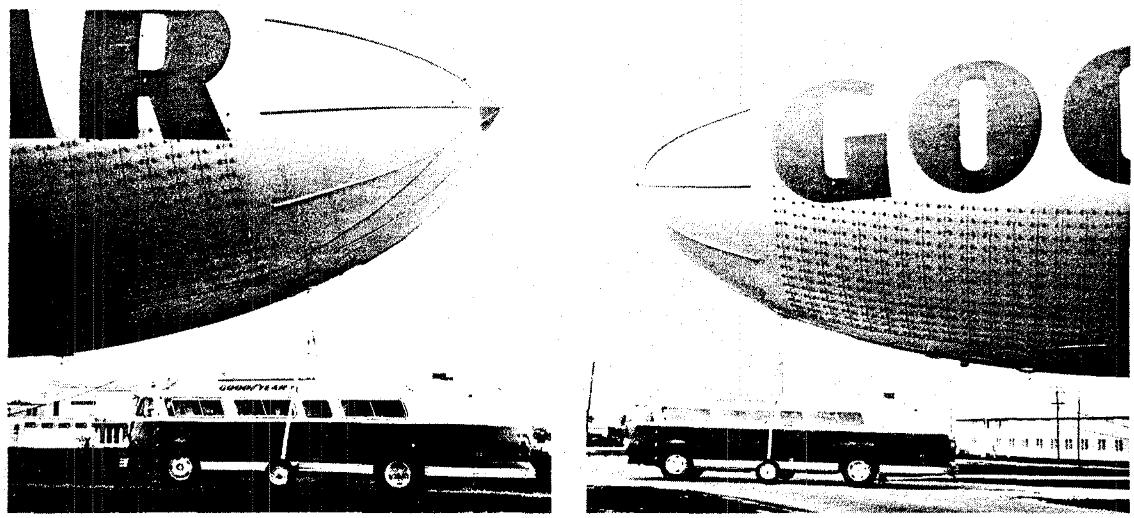
BELLY PLATE



MAST ON BUS



SPINDLE APPROACHING MAST CUP



BUS MANEUVERING AIRSHIP

Figure 1-14 - Belly Mooring Mast (1964)

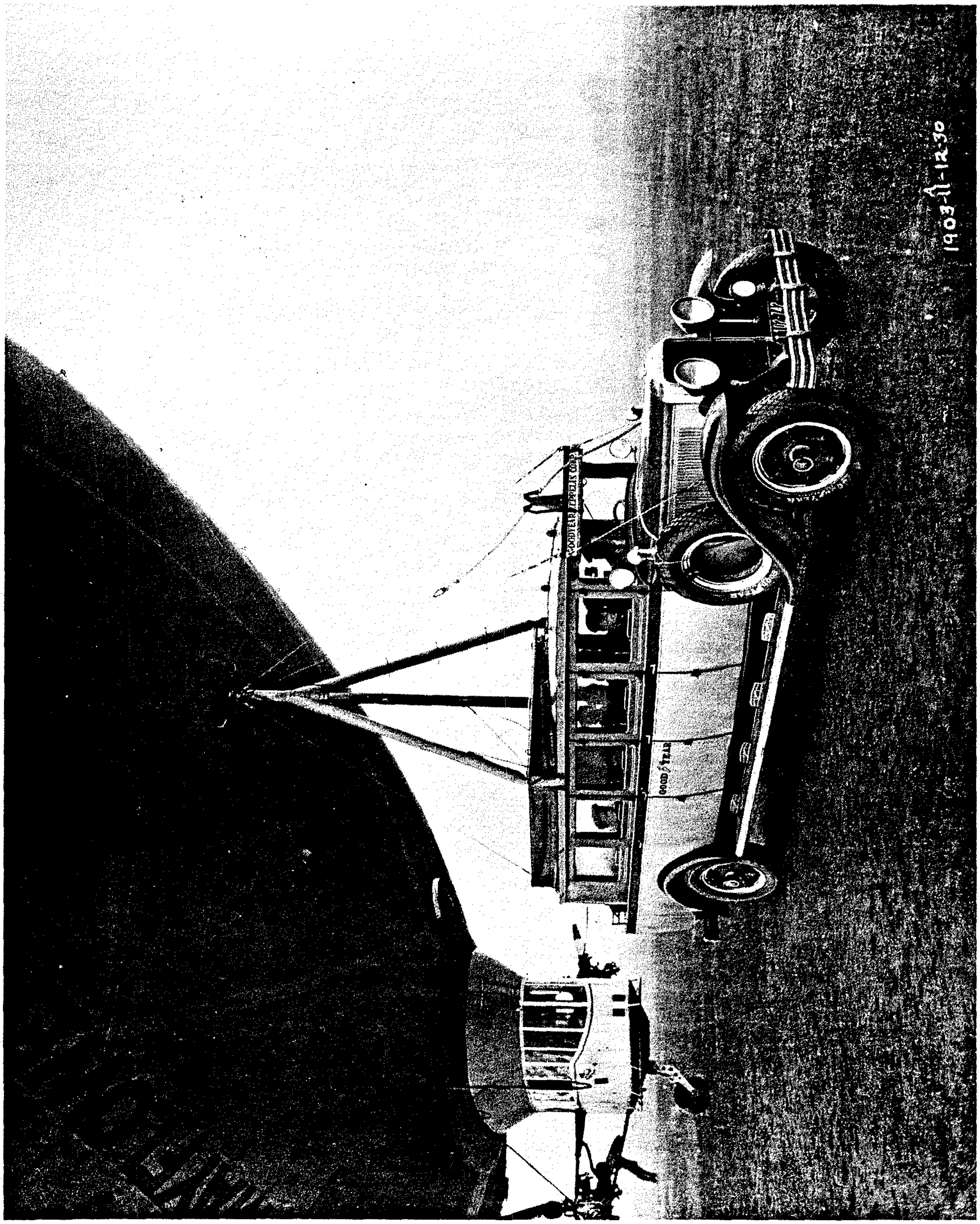


Figure 1-15 - Early Belly Mooring System (1930) a pull-in rope down through the cup to a pull-in man standing alongside the bus on the ground. The bus would be driven under the nose of the airship, at which time the mast man would couple the ground pull-in rope to the short pull-in cable on the belly mooring disc. The pull-in man then pulled down on the rope at the same time the tail line man slowly slacked off his pull on the tail line. This allowed the nose of the airship to slowly lower until the spindle slid into the mast cup. The mast man then locked the spindle in the cup, thereby securing the airship to the mast. With the airship secured to the bus mast, the bus could be driven to any location on the field or into a hangar if men were put on tail lines to maintain directional stability.

Though the buses used in the early operations have gradually evolved into a modern configuration, the mooring operation described above has remained the same (see Figure 1-16).

2. DEVELOPMENTS AFTER WORLD WAR II

a. Expeditionary Mast

An air-transportable mast was developed for the Navy by Meckum Engineering, Inc. (see Figure 1-17). The mast was an aluminum structure supported by steel cables and anchors. By removing or adding sections, the mast could accommodate models SG, M, or ZPG airships. Figure 1-18 shows the anchor layout of the system. A similar mast was developed for Goodyear's commercial airship operation (see Figure 1-19).

A description of the mooring technique used with expeditionary masts follows:

1. Right and left nose lines and a pull-in line attached to the nose of the airship hang free during the landing approach.
2. The airship is flown upwind to the ground crew. Linemen grab the nose lines and spread them out approximately 45 degrees to the airship. The ground crewman assists in stopping the airship. Once the airship is stopped, the nose lines are further spread 90 degrees to the airship. Sufficient tension is then maintained on the lines to keep the nose of the airship into the wind.
3. Another group of ground crewmen called the car party moves in around the airship car. Their responsibilities include ballasting and maneuvering the airship as required.

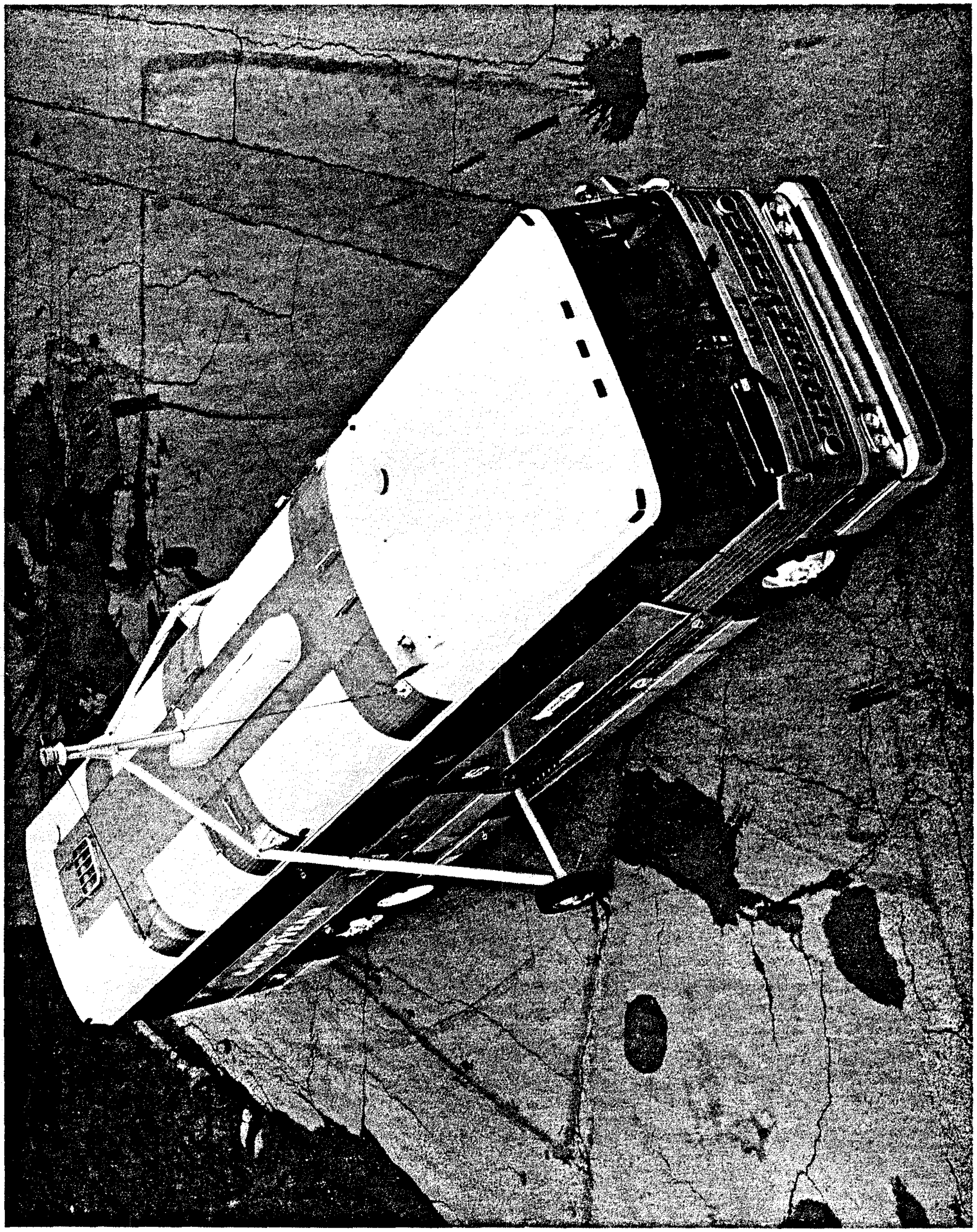


Figure 1-16 - Modern Goodyear Bus with Belly Mooring Mast (1979)

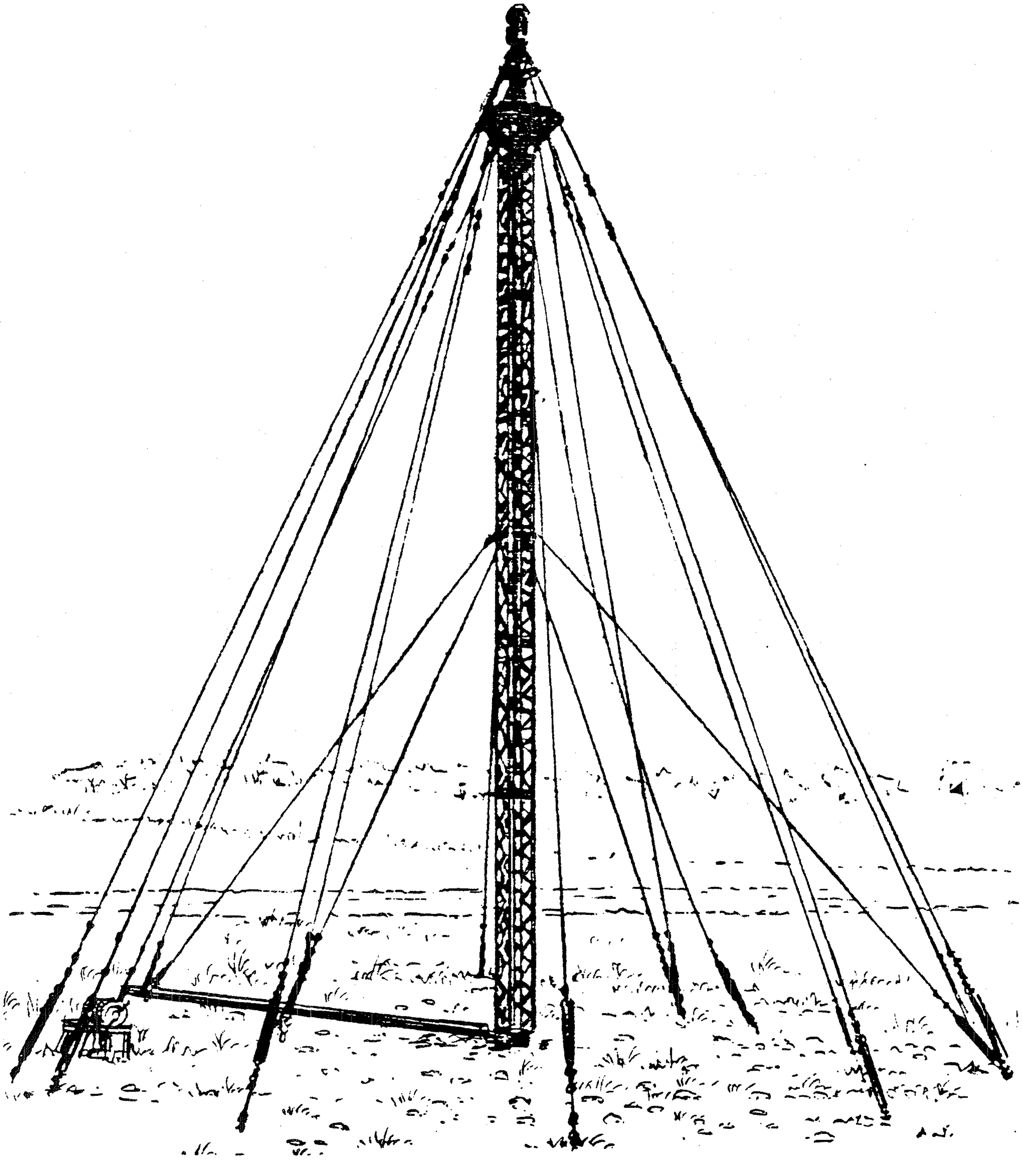


Figure 1-17 - Mooring Mast after Raising

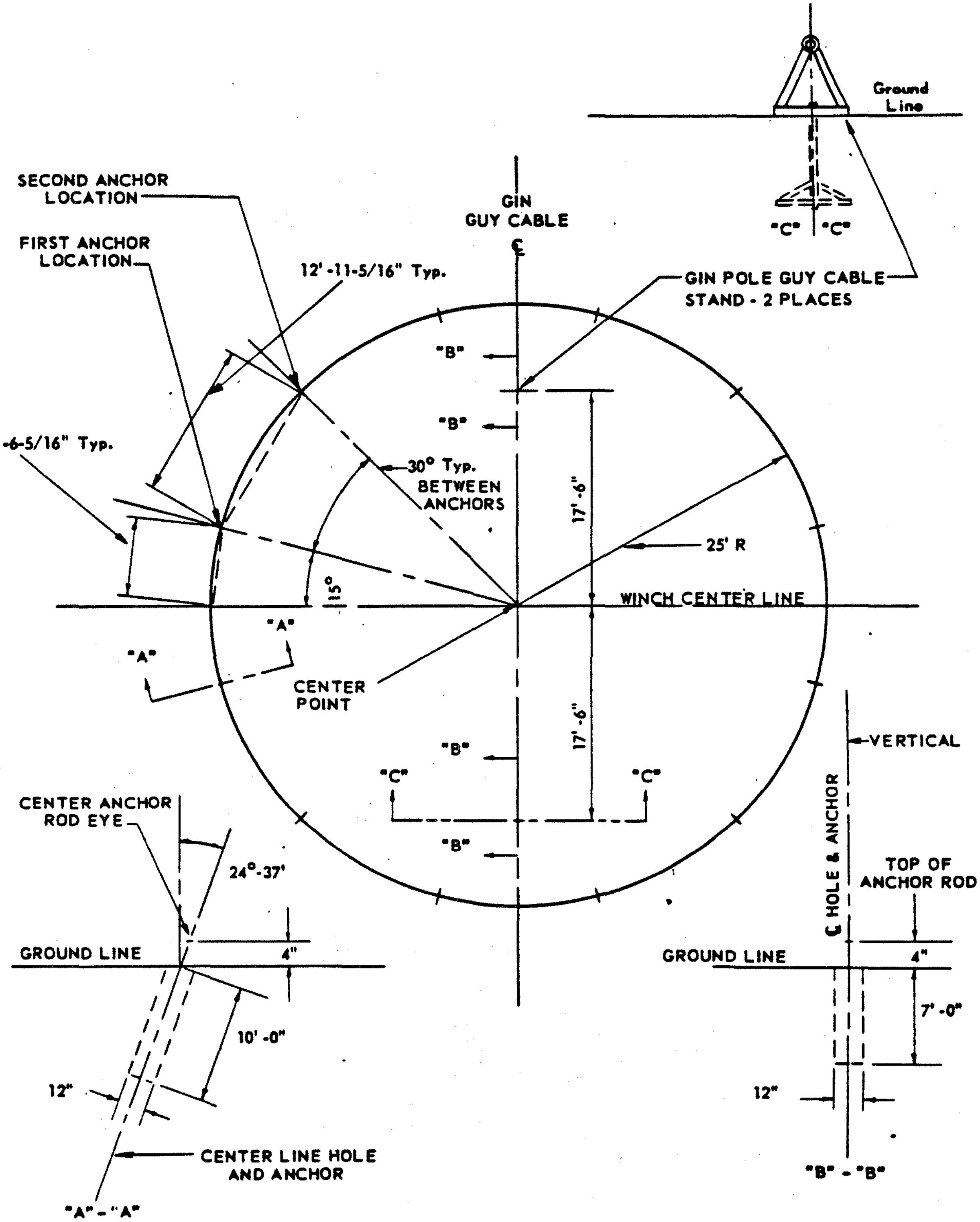
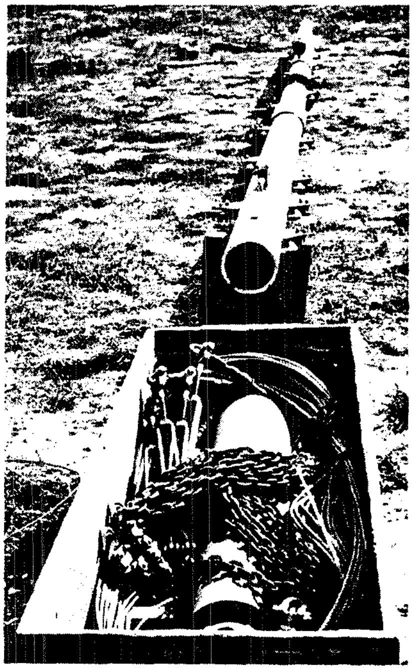


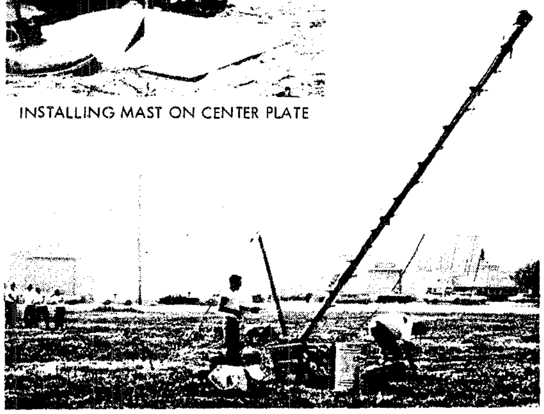
Figure 1-18 - Anchor Layout (Reference 11)



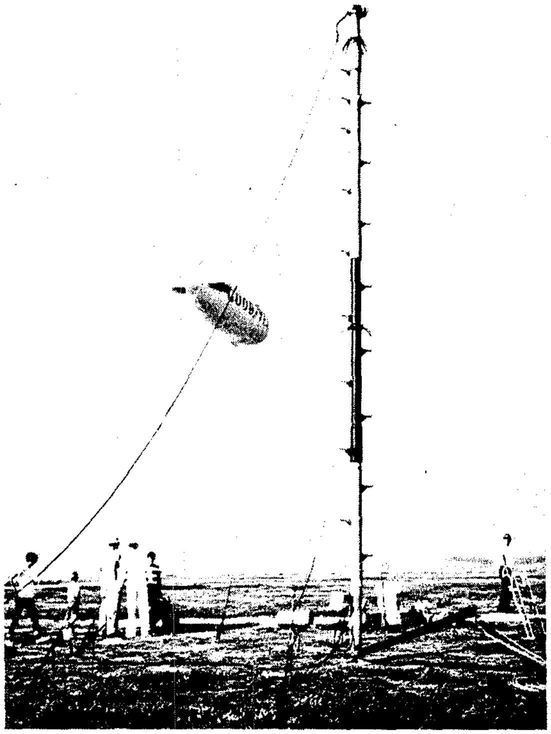
MAST LAID OUT FOR ASSEMBLY

DRIVING STAKE

INSTALLING MAST ON CENTER PLATE



RAISING MAST



MAST FULLY ERECTED

Figure 1-19 - Goodyear Expeditionary Mast (1964)

4. Directing the ground handling operation from a position under the nose of the airship stands the crew chief.
5. The airship is maneuvered to a position 50 feet downwind from the mast.
6. At this point, the mast and airship pull-in lines are connected.
7. The mast pull-in line is extended until tension is experienced in the line.
8. A four-point mooring control is now effected.
   a. Nose linemen pull right and left on the nose lines for cup alignment.
   b. Pull-in men pull the airship forward toward the mast cup.
   c. The pilot uses reverse thrust to keep the airship from overriding the mast cup.
9. The airship is eased forward until the airship nose spindle mates with the mast cup, at which time a top man on the mast throws a locking lever engaging four dogs into a groove on the spindle securing the airship to the mast.

A total of 16 ground personnel was required.

b. Mobile Mast

Since the rigid airship self-propelled masts were too large for the non-rigid airships, a smaller towed mast was developed prior to World War II. As airships became larger, modifications and improvements were made to accommodate the new airships. Various types of mobile masts are described below:

1. Type III mast - weight of 39,000 pounds, used with ZS2G-1 and ZSG-2/3/4 airships
2. Type IV mast - weight of 44,020 pounds, used with ZPG-2/2W, ZS2G-1, and ZSG-2/3/4 airships
3. Type IVB mast - weight of 47,900 pounds
4. Type IVB mod mast - weight of 55,900 pounds
5. Type V mast (see Figure 1-20) - weight of 128,670 pounds, used with ZPG-2/aW and ZPG-3W airships

Ground handling maneuvers are affected by many variables such as shifting of wind velocities, ground effects, hangar effects, variable mule line tension, tractor speed and direction, and mule speed and direction.

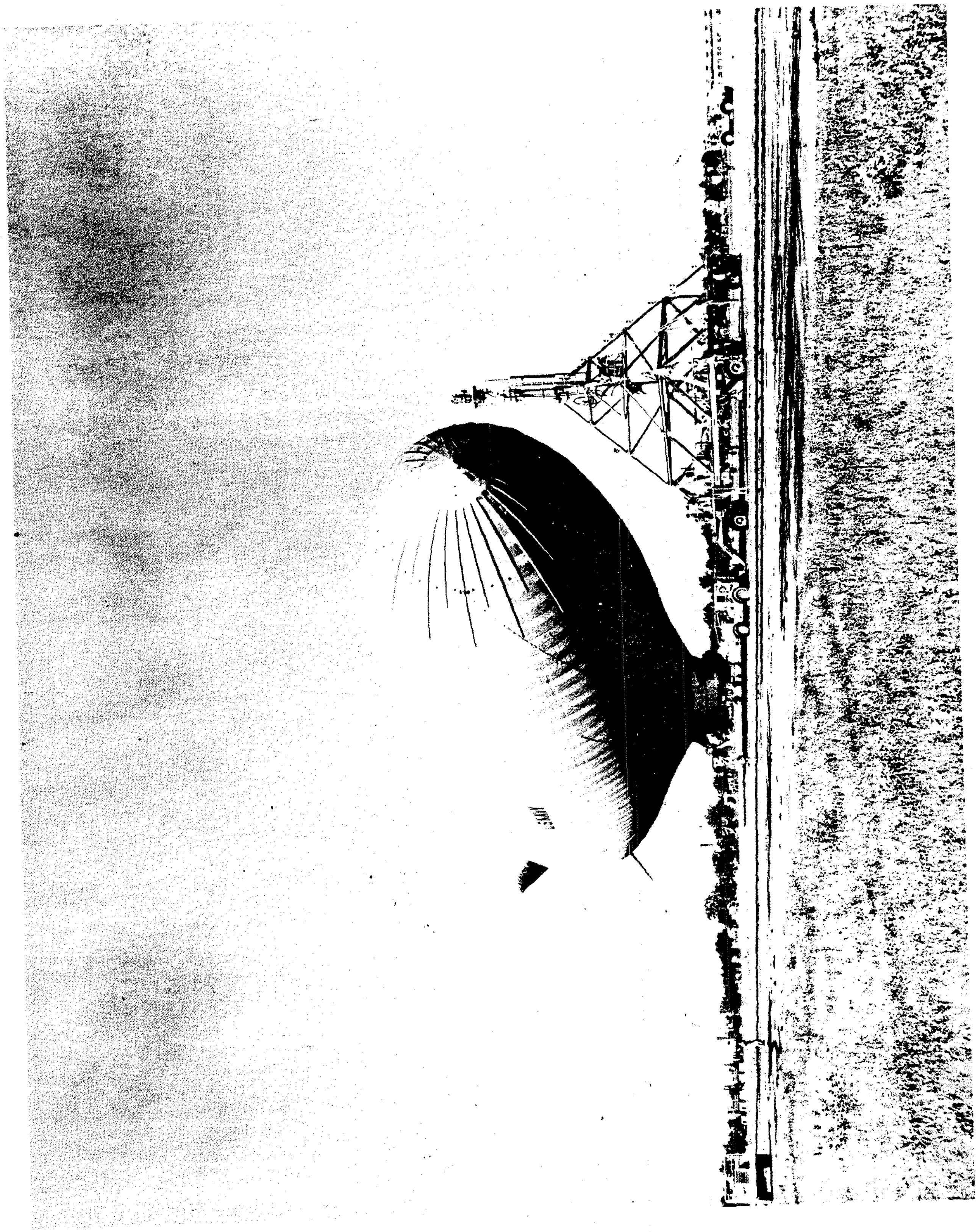


Figure 1-20 - ZPG-3W Airship Mooring to Type V Mast with MC-3 Mules on Nose Lines (1958)

Table 1-1 reflects the mast and airship mooring wind limitations imposed by the Navy while utilizing the various mobile masts. The wind direction is assumed to be colinear with the major axis of the airship. The table assumes no accounting for side loading.

TABLE 1-1 - MAST AND AIRSHIP WIND SPEED MOORING LIMITATIONS (MPH)

Mast	Airship condition*																	
	ZPG-3W					ZPG-2/2W				ZS2G-1				ZSG-2/3/4				
	1A	1B	2	3	4	1A	1B	2	3	1A	1B	2	3	1A	1B	2	3
V	78	71	58	14	58	66	66	66	12	-	-	-	-	-	-	-	-
IVB mod	-	-	-	-	-	63	58	42	12	66	66	60	14	66	66	66	14
IVB	-	-	-	-	-	63	54	36	12	66	66	55	14	66	66	65	14
IV	-	-	-	-	-	61	52	32	12	66	61	52	14	66	66	61	14
III	-	-	-	-	-	-	-	-	-	49	46	28	11	58	58	38	13

*Conditions:

1A: Mast dogged - airship free to weather vane.
1B: Mast undogged (tied to tractor) - airship free to weather vane.
2: Mast towed and maneuvered at 5 mph with airship free to weather vane.
3: Mast undogged (tied to tractor) - standard docking and undocking .
4. Mast undogged (tied to tractor) - upper tube extending or retracting.

c. Mobile Winches (Mules)

The K-type airship required from 50 to 100 men, depending on wind velocity and direction, for ground handling. The Navy became interested in developing a technique that could reduce this manpower requirement, which led to the development of mobile winches, commonly called mules (see Figures 1-20 and 1-21). These units are basically four-wheel drive, fore and aft steering tractors with a winch mounted on the back. The Navy referred to a 30,000-pound type as an MC-3 (see Figures 1-20 and 1-22) and a lighter 17,500-pound type as an MC-4 (see (see Figure 1-21).

Heavy takeoffs and landings on non-rigid airship main landing gears were standard practice by the beginning of World War II. The installation of reverse pitch propellers provided the pilot with the capability of braking the airship. Integrating these innovations with the mobile mast and mules resulted in landing and mooring procedures as follows:

1. The slightly heavy airship lands into the wind.
2. At touchdown, the pilot applies reverse thrust to slow the airship.

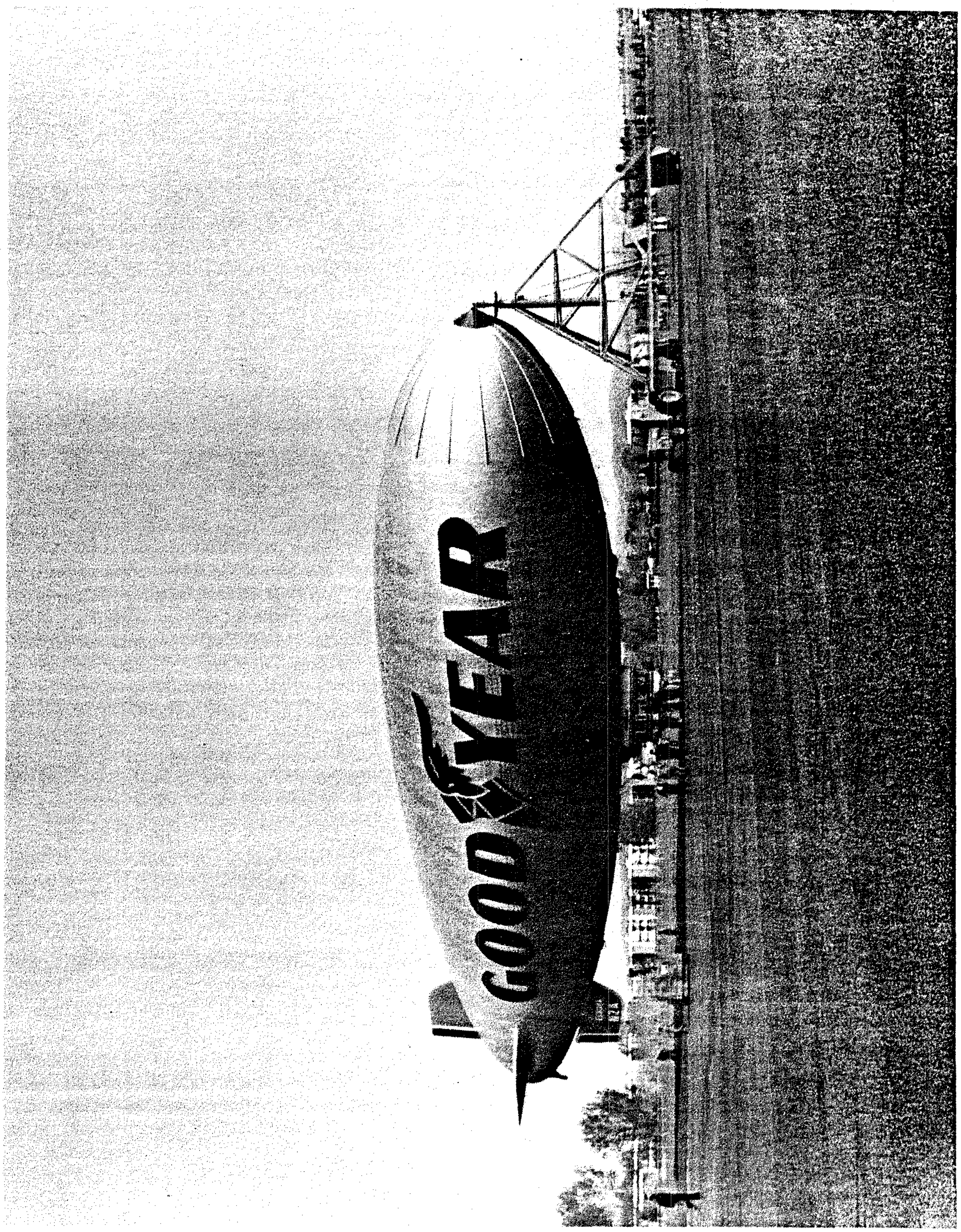


Figure 1-21 - Goodyear Commercial Airship Ground Handling Equipment (Rome, Italy), 1973

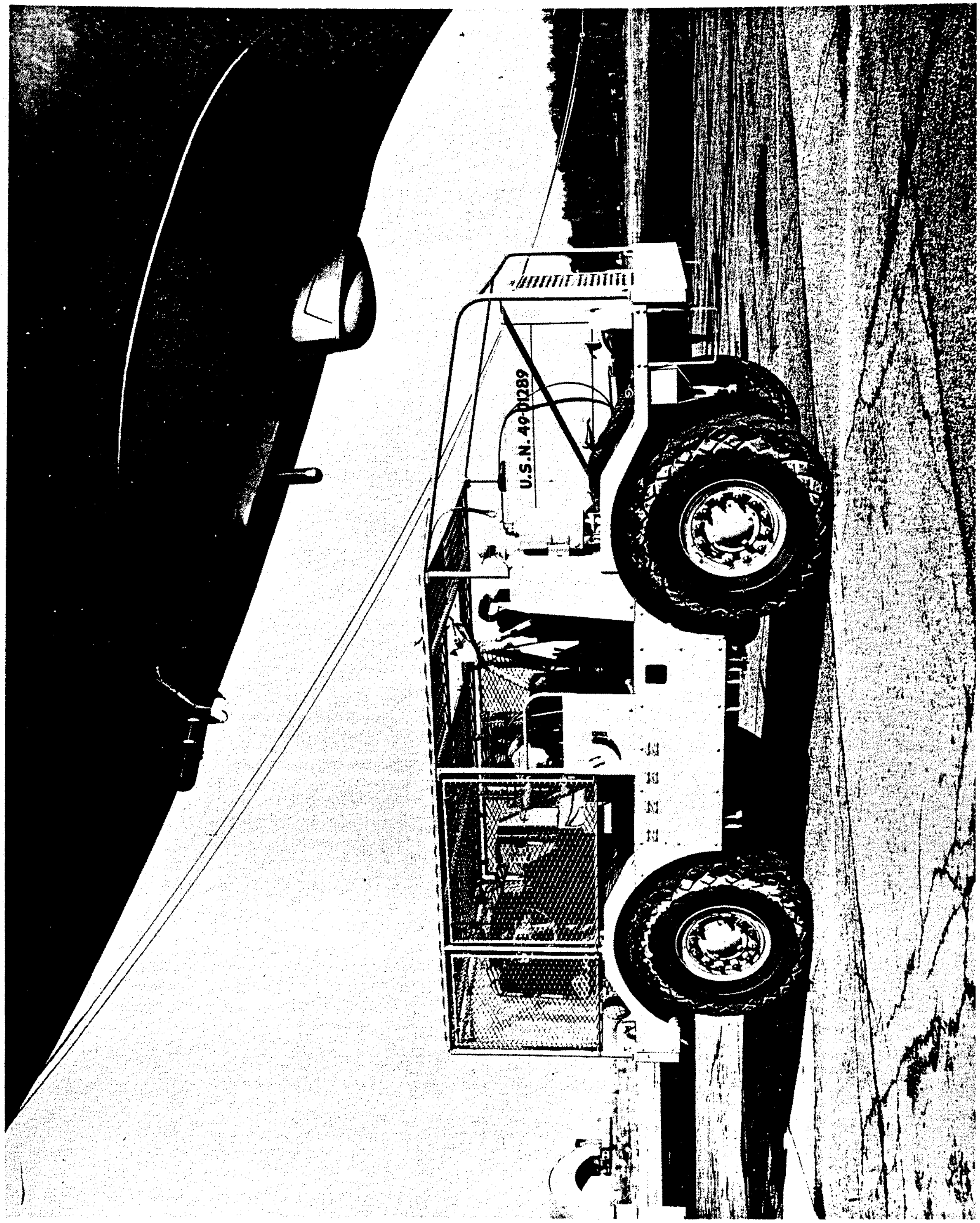


Figure 1-22 - MC-3 Mobile Winch (1958)

3. Mules stationed on each side of the approach end of the landing area swing in and run parallel to the airship.
4. Linemen run in and pick up nose lines and spread them out.
5. The mules move in and the winch cables are connected to the nose lines.
6. Tension is taken on the winch cables, and the mules assist in bringing the airship to a stop, as required.
7. The mules are driven outward and abreast of the airship nose.
8. The airship is held in position by mule winch cable tension, pilot engine, and empennage control.
9. The mobile mast is brought into and stationed in front of the airship until the airship pull-in line is coupled to the mast pull-in line.
10. Slowly, the airship is winched in to the mast until the nose spindle locks into the mast cup.
11. The nose lines are then disconnected from the mules and stored out of the way of the airship.
12. The mast tractor tows the mast and airship to a safe position in front of the airdock.
13. The mules proceed to each side of the airship tail, where tail lines are attached between the airship tail handling points and the winch cables.
14. Tension is taken on the winch cable tail lines.
15. When all is ready, the mules pull the tail into the wind as the mast is maneuvered until the airship lines up with the airdock. The airship is then moved into the airdock and secured.

Those Goodyear airship operations bases equipped with hangars (Houston, Texas and Rome, Italy) still use the MC-4 type mule for docking and undocking.

3. SUMMARY

The historical development of ground handling systems has been adversely impacted by two items: (1) the lack of low-speed controlability of an airship; and (2) the large surface area of the airship.

In order to compensate for the first item above, airships have traditionally been designed to accommodate external loads applied through ground handling lines to some point on the ship. The availability of large numbers of ground personnel was a prerequisite for airship operations. The large rigid airships built in Akron typically required 300 men for ground handling. As the airship industry evolved and large non-rigids became dominant, the desire to develop a ground handling approach that was less dependent on manpower grew. This resulted in the mobile mast/mule system, which still remains as the state-of-the-art for ground handling.

Once the airship was on the ground, its susceptibility to weather conditions became obvious. Early airships were placed in hangars to avoid environmental effects, but the limitation this placed on the airship as a viable transportation mode was intolerable. Hence, a variety of experiments was undertaken in order to develop a mooring system that would permit the airship to sustain most weather conditions. The eventual outcome, when the various cable systems and mast types had proven unsuccessful, was the bow mooring concept. While this approach still has limitations, it has proven to be the best solution to date.

SECTION II - VEHICLE CONCEPTS

1. GENERAL

The heavy-lift airship (HLA) consists of a non-rigid, buoyant hull attached to a structural frame supporting the propulsion components. Two variations of this concept are presented in Sections 2 and 3, below.

2. HLA WITH EMPENNAGE

a. General

The HLA with empennage, as shown in Figure 2-1 (Reference 35), has a conventional airship envelope. Propulsive forces are generated by the lifting rotors and auxiliary propellers of the rotor modules. It is intended to carry a payload of 150,000 pounds at an altitude of 5,000 feet. This requires an envelope volume of 2,600,000 cubic feet and four rotors each capable of providing a maximum thrust of 53,000 pounds. Overall dimensions are a maximum length of 453 feet, an overall height of 125 feet, and a width of 231 feet. With the rotors folded aft, the width is reduced to 175 feet. Maximum diameter of the envelope is 107.2 feet, and length is 447.4 feet.

General arrangement of the vehicle consists of an envelope with the conventional airship contours. At the stern, three fins together with movable control surfaces are mounted in an inverted Y configuration. The bow stiffening is typical and consists of a nose cone, mooring spindle, and battens that extend to 10 percent of the envelope length.

A control car, similar to a foreshortened K-ship, is located at the forward section of the envelope about 108 feet from the nose. A separate internal and external suspension system provides the support. Catenaries, starframe, and outrigger struts are positioned at the center of buoyancy of the airship. The four rotor modules in the concept are interchangeable. They house the engines, gear boxes, and shafting for the vertical thrust rotors and the horizontal thrust propellers. Four ballonets, with the two lateral center ballonets being interconnected to act as one, provide a total of 650,000 cubic feet of air volume.

b. Envelope and Accessories

The envelope, as envisioned, is tailored to circular cross-sections, made of neoprene-coated polyester fabric. At 5,000 feet altitude with the envelope 97 percent full and two percent volume stretch, static lift is 140,807 pounds.

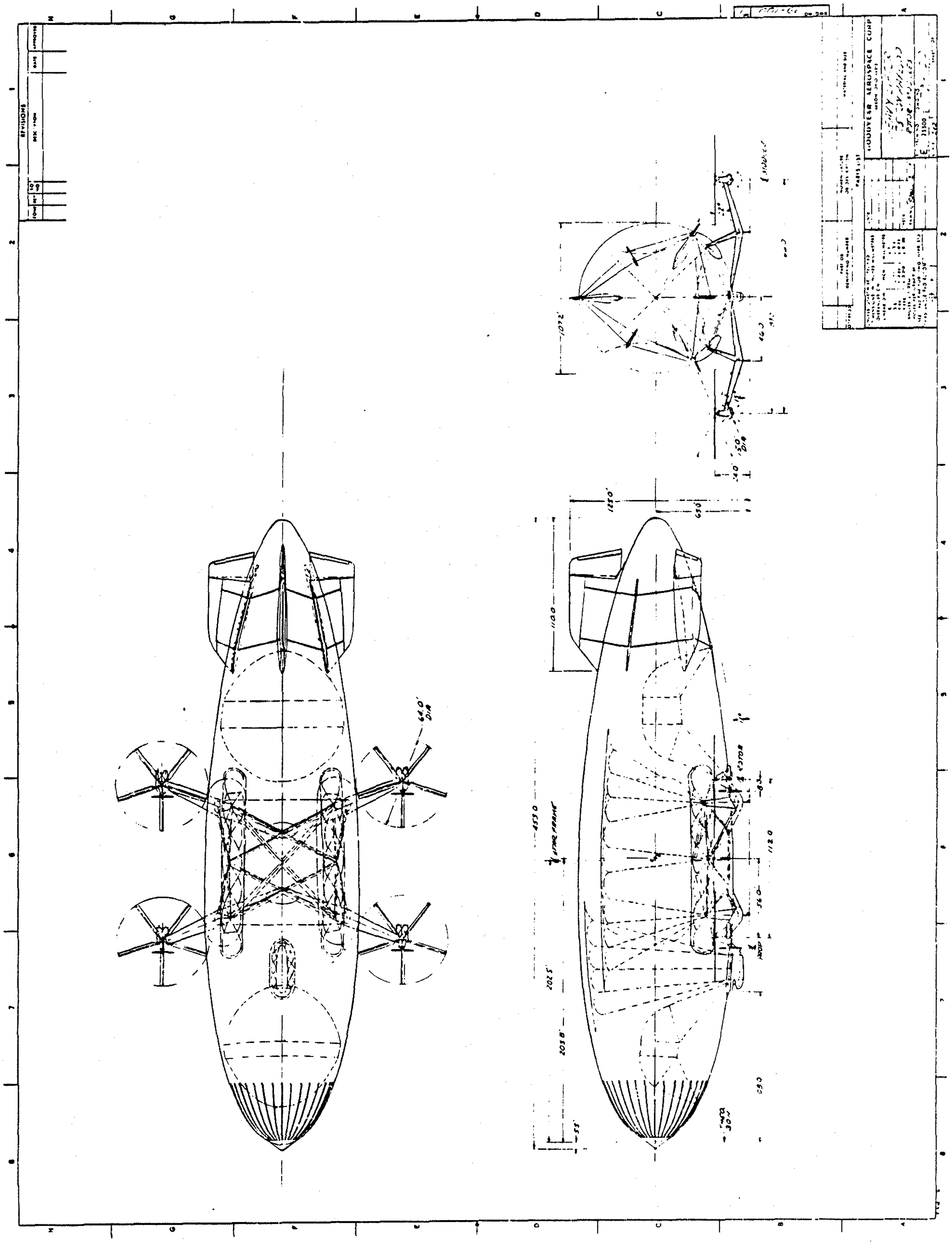


Figure 2-1 - HLA With Empennage

If inflated for 3,000 feet altitude in lieu of 5,000 feet altitude, static lift would be increased by 8,657 pounds.

The ballonets make up 25 percent of the envelope volume. The forward ballonet has a volume of 162,000 cubic feet, the aft has a volume of 195,000 cubic feet, and the two center ballonets have a total volume of 293,000 cubic feet. The ballonet configuration limits the ceiling height in a standard atmosphere and no superheat to 9,500 feet.

Two separate suspension systems are employed in the concept: the car and the starframe system. Both rely on an internal and external catenary to support the structure. The internal catenary suspension catenaries are assumed to carry 85 percent of the car weight. They are made integral with the envelope and extend fore and aft in planes intersecting in a plane at 22½ degrees off the vertical. The external catenary around the car is expected to carry the remaining 15 percent. The starframe internal catenary is also integral with the envelope and intersects in a plane 45 degrees to the equator; the cables cross at the centerline of the envelope to attach at the strong points on the starframe. Sixty percent of the suspended weight is supported by this catenary. The remaining 40 percent is carried by the external suspension system, which is located within a pressurized fairing (see Figure 2-2).

c. Tail Group

As mentioned in item a, above, the empennage concept consists of three fins and control surfaces or ruddervators in the inverted Y configuration. This approach provides an acceptable ground clearance with the tail during conventional airship takeoff runs. The three fins are interchangeable and made in two sections to facilitate shipping and handling. The empennage is basically a trussed aluminum framework braced with steel wires and covered with doped fabric. The tail surface base is 81 feet long, 7½ feet wide, 38 feet high with the ruddervator attached. The overall length of the empennage is 96 feet. In plan form, total area of the fins and ruddervators is approximately 6,714 square feet.

In the design, the fin bracing is simplified compared to the conventional multicable system used in the past. Each fin is supported by four cables. Actually, each cable consists of two steel ropes enclosed in a streamlined fairing. This results in less drag and a reduction in fin weight due to less redundancy in the structural analyses. Furthermore, it is less complex to maintain cable tensions on the installation.

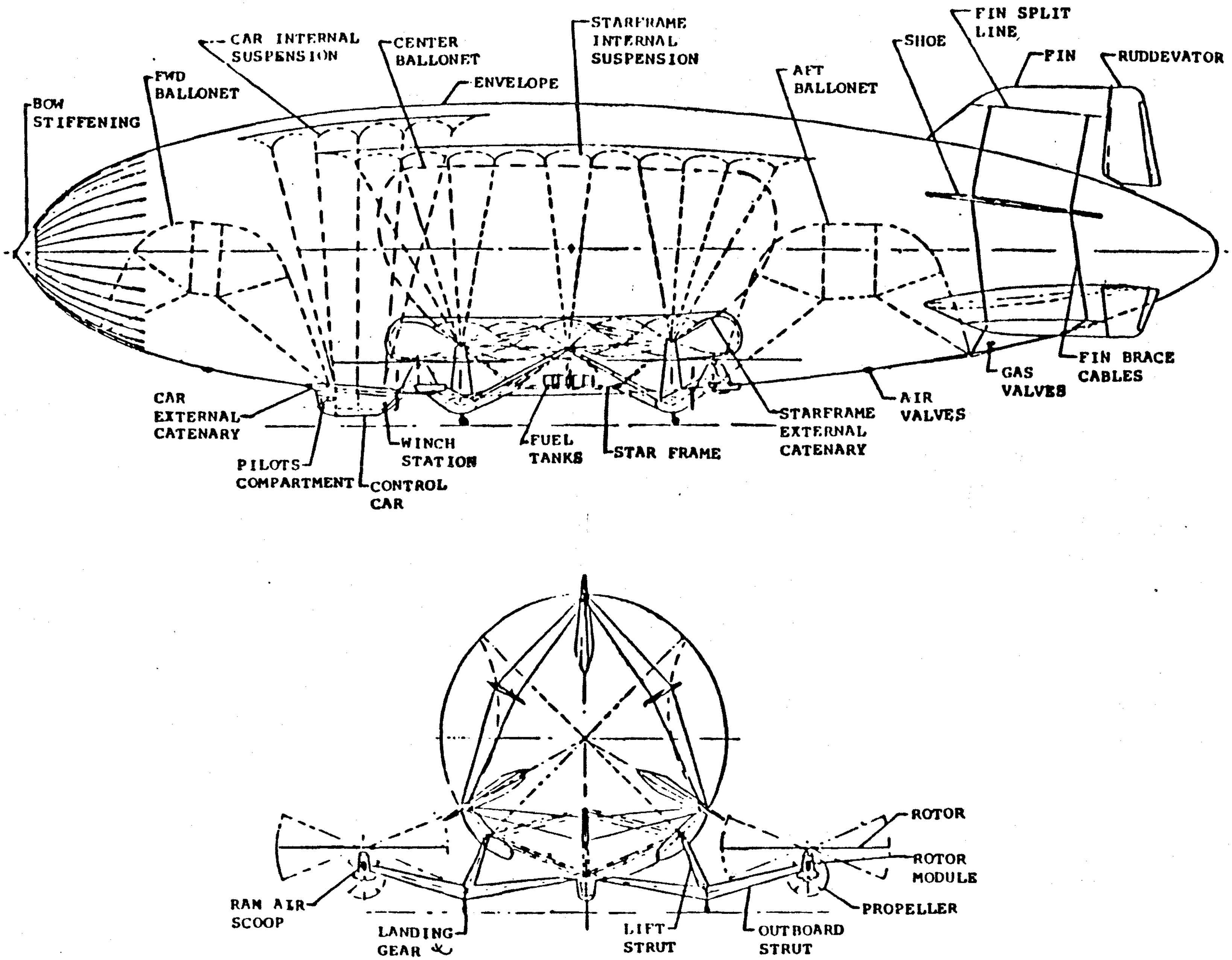


Figure 2-2 - HLA General Arrangement

Distribution of these high cable loads into the envelope, using the conventional catenary system, imposes highly concentrated loads on the curtain. However, the incorporation of a shoe or base, laced to the envelope, effectively distributes the cable loads along the envelope.

d . Support Structure

The support structure includes the starframe and the outrigger struts that carry the rotor modules. The starframe is the backbone of the vehicle (see Figure 2-3). It is supported by the main suspension system and, in turn, becomes the attachment points for the outboard struts. The frame provides the pickup points for the vehicle payload and serves as a structural backup for portions of the fuel, winch, and pressure system. Basically, the starframe is a statically determinate structure consisting of beam columns pin-jointed together. To minimize weight and attain efficiency, the beam columns are of a triangular cross-section and taper from midspan to the joint attachment. A typical section consists of three tubes at the three points of the triangle, with a tubular truss arrangement welded into each plane of the beam.

The outboard struts that support the rotor modules also provide attachment points for the landing gear, ducting for the ram air from the propellers to the plenum chamber, and strong points for sway bracing the payload. The struts have an elliptical cross-section, with a two-to-one ratio, and taper from the elbow to the rotor and starframe. In the frontal view, the main strut is configured with a 15-degree dihedral to provide ground clearance for the propeller and 20-degree transient flap angle clearance for the rotor. The structure is envisioned as an aluminum sandwich skin with a sandwich spar at the 50-percent chord. Chord lengths for the outrigger vary from 5 feet at the module to 12 feet at the elbow. From the elbow inboard, the chord tapers to 4½ feet at the frame. The overall length of the strut from centerline of the envelope to the module is 83 feet. The planform area of the outrigger is half the wing area of the Boeing 747.

A lift strut, intersecting the elbow and terminating at the outboard edge of the starframe, is similar in construction to that of the main outrigger. Its maximum chord at the base is 10 feet, which tapers to 4 feet at the tip. From the base of the lift strut and elbow, a drag strut extends to the

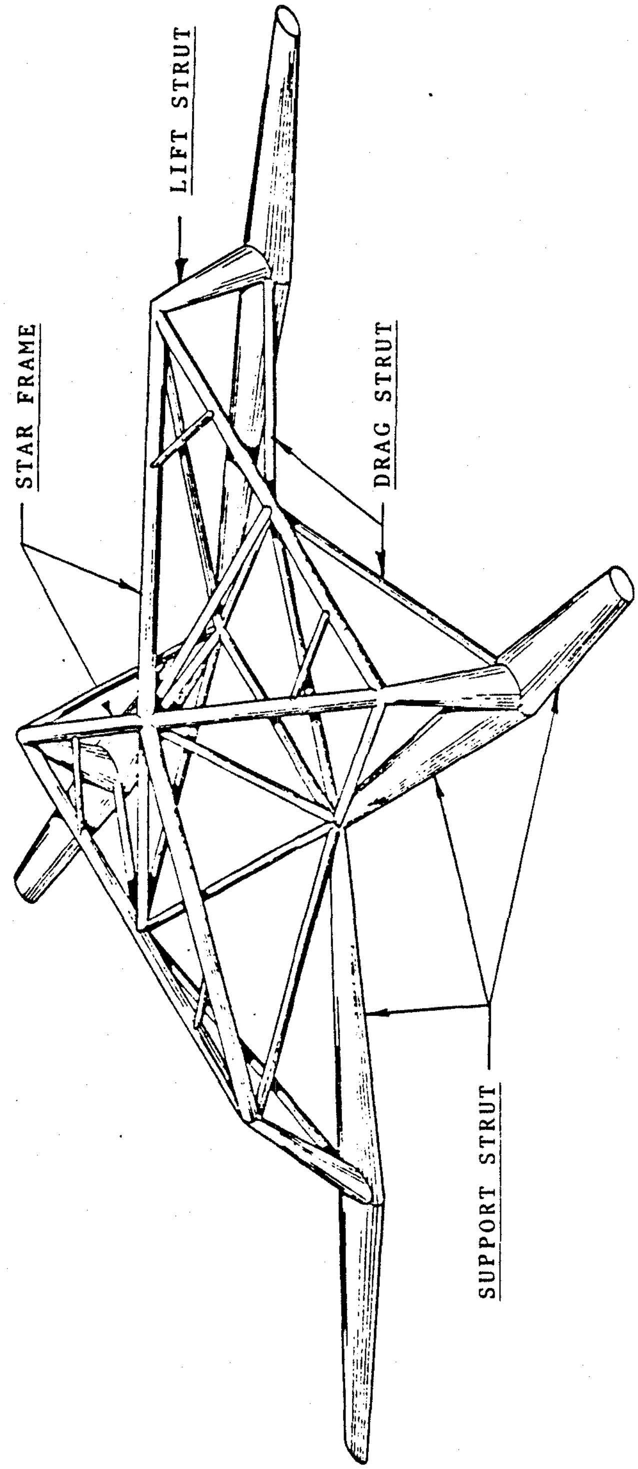


Figure 2-3 - Interconnecting Structure (Consisting of Four Lift Struts, Four Drag Struts, Four Support Struts and One Internal Starframe) outboard centerline of the starframe. It is basically an aluminum tube and is approximately 15 inches in diameter and 39 feet long, with adapter fittings on each end.

e. Rotor Module

This HLA concept uses four rotor modules. The modules are interchangeable and are mounted to the support strut interface with a series of bolts. Each module contains two engine installations, gear boxes, electronic components for the fly-by-wire (FBW) system, and shafting for the rotor and propeller. Rotor and propeller are driven by the same engines that have a combined rating of 8,760 horsepower.

The rotor has a diameter of 64 feet, with five blades that have a chord length of 2.43 feet. It incorporates a simplified automatic blade-fold system and an increased blade steady-state flapping limit of 10 degrees. The blades have a 20 percent rotor radius root cutout and a 4-degree twist built in to provide a 60 percent reverse thrust capability. The folding system enhances the vehicle's efficiency by reducing drag in the ferry mode when rotor propulsion is not required.

The main transmission has two opposed inputs from the engines to the main bevel gear. The accessory drive and propeller shaft drive gearing are also opposite each other in the fore-and-aft position. The accessory section includes the drive and mounting for the oil pump, hydraulic pump, and the oil cooler. A tubular structure off the main transmission case supports the propeller gear box.

The propeller and gear box is designed for a maximum of 3,700 shaft horsepower. The propeller, which is 15 feet in diameter and has four blades, provides 13,000 pounds of static thrust and available thrusts for vehicle speeds up to 80 knots with maximum payload. In addition, the propeller supplies the ram air for the pressure system. An air scoop with adjustable louvers in the upper portion of the module controls and directs the airflow to the duct in the support strut.

The rotor module also includes the required mounts, controls, inlets, and cowlings for the two engines. Engines are started by starter/generators and use electrical energy supplied by the auxiliary power unit installed in the control car. Engine cowlings fold down to serve as work platforms for engine and accessory maintenance. In an emergency, the module is accessible in flight through the ducts in the pressure system.

f. Control Car

The heavy lifter car is a foreshortened version of the ZP2K airship car. The maximum height is 10 feet, the width is 8 feet at the top, and the length is 32 feet overall. The pilot's compartment is configured to a conventional airship. The major controls, however, are similar to those of a helicopter. The cyclic stick controls the direction of the rotor thrust vectors while the collective stick controls their magnitude. Pitch and roll are maintained automatically. Ruddervators are coupled with the yaw and pitch controls. Aft of the pilot's compartment are furnishings and equipment for the crew; bunks and living facilities are included. In the rear of the car, a winch operator station controls the sway brace cables. When necessary, the winch positions and maintains the location of the payload. The remainder of the car contains the APU, the electric and hydraulic power supply, blowers for the envelope pressure system, air conditioning, and instrumentation and electronics for control and communications.

g. Alighting Gear

At present, the landing gear is envisioned as four wheels and struts supported at the elbows of the module outriggers. Wheels and gear geometry are the same as those used on the 3W airship except that the HLA gears are fixed. The concept incorporates the same 11.00 x 12 tires, but the oleo strut has been increased in length to provide a 20-inch stroke instead of the 3W's 16.5-inch stroke. This arrangement permits a sinking speed of three feet per second with a heaviness of 4,075 pounds.

h. Buoyancy Alternatives

Another feature of the HLA concept is the growth potential of the payload capability. A key element of the design has been to initially configure the vehicle so that an increase in useful load up to 240,000 pounds can be realized by changing the envelope system alone. In this regard, provisions have been made to increase the envelope size and change the pressure system, with no foreseeable change in other major components, to achieve greater static lift. Layouts of the larger envelopes have been used in predetermining the clearances for the vehicle structural components. It is important to note that the negative thrust capability of the rotors is implicit in achieving this flexibility in design. Further studies are required to fully explore the potential of this feature in a demonstration vehicle and subsequently in operational environment.

3. HLA WITHOUT EMPENNAGE

a. General

The HLA concept with no tail as defined by Reference 24 was the forerunner of the vehicle described in Section 2 (see Figure 2-4). Because of this, many features are similar; therefore, only variations from the previously described design will be elaborated upon.

b. Envelope and Accessories

The configuration involves a 2,500,000 cubic foot volume non-rigid hull fabricated from present-day proven airship fabrics. The basic envelope and catenary curtain fabric is neoprene-coated dacron; the ballonet fabric is neoprene-coated nylon. Basic fabric and seam strengths required are only slightly greater than the maximum of the ZPG-3W airship built by Goodyear for the U. S. Navy in the late 1950's.

Twenty-five percent ballonets have been considered that result in a ballonet ceiling of approximately 8,200 feet and an operational capability up to 5,000 feet under all expected superheat conditions. For sea level operations, a 93 percent envelope inflation would be used to permit a thousand feet of operational altitude and 20 deg F of superheat.

c. Propulsion

Four modified Sikorsky CH-54B helicopters have been adapted to the interconnecting structure by means of a gimbal device. While substantial changes of direction in the main rotor thrust vector can be achieved by cyclic pitch control, this approach cannot be used with the helicopters affixed rigidly to the interconnnecting structure. With the helicopter rigidly affixed, large cyclic bending loads would be experienced in the main rotor mast, which would unacceptably reduce the mast life. The gimbal permits the rotor mast to realign with the tilted thrust vector much the same as in normal helicopter flight. The helicopters are pitched about the gimbal by main rotor cyclic pitch and driven by servo-controlled actuators in roll to negate gimbal coupling forces resulting from main rotor torque. Main rotor torque is counteracted by a differential cyclic pitch bias between port and starboard rotors. The bias is accomplished by an electrical input to the fly-by-wire (FBW) flight control system. Thus, the tail rotors are not required for main rotor anti-torque purposes.

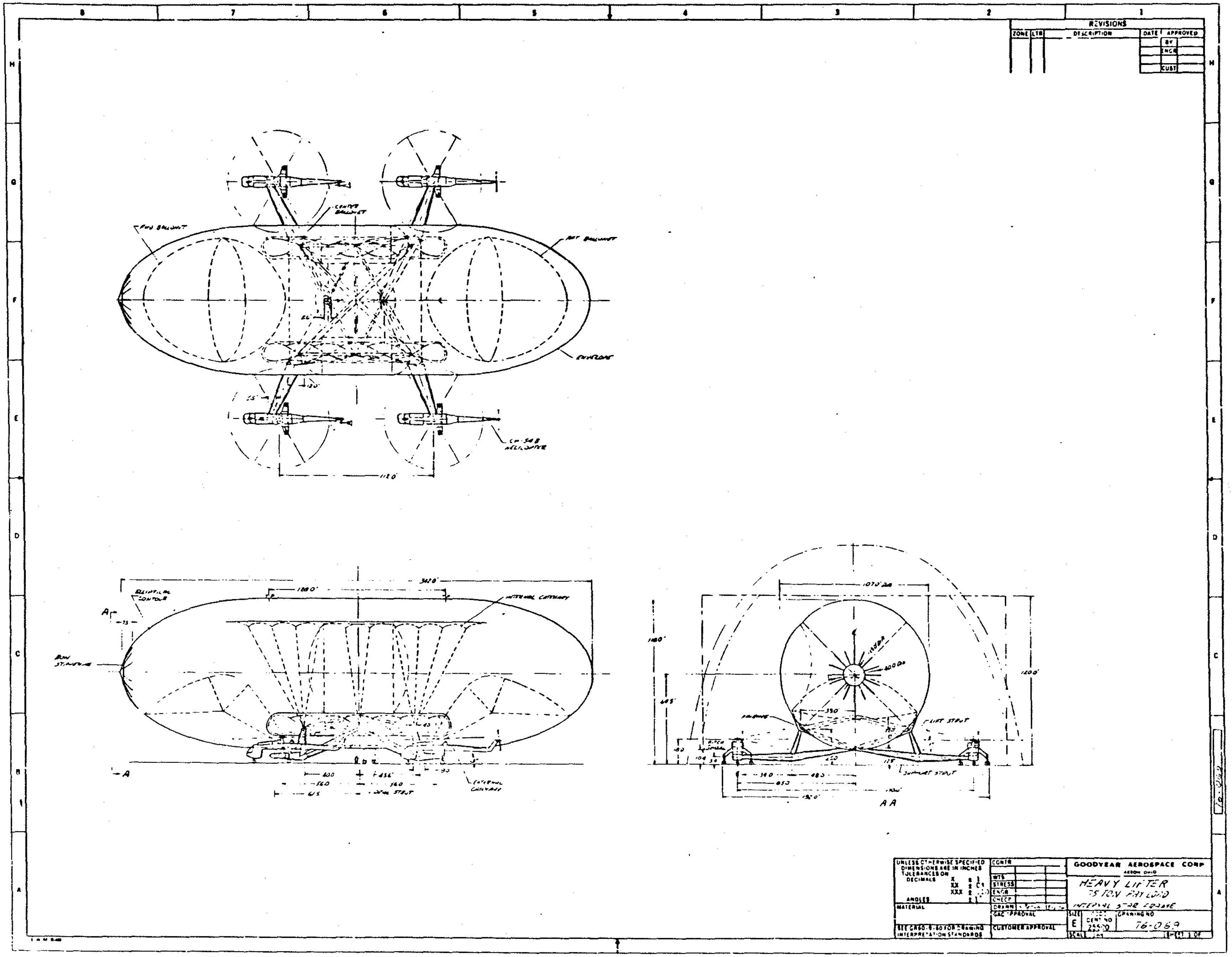


Figure 2-4 - HLA Without Empennage

The tail rotors of the aft helicopters are replaced with propellers and reoriented to provide sufficient propulsive force for forward flight and directional control at or near minimum gross weight. The tail rotors of the forward helicopters are used to provide side force for increasing the cross-wind stationkeeping ability.

The vehicle is controlled through a FBW flight control system, with the aft left helicopter serving as the command station. The FBW control system is similar to that developed during the heavy lift helicopter (HLH) program, which was successfully flown on a prototype basis in the tandem rotor CH-47 helicopter with more than 300 hours of flight time accumulated. The HLH automatic flight control system (AFCS), precision hover system (PHS), and cargo-handling system have also been integrated into this HLA configuration.

4. VEHICLE STATISTICS

A comparison of each vehicle's attributes is provided in Table 2-1.

TABLE 2-1 - HLA VEHICLE ATTRIBUTES

Item	HLA with empennage	HLA without empennage
Overall dimensions (ft)		
Length	453	342
Maximum diameter	107.2	107
Maximum width	230	192
Height	125	118
Envelope and accessories		
Design volume (cu ft)	2,600,000	2,500,000
Volume stretched 2% (cu ft)	2,652,000	2,550,000
Surface area (sq ft)	118,287	118,562
Fineness ratio	4.18	3.20
Distance to CB from bow (ft)	203.8	170.8
Total ballonet volume (cu ft)	650,000	625,000
Empennage planform areas (sq ft)		
Fins (3)	4936	-
Ruddervators (3)	1779	-
Total area	6714	-

5. SUMMARY

Of the two vehicles presented above, the BQR with empennage is preferred. The BQR without empennage, which was generated during the Phase II study (Reference 24), was based on U.S. Naval requirements that are no longer valid. Specifically, the task definition called for hover capability in a substantial cross wind. That mission is simplified with a no-tail configuration, but a significant performance penalty results in the forward flight mode. Ultimately, the specifications for a heavy-lift airship were changed because of the inherent behavioral tendencies of such a large mass and the conclusion that a hovering task could be performed with the nose into the wind. The addition of tail surfaces was then desirable for provision of control. The vehicle with tail is characterized by its efficiency in forward flight. Hence, during the analysis phase of the study, the BQR with empennage is assessed with respect to bow, belly, and total restraint mooring, while the BQR without empennage is restricted to the center point mooring style that was its basis for design.

SECTION III - STRUCTURAL ANALYSIS OF A FULLY RESTRAINED AIRSHIP

1. GENERAL

A first-order study of airship empty weights versus wind velocity for different mooring concepts, airship configurations (with and without tails), and structural concepts (different internal suspension systems, envelope pressures, or other attachment approaches) was initiated to establish practical wind velocity operating limits. The following analysis is limited to a static condition, and envelope deformation is not considered. The static analysis is appropriate for a fully restrained airship.

2. STATIC AERODYNAMIC FORCES AND MOMENTS

The first task was to estimate the static aerodynamic forces and moments acting on the different configurations for the different mooring concepts. The static data for these curves was selected from References 12 through 20. The type and scope of data presented in each reference are listed in Table 3-1. The model description, test Reynolds number, range of data collected, and any simulation of the ground effect as indicated by the vertical velocity gradient are presented in Table 3-1.

In Reference 12, the authors considered that direct extrapolation by continuation of the curves for model results to the Reynolds number of the full-size airships is not justified or satisfactory, inasmuch as an extension of a curve too many times its original length can lead to erroneous conclusions. They suggest instead that a more satisfactory method is to consider the flows about the bodies for the two cases of model and full size to see if any critical change in the flow is expected in passing from model scale to full scale. For 90 degree yaw angles, a section of the hull becomes circular, and two types of flow occur. For Reynolds numbers less than 4 to 5 x 10^5, based on diameter, the flow is characterized by early separation. For Reynolds numbers greater than this value, the flow becomes turbulent, and separation occurs further back on the cylinder. Once the Reynolds number for this critical range has been exceeded, the flow in cylinder tests has shown no marked changes with increasing Reynolds number. Thus, it is believed that the flow over the full-size airships will be generally similar to the flow over models tested above the critical Reynolds number range. It was further pointed out that the effects due to the ground gradient should scale almost directly with the larger Reynolds number. The system of coordinates

TABLE 3-1 - TYPE AND SCOPE OF DATA USED IN REFERENCES

Ref No.	Model Size Where Tested	ℓ/D	R_N & Velocity	Static Coefficients for Range of Model Angles Deg. Pitch	Yaw	Roll	Reference Dimensions R_N	Force	Moment	Model Location Relative to Ground Plane Height/Diam.	Vertical Velocity Gradient
12	1/40 Akron ℓ=235.5 in. full-scale wt	5.9 $(\frac{235.5}{39.8})$	(5 to 19) 10^6 28-100 mph 4.04 (R_N on $\mathcal{V}^{1/3}$)	-2-2 at ψ=0,30, 180 0→20	0,30,60 90,180	0-10 at ψ=0,30, 180	ℓ Ref vel measured at 5 ft or 200 ft full-scale height	$\mathcal{V}^{2/3}$	$\mathcal{V}$	H/D=$\frac{5.6}{39.8}$ to $\frac{11.6}{39.8}$	V ∝ $h^{1/7}$ q ∝ $h^{2/7}$
13	8 Models - ZRS-4 Bare Hull, with Fins, finishes, VDT	3.6→ 7.2 5.3→ 6.8	(1-40)10^6	0→20	0	0	ℓ	$\mathcal{V}^{2/3}$	$\ell\mathcal{V}^{2/3}$	Centerline	None
14	Cylindrical Models 1, 1.75, & 2.5 D inches 7 x 10 wt	∞	(0.6-1.6)10^5	0-Two cylinder relative to each other - cross flow	90		Diam.	Frontal Area D x ℓ	None	H/D=0 to 4	None
15	1/79th Heavy Lifter No Tail & Tail 76-069 7x10 wt; q=3.1 psf	2.9 (equiv. ellipsoid)	0.75x10^6 Hull Roughed; sand grains	0-90 at ψ-0	0-90 at α=0	0	ℓ	$\mathcal{V}^{2/3}$		H/D=0.5 to 2	None
16	1/75th ZPN Docking Unlocking-Hanger X Tail - Nose First, Water	4.37 $(\frac{51.88}{11.75})$	5x10^5 V=1.18 fps water	0	0,30,60, 90,120, 150 180	0	ℓ	$\mathcal{V}^{2/3}$	$\mathcal{V}$	Scaled ZPN to Ground Plane	V ≈ $h^{1/33}$ q ≈ $h^{2/33}$ V ≈ $h^{1/7}$ q ≈ $h^{2/7}$
17	1/75th ZPN Docking Unlocking with Hanger (1) ZPN Only (2) Tail First, Water Basin	4.37 $(\frac{51.88}{11.75})$	5x10^5 V=1.18 fps water	0	0,60,90, 120(1) 0,30,60, 90,120, 150, 180(2)	0	ℓ	$\mathcal{V}^{2/3}$	$\mathcal{V}$	Scaled ZPN to Ground Plane	V ≈ $h^{1/33}$ q ≈ $h^{2/33}$
18	1/120 Navy C Balloon - 3 ft. wt. University of Washington	3 (12/4)	6x10^5 V=92 fps	0-90 at ψ=0	0	0	ℓ	$\mathcal{V}^{2/3}$	$\ell\mathcal{V}^{2/3}$	Tunnel Centerline	None
19	Aerocap Model without Tails 7x10 U of D	2.64 $(\frac{67.95}{25.77})$	4.9x10^6 V=148 fps	0-30 at ψ=0 5,10	0,5,10	0	ℓ	$\mathcal{V}^{2/3}$	$\mathcal{V}$	Tunnel Centerline	None
20	Single Hull Model Thin & Thick Tails 4x4 GAC Tunnel	2.99 $(\frac{16.88}{5.64})$	1.7x10^6 V=212 fps	(-) 15-45 at ψ=0	(-) 15-45 at α=0	0	ℓ	$\mathcal{V}^{2/3}$	$\mathcal{V}$	Tunnel Centerline	None

selected is based on that used in Reference 12 and is repeated in Figure 3-1. The data used from the references to establish aerodynamic loads for the analysis are presented in Figures 3-2 and 3-3 for airships with and without tails, respectively.

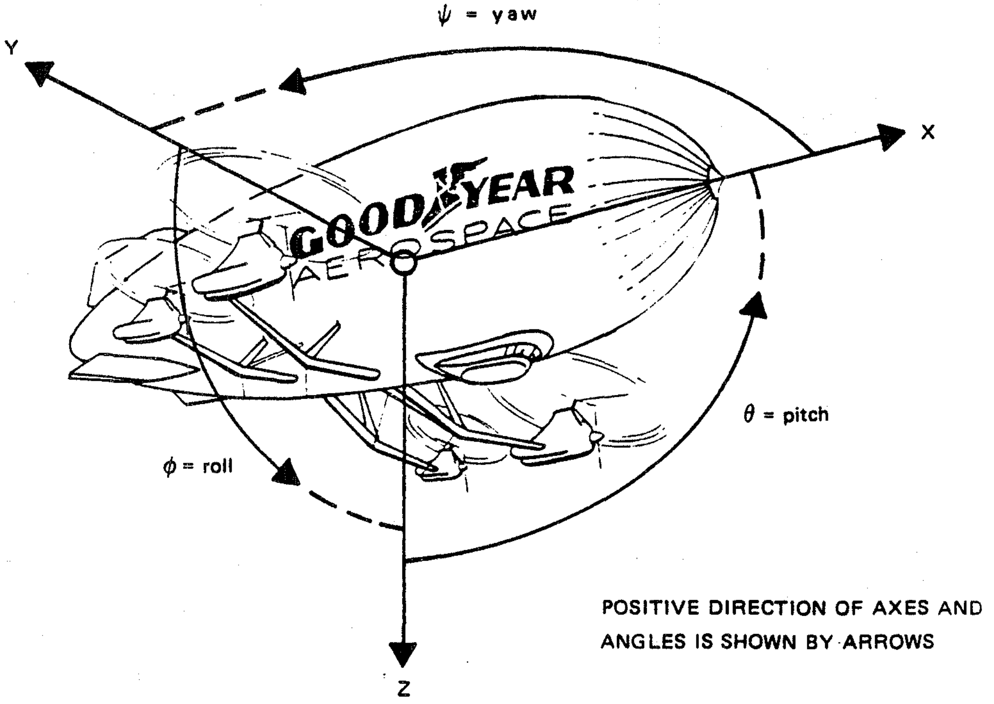


Figure 3-1 - Coordinate System

Figure 3-2 includes data presented as a curve from the extensive testing of a large airship model of the Akron in a large wind tunnel at yaw angles from 0 to 180 degrees (Reference 12), testing of a model of the heavy lifter in the 7 x 10 wind tunnel at yaw angles presented as a curve from 0 to 90 degrees (Reference 15), testing of a model of the ZPN in a water basin at yaw angles from 0 to 180 degrees (References 16 and 17), and wind tunnel tests of tethered balloon shapes (References 18 and 20). The coefficient values for the forces based on $\forall^{2/3}$ are similar despite the different model fineness ratios and testing facilities and techniques. The coefficient values from References 12, 15, 16, 17, 18 and 20 are most similar for C_y, which corresponds to the largest force acting on an airship at yaw angles from 60 to 120 degrees. The second largest force acting at yaw angles from 60 to 120 degrees is lift corresponding to minus values of C_z.

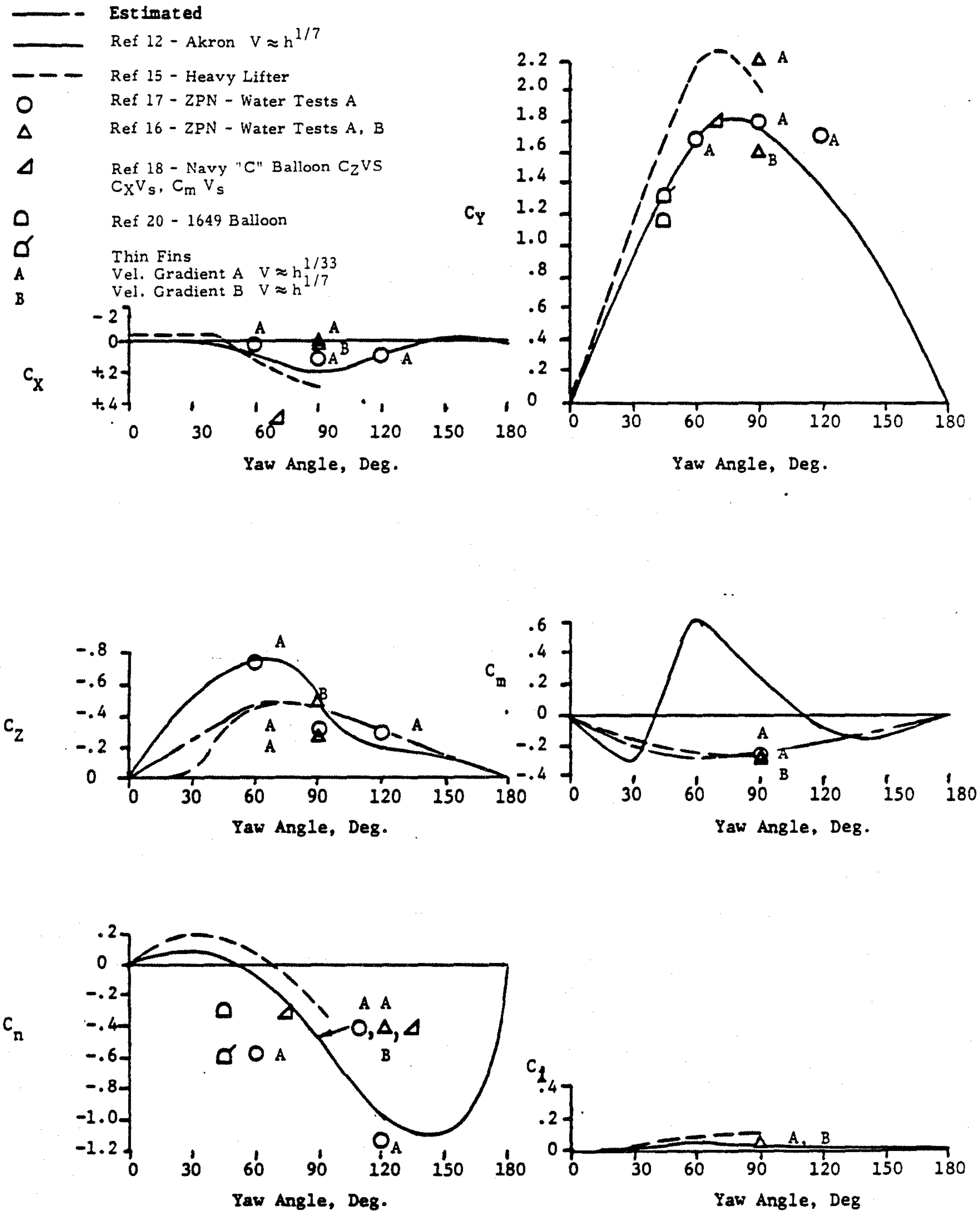


Figure 3-2 - Force and Moment Coefficient Values About Center of Buoyancy of Airships with Tails versus Angle of Yaw (Pitch and Roll Angles of Zero)

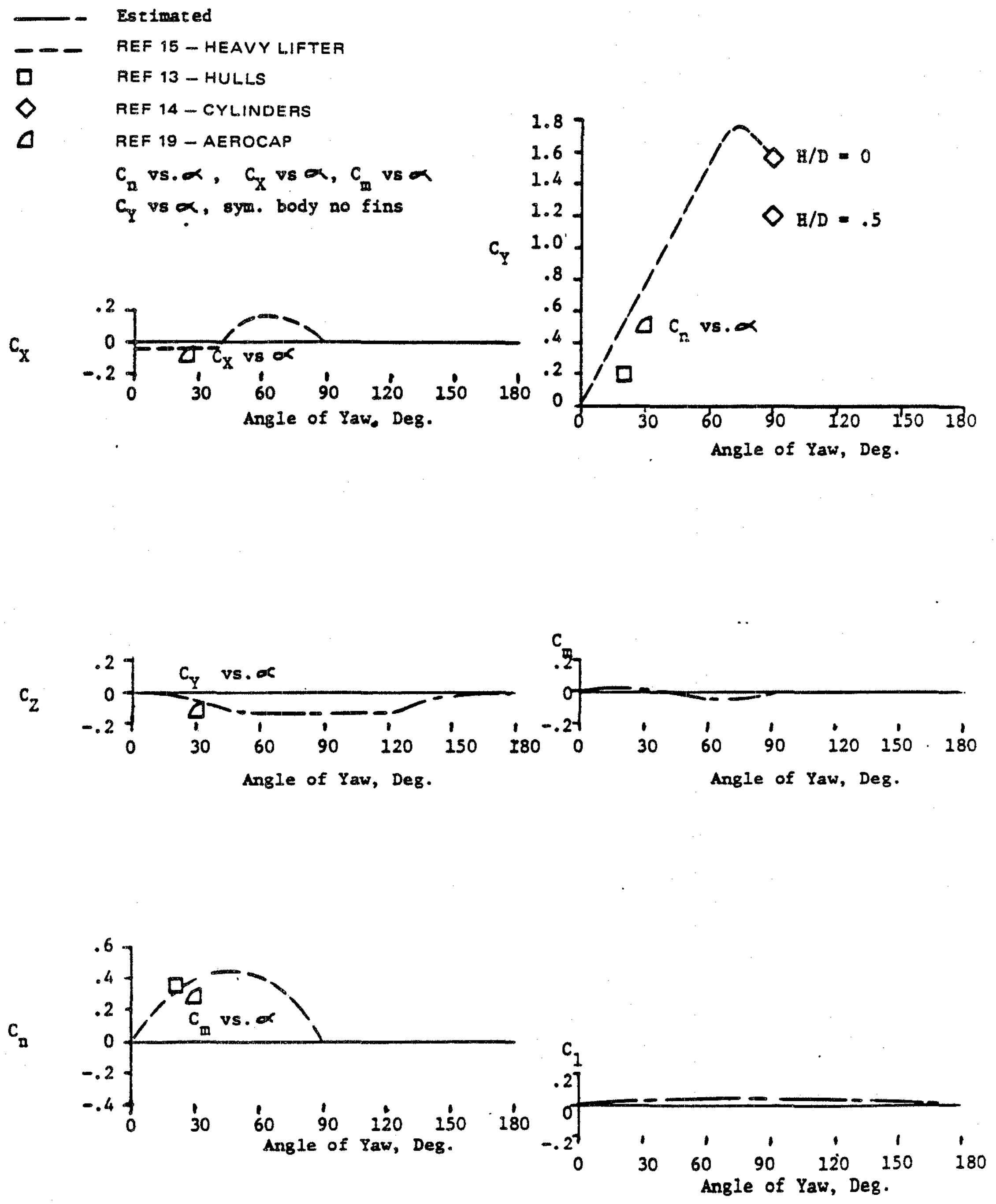


Figure 3-3 - Force and Moment Coefficient Values About Center of Buoyancy of Airship Without Tails versus Angle of Yaw (Pitch and Roll Angles of Zero)

Agreement of the C_z values at 90 degrees of yaw is very good between Reference 12, 15, and 16 with the velocity gradient B. The difference in coefficient values at 60 degrees of yaw may be due to the differences in the values of fineness ratio of the different models, the selected test velocity gradients over the models, and the test H/D ratios (distance from ground/model diameter). The least similar values are associated with the longitudinal forces that have the smallest coefficient values, and the values appear to be very sensitive to the selected test velocity gradients and the test H/D ratios.

The similarity of values for the moment coefficients based on $\forall$ from the different references is not always as good as for the force values. The yawing moment coefficient, C_n, which corresponds to the largest moment, has fair correlation between References 12, 15, 16, and 18 at 90 degrees of yaw. The pitching moment coefficient, C_m, is very sensitive to model fineness ratio and relative tail sizes as can be observed from the data of Reference 12 as compared to the data from References 15, 16, and 17 at a yaw angle of 90 degrees. From these data, specific coefficient values were selected at 60, 90, and 120 degrees of yaw for use in the structural weights analysis. The selected values are listed in Table 3-2.

Figure 3-3 includes data presented as a curve from testing a heavy lifter hull model in the 7 x 10 wind tunnel at yaw angles from 0 to 90 degrees (Reference 15), symmetrical airship hull models in the propulsion wind tunnel at pitch or yaw angles from 0 to 20 degrees (Reference 13), parallel cylinders at 90 degrees yaw tested in a low-speed tunnel(Reference 14), and an aerocap model tested in a 7 x 10 tunnel at 0 to 30 degrees of pitch at yaw angles of 5, 10, and 15 degrees (Reference 19). Available data are much more limited for airship hulls as compared to airships with tails at large angles to the wind. The data from References 13, 15, and 19 (considering pitch and yaw values are equal for symmetrical bodies) can be compared at yaw angles of 20 and 30 degrees. Rough comparisons can be made with the data from Reference 14 at yaw angles of 90 degrees. Reference 14 presents data for two infinite length cylinders for various separation distances. Assuming that the ground acts as a reflection plane, the drag value at 90 degrees at the proper spacing of the cylinders should be similar to the C_y value for large fineness ratio bodies tethered near the ground. The only large force acting on an airship without tails is associated with the values of the coefficient C_y. Values from the curve from Reference 15 at 20 degrees, 30 degrees, and 90 degrees can be compared with those of References

TABLE 3-2 - AIRSHIP WITH TAILS, FIRST-ORDER BODY AXIS

STATIC AERODYNAMIC COEFFICIENTS

Yaw Angle	Units	60 Deg	Force	90 Deg	Force	120 Deg	Force
Forces C_x	lbs	+0.10	+1,916q	+0.20	+3,832q	+0.10	+1,916q
C_y	lbs	+1.70	+32,571q	+1.60	+30,654q	+1.50	+28,739q
C_z, C_L @ $\alpha = 0°$	lbs	-0.76	-14,561q	-0.60	-11,495q	-0.20	-3,832q
			Moment		Moment		Moment
Moments C_m Pitching	lb-ft	+0.60	1,591,200q	-0.20	-530,400q	-0.10	-265,200q
C_ℓ Rolling	lb-ft	+0.030	79,560q	+0.02	53,040q	+0.03	+79,560q
C_n Yawing	lb-ft	+0.05	132,600q	-0.5	-1,326,000q	-1.0	-2,652,000q

Forces = $C_{x,y,z}\ q\ V^{2/3}$, lbs, q = lb/sq ft; $\mathcal{V}$ = volume, cubic ft; Moments = $C_{m,\ell,n}\ q\ \mathcal{V}$, lb-ft

Wt = 140,564 lbs

$\mathcal{V}$ = 2,652,000 cu ft

$\mathcal{V}^{2/3}$ = 19,159.4 sq ft

Buoyancy = 140,807 lb @ 5,000 ft

= 163,404 lb @ sea level

13, 19, and 14, respectively. The value at 120 degrees is estimated to be the same as that at 60 degrees based on hull symmetry without tails. The only significant moment acting is the yawing moment. A comparison of the Reference 15 curve values with the value from Reference 13 at 20 degrees and with the value from Reference 19 at 30 degrees is possible. The curve from 90 to 180 degrees is estimated to be similar based on symmetry.

From these data, specific coefficient values were selected at 60, 90, and 120 degrees of yaw for use in the structural weight analysis. The selected values are listed in Table 3-3. The values selected for C_y were greater by approximately 0.15 than the curve values to account for ground effects.

3. LOADS ON A FULLY RESTRAINED AIRSHIP

a. General

A preliminary analysis was conducted to determine the loads imposed on the landing gear due to winds acting on the airship when the landing gear totally constrains the airship's motion. For this first-order analysis, the airship is considered to be a rigid body with a rigid four-point landing gear. The assumed distribution of the landing gear forces in the different directions due to the different aerodynamic forces and moments acting on the airship is listed in Table 3-4. Sketches defining the aerodynamic sign conventions follow this table. The coordinates used are further defined in Table 3-5 and Figures 3-4 through 3-7. The analysis determines the landing gear forces due to the different aerodynamic forces and moments, proportions the forces between each of the four landing gear points, and superimposes the values at each point of the corresponding components and adds them to determine the total force values in the vertical, longitudinal, and lateral directions at each landing gear point. The signs in the resulting equations were made so that tensions between the landing gear and the constraint are positive (+).

b. Vertical Landing Gear Forces

Transferring the rolling moments to the plane of the landing gear, the components of the vertical forces can be determined by the sum of the moments due to the values of $C_y qV^{2/3}$ about y = 0, and Z = 0; that is, the intersection of vertical centerline and the ground and $C_1 qV$ (see Figure 3-4).

TABLE 3-3 - AIRSHIP WITHOUT TAILS, FIRST-ORDER BODY AXIS STATIC AERODYNAMIC COEFFICIENTS

Yaw Angle	Units	60 Deg	Force	90 Deg	Force	120 Deg	Force
Forces C_X	lbs	+0.15	2874q	0	0	-0.15	-2874q
C_Y	lbs	+1.70	32,571q	+1.55	29,697q	+1.70	32,571q
C_Z, C_L @ $\alpha = 0$	lbs	-0.15	-2874q	-0.15	-2874q	-0.15	-2874q
			Moment		Moment		Moment
Moments C_m Pitching	lb-ft	-0.05	-132,600q	0	0	+0.05	132,600q
C_ℓ Rolling	lb-ft	+0.025	61,300q	+0.02	53,040q	+0.025	61,300q
C_n Yawing	lb-ft	-0.375	-994,500q	0	0	+0.375	994,500q

Forces = $C_{x,y,z}\, q\, V^{2/3}$, lbs, q = lb/sq ft; V = volume, cubic ft; Moments = $C_{m,\ell,n}\, q\, V$, lb-ft

Wt = 140,564 lbs

V = 2,652,000 cu ft

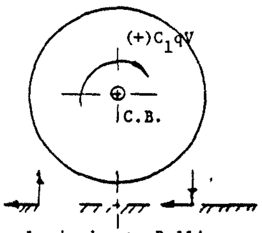
$V^{2/3}$ = 19,159.4 sq ft

Buoyancy = 140,807 lb @ 5,000 ft

= 163,404 lb @ sea level

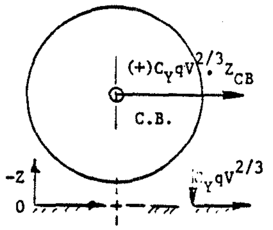
TABLE 3-4 - ASSUMED DISTRIBUTION OF LANDING GEAR FORCES IN THREE DIFFERENT AXIAL DIRECTIONS

Axial Direction of Resulting Landing Gear Forces	Aerodynamic Forces Through CB: Longitudinal C_X	Lateral C_Y	Vertical C_Z	Aerodynamic Moments About CB: Rolling C_l	Pitching C_m	Yawing C_n
Vertical	$C_X q\ V^{2/3}$	$C_Y q\ V^{2/3}$	$C_Z qV^{2/3}$	$C_l qV$	$C_m qV$	-0-
Horizontal Longitudinal	$C_X qV^{2/3}$	-0-	-0-	-0-	-0-	$.5C_n qV$
Horizontal Lateral	-0-	$C_Y qV^{2/3}$	-0-	-0-	-0-	$.5C_n qV$



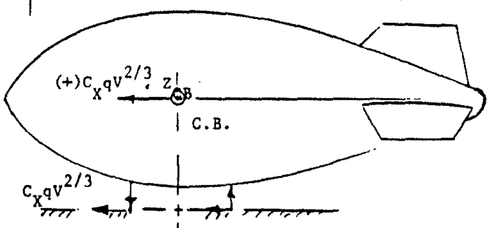
Loads due to Rolling Moment $C_l qV$

(End View)



Loads due to Lateral Force $C_Y qV^{2/3}$

(End View)



Loads due to Longitudinal Force $C_X qV^{2/3}$

(Side View)

TABLE 3-5 - COORDINATE SYSTEM

A. The aerodynamic forces pass through the coordinates of the CB located at:

x	y	z
l_{CB}	0	$-Z_{CB}$

where: ℓ = 0 at nose; (+) toward tail

y = 0 at centerline; (+) centerline to starboard

Z = 0 at ground level; (+) downward

B. Landing gear coordinates are:

Landing gear	X	Y	Z
A_1	l_{LG_F}	$-Y_{LG_F}$	0
B_1	l_{LG_R}	$-Y_{LG_R}$	0
A_2	l_{LG_F}	Y_{LG_F}	0
B_2	l_{LG_R}	Y_{LG_R}	0

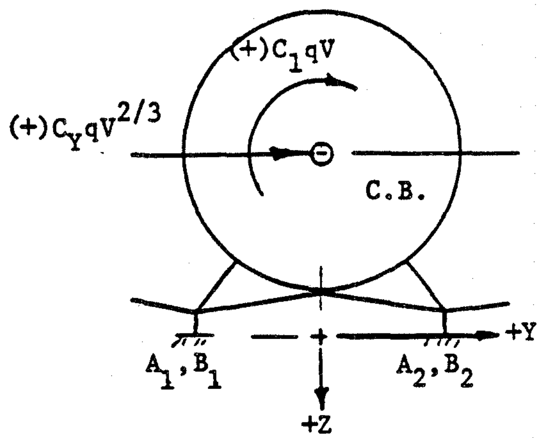


Figure 3-4 - Moments About Y=0, Z=0; View Looking Forward Along Centerline

Assuming all four landing gear points share the vertical forces equally (symmetrical stiffness), then these components are:

$$\text{Vertical force at } A_1, B_1, A_2, B_2 = \left[\frac{C_1qV + C_YqV^{2/3}(Z_{LG} - Z_{CB})}{4\,(Y_{CB} - Y_{LG})}\right] \quad (1)$$

where: $Z_{LG} = 0$

$Y_{CB} = 0$

Z_{CB} = height of airship center of buoyancy above ground (ft)

Y_{LG} = lateral locations of A_1, B_1, A_2, B_2 (ft)

Tension = (+)

Again, transferring the pitching moment to the plane of the landing gear, the components of the vertical forces can be determined by the sum of the moments due to the values of $C_xqV^{2/3}$ about l_{CB} and Z = 0, and C_mqV (see Figure 3-5).

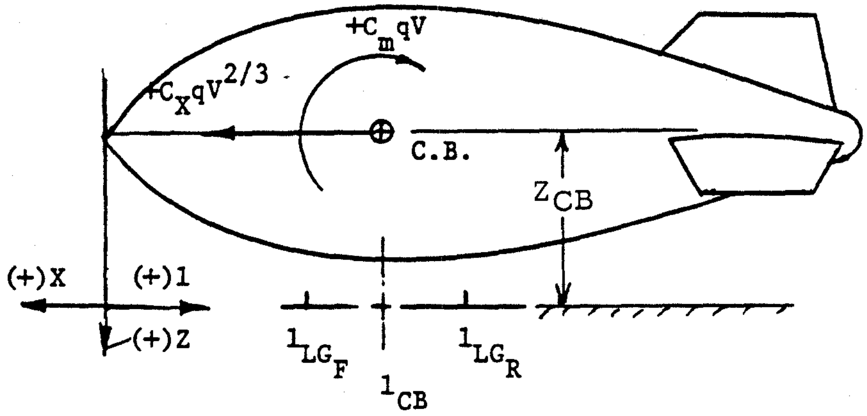


Figure 3-5 - Moments About l_{CB}, Z=0, View Looking Port to Starboard

Assuming all four landing gear points share the vertical forces equally, then the values of these vertical force components are:

$$\text{Vertical force at } A_1, B_1, A_2, B_2 = \frac{C_m qV - C_x qV^{2/3}\,(Z_{LG} - Z_{CB})}{4\,(l_{CB} - l_{LG})} \qquad (2)$$

Where: l_{CB} = distance of airship center of buoyancy from nose (ft)

l_{LG} = longitudinal location of A_1, B_1, A_2, B_2 (ft)

The vertical forces due to the vertical loads, $C_z qV^{2/3}$, buoyancy and weight, can be determined by summing only the vertical forces assuming the forces are in alignment (see Figure 3-6).

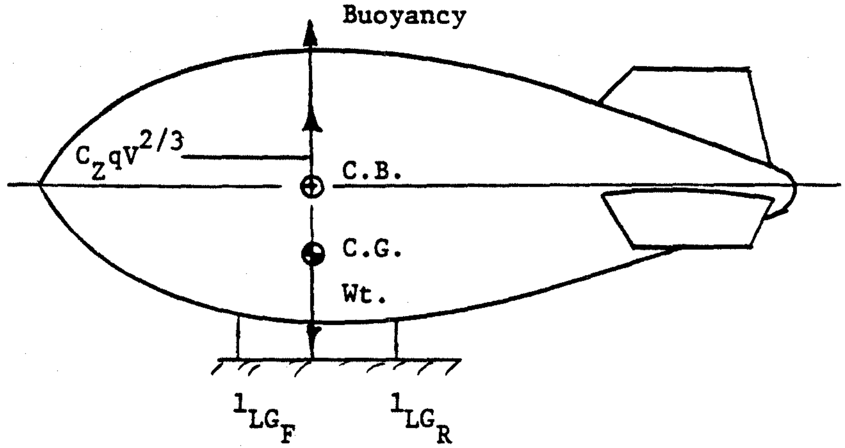


Figure 3-6 - Vertical Loads, View Looking Port to Starboard

Assuming all four landing gear points are equally spaced forward and aftward of the CB, they will share the vertical forces equally. The values of these vertical force components are:

$$\text{Vertical force at } A_1, B_1, A_2, B_2 = \frac{\Delta \rho V - C_Z qV^{2/3} - \text{weight}}{4} \qquad (3)$$

Where: $\Delta \rho$ = difference in the densities of air and helium (lb/cu ft)
wt = Weight of airship (lb)

Superpositioning and adding the vertical components from (1), (2), and (3) results in the total vertical landing gear forces at A_1, B_1, A_2, B_2 or

$$\text{Total vertical force at } A_1, B_1, A_2, B_2 = \frac{C_1 qV + C_Y qV^{2/3}(Z_{LG} - Z_{CB})}{4(Y_{CB} - Y_{LG})} +$$

$$\frac{C_m QV - C_X qV^{2/3}(Z_{LG} - Z_{CB})}{4(l_{CB} - l_{LG})} + \frac{\Delta \rho V - C_Z qV^{2/3} - Wt}{4} \qquad (4)$$

Where tension at restraint = (+)

c. Horizontal Landing Gear Forces

The horizontal forces in the longitudinal and lateral directions were established in a similar manner. Longitudinal landing gear forces were determined assuming one-half of the yawing moment results in longitudinal landing gear forces and the other half results in lateral forces; the longitudinal forces can be determined from the value of $C_X qV^{2/3}$ acting through and about l_{CB} and Z=0 (see Figure 3-5) and a 0.5 $C_n qV$ acting about a vertical centerline through the CB (see Figure 3-7).

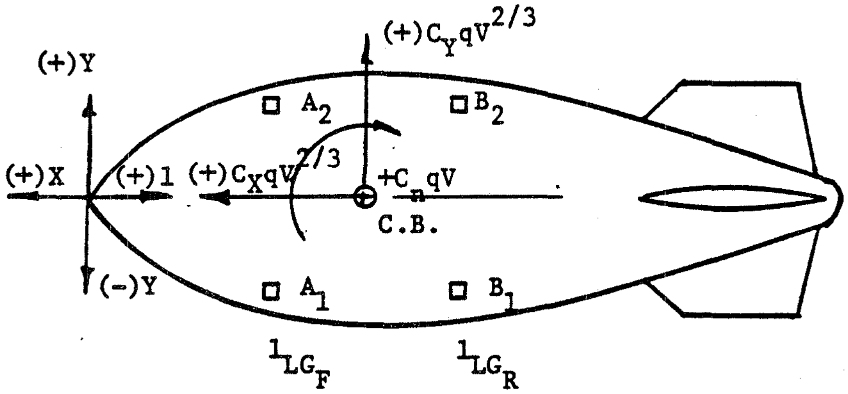


Figure 3-7 - Moments About Vertical Axis through CB, View Looking Down at Airship

Assuming all four landing gear points share each of the longitudinal forces equally, then the total longitudinal forces imposed by each landing point are:

Total longitudinal landing gear forces at A_1, B_1, A_2, B_2 =

$$\frac{C_X q V^{2/3}}{4} + \frac{.5C_n qV}{4(Y_{CB}-Y_{LG})} \tag{5}$$

Where a force forward = (+)

The lateral landing gear forces were determined assuming the values of $C_Y qV^{2/3}$ and $0.5C_n qV$ acting through and about a vertical centerline through the CB (see Figure 3-4) and $0.5C_m qV$ acting about 1_{CB} and Z=0 (see Figure 3-5).

Assuming all four landing gear points share each of the lateral forces equally, then the total lateral forces imposed by each landing gear point are:

Total lateral landing gear forces at A_1, B_1, A_2, and B_2 =

$$\frac{C_Y q V^{2/3}}{4} + \frac{.5C_n qV}{4(1_{CB}-1_{LG})} \tag{6}$$

Where a force from port to starboard = (+)

The aerodynamic coefficients to be used with the prior equations were presented as curves in Figure 3-2.

4. COMPUTER MODEL FOR FULLY RESTRAINED AIRSHIP

A computer model to evaluate the static loads developed at the gear points in a fully restrained airship mooring system was developed in accordance with the equations presented in the preceding section. Forces in the vertical, lateral, and longitudinal directions are computed. Figure 3-8 shows the effect of wind speed on these forces. Note that the maxima do not occur at the same wind angle. The highest vertical load is a result of a cross wind, while the lateral and longitudinal peaks occur at 120 degrees and 150 degrees respectively.

One major attribute of this model is the ability to assess configurations with varying buoyancy factors (β). For this concept, a lower buoyancy ratio would enhance its capabilities, but some airship operational penalty would result. Figure 3-9 shows the effects of β on the maximum vertical reaction of the four landing gear for the BQR with empennage at various wind speeds. Since this is representative of the highest load, the wind is acting at 90 degrees.

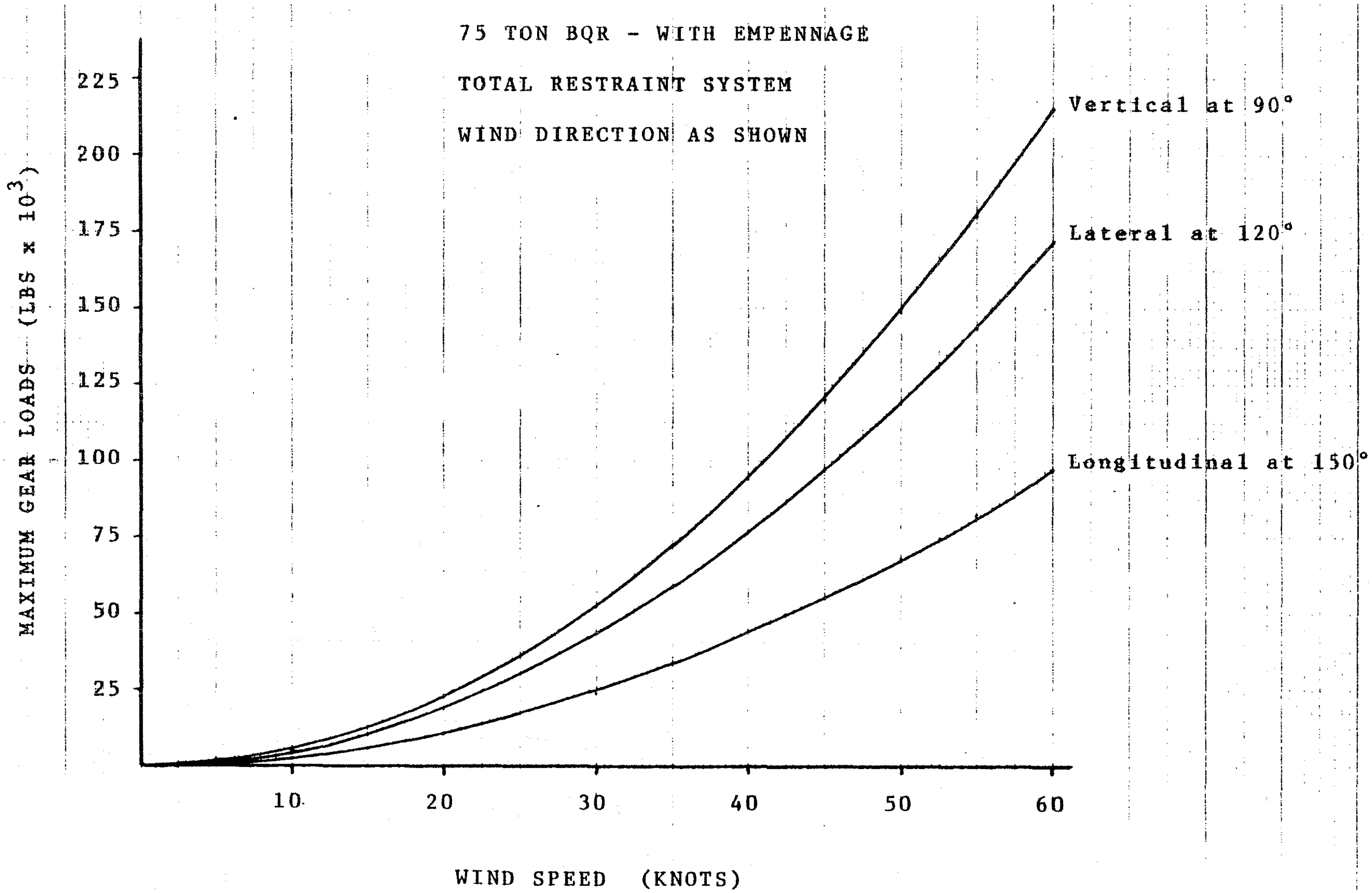


Figure 3-8 - Maximum Gear Forces vs Wind Speed for Fully Restrained BQR With Empennage

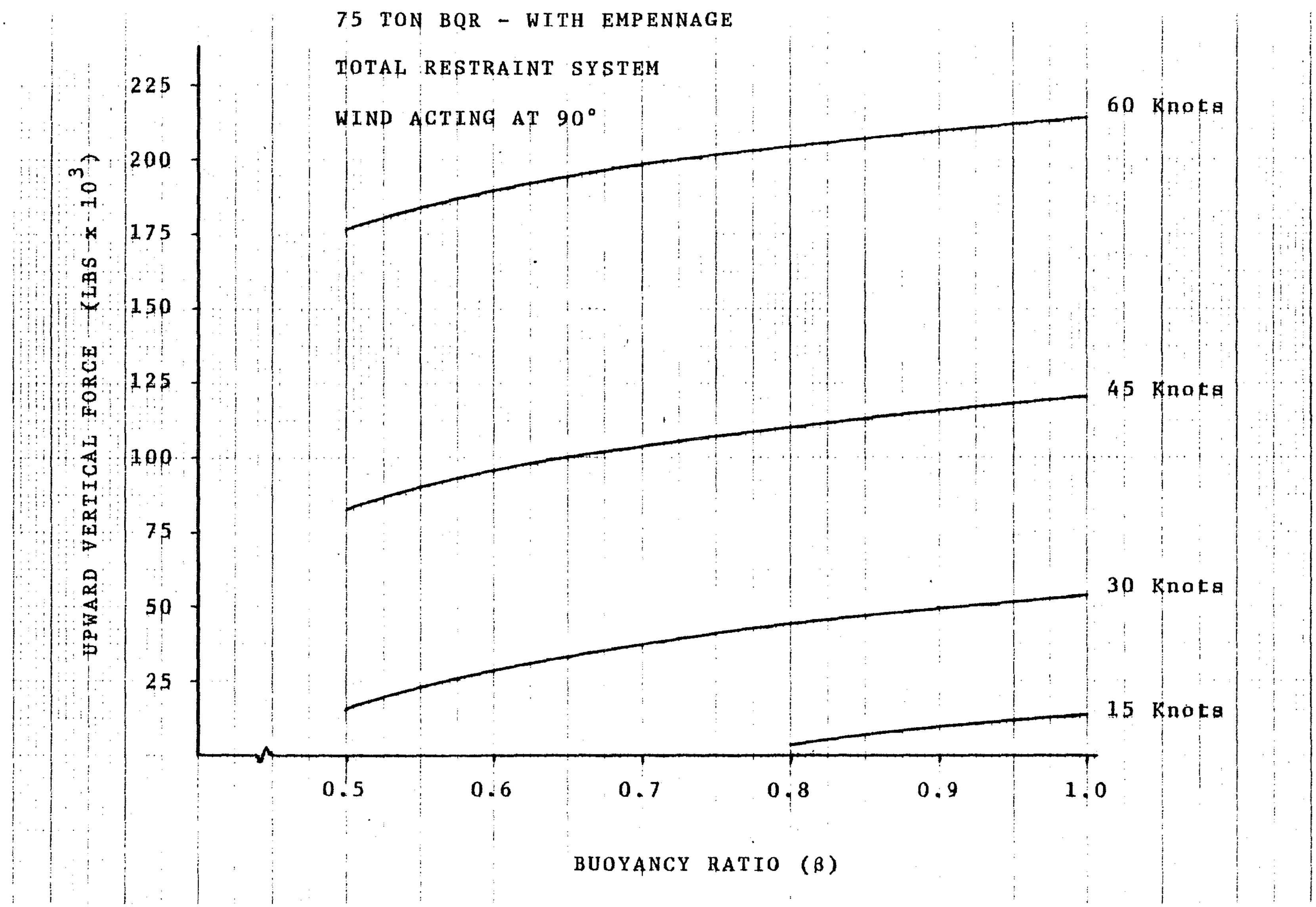


Figure 3-9 - Buoyancy Ratio vs Maximum Upward Vertical Load for Fully Restrained BQR With Empennage

5. ENVELOPE AND SUSPENSION SYSTEM WEIGHTS

The weight of the suspension system is a function of the suspended load. In a conventional airship, the suspended load is approximately 50 percent of the gross weight, where the gross weight is the product of the displaced volume and the local air density. For standard atmosphere, the suspended load is (0.5) (0.0765)V. The suspension system is normally designed to carry an additional acceleration factor of 0.5 g. The design suspension system load is defined as $L_s = (1.5)\ (0.5)\ (0.0765V) = 0.0574V$. The suspension system weight for a standard airship is $C_{ws}\ (0.0574V)$. The coefficient C_{ws} varies somewhat with configuration and load distribution between internal and external systems.

Restraining the airship by rigidly attaching the starframe to the ground results in the airload acting on the envelope being transferred by the suspension system to the starframe and ground in addition to the nominal suspended load. The suspension system of a conventional airship is designed to carry an axial load resulting from a 30-degree pitch combined with maximum thrust. This, in effect, is equal to half of the car weight plus engine thrust. The maximum engine thrust is equal to drag at maximum velocity. A typical airship zero lift drag coefficient (C_{DO}) of 0.0498 is used.

$$F_x = (0.5)\ (0.5)\ (0.0765V)+T$$
$$= 0.0191V + T \qquad (7)$$

where $$T = V^{2/3} \left(\frac{(KT)_D^2}{295.1} \right) (0.0498)$$

and $(KT)_D$ = design velocity in knots

Equating the axial forces and using the maximum C_x value of 0.20 as identified in Table 3-2 produces the following:

$$(0.20) \left[V^{2/3} \frac{(KT)_w^2}{295.1} \right] = 0.0191\ V + 0.0498\ V^{2/3}\ \frac{(KT)_D^2}{295.1}$$

where $(KT)_w$ = wind velocity knots

$$V^{2/3} = \frac{0.0191V}{\left[0.20 \frac{(KT)_w^2}{295.1} - 0.0498 \frac{(KT)_D^2}{295.1} \right]}$$

$$V^{1/3} = \frac{1}{(0.0191)\ 295.1} \left[0.20\ (KT)_w^2 - 0.0498\ (KT)_D^2\right]$$

$$= 0.177\ (KT)_w^2 \left[0.20 - 0.0498\ \frac{(KT)_D^2}{(KT)_w^2}\right]$$

$$= 0.0354\ (KT)_w^2 \left[1 - 0.249\ \frac{(KT)_D^2}{(KT)_w^2}\right]$$

Solving for V:

$$V \geq 4.436 \times 10^{-5}\ (KT)_w^6 \left[1 - 0.249 \left\{\frac{(KT)_D}{(KT)_w}\right\}^2\right]^3$$

Therefore, the volume at which the suspension system design force is equal to or greater than the axial tiedown load is

$$V \geq 44.36 \left(\frac{KT_w}{10}\right)^6 \left[1 - 0.249 \left\{\frac{(KT)_D}{(KT)_w}\right\}^2\right]^3 \qquad (8)$$

Solving for volume at various wind speeds, Table 3-6 is generated:

TABLE 3-6 - EQUILIBRIUM VOLUMES (CU FT X 10^6)

$(KT)_w$ knots	$(KT)_D$ - knots 70	60	55
70	2.21	2.85	3.16
60	0.60	0.88	1.02
50	0.09	0.18	0.24
40	0.002	0.015	0.027

The customary suspension system axial design load exceeds the axial wind mooring load for volumes greater than those shown in the above table for the specified conditions. This analysis assumes the normal design axial load on the suspension system is greater than the axial wind mooring load component; therefore, the axial wind mooring load has no effect on suspension system weight.

The transverse load, F_Y, causes a shift of load within the suspension system, increasing the load in the leeward half and decreasing the load in the windward half, in general. The load in one-half of the suspension system is used as the reference for evaluating the effects of the mooring airloads on the suspension system weight.

The suspension system forces for a total restraint system are identified in Figure 3-10. Note that all forces are acting in the same plane.

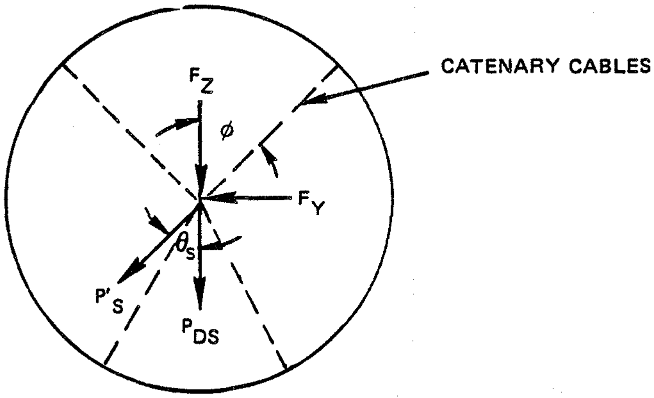


Figure 3-10 - Suspension System Forces for Total Restraint System

These forces are defined as follows:

$$F_Y = C_Y V^{2/3} q$$

$$F_Z = C_Z V^{2/3} q$$

P_{DS} lift on suspension = 0.5 (0.0765)V

P'_s is the resultant force in the suspension system

The load in the suspension system due to static lift, dynamic lift, and transverse force is:

$$\vec{P'_s} = (\vec{P}_{DS} + \vec{F}_Z) + \vec{F}_Y \qquad \text{where } q = \frac{(KT)_w^2}{295.1}$$

The magnitude of P'_s acting at angle θ is:

$$P'_s = \left(\overrightarrow{0.0383\ V + C_Z V^{2/3} \frac{(KT)_w^2}{295.1}}\right) + \vec{C}_Y V^{2/3} \frac{(KT)_w^2}{295.1}$$

$$P'_s = \left[\left\{\overrightarrow{\frac{11.3\ V^{1/3}}{(KT)_w^2} + C_Z}\right\} + \vec{C}_Y\right] \frac{(KT)_w^2\ V^{2/3}}{295.1}$$

For values of θ_s less than ϕ, the maximum load in one-half of the suspension system, defined as $P'_{s/2}$, is:

$$P'_{s/2} = 1/2\ P'_s \left(\frac{\text{SIN}\,\theta_s}{\text{SIN}\,\phi} + \frac{\text{Cos}\ \theta_s}{\text{Cos}\ \phi}\right) \qquad (9)$$

For values of θ_s greater than ϕ, the load in one-half of the suspension system is assumed to be P'_s; that is:

$$P'_{s/2} = P'_s.$$

For

$$\theta_s \geq \phi$$

$$\frac{11.30V^{1/3}}{(KT)_w^2} + C_Z \leq \frac{C_Y}{\tan \phi}$$

$$\frac{11.30V^{1/3}}{(KT)_w^2} \leq \frac{C_Y}{\tan \phi} - C_Z. \quad (10)$$

In conventional bow moored airships, side loads are very limited and are assumed negligible. Typical values of ϕ are approximately 30 degrees. Totally restraining an airship introduces substantial side forces, however, that result in the flattening of the plane of the suspension system. Thus, a value of ϕ = 40 degrees is selected to account for this.

Solving equation (10) for V at ϕ = 40 deg, Table 3-7 is generated:

TABLE 3-7 - ENVELOPE VOLUMES FOR SUSPENSION SYSTEM LOADS

Yaw Angle	C_Y	C_Z	$\frac{C_Y}{\tan \phi} - C_Z$	Volume (cu ft x 10^6) @ $(KT)_w$ 70 kts	35 kts
60	1.70	0.76	1.27	167.02	2.61
90	1.60	0.60	1.31	183.30	2.86
120	1.50	0.20	1.54	297.79	4.65

All volumes less than those shown in the table will result in angles θ_s equal to or greater than ϕ=40 degrees. Therefore, all of the load (P'_s) is carried by one-half the suspension system.

The pitching and yawing moments are added vectorially, and a linear load variation over the length of the suspension system is assumed. The average increase in load (f''_s) over one-half the length of the suspension system of length L is defined as:

$$\vec{f''_s} = \frac{3\vec{M}}{L^2} \quad \text{(lb/ft)}$$

where $$\vec{M} = (\overrightarrow{C_{MY}} + \overrightarrow{C_{MZ}})\ V\ \frac{(KT)_w^2}{295.1}$$

The length, L, of the suspension system is estimated as 55 percent of the over-all length of the ship. The ship length, L_M, is related to the volume by:

$$L_M = \left(\frac{4\lambda^2 V}{\mu \P}\right)^{1/3} \tag{11}$$

where λ is the length to diameter ratio and μ is the prismatic coefficient. Typical values of μ and λ, 0.643 and 4.0, respectively, are inserted in the above equation:

$$L_M = \left(\frac{4\ (4)^2 V}{0.643 \P}\right)^{1/3}$$

$$= 3.164\ V^{1/3}$$

$$L = 0.55\ L_M$$

Therefore $$L = 1.74\ V^{1/3}$$

and $$\overrightarrow{f''_s} = \frac{3\ (\overrightarrow{C_{MY}} + \overrightarrow{C_{MZ}})\ V\ (KT)_w^2}{(1.74\ V^{1/3})^2\ (295.1)}$$

The added effective load in one-half of the suspension system due to moment is:

$$P''_s = \overrightarrow{f''_s}\ L$$

$$= \frac{3\ (\overrightarrow{C_{MY}} + \overrightarrow{C_{MZ}})\ V\ (KT)_w^2}{(1.74\ V^{1/3})^2\ (295.1)}\ (1.74\ V^{1/3}) \tag{12}$$

The magnitude of P''_s is:

$$P''_s = 0.00584\ (C_{MY} + C_{MZ})\ V^{2/3}\ (KT)_w^2\ . \tag{12a}$$

This added load in the suspension system is small. Performing the algebraic addition and assuming that P'_s and P''_s are in the same plane, the total design load in one-half of the suspension system is:

$$P_s = P'_s + P''_s$$

$$= \left[\overrightarrow{\left(\frac{11.3\ V^{1/3}}{(KT)_w^2} + C_Z\right)} + \overrightarrow{C_y}\right]\left[\frac{(KT)_w^2\ V^{2/3}}{295.1}\right] + 0.00584\ (\overrightarrow{C_{My}} + \overrightarrow{C_{MZ}})\ V^{2/3}\ (KT)_w^2$$

$$\frac{P_s}{0.5L_s} = \frac{2\,V^{2/3}\left\{\left[\left(\overrightarrow{\frac{11.3\,V^{1/3}}{(KT)_w^2} + C_Z}\right) + \vec{C}_y\right]\frac{(KT)_w^2}{295.1} + 0.00584\,(\vec{C}_{My} + \vec{C}_{MZ})\,(KT)_W^2\right\}}{0.0574V}$$

$$= \frac{(KT)_w^2}{V^{1/3}}\left\{0.1181\left[\left(\overrightarrow{\frac{11.3\,V^{1/3}}{(KT)_w^2} + C_Z}\right) + \vec{C}_y\right] + 0.2035\,(\vec{C}_{My} + \vec{C}_{MZ})\right\}$$

Let $K_{ws} = \frac{P_s}{0.5\,L_s}$

The weight of the suspension system is proportional to the load in the system. K_{ws} is defined as the ratio of the suspension load in a fully restrained airship to the suspension load in a conventionally bow-moored airship. It is, therefore, a ratio of the respective suspension system weight. Table 3-8 gives values of K_{ws} for each HLA configuration at various wind speeds. Note that envelope volume, and hence envelope weight, is held constant.

TABLE 3-8 - SUSPENSION SYSTEM WEIGHT FACTOR (K_{ws})

Yaw Angle	With Tail			Without Tail	
$(KT)_w$	60°	90°	120°	60°, 120°	90°
76.7	15.2	13.8	16.6	12.1	8.1
70.0	12.8	11.6	13.9	10.0	6.8
60.0	9.6	8.7	10.3	7.5	5.1
55.0	8.2	7.4	8.8	6.4	4.4
45.0	5.7	5.2	6.1	4.5	3.0
35.0	3.9	3.5	4.0	3.0	2.2

The weight of the suspension system in a conventionally designed airship is defined as C_{ws} (0.0574V). The suspension system weight for a restrained vehicle would be impacted by the factors defined above such that the system weight, W_s, would be

$$W_s = C_{ws}\,K_{ws}\,(0.0574V) \qquad (13)$$

The suspension system weight coefficient, C_{ws}, is derived by averaging the weight coefficients of previously constructed airships. This is shown in Table 3-9. Note that the use of an average value provides an acceptable correlation to the actual data.

TABLE 3-9 - SUSPENSION SYSTEM WEIGHT COEFFICIENT (C_{ws})

Ship	Volume (ft^3)	W (lbs)	C_{ws} (Actual)	W' (lbs)
ZS2G-1	650,000	1001	0.0268	910
ZPG2	975,000	1269	0.0227	1365
ZPG2W	975,000	1359	0.0243	1365
ZPG3W	1,465,000	2000	0.0238	2051
		Mean	0.0244	

Note: W is the actual suspension weight of the airship. W' is the weight defined by the product of the mean value of C_{ws} and (0.0574V).

Using 0.06 lb/cu ft as nominal lift of helium, the weight fraction of the suspension system is:

$$\% W_s = \frac{0.0244\ (0.0574)\ V}{0.06V} Kw_s \times 100 \qquad (14)$$

$$= 2.334\ Kw$$

Results of this equation using the maximum values of K_{ws} shown previously in Table 3-8 are provided in Table 3-10.

TABLE 3-10 - SUSPENSION SYSTEM WEIGHT FRACTION

KT_w (knots)	$\% W_s$	
	With Tail	Without Tail
76.7	38.7	28.2
70.0	32.4	23.3
60.0	24.0	17.5
55.0	20.5	14.9
45.0	14.2	10.5
35.0	9.3	7.0

This table indicates that the suspension system weight is increased from the 2.33 percent of conventional airship gross lift (gross lift equals 0.06V) to 9.3 percent for 35-knot wind and 38.7 percent at 76.7-knot wind when the airship is anchored to the ground through suspension systems.

The effect on the envelope weight is a function of how the increase in suspension system strength is obtained. The increase in suspension system strength can be obtained by either increasing the size of a fixed number of suspension systems or increasing the number of suspension systems. If the number of suspension systems is increased by the required factor, there is no increase in envelope weight.

If a fixed number of suspension systems is increased in strength by the required factor, the envelope structural weight is increased by some factor. The envelope structural weight is the envelope weight minus ballonets, airlines, patches, fairings, etc. The envelope structural weight is a function of the maximum design velocity of the airship. The structural weight fraction of conventional ships designed to fly 75 knots is 12.5 percent. The airship experiences loads that produce fabric stress greater than that required to carry the suspended load. A factor greater than one is inherent in the envelope structural weight with respect to the strength required to carry the suspended load. This factor varies with several design parameters: speed, configuration, pitch angle, gas valve size, and ascent and descent rate. The factor is estimated to be 2.25 for a 75-knot ship. The envelope weight fraction is increased by the ratio of the suspension system weight factor to the 2.25 inherent factors in the envelope.

$$K_{we} = \frac{K_{ws}}{2.25} = 0.44\ K_{ws}$$

$$\%W_e = 12.5\ K_{we} \qquad (15)$$

The total weight fraction for the structural envelope plus the suspension system is identified as $\%W_i$ in Table 3-11 and is the algebraic sum of $\%W_e$ and $\%W_s$. Whereas the $\%W_i$ for a conventional airship is 14.83 percent, the weight penalty associated with a restrained or center point moored airship is considerably higher. Depending on the wind speed, the end result would vary from a significant decrease in payload capability to being too heavy to fly.

Graphic representations of the data provided in Tables 3-10 and 3-11 are shown in Figure 3-11.

Regardless of the type of airship (non-rigid, semi-rigid, or rigid), the transference of large lateral forces through the structure to the ground will result in structural weight changes comparable to those predicted above.

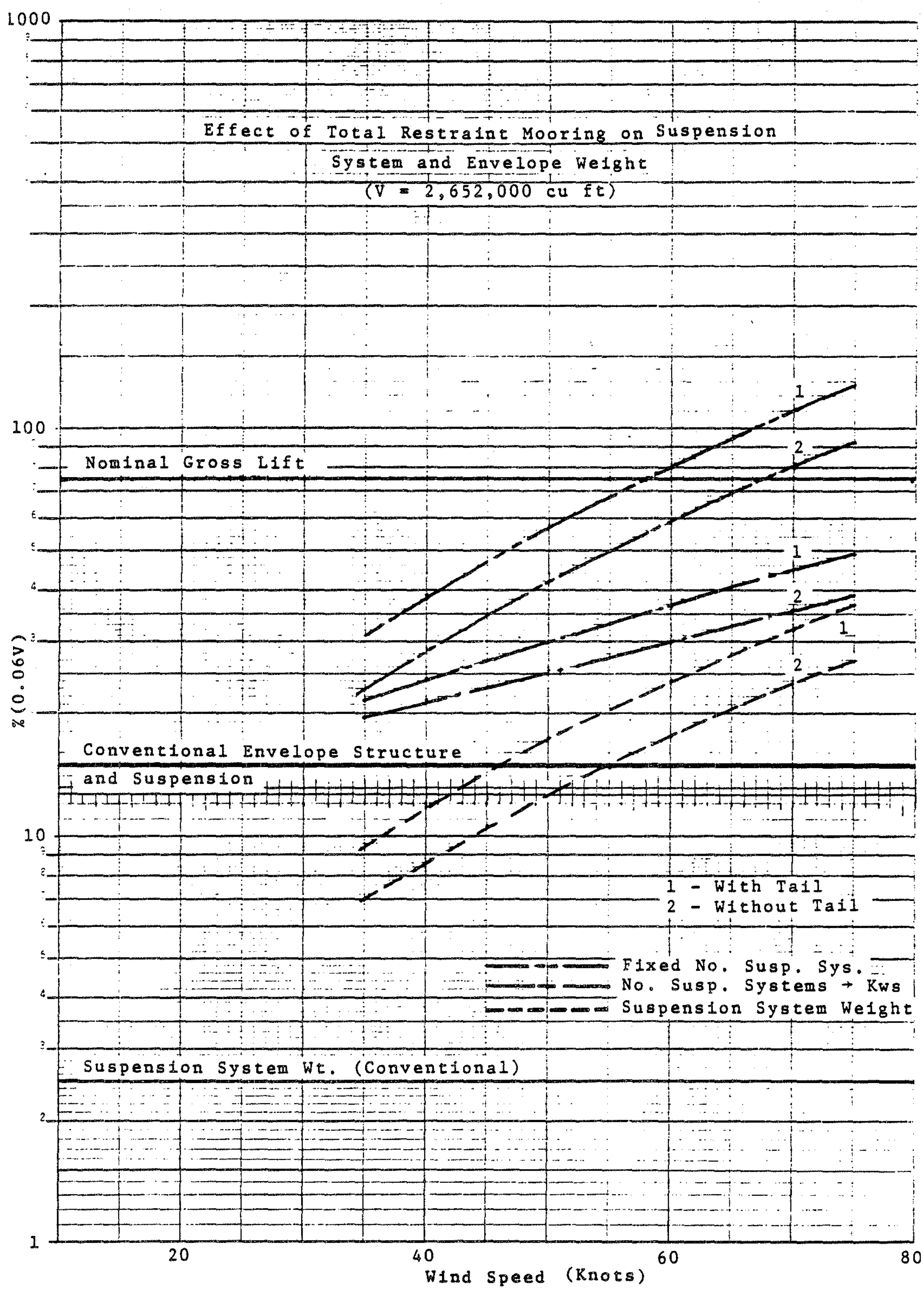


Figure 3-11 - Effect of Total Restraint Mooring on Suspension System and Envelope Weight

TABLE 3-11 - ENVELOPE WEIGHT FRACTIONS FOR FIXED NUMBER OF SUSPENSION SYSTEMS

$(KT)_w$ (knots)	With tail					Without tail				
	K_{ws}	K_{we}	$\%W_e$	$\%W_s$	$\%W_i$	K_{ws}	K_{we}	$\%W_e$	$\%W_s$	$\%W_i$
76.7	16.6	7.4	93	39	132	12.1	5.4	68	28	96
70	13.9	6.1	76	32	108	10.0	4.4	55	23	78
60	10.3	4.6	58	24	82	7.5	3.3	41	18	59
55	8.8	3.9	49	21	70	6.4	2.8	35	15	50
45	6.1	2.7	34	14	48	4.5	2.0	25	11	36
35	4.0	1.8	23	9	32	3.0	1.3	16	7	23

SECTION IV - DYNAMIC LOADS AND COMPUTER SIMULATION MODELS

1. GENERAL

Dynamic loads analysis and associated computer programs were developed in order to determine mooring loads for each of the mooring applications for systems with rotational capability. A description of the logic and results of the calculations are presented.

2. DYNAMIC FORCES AND MOMENTS ACTING ON THE AIRSHIP

For those mooring styles in which the airship is free to rotate (bow moored, belly moored, and center point moored), consideration must be given to dynamic forces and moments. The static analysis previously described is therefore extended to encompass this realm.

A segmented approach was taken to determine the overall forces acting on the airship while it is rotating because the relative wind speed and direction change drastically over the length of the airship as its angular velocity and the distance of the segments from the point of rotation increase. For instance, with bow mooring the relative wind velocity acting on the tail becomes negative long before the airship reaches its maximum angular velocity. The segments method simulation also predicts that the airship will align with the wind with very little over-shoot, thus eliminating the need for incorporating the damping terms to a standard simulation to compensate for the drastic wind velocity variation over the airship. The airship was divided into ten equal length segments for the analysis. The following assumptions are integral with this approach:

1. The aerodynamic forces and moments acting on the entire airship are a summation of the individual forces and moments for each segment. The forces on each segment are simply a function of the localized airspeed and yaw angle, while the individual moments consist of the product of segmental forces and their moment arms.
2. The airship rotates in the horizontal plane only. It is recognized that kiting of a moored airship will undoubtedly occur, but the magnitude of the kiting forces are insignificant compared to the lateral forces at large yaw angles. The vertical forces were uncoupled from the horizontal forces.

3. The rotational accelerations of the airship are limited only by the effects of rotational inertia. No attempt was made to quantify forces such as those to initiate rolling in the landing gear to overcome rolling resistance.
4. The rotational velocity is limited when the sum of the moments about the mast due to the aerodynamic forces acting on the segments become zero.

The average C_x and C_y values for each of the ten segments were developed from force distribution data for airships versus angle of yaw (Reference 33). These data were supplemented for additional yaw angles by calculating force distributions for the airship using pressure distribution data from References 33 and 34, and the areas of the corresponding airship segments. The resulting average force coefficient values for each of the ten segments were integrated to obtain C_x and C_y values for comparison with the values of C_x and C_y that were measured for the total airship.

The resulting yawing moment coefficients calculated from the force coefficients of the ten segments and the position of each segment from the center of buoyancy were compared with the yawing moment coefficient (C_n) values measured for the total airship. The values for the force distributions were adjusted until the values of C_x, C_y, and C_n calculated from the coefficients and locations of the ten segments agreed with the values of C_x, C_y, and C_n measured for the total airship.

The resulting average values of C_x and C_y for each of the ten segments versus angle of yaw are presented in Figures 4-1 and 4-2, respectively. The sign conventions used in the analysis are indicated in Figure 4-3.

The aerodynamic forces and moments acting on the airship segments were calculated using a computer program that allowed the airship to rotate in a horizontal plane about a vertical mooring mast. The program allowed positioning the mast at any airship station. The relative wind velocity (vector) at each airship segment due to the selected wind velocity and the velocity of the airship segment determined the value of the coefficient and dynamic pressure acting on each segment. Initially, the resistance to rotation is due to inertia of the airship and its virtual mass. As time passes, the airship's rotational velocity increases and the aerodynamic forces acting on the tail of the airship become less, and then they resist the actions of the aerodynamic forces on the more forward sections. Finally, it was calculated that the aerodynamic forces resist rotation of the airship

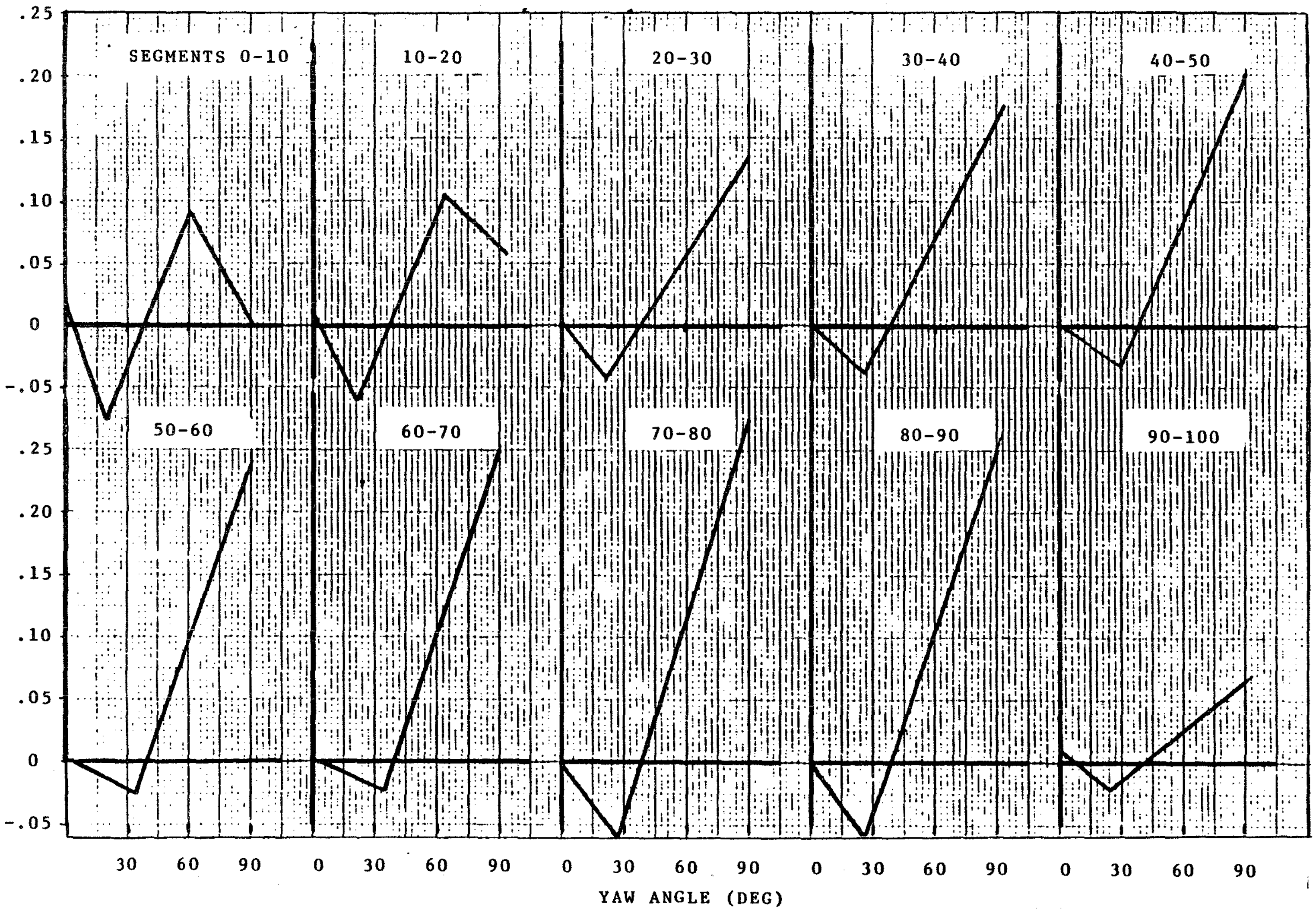


Figure 4-1 - C_x by Segments, Nose to Tail (-)

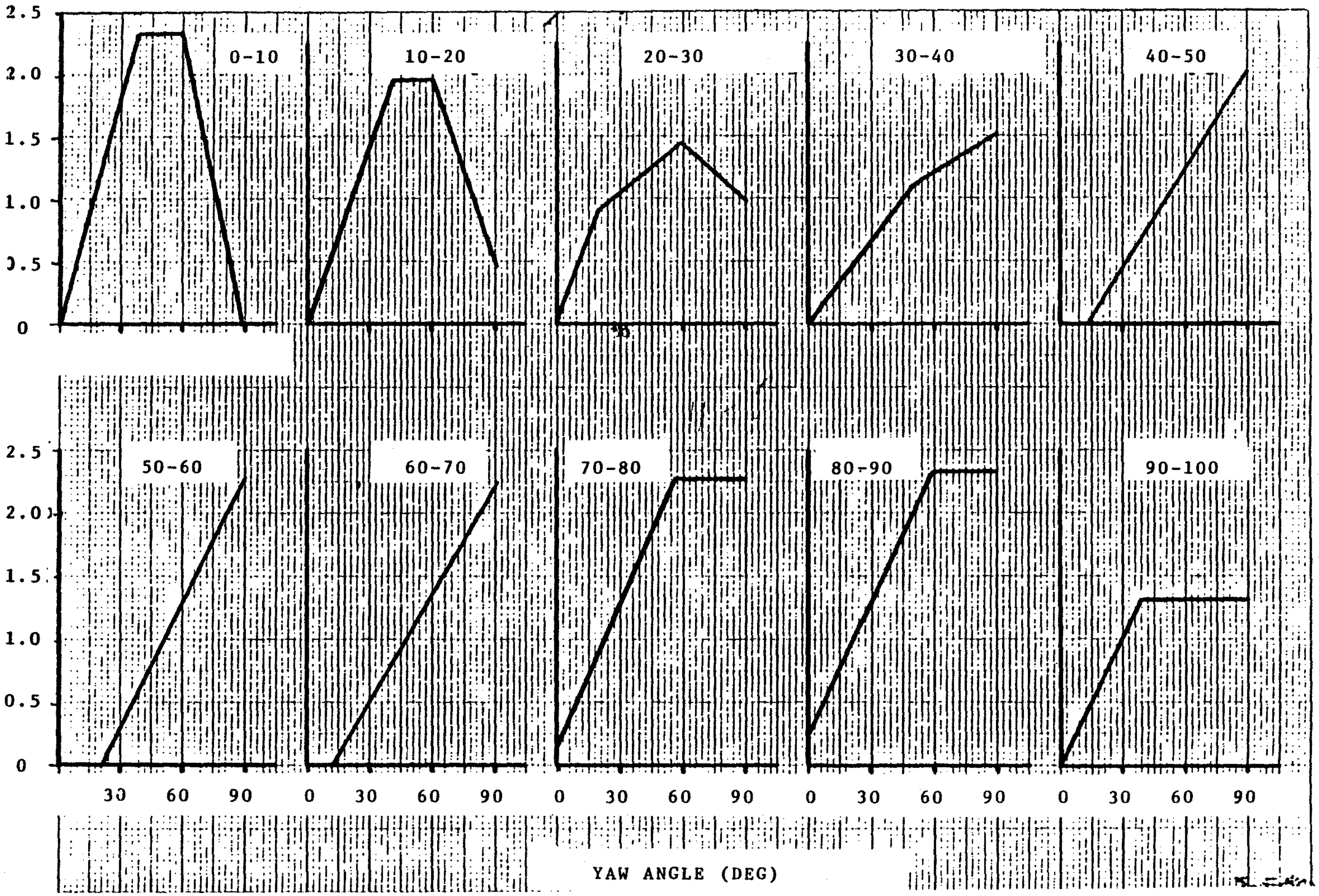


Figure 4-2 - C_y by Segments, Centerline to Starboard (+)

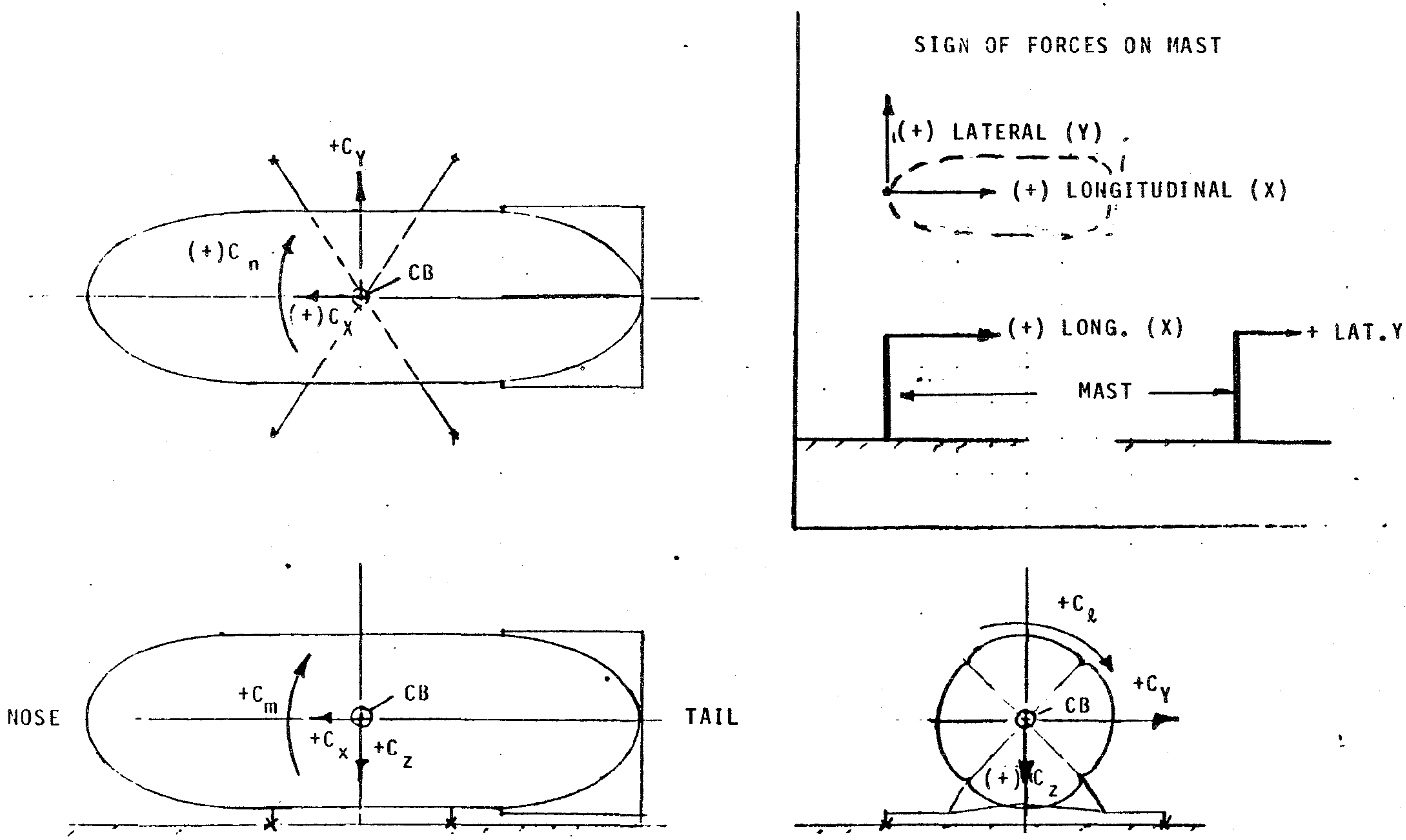


Figure 4-3 - Sign of Forces and Moments

and slow the rotational velocity of the airship to small values as the airship heads into the wind. The airship rotates only a few degrees beyond heading into the wind because of the small rotational momentum remaining.

The following equations were developed for this analysis:

$$F_{latr} = \sum_{i=1}^{10} F_{y_i} - \sqrt{\frac{M}{I_y}} \sum_{i=1}^{10} (L_i - L_m) F_{y_i} \tag{16}$$

$$F_{long} = \sum_{i=1}^{10} F_{x_i} + \sqrt{MI_y}\ \dot{\theta}^2 \tag{17}$$

$$F_{mast} = \sqrt{F_{latr}^{\ 2} + F_{long}^{\ 2}} \tag{18}$$

$$\ddot{\theta} = \left[\sum_{i=1}^{10} (L_i - L_m) F_{y_i}\right] / I_y \tag{19}$$

where

$$F_{y_i} = 1916\ \rho \frac{V_T^2}{2}\ C_{y_i} \tag{20}$$

$$F_{x_i} = 1916\ \rho \frac{V_T^2}{2}\ C_{x_i} \tag{21}$$

$$V_T^2 = V_w^2 \sin^2 (\psi - \theta) + \left[V_w - \cos (\psi - \theta) - \dot{\theta} (L_i - L_m)\right]^2 \tag{22}$$

and

$$I_y = I_{cg} + (L_{cg} - L_m)\ m \tag{23}$$

3. COMPUTER MODEL FOR SYSTEMS WITH ROTATIONAL CAPABILITY

The computer program deals with the dynamic loads analysis for bow, belly, and center point mooring situations. An annotated logic sequence for the program is shown in Figure 4-4.

a. Data Inputs

A description of the data input requirements is as follows:

1. Airship profile table of distance from the nose versus envelope radius

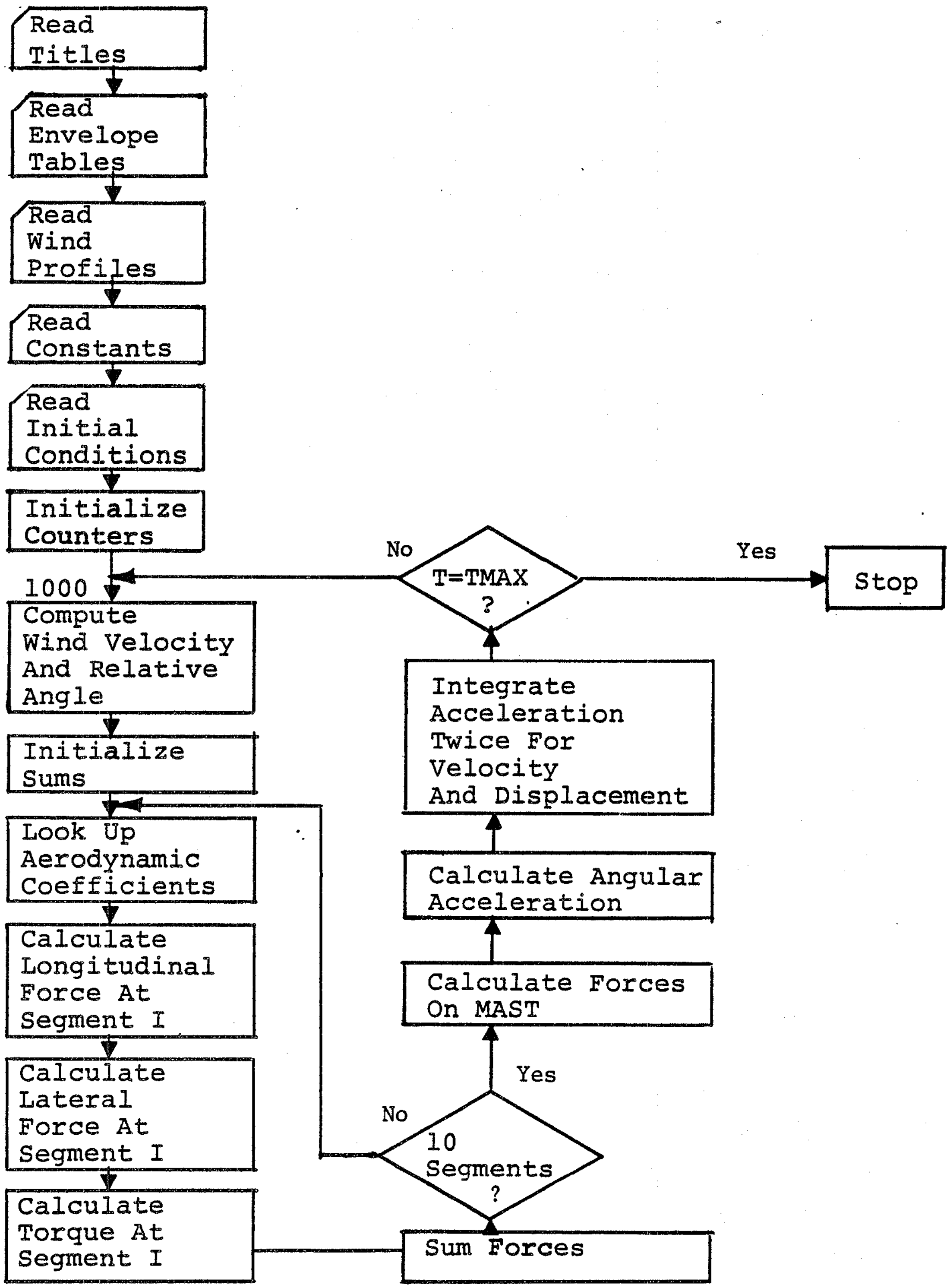


Figure 4-4 - Moored Airship Dynamic Simulation Logic Sequence

2. Wind ramp input that permits the analysis of various wind loading characteristics. A linear wind ramp from zero to maximum wind speed at five seconds has been arbitrarily utilized for this study. The capability of altering this parameter is, however, provided.
3. Segment location identifying the location of each analyzed segment with respect to the nose
4. C_x and C_y tables providing tabular data of the information that is graphically illustrated in Figures 4-1 and 4-2
5. Moment of inertia about the center of gravity, including the effect of virtual mass
6. Airship mass, including virtual mass
7. Location of the mast with respect to the nose of the airship
8. Location of the airship's center of buoyancy with respect to its nose
9. Time and iteration intervals
10. Height of the airship's center line
11. Initial values for angular displacement, angular velocity, wind speed, and wind direction

b. Computed Inputs

Two computed inputs for the simulation model are: (1) mast height, which is a function of mast location and the airship profile; and (2) moment of inertia about the mast.

c. Outputs

A tabular listing of the airship configuration data, mooring style data, and initial conditions is provided at the beginning of a computation. Computed values of angular acceleration (THEDD), angular velocity (THED), angular displacement with respect to the original airship location (THE), the transverse load on the mast (FLATR), the longitudinal force on the mast (FLONG), the total force on the mast (FMAST), and the forces at each of the four landing gears (FLGA1, FLGA2, FLGB1, FLGB2) are output. All calculations are based on airship-fixed coordinates.

4. COMPUTER MODEL RESULTS AND ANALYSIS

a. General

A series of graphs was generated to identify predicted performance attributes of the dynamic mooring systems for varying input conditions. Initial wind characteristics (speed and direction) are indicated on the graphs. Peak forces are defined as the highest occurring force over the integration time.

b. Mast Forces Versus Mast Location

Three graphs plotting the peak mast forces against the mast location are shown in Figures 4-5, 4-6, and 4-7 for total mast force, lateral mast force, and longitudinal mast force, respectively. Distance "0" represents bow mooring, 203.8 indicates center point mooring, and all intermediate values are belly mooring.

As the mast is moved from the bow toward the center of the airship, FLATR increases while FLONG decreases. The net effect on FMAST is to increase as the mast distance from the bow increases.

c. Bow Moored BQR With Empennage

The peak forces generated on the mast are sensitive to both the wind's originating direction with respect to the airship and its speed. Figures 4-8 and 4-9 illustrate these relationships. Note that the longitudinal force predominates at wind angles above 64 degrees.

d. Belly Moored BQR With Empennage

For this analysis, the mast location for a belly moored airship was arbitrarily assigned at 108 feet from the nose. This value coincides with the leading edge of the control car and represents a point that is approximately midway from the nose to the airship's center of gravity. In this case, as shown in Figures 4-10 and 4-11, the lateral force is predominant for all angles.

e. Equilibrium Angle

In these dynamic mooring concepts, the wind causes the airship to rotate about the mast. As indicated in Figure 4-12, however, once the mast distance from the nose exceeds 140 ft, the airship no longer lines up with the prevailing wind. For example, at an initial wind direction of 30°, with the mast at 175 feet from the nose, the airship would be at equilibrium at approximately (80° - 13°) or 67°.

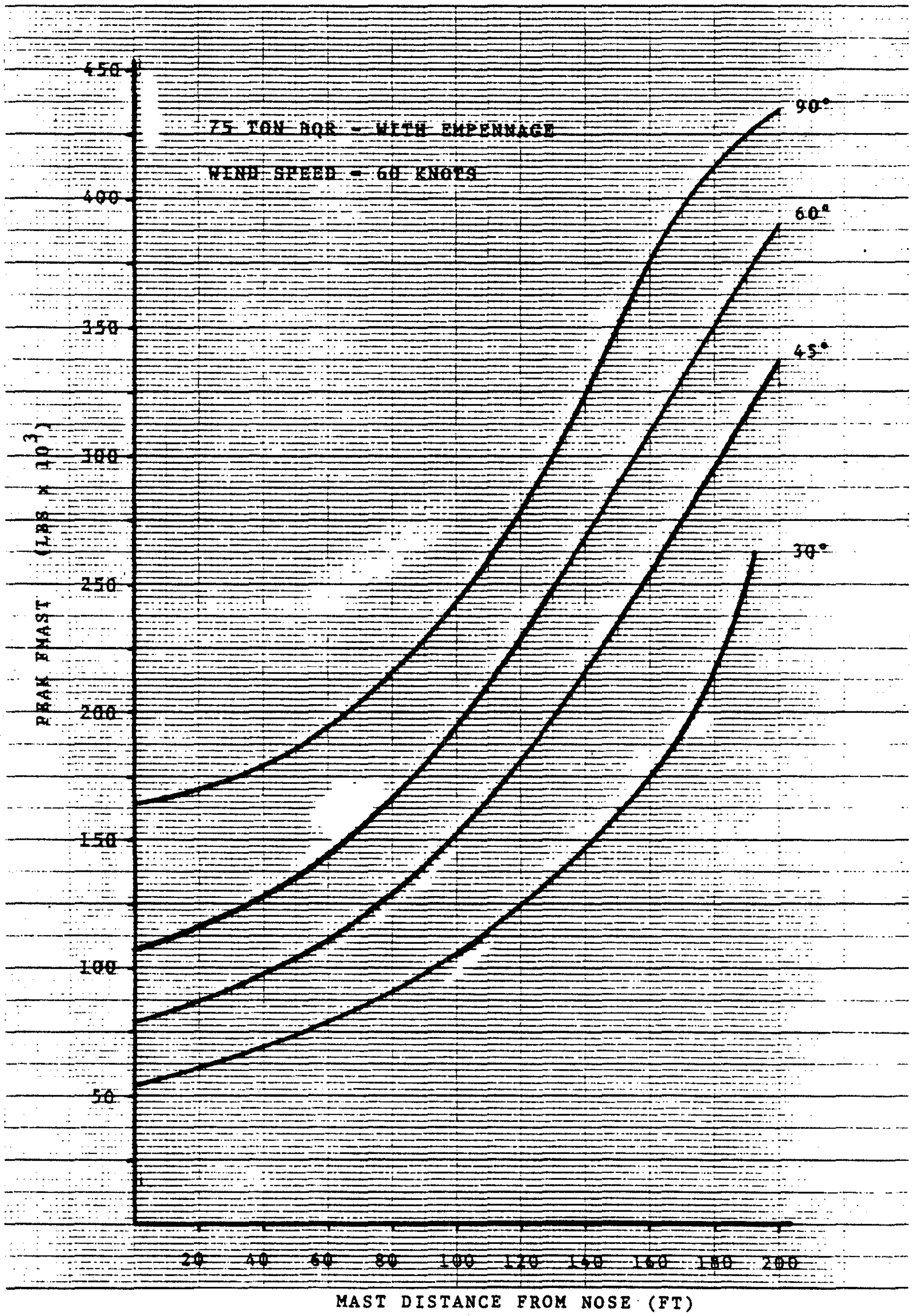


Figure 4-5 - Peak FMAST vs Mast Location

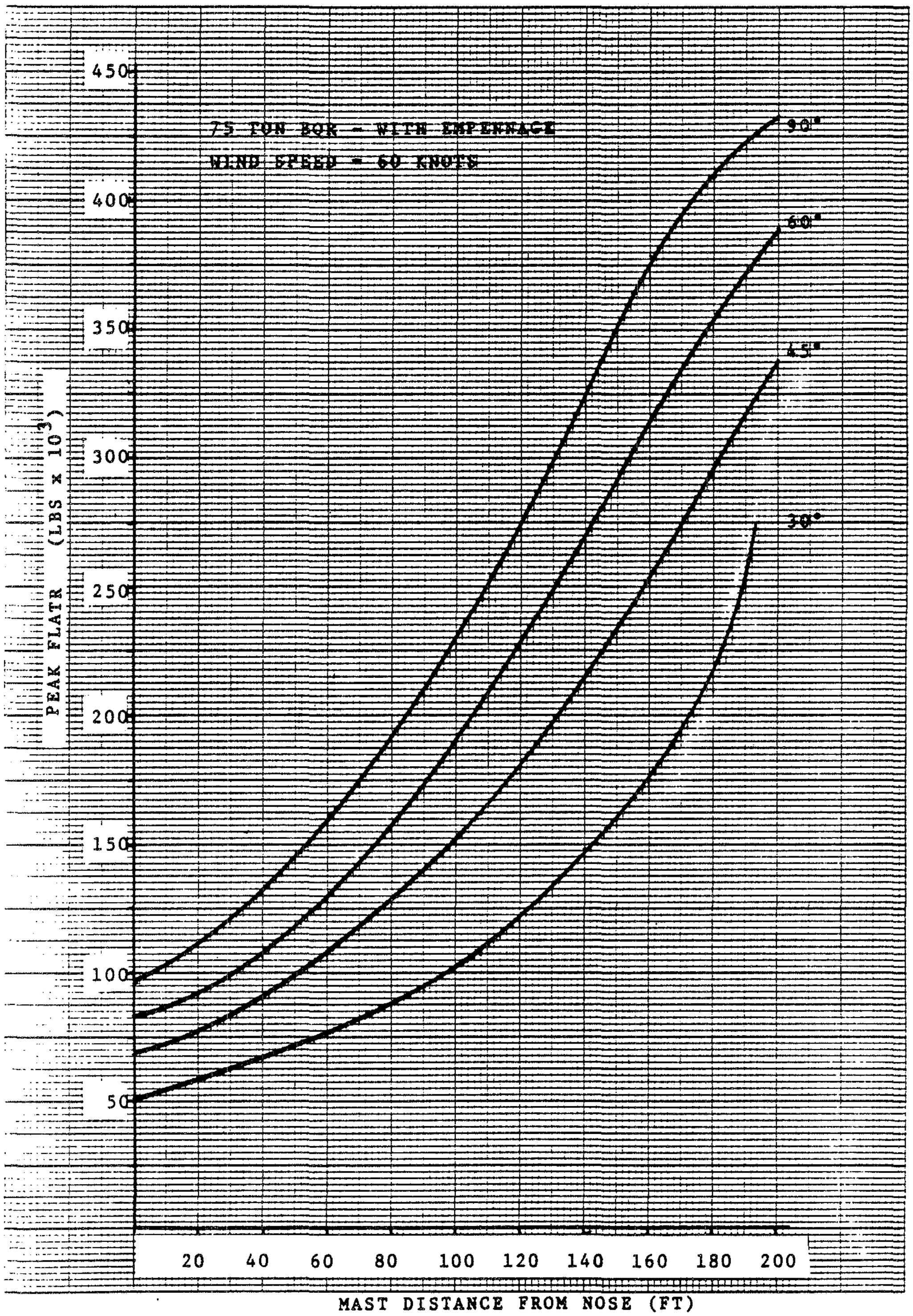


Figure 4-6 - Peak FLATR vs Mast Location

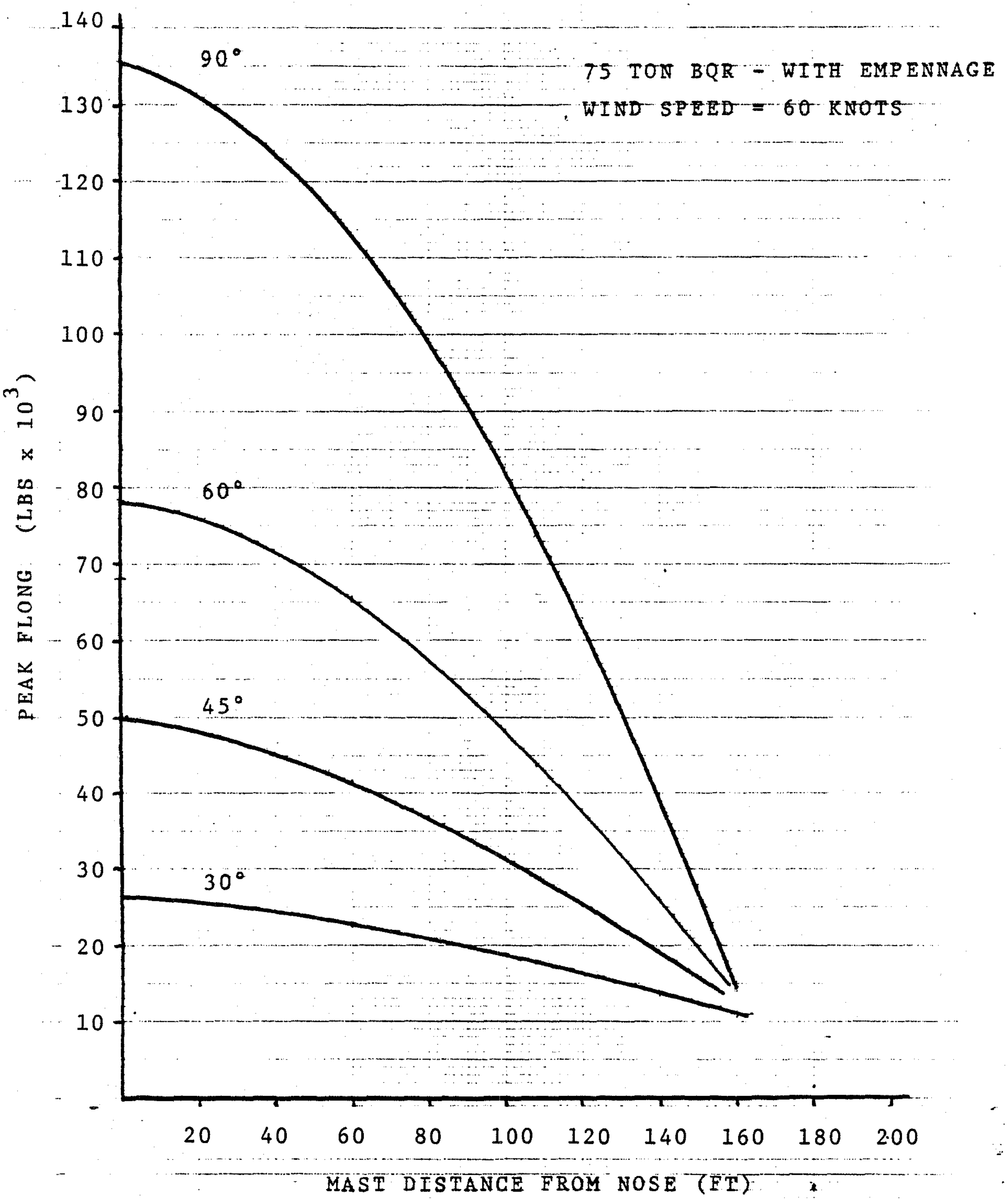


Figure 4-7 - Peak FLONG vs Mast Location

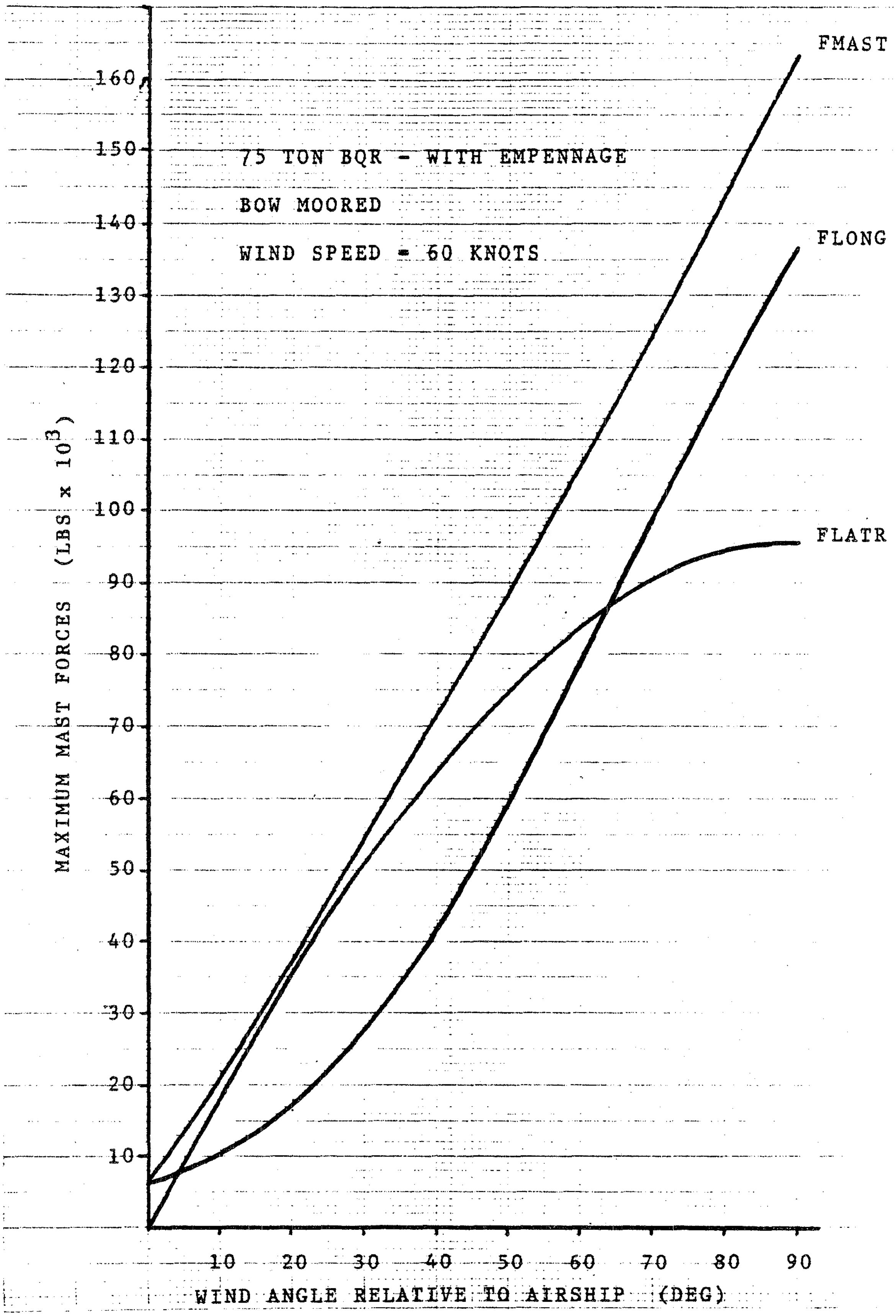


Figure 4-8 - Peak Mast Forces vs Wind Angle for Bow Moored BQR

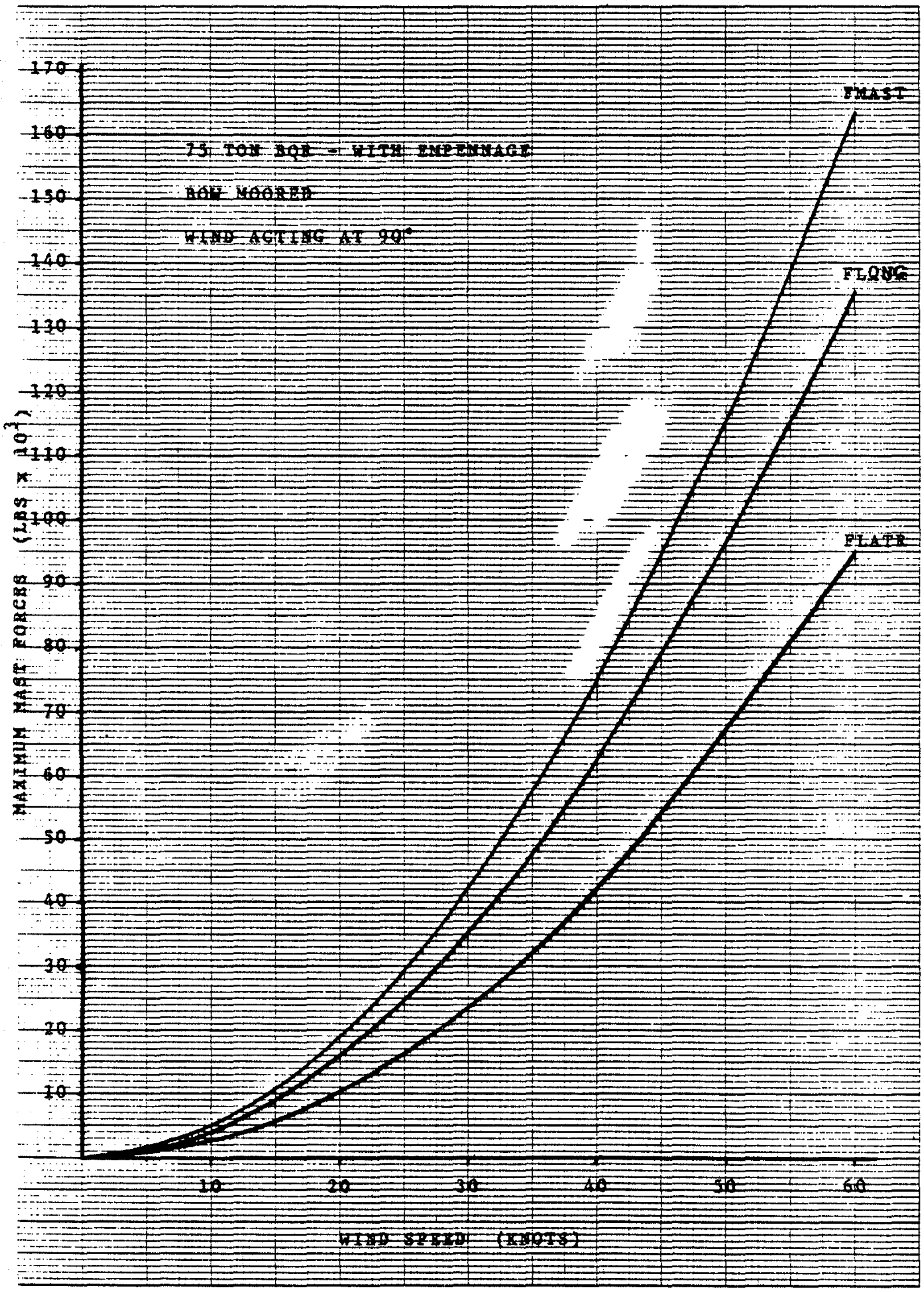


Figure 4-9 - Peak Mast Forces vs Wind Speed for Bow Moored BQR

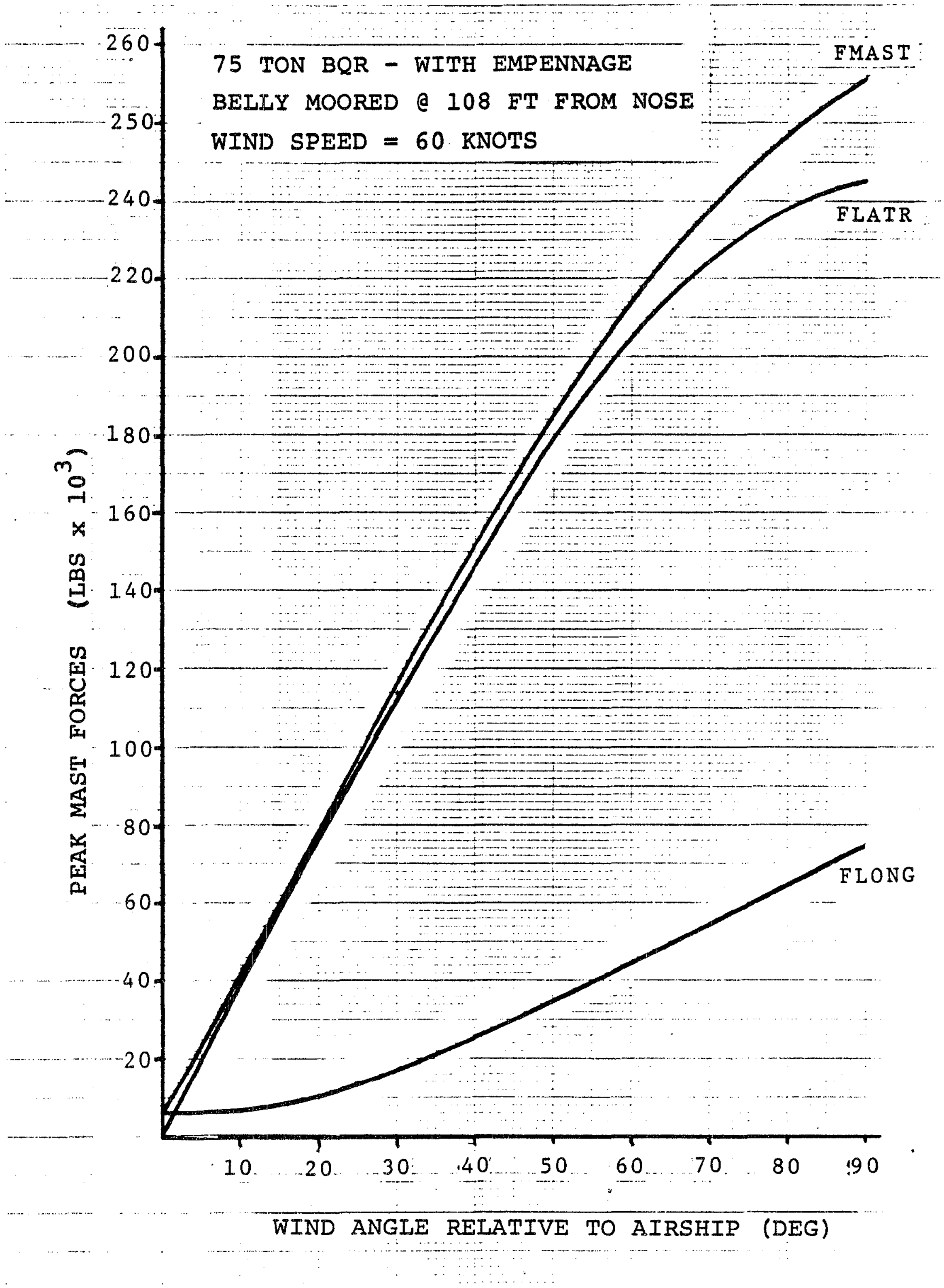


Figure 4-10 - Peak Mast Forces vs Wind Angle for Belly Moored BQR

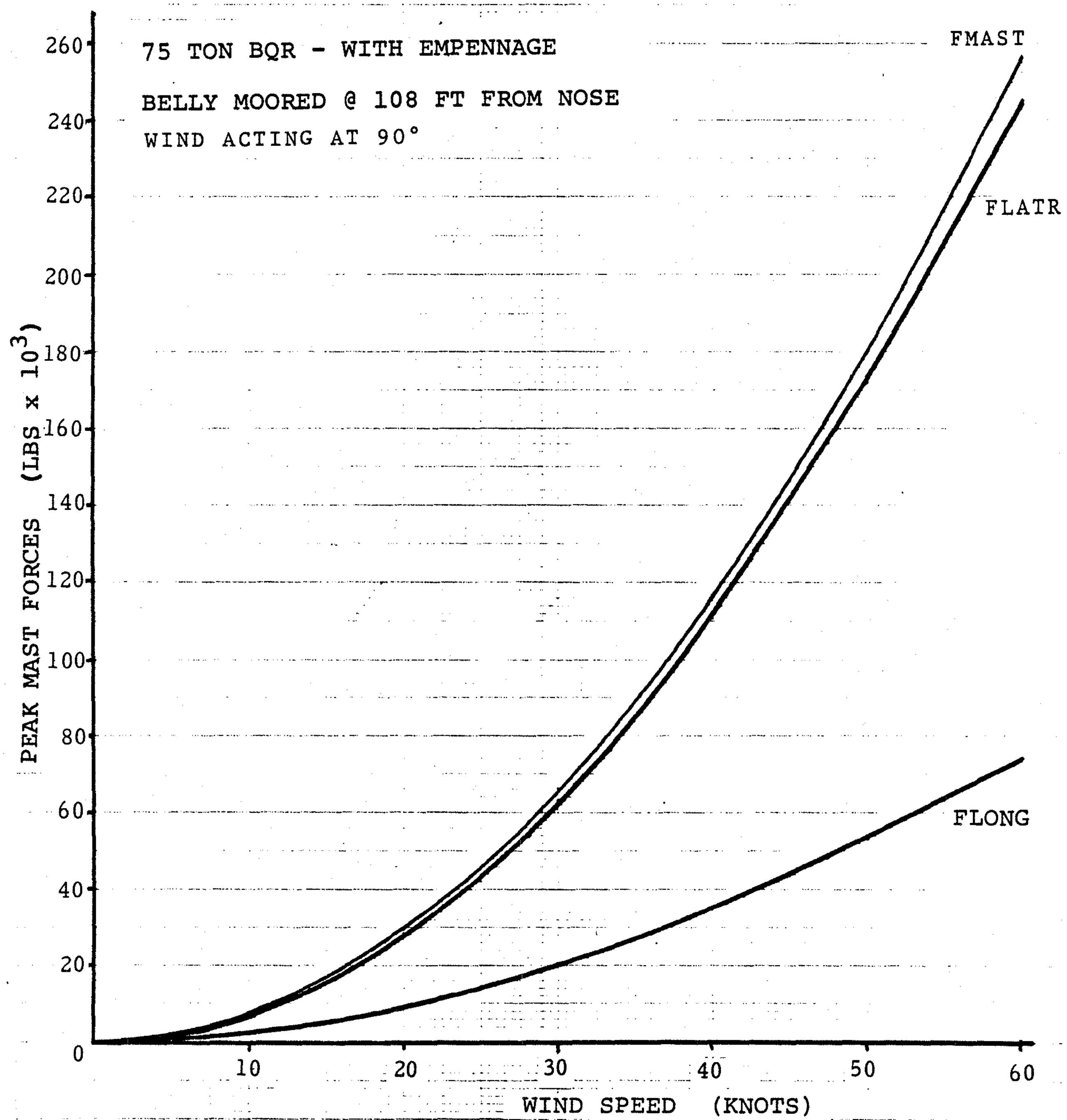


Figure 4-11 - Peak Mast Forces vs Wind Speed for Belly Moored BQR

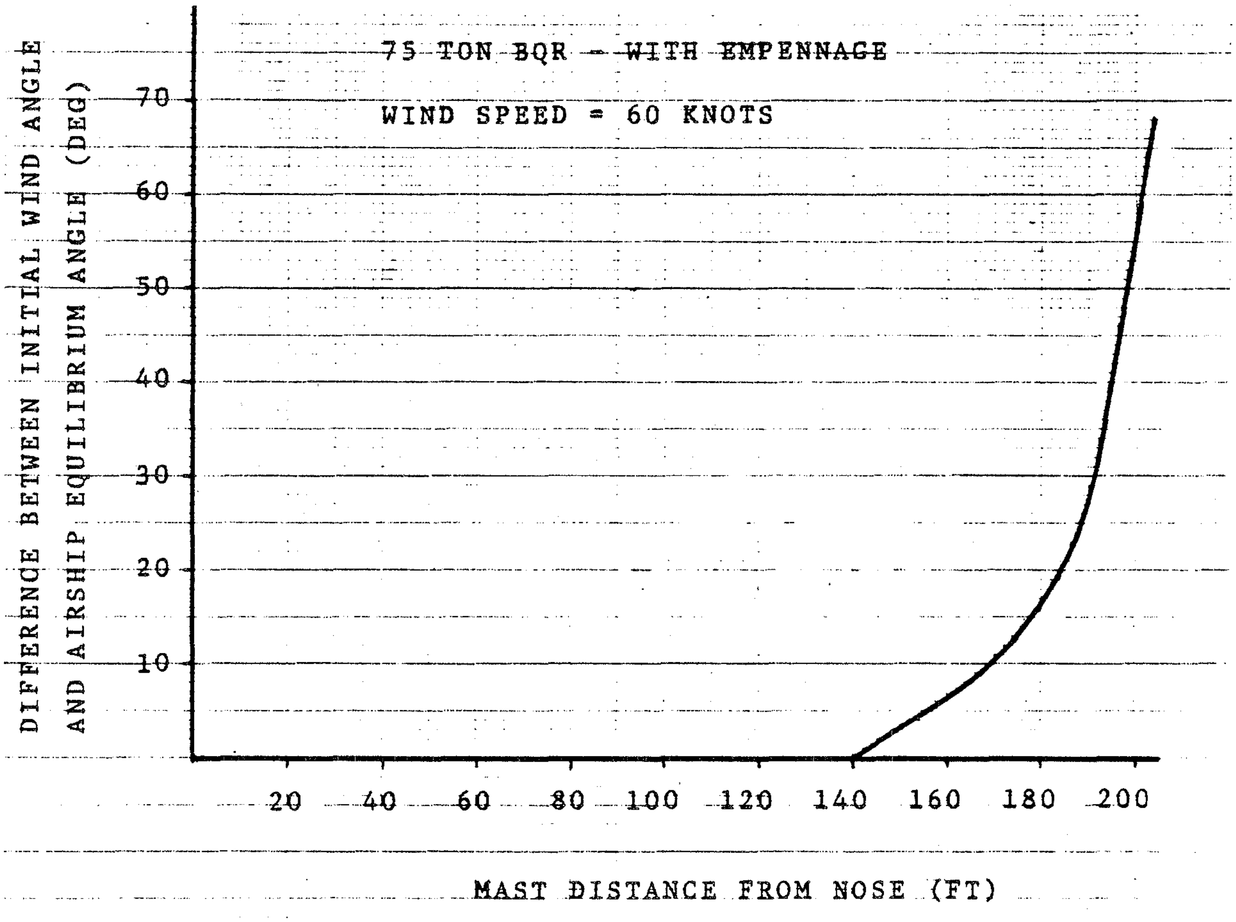


Figure 4-12 - Equilibrium Position for BQR with Respect to Mast Location

f. Center Point Moored BQR Without Empennage

For the BQR without empennage moored about its center point, the mast forces are as indicated in Figure 4-13. Note that the equilibrium position for this vehicle is normal to the wind direction. Therefore, the lateral force component is significantly greater than the longitudinal.

Appendix I contains complete output listings for the following cases:

1. Airship with empennage; bow moored; wind speed of 60 knots; angles of attack at 15°, 30°, 45°, 60°, and 90°
2. Airship with empennage; belly moored at 108 feet from the nose; wind speed of 60 knots; angles of attack at 15°, 30°, 45°, 60°, and 90°
3. Airship without empennage; center point moored; wind speed of 60 knots; angles of attack at 15°, 30°, 45°, 60°, and 90°

Also included are graphical representations FMAST, FLATR, FLONG, and θ versus time. These figures show the rapidity with which the airship reacts to the given wind condition, the peak values, the rapid damping effect on the system, and the ultimate equilibrium values.

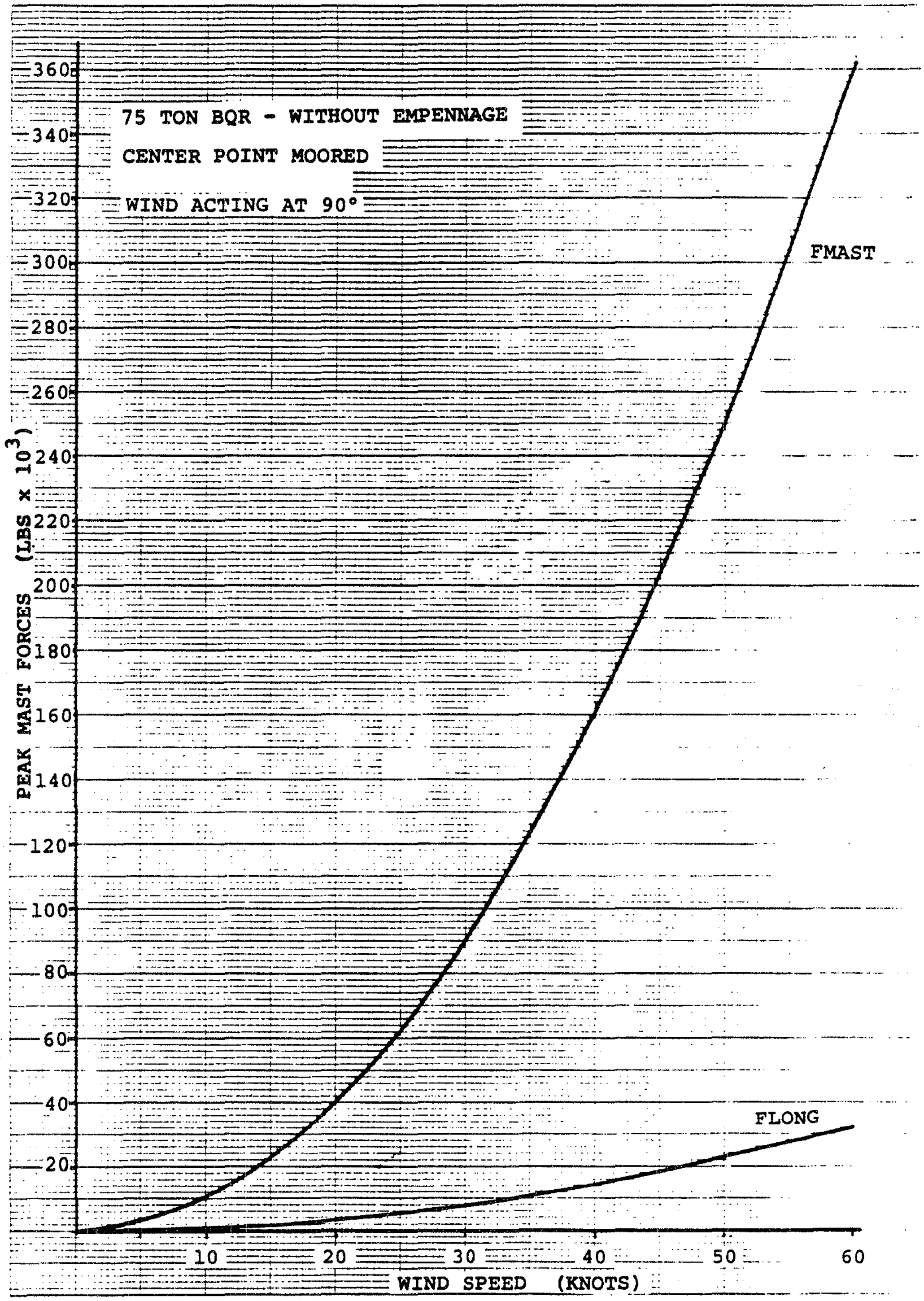


Figure 4-13 - Peak Mast Forces versus Wind Speed for Center Point Moored BQR without Empennage

SECTION V - AIRSHIP MOORING SITE CONSIDERATIONS

1. GENERAL

The selection and operation of an airship mooring site is dependent on a number of physical constraints imposed by the geography of the area. The principal geographic factors to be considered are topography, soil type, site size and shape, and weather conditions.

2. TOPOGRAPHY

Fundamental to the selection of a mooring site is a consideration of the site topography. Ideally, a smooth, flat, level surface of appropriate size will be available. Realistically, this will rarely be the case. Certain civil engineering functions will then be required in order to convert the available area to a suitable mooring site. This will typically involve the use of a bulldozer to provide a generally smooth, flat area free from significant relief differences and stumps. The degree to which this must be accomplished is defined by the mooring styles, which are described in Section VI.

3. SOIL CONDITIONS

The ability of a soil to support a given load is paramount in the provision of a mooring site both in terms of the load applied by the airship through its landing gear and the forces incurred at any mast anchor points.

The California Bearing Ratio (CBR) test serves as a standard procedure for determining load bearing capability. The CBR number is a ratio of the unit load (psi) required to generate a certain penetration in the test sample to a standard unit load (Reference 21). The CBR is generally used to rate the predicted performance of soils. Table 5-1 gives typical ratings (Reference 21).

TABLE 5-1 - TYPICAL CBR RATINGS

CBR No.	General Rating	Typical Soil Types
0-3	Very Poor	Clays of high plasticity, some silts
3-7	Poor to Fair	Same as above
7-20	Fair	Low plasticity clays, inorganic silts, fine sands
20-50	Good	Silty, sandy, or clayey grounds
>50	Excellent	Well graded gravels with few fines

More empirical data has been developed by industry, particularly with respect to the "holding power" of ground anchors. In essence, a soil probe was developed for field testing to provide instant access to anchor design charts. A typical soil classification system is shown in Table 5-2 (Reference 22).

TABLE 5-2 - SOIL CLASSIFICATION DATA

Class	Description of Soil
1	Solid Bed Rock
2	Dense Clay; Compact Gravel; Dense Fine Sand; Laminated Rock; Slate; Schist; Sandstone
3	Shale; Broken Bed Rock; Hardpan; Compact, Clay-Gravel Mixtures
4	Gravel, Compact Gravel and Sand; Claypan
5	Medium-Firm Clay; Loose Sand and Gravel; Compact Coarse Sand
6*	Soft-Plastic Clay; Loose Coarse Sand; Clayey Silt; Compact Fine Sand
7	Fill; Loose Fine Sand; Wet Clays; Silt
8**	Swamp; Marsh; Saturated Silt; Humus

*Includes areas only seasonally wet with slow drain as in fairly flat terrain.

**Install anchors deep enough, by the use of extensions, to penetrate a Class 5, 6, or 7 underlying the Class 8 Soil.

The forces developed at the landing gear when the airship lands or when it is moved and is resisting rolling moment must also be addressed. Landing gear and tire arrangements and types are sensitive to the bearing strength of the contacted surface. Table 5-3 gives the realm of recommended tire pressures for various surface types (Reference 32).

4. SITE SIZE AND SHAPE

The size of a landing and mooring area needed to support one HLA should be determined based on the minimum width that will permit an airship to land without damaging any airship components, obscuring visibility, or causing ingestion in the engines from blowing soil and debris due to dynamic pressure. Consideration must be given to the airship mooring style as well.

The amount of blowing soil and debris that is generated while the rotors are operating is a function of the soil type, soil strength, and amount of vegetation.

TABLE 5-3 - TIRE PRESSURE RECOMMENDATIONS

Landing Surface	Max Tire Pressure (psi)
Aircraft carrier deck	>200
Large military airport pavement	200
Large civil airport pavement	120
Small tarmac runway; good foundation	70-90
Small tarmac runway; poor foundation	50-70
Temporary metal runway	50-70
Hard grass, depending on soil	45-60
Wet, boggy grass	30-45
Hard desert sand	40-60
Soft, loose, desert sand	25-35

Vegetation such as heavy sod may provide favorable initial conditions, but deterioration will occur with frequent operations (Reference 23). Because of this, a system should be considered that will combat these potential problems.

The determination of a minimum landing area size is parametrically derived from the results published in Reference 23. The approach taken in that publication is summarized below, with modifications for airship considerations.

The method for the calculation of a landing pad diameter as a function of downwash and soil erosion characteristics was developed based on theories and experimental data for downwash by a single uniform jet impinging normally on a flat plate. The development of an empirical formula to compute a pad's minimum diameter is based on aircraft gross weight, type of propulsion, propulsion exhaust area, and soil erosion values. The soil erosion thresholds that were defined represent approximations only, and actual insitu soil conditions may vary substantially.

The formula for rotor craft is as follows:

$$D_{pad} = 2.3\ (D)^{0.13}\left(\frac{T}{q_{max}}\right)^{0.435} \qquad (24)$$

where

D_{pad} = the minimum pad diameter, $D = (4A/\pi)^{0.5}$, where A is 1/2 the total disc area,

T = the total thrust,

q_{max} = the maximum allowable dynamic pressure at pad edge for various soil types.

The graph shown in Figure 5-1 is based on the rotor parameter defined for the BQR in Section II. The limiting pad width suggestion per module, while arbitrary, is consistent with assumptions made in Reference 23. By transposing the results from the above to the entire airship, it is possible to define minimum standard landing area sizes for the BQR with respect to soil conditions as presented in Figure 5-2.

Should soil erosion become a problem due to vegetation degradation, steps should be taken to minimize its effect through soil consolidation and stabilization with either chemical or soil cement treatments. Costs would vary considerably depending on the extent of the problem. While various concepts exist for the provision of landing mats, these would prove uneconomical for BQR applications unless a specific long-term site on previously unprepared soil was a dictum.

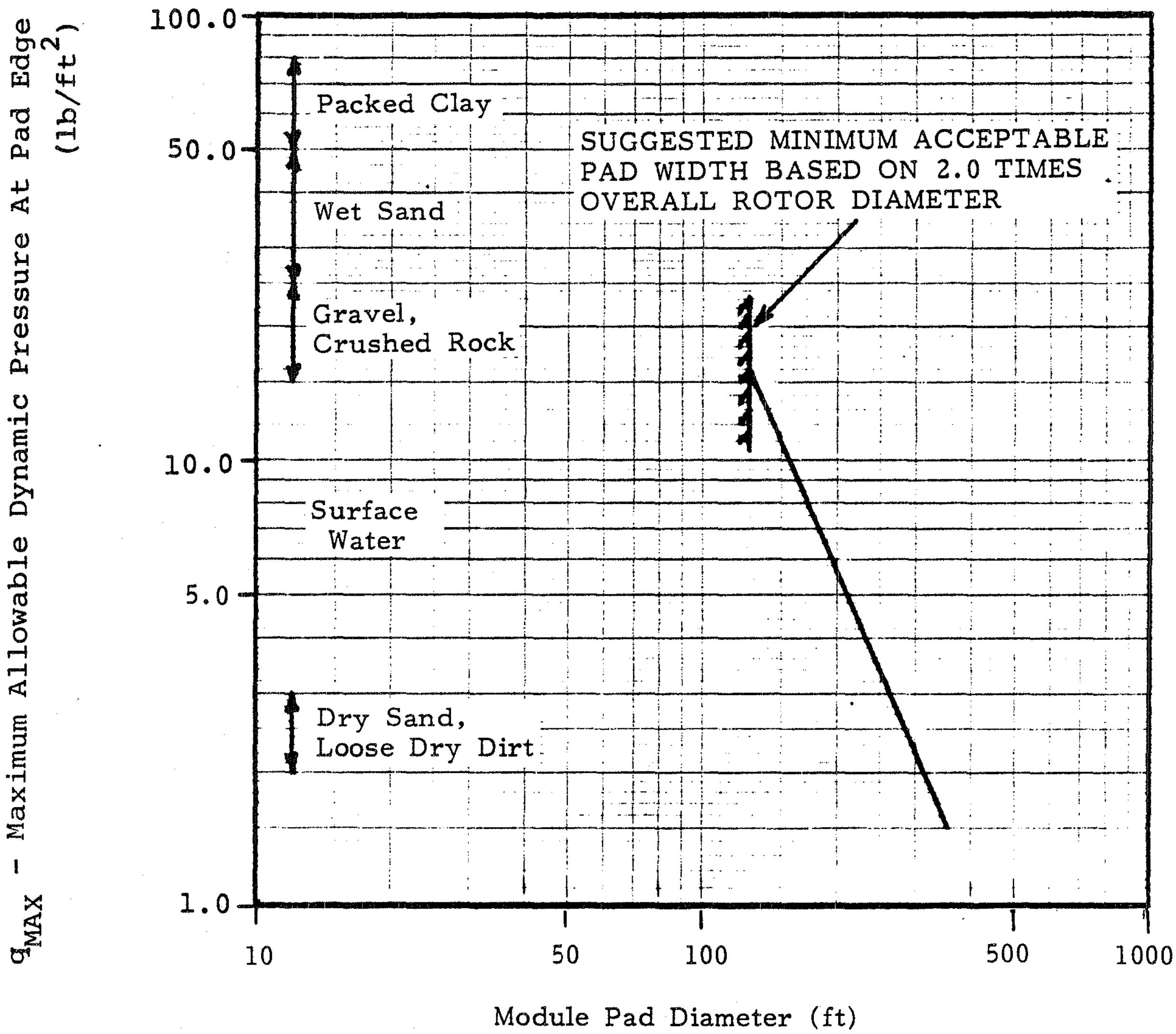
5. WEATHER CONDITIONS (References 24 - 28)

The major weather factor influencing BQR mooring capabilities is wind. Strong gusts attacking a moored airship at large angles with respect to the center-line axis can impart tremendous loads that must either be handled by the envelope and suspension system or transferred to the mooring mast. Failure in either mode could lead to catastrophy.

The value of 60 knots has been used as the design value for airship and mooring loads in this report. This is considered to be representative of the extreme value that the airship would encounter.

The buildup of snow or ice on a moored airship is a critical problem. Due to the immense size of the surface of the airship, relatively small depths can impact a significant load on the envelope system and landing gear. Assuming that the snow buildup occurs over one-fourth of the total envelope area and based on an average snow density of 8 pounds per cu ft, each inch of accumulated snow adds 20,000 pounds of weight.

The problem of snow removal has been investigated for many years, but as yet, no satisfactory solution has been generated. Some of the approaches that have been tried or hypothesized are as follows:



Example: For a dry sand condition, the pad diameter required for each rotor module would be approximately 285 feet.

Figure 5-1 - Maximum Allowable Dynamic Pressure at Pad Edge versus Minimum Operational Pad Diameters

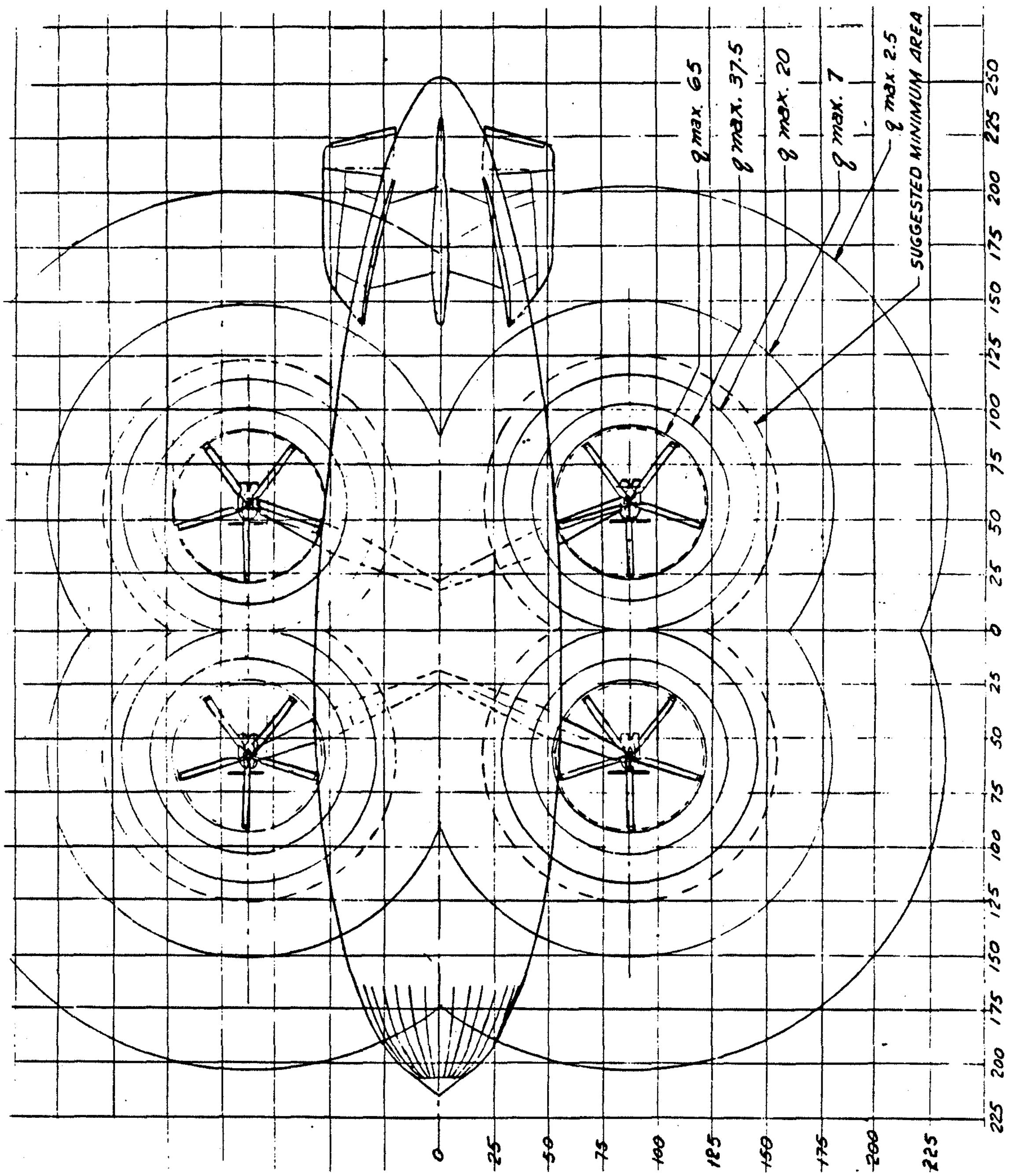


Figure 5-2 - Landing Area Requirements for a BQR With Empennage for Various Soil Conditions

5-6

1. Scraping and brushing, a technique using a rope, was slow and required constant attention during storms. Rope action also chafed the envelope, and the development of larger airships precluded its use.
2. Vibration met with limited success. The major problem of inducing a vibration in the envelope was difficult to satisfy. Sound generation inside the envelope was difficult to satisfy.
3. Envelope distortion was discarded due to the potential of fabric damage. It would not have been effective for snow.
4. External heat required too much power and equipment, and the problem was compounded by inaccessibility to upper envelope surfaces.
5. Super heating the helium was experimented with but was not developed despite its apparent feasibility.
6. Chemical systems, the application of substances to reduce adhesion or act as freeze depressants, have been ineffective.
7. Water systems have also been used. The most widely used technique was to attempt to spray the snow from the envelope. In many cases, this compounded the problem; however, this remained the recommended approach of the Navy.

Though other weather factors can adversely affect the operation of an airship mooring system, none have the capability of impacting the airship and mooring equipment in the same manner as high, off-angle winds or large accumulations of snow or ice.

SECTION VI - MOORING SYSTEM ALTERNATIVES AND EVALUAT. N

1. GENERAL

As previously indicated in this report, four mooring concepts are investigated for the BQR vehicles:

1. Bow mooring
2. Belly mooring
3. Center point mooring
4. Total restraint

For each mooring concept, a series of system attributes is reviewed encompassing ground handling manpower and equipment requirements, landing area requirements, impact on maintenance procedures, environmental considerations, and mooring system mobility.

In order to assess the alternatives, certain operational assumptions are made. These are not intended as design criteria, but rather as reference points for ground handling implications. The major assumed features are:

1. The BQR is capable of true VTOL operation.
2. The BQR is capable of taxiing.
3. Aerodynamic lift on the BQR with empennage is approximately 7.5 tons.
4. Any necessary site preparation equipment shall be transported by the BQR to the site from the nearest available location.
5. Landing area requirements for those mooring systems with rotational capability are based on a circular area with a radius equal to the distance from the stem to the mast point plus 50 feet. The minimum acceptable radius is one-half of the ship's length plus 50 feet. Figure 6-1 illustrates the maximum and minimum requirements.
6. The flight crew is composed of four members.
7. All provisions and quarters are supplied at campsite.

Additionally, the BQR without empennage is limited to the center point mooring case. The reasons for this are threefold. First, the original design of this vehicle was premised on a center point mooring approach (Reference 24). Second, the absence of any tail surfaces precludes the use of a bow or belly system

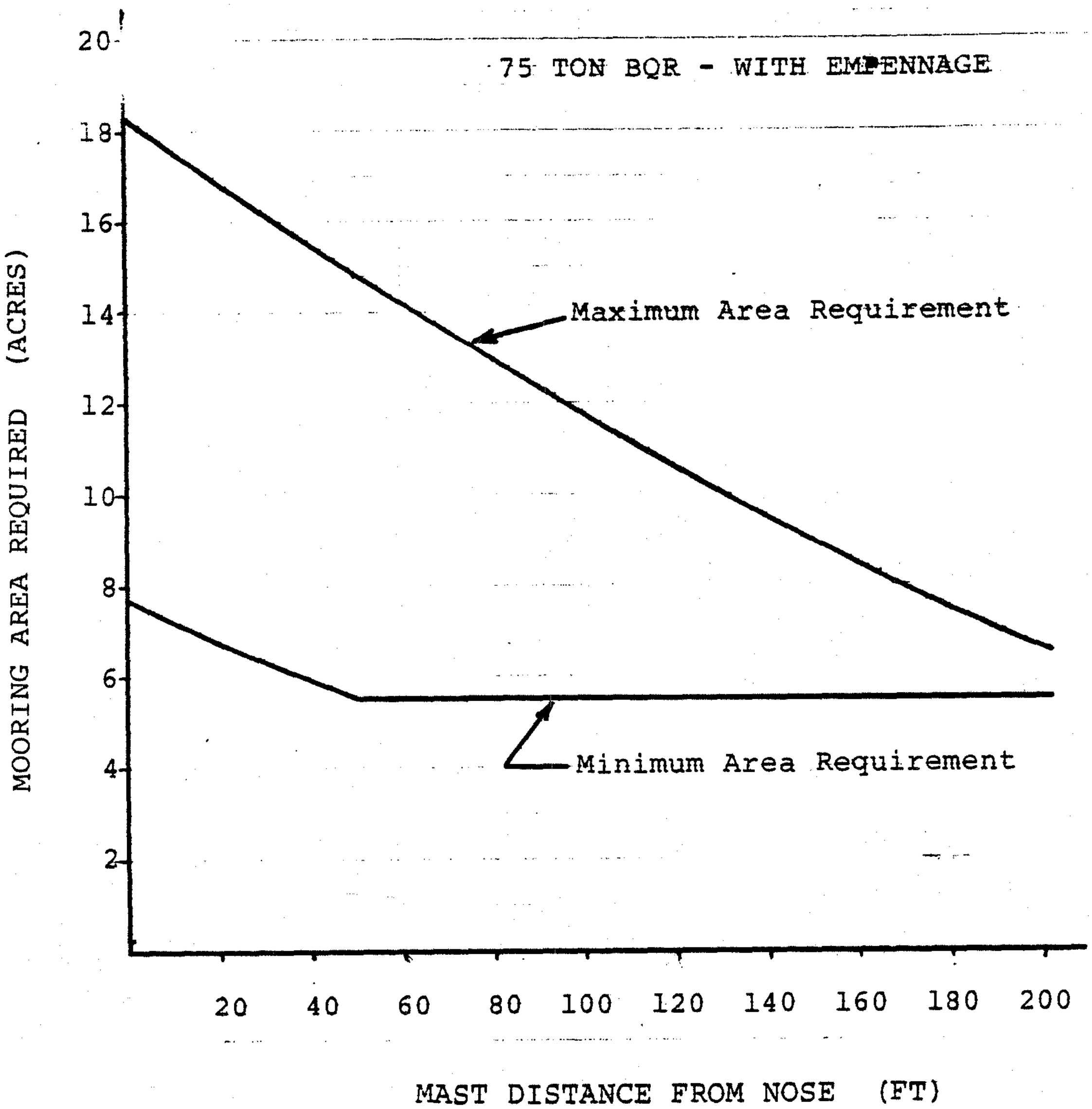


Figure 6-1 - Land Requirements for Mooring Systems with Rotational Capability

approach. Third, the worst case condition in a fully restrained analysis coincides with the values derived for the center point system, and both these systems are therefore accounted for.

Conversely, the BQR with empennage is not evaluated in a center point mooring condition.

In performing the individual reviews of each of the systems, only the key operational parameters are addressed. Other quantitative information is given in the summary.

2. BOW MOORING

a. Structural Requirements

Fundamental to the design of a mast for a bow mooring system is the load transference from the airship through the nose to the mast. This precludes the presence of mooring loads on the envelope or suspension system. In the most extreme case as defined in this report, a 60-knot wind attacking at 90 degrees to the centerline axis, the maximum forces are approximately 95,000 pounds for FLATR and 135,000 pounds for FLONG. The maximum resultant force (FMAST), which in this instance is coincident with the maximum FLONG, equals 163,000 pounds. Both the maximum moment that is developed by the forces and the determination of the ultimate axial load are of critical design importance.

The peak vertical force acting on the mast is determined by summing the system forces – the aerodynamic load and the force created at the bow by the pitching moment. The result, based on the figures provided in Table 3-2, is a net upward vertical force of 108,000 pounds that must be restrained.

Initial indications are that a tubular aluminum mast could be constructed to satisfy the design loads. The mast would vary from a 30-inch outside diameter and 1-inch wall thickness at the mast head to a 24-inch diameter, one-half inch wall thickness at the base. Guy cable attachment rings would be provided at one-third intervals. Permanently attached guy cables would emanate from these points to ground anchors (see Figure 6-2). Each main anchor would need to develop an ultimate load of 72,405 pounds. The mast would be placed on a base plate. The anchors that are recommended for the application are multi-helix screw anchors. A number of helixes are stacked on a 1.5-inch square steel shaft. Once in place, the helixes act essentially as separate anchors; however, during installation they work together so that only a small amount of torque is required for installation in firm soil. Various attributes of this type of anchor are given in Table 6-1 (Reference 22).

Multi-helix screw anchors require the use of a power digger for installation. A typical unit mounted on the back of a light truck is shown in Figure 6-3. This vehicle may or may not constitute part of the transportable ground handling equipment. The use of such equipment can result in anchor installation times of five minutes per unit for a two-man crew. For the 49 anchors required in this analysis, total installation time would be slightly over four hours. The base plate and mast are intended to mate together as shown in Figure 6-2 to facilitate the placement of the mast.

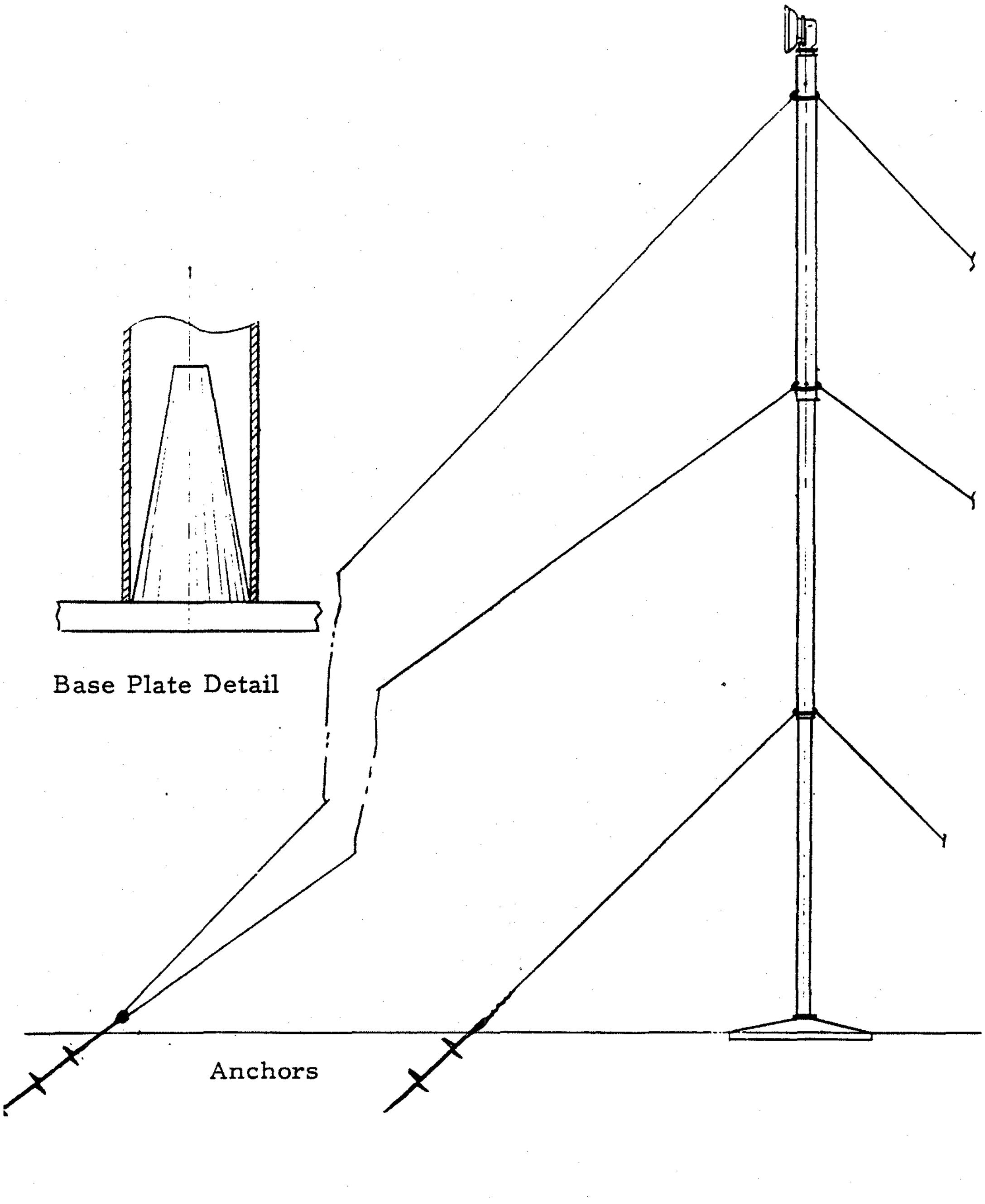


Figure 6-2 - Bow-Mooring Mast Arrangement

TABLE 6-1 - MULTI-HELIX SCREW ANCHORS

Number of helixes	Helix diameter (bottom to top) (inches)	Unit weight (lbs)	Holding strength by soil class* (lbs) 2	3	4	5	6
2	8; 10	63	41,000	36,000	32,000	27,000	23,000
2	10; 11-5/16	68	46,000	41,000	36,000	31,000	26,000
3	8; 10; 11-5/16	87	58,000	51,000	46,000	39,000	32,000
3	10; 11-5/16; 13-1/2	98	69,000	61,000	53,000	45,000	37,000
4	10; 11-5/16; 13-1/2; 15	146	-	-	73,000	62,000	51,000

*Refer to Table 5-2 for soil class description.

b. Landing Area Requirements

The bow mooring concept requires the most land when compared to the other concepts. For the BQR vehicle with tail, the minimum reasonable circle radius would be in the order of 500 feet. This amounts to a circular cleared area of 18 acres (see Figure 6-1).

An alternative would be to clear only the minimum required area as suggested by Figure 5-1. This would result in a circle with a diameter of 656 feet and an area of 7.8 acres. The remaining 10.2 acres would require only partial clearing to ensure that vertical clearances were maintained in the aft portion of the airship. The wheel paths would possibly require additional strengthening, but this is a function of wheel loading frequency. Figure 6-4 is an illustration of the BQR with tail in a bow-moored condition.

c. Operational Concept

The operational sequence for establishing a base begins with the BQR delivering the mast, mast base plate, anchors, truck-mounted power digger, winch, ancillary tools, and a two-man crew. The airship then departs the area temporarily while the mast base plate with integral winch is centrally located in the field and all anchors installed. The mast is drawn toward the base plate with the winch, and all cables (slack) are attached to their respective anchors. The mast is hoisted to a vertical position atop the base plate by the winch and a block and tackle. All guy cables are then secured. The airship lands near the mast and taxis toward it. When the airship is sufficiently close, a nose line is attached to a line leading through the mooring cup, through the mast to the winch. The vehicle is then drawn into the mast and secured in position.

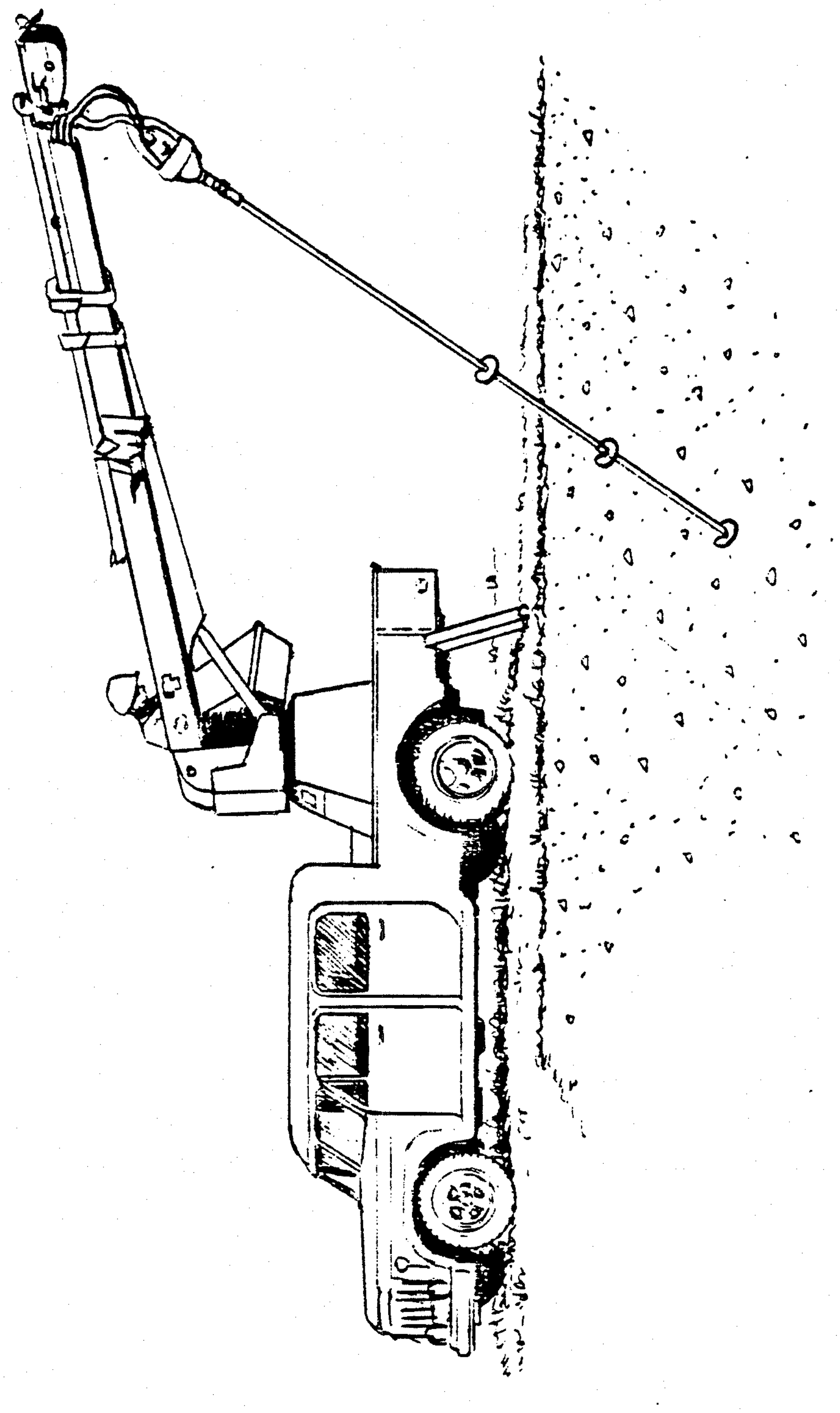


Figure 6-3 - Truck-Mounted Power Digger

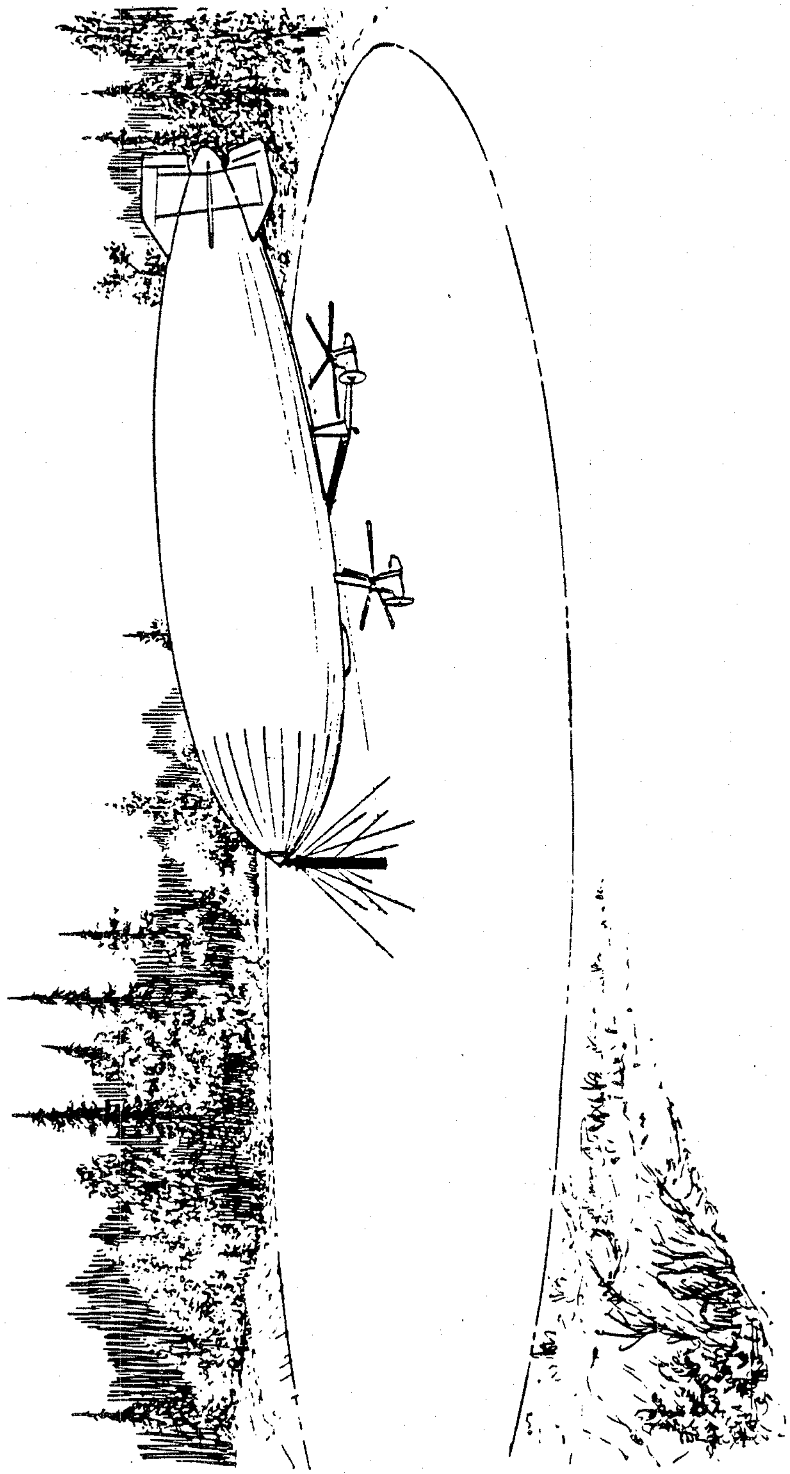


Figure 6-4 - Bow-Moored BQR with Tail

To unmast the airship, the nose pin is removed, and the BQR can then move up and away from the mast. Removal of the mast can be handled by reversing the installation sequence. The anchors can be removed and re-used. The mast is stowed under and attached to the starframe during flight.

As discussed earlier, a truck with a power digger is necessary to the operation since it would be impossible to secure the anchors with manpower alone. This vehicle can be retained as an integral component of the BQR, or a suitable vehicle can be rented in a location near the job site. Each of these approaches has its advantages and disadvantages.

The option of retaining the truck on a full-time basis has some positive aspects; (1) the vehicle is always available, and (2) it can serve as a personnel transport vehicle. The prime disadvantage is the additional dead weight added to the vehicle for the ferry mission. Compensation through increased envelope size will adversely affect overall performance, while utilization of rotor power in the ferry mode will impact operating costs.

Renting a vehicle near the job site is an attractive option in terms of reducing dead weight, but truck unavailability could seriously hamper airship operations.

d. Weight Considerations

When bow moored, the airship should be near neutral buoyancy, but slightly heavy. The reason for this is the effect of kiting. Unless the airship is physically tied down, some kiting is inevitable. Substantial experience with airships has shown that any attempt to create an extremely heavy condition by adding additional ballast has created problems. Since the airship will always kite, a heavy condition will cause excessive and damaging impact loads when the airship returns to the ground. The solution to this is to permit the airship to kite while maintaining it near equilibrium.

In view of the above, if the airship's normal operating condition is light ($\beta > 1.0$), then sufficient ballast must be added when at the mast to attain the recommended buoyancy ratio.

As previously indicated, since all mooring loads are transferred through the bow, no special provisions are required of the envelope or suspension system, and hence there is no associated weight penalty.

The weight of the necessary ground handling equipment is tabulated in Table 6-2.

TABLE 6-2 - EQUIPMENT WEIGHT FOR BOW MOORING SYSTEM

Item	Estimated weight (lb)
Mast head	500
Mast	5770
Cables and fittings	6850
Base plate	1250
Anchors	4500
Winch	400
Truck with power digger	6000
Tool kits	200
Total	25,470 (19,470 without truck)

The effect of the total weight, which is in excess of the dynamic lift capabilities of the airship, would be to deteriorate airship ferry performance.

e. Environmental and Maintenance Considerations

The bow mooring concept defined above meets the wind load criteria of sustaining a 60-knot gust that hits the envelope perpendicular to its center line axis. Although still susceptible to snow loads, this mooring system approaches the all-weather capability feature that would be a requirement for any operator.

The provision of maintenance service during bow mooring should be a consideration during the vehicle design stage. Working platforms that are part of the vehicle or that can be easily attached will be needed due to the airship's dynamic tendencies. Any major overhaul work will necessitate the use of a hangar.

3. BELLY MOORING

a. Structural Requirements

The placement of a mooring mast at any location other than the bow necessitates the assessment of the rolling moment effects on the airship as well as on the mooring system. The critical areas are: (1) the point of attachment for the mooring mast to the airship; (2) the landing gear; and (3) the mast and anchors. The operational capability of a belly mooring concept is limited by the least capable of the above. For the purpose of this analysis, a mast position 108 feet from the nose has been selected. This coincides with the front edge of the control car and is approximately midway between the nose and the center of gravity of the ship (see Figure 6-5).

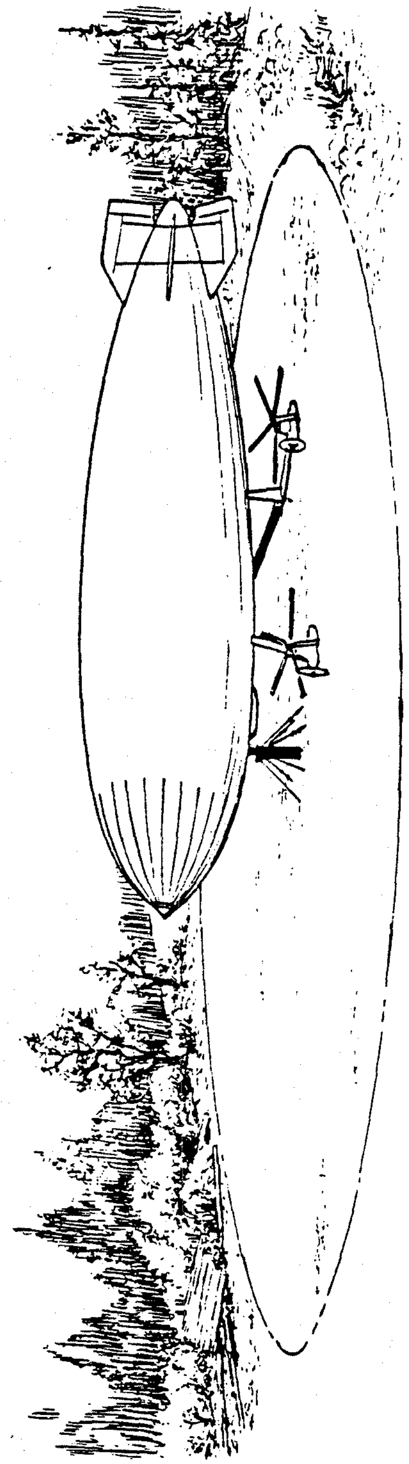


Figure 6-5 - Belly-Moored BQR with Empennage

In order to secure a mast to the underside of the airship, all the forces occurring at that point must be distributed over a sufficiently large envelope area such that the strength limits of the fabric are not exceeded. For the case of the mast at a point 108 feet from the nose, the maximum FMAST is 256,000 pounds. Since the design limit for the fabric is 150 pounds per inch, a total external catenary curtain of 142 feet would be required on each side of the airship to accommodate this load. It is unlikely that the force could be evenly distributed over such a length, even if the curtain could be physically placed. An alternative would be to provide an internal curtain to support this point. Again, however, the physical arrangement of the system is inhibited by the forward ballonet. In view of the above, significant redesign of the airship would be required. Assuming this is feasible, an acceptable mooring suspension system would weigh approximately 6000 pounds more than the weight required for the standard suspension system.

The forces required to resist the overturning moment of the airship are substantial. Figure 6-6 provides a graph of the relationship between wind speed and the force required at a single gear point to maintain the ship in equilibrium with respect to rolling. At 60 knots, this force is 145,000 pounds. As indicated in Table 5-3, the maximum allowable tire pressure for an unprepared site is 45 to 60 psi. Taking the mid-point of this range, the total required footprint area of the tires at each landing gear would be 2762 sq in. To put this in perspective, each of the eight tires on the main gear of a Boeing 747-200C has a footprint of 270 sq in. Assuming the same tire size, the BQR would require 11 tires at each gear. This would be totally unacceptable. Since the gear must be capable of castening, a two-tired gear is far more realistic. Assuming a total footprint of 540 sq in., the maximum allowable load would be 28,350 pounds. Using Figure 6-6, this translates to a maximum wind speed of 26 knots.

Based on the original design requirements of withstanding a 60-knot cross wind, and using the same approach used for the bow mast, a tubular aluminum mast with the following dimensions could withstand the predicted FMAST of 256,000 pounds: 15 feet high, 34 inches outside diameter, wall thickness of one inch. A total of forty-two anchors, each capable of withstanding 73,000 pounds, would be required (see Table 6-1). Total weight of the ground handling equipment would be 27,100 pounds (including truck). Due to the limitation imposed by the landing gear, however, the maximum FMAST is reduced to 50,000 pounds. This would substantially reduce the size and weight of the mast and supporting

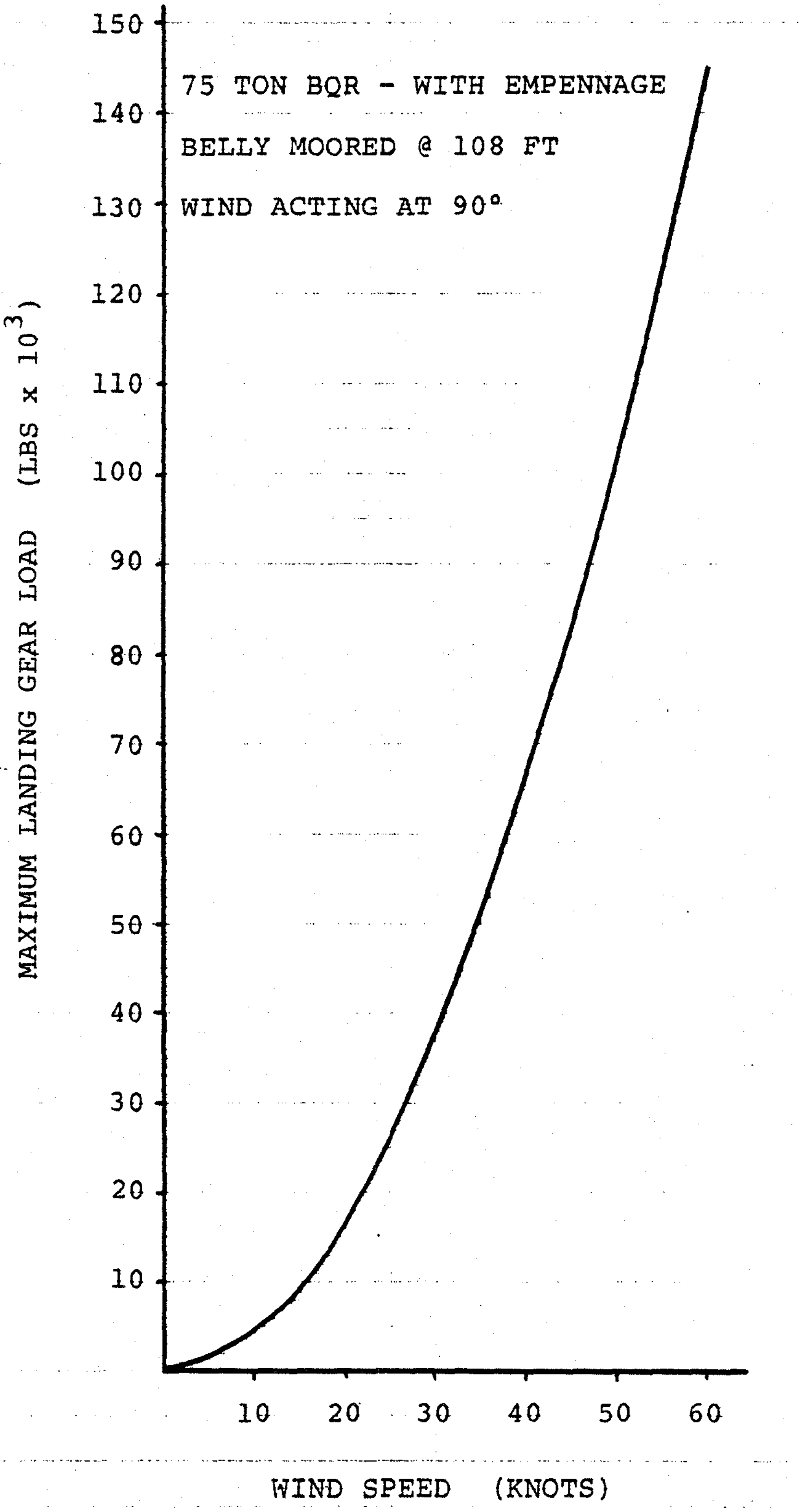


Figure 6-6 - Wind Speed versus Landing Gear Load for Belly-Moored BQR with Empennage anchors. From a structural assessment, therefore, the vehicle's largest limitation is due to the loads imposed on the landing gear. This will limit the belly mooring approach to a maximum wind speed of 26 knots.

b. Landing Area Requirements

As indicated in Figure 6-1, the land requirements for a belly-moored airship are largely dependent on the mast location. For the specific case indicated above, the computed area varies from a maximum of 11 acres to a minimum of 5.5 acres; the latter value refers to the concept of partial clearing to maintain vertical clearances in the aft portion of the airship.

c. Other Considerations

The utilization of a belly-mooring system would parallel that described earlier for a bow-mooring approach. The need for a truck-mounted power digger would still be a drawback. Maintenance procedures would be the same.

4. CENTER POINT MOORING

a. General

The center point mooring concept was developed as part of the design study for the BQR vehicle without empennage (Reference 24). Unfortunately, the concept was premised on some erroneous assumptions concerning C_y values. Analysis has shown that the actual C_y values were more than three times those predicted in the original Phase II report.

b. Structural Requirements

The aerodynamics of the BQR without a tail creates a stable condition with the hull broadside to the wind when center point moored. The concept calls for a central pivot located at the ground plane at the center of the planform with cables connected to the frame joints. The pivot is set in a concrete base that is further enhanced with wooden piles. Based on the findings in this report, however, the maximum allowable wind speed would be 18 knots (see Figure 6-7). Since this concept essentially corresponds to total restraint, the weight penalties identified in Section III apply for higher wind speeds.

c. Landing Area Requirements

Center point mooring is the most frugal regarding land requirements. Using the ship's length as the diameter plus an additional fifty feet, the required area computes to 3.2 acres.

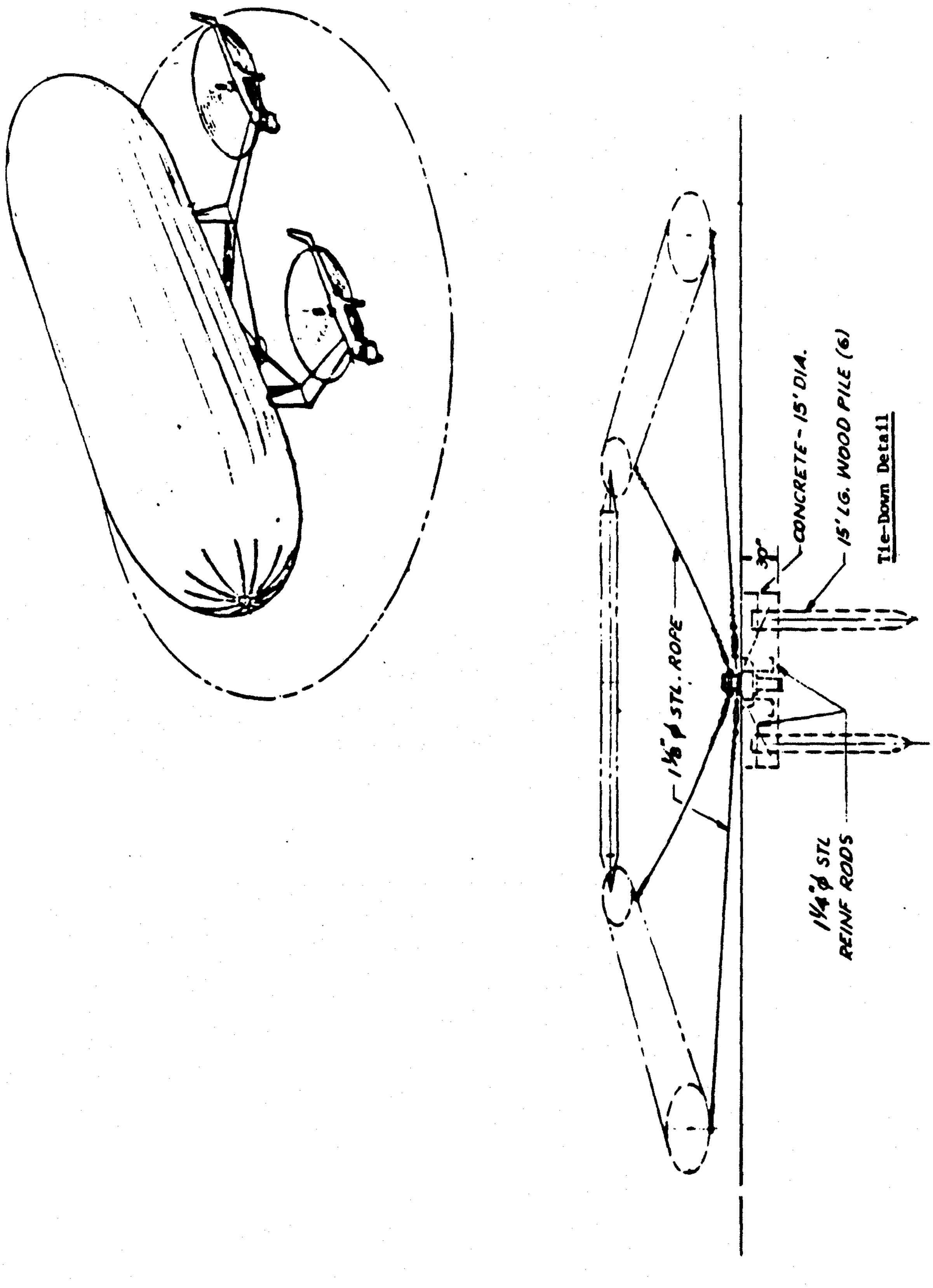


Figure 6-7 - Center Point Moored BQR without Empennage

5. FULLY RESTRAINED VEHICLE

a. Structural Requirements

The fully restrained BQR with empennage would be held in place at each of its four gear points. Maximum loads for a 60-knot wind are as follows:

Vertical force = 213,500 pounds at 90 deg
Longitudinal force = 96,600 pounds at 150 deg
Lateral force = 169,000 pounds at 120 deg

The concept presented to counteract these forces is illustrated in Figure 6-8. The airship would sit on skids on four concrete slabs with cable attachments from the concrete to the starframe.

In order to counteract the vertical force, each slab must exert a downward force equal to this load. In this instance, over 100 tons of concrete per gear would be required. This would be operationally unacceptable. A more rational approach would be to limit the total concrete weight to the payload capability of the airship; that is, 75 tons. This would then provide 37,500 pounds of downward force per gear. Each concrete pad would measure approximately 10 feet by 10 feet by 2.6 feet. Examining Figure 3-8, this would result in a maximum allowable wind speed of 26 knots.

This wind speed would not significantly increase the suspension weight requirements of the airship, although some redesign would be in order.

The lateral and longitudinal forces on the system are resisted by the frictional forces developed between the pads and the ground beneath them. Typical handbook value for the coefficient of friction between concrete and earth is 0.33. In order to assess this total restraint system, all the resultants of the lateral and longitudinal forces must be summed and compared to the resisting forces developed at all the concrete pads. Naturally, only those pads at which a downward vertical force is acting generate any resistance. Figure 6-9 indicates the relationship between these forces for varying wind speeds at an airship buoyancy ratio of 1.0. The point at which these curves cross is the limiting wind speed for resisting lateral and longitudinal forces. In this instance, the value is 17.5 knots. Any wind speed in excess of this would result in movement of the system.

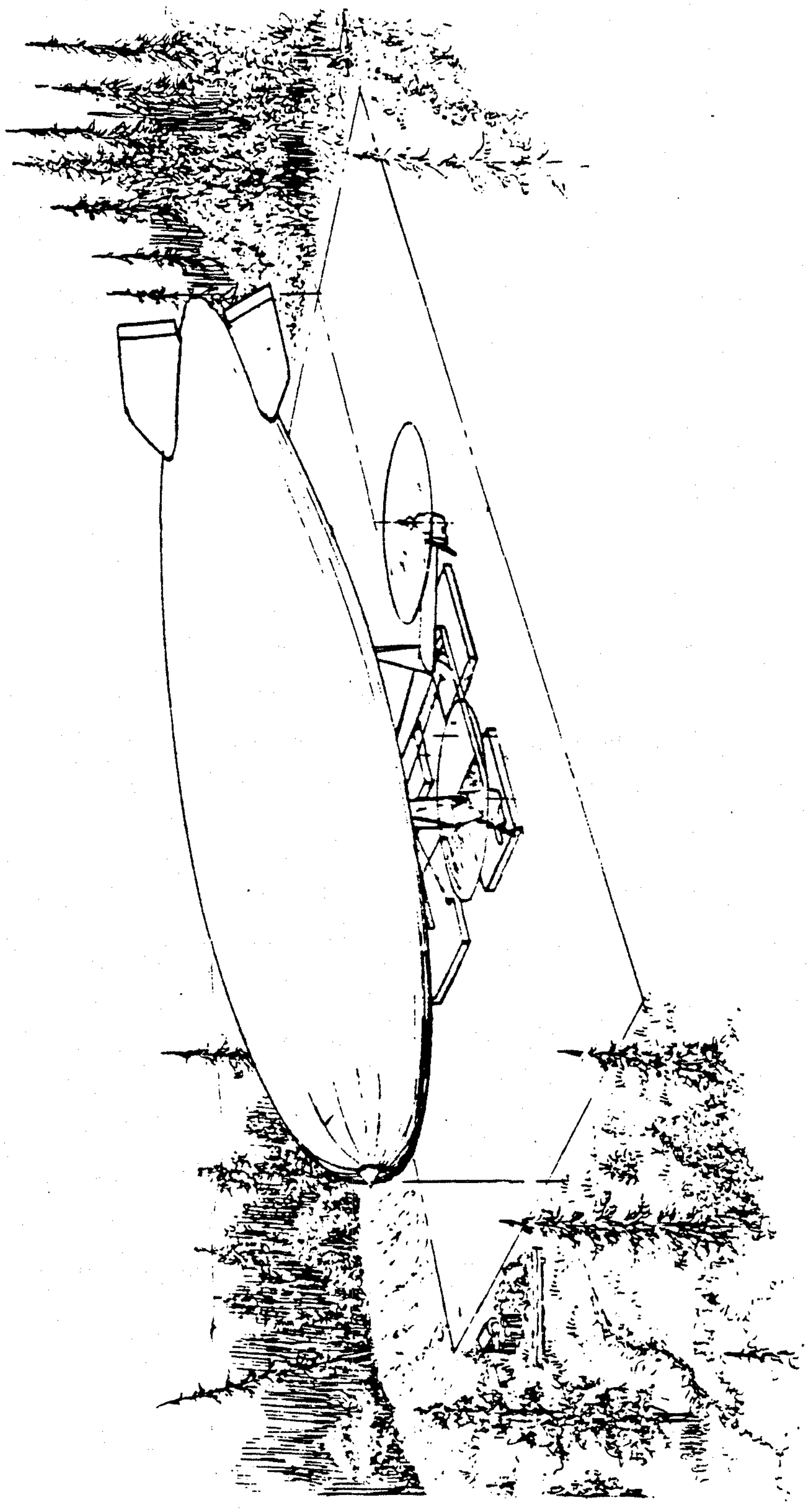


Figure 6-8 - BQR with Empennage Total Restraint System

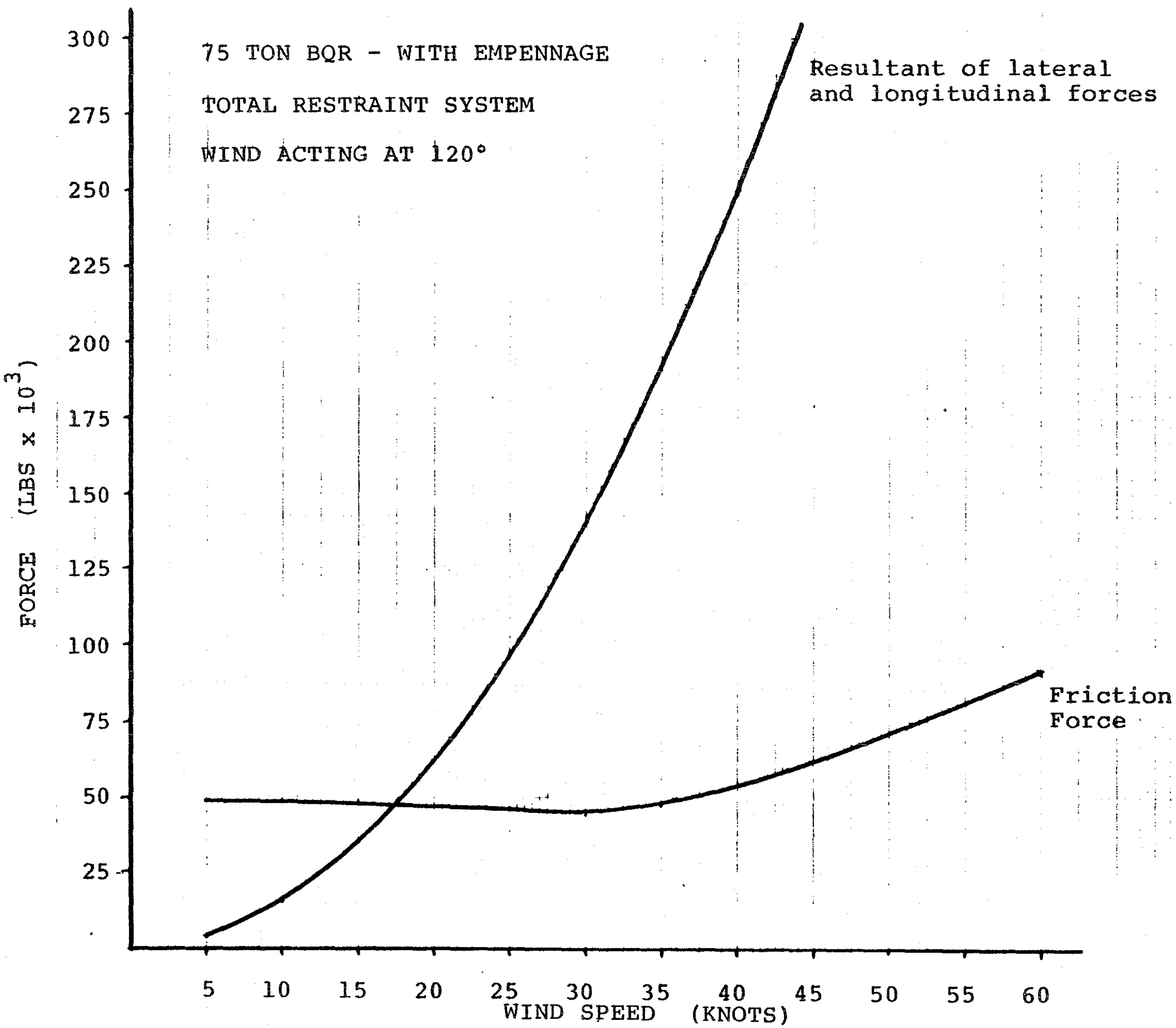


Figure 6-9 - Operational Limit of Lateral and Longitudinal Forces

b. Landing Area Requirements

A landing area rectangle that has the dimensions of vehicle length plus 50 feet by vehicle width plus 50 feet would probably satisfy the needs of this concept. The area would be 3.25 acres (see Figure 6-8).

Due to the nature of this system, only a minimal amount of clearing would be required. A relatively flat area free of loose debris could function as a mooring site. Pad pressure on the soil would be 2.6 psi.

c. Operational Concept

The following sequence is suggested as viable for a fully restrained airship mooring system:

1. In advance of scheduled airship activity at a given site, four concrete pads (10 ft x 10 ft x 2.6 ft) with necessary attachment hardware are produced in the nearest available location to the job site.
2. Enroute to the job site, the concrete pads are picked up. System is developed that stacks the pads and permits individual release.
3. At the site, a crew of two men and the required tools and cables are put down in a previously cleared area.
4. Concrete pads are placed in appropriate pattern by BQR guided by ground crew.
5. BQR lands on the pads and is secured to them with cables.

Upon termination of the job, the concrete pads can be left behind or otherwise disposed of.

d. Other Considerations

With the airship held firmly in place, any necessary maintenance functions can be more easily attended to.

6. OTHER MOORING CONCEPTS

Although not specifically addressed in the preceding sections, several alternative mooring concepts have been considered. While many have some positive features, their exclusion from this report is based on their operational similarities to those already described.

Essentially, if the airship is moored at any point other than the bow, the vehicle must withstand those forces that result from a rather large rolling moment. These forces manifest themselves in terms of additional envelope and suspension system requirements, excessive loads on landing gear, and excessive loads on the mooring structure. The proper resolution of these forces will result in additional weight requirements for the airship, which in turn results in a decrease in operational efficiency.

7. PERMANENT VERSUS REMOTE BASE REQUIREMENTS

Three distinct levels of basing exist within the realm of BQR operations. These are identified in Table 6-3. The first level, which would serve as the home base or headquarters for the operator, would be the maintenance depot equipped with a spare parts inventory to handle all service functions not requiring a hangar. A mooring circle would be established with a paved surface, permanently installed anchors, and mast base plate.

TABLE 6-3 - LEVELS OF BQR BASES

Level	Attribute
I	Permanent base; operational headquarters
II	Remote base; BQR commutes daily to job site
III	Remote base; adjacent to job site

The second level would constitute a base away from the headquarters but not directly adjacent to the job site. It would typically be a site that did not require any clearing or levelling prior to establishment of the base. An open field near a small airport would be a candidate location. From this site, the BQR would travel daily to the work site and return in the evening. The mast would remain erected at this location for the duration of the project. Similar to operating from a level I base, a BQR could service several job sites from a single location.

The level III base would be adjacent to the job site. It would likely require some advance engineering effort to clear and level sufficient mooring area. For this operation, the airship would be entirely self-sufficient for extended periods. This would involve the transportation of necessary fuel and supplies, and the performance of regular maintenance functions.

All of the mooring concepts that have been defined could be accommodated at any of the bases described above. There are some trade-offs, however. For example, it may not be reasonable to develop a level III base for bow mooring due to the land requirements. Or, since center point mooring involves extensive civil engineering effort, it is perhaps better suited to a level I base. The prevailing conditions at a specific site will ultimately dictate the mooring style that can be utilized.

8. CONCEPT SUMMARY

a. General

The key attributes of each of the four principal mooring concepts (i.e., bow, belly, center point, and total restraint) are assessed with respect to their predicted operational effectiveness.

b. Manpower

A basic premise of the BWR is that it will permit the ground handling function to be executed with no dedicated staff. The basis for this statement is that the BQR has substantially improved low-speed controllability over previous airships, and is also capable of VTOL and taxiing. Thus, for all of the concepts examined, a ground crew party of two men (from an airship complement of four men) properly equipped, could perform the necessary tasks.

c. Equipment

For both the bow- and belly-mooring concepts, a full complement of mast, base plate, and ancilliary equipment is required. This equipment, with the possible exception of the truck mounted power digger, would always remain with the airship. The airship associated with the other two concepts would have substantially less equipment as an integral part of its inventory, but is much more dependent on engineering services that must be undertaken in advance of the airship's arrival. Spontaneous mooring is therefore precluded.

d. Impact on Vehicle Empty Weight

Assuming that the operational design speed of 60 knots must be attained with each concept, the effect of this on the vehicle's empty weight can be estimated.

For bow-mooring, there would be no requirement for additional envelope or suspension system weight since all mooring loads are transferred directly to the mast. The only adverse impact would be the weight of the mooring equipment that would become an integral part of the airship in the ferry mode. In the heavy-lift operational mode, there would be no weight penalty, since all of the equipment will have been off-loaded.

The belly-mooring concept would be impacted by transportable loads similar to those indicated above for the transfer of the ground handling equipment. This approach is further impacted, however, by additional weight requirements for the suspension system, landing gear, and starframe. Assuming that satisfactory design changes could be developed to incorporate these additional loads, the weight penalty would be approximately 20,000 pounds. Note that the probability of success in developing the necessary features (i.e., many-wheeled landing gear; complex catenary system to support mast/airship interface point) is very small.

If a BQR moored at its center point (vehicle without empennage) or totally restrained (vehicle with empennage) could be held in place, the weight penalty associated with the increase in envelope and suspension system structural capabilities is 70,300 pounds and 106,900 pounds, respectively. These figures are derived from the graph of Figure 3-8.

e. Landing Area Requirements

The amount of cleared land required for effective ground handling varies from a maximum of 18 acres for bow mooring to a minimum of 3.25 acres for a fully restrained airship. Some savings can be realized in those concepts with rotational capability by only partially clearing the area to maintain vertical clearance requirements in the aft portion of the airship.

f. Maximum Wind Speed

For the BQR vehicles specified in Section II of this report, there are identifiable wind speed limitations for each of the mooring concepts.

A bow-moored BQR is limited to 60 knots. The limiting condition is the retention capability of the ground anchors.

The belly-mooring concept cannot withstand wind speeds in excess of 26 knots. The critical element is the landing gear, but the development of an effective mooring point on the underside of the envelope and the retention capability of the ground anchors are also limiting factors.

The center point-moored airship is limited by its envelope and suspension system capabilities to 18 knots.

The fully restrained concept is limited by the weight of the concrete pads that can be carried in as well as the weight growth of the envelope and suspension system. Maximum allowable wind speed is 17.5 knots.

g. System Mobility

The transportability of the bow- and belly-mooring systems is implicit in their designs. The masts, complete with guy cables, would be attached to the starframe with all support equipment stowed as required. Thus, each airship would have a mooring system as an integral vehicle component. The single limitation that may occur is with respect to the power equipment necessary to drive the anchors.

The center point concept, due to its reliance on advance preparation, is not a mobile system. Likewise, the total restraint system is dependent on the availability of preformed concrete pads.

h. Cost

The costs pertinent to the BQR mooring concepts are somewhat nebulous since for the bow and belly concepts the mooring hardware is an integral part of the BQR and is not optional equipment. Similarly, ground handling operations are a necessary part of the overall utilization of the airship and are highly dependent on the specifics of the situation. A cost analysis is therefore deferred to Section VII.

i. Rating

1. The bow-mooring concept is the only approach that fulfilled the operational wind load requirements without adversely affecting the overall BQR design. There was no weight penalty associated with this concept, although some adverse performance effects in the ferry mode could result due to the overall weight of the mooring equipment. The large land area associated with the bow mooring is a disadvantage.
2. A distant second in terms of overall effectiveness is the belly-mooring concept. The structural integrity of the system is jeopardized at wind speeds in excess of 26 knots. Additionally, this concept would suffer from some performance degradation in the ferry mode due to mooring equipment weight.
3. The fully restrained approach has only limited applicability as defined above. It is conceivable that some peripheral stakes or anchors could be incorporated in the design in

circles to increase the displacement of the sytem along the ground surface. As is, the limiting wind speed is 17.5 knots; if the limit became a function of vertical load, the tolerable wind would be 26 knots.

4. The center point mooring concept was specifically designed for the BQR with no empennage. For reasons previously indicated, that airship style is now considered inappropriate. The mooring concept for this airship was only capable of withstanding 18 knot winds.

Table 6.4 summarizes the key attributes of each mooring concept.

TABLE 6-4 - MOORING CONCEPT SUMMARY

	Bow moored	Belly moored	Center point moored*	Fully restrained
Ground personnel	2	2	2	2
Equipment	Mast, base plate, anchors, truck with power digger, winch, tools, etc.	Same as for bow moored	Concrete, wood piles, cables, tools, etc.	Pre-fab concrete pads, cables, tools, etc.
Impacts on vehicle empty weight	The additional weight of the mooring equipment is compensated somewhat by the dynamic lift of the airship; some redesign may be required to achieve predicted performance efficiencies	The need to strengthen the attachment point will require additional suspension system weight; mooring equipment impacts same as for bow mooring	Previous study underestimated mooring loads - suspension system weight would increase	Increase in suspension or envelope system weight
Landing area (acres) Note: Figure in parenthesis is hypothetical minimum - see text	18 (7.8)	11 (5.5)	3.5	3.25
Maximum wind speed (knots)	60	26	18	17.5
Limiting feature	Anchor holding strength	Landing gear	Vehicle empty weight	Concrete pad weight
System mobility	Mast integrated with starframe; truck need may inhibit	Same as bow moored	Too reliant on civil engineering; not compatible with remote sites	Dependent on access to preformed concrete pads
Permanent/remote	Both	Both	Permanent	Both
Rating - order of preference	1	2	4	3

*This concept relates to the BQR without empennage.

SECTION VII - OPERATIONAL SCENARIOS

1. GENERAL

The development of operational scenarios is required to perform the following:

1. Examine local wind and soil condition and evaluate applicability of the preferred mooring styles to these geographic features
2. Evaluate the possibility of commuting from a permanent base in lieu of establishing a remote base
3. Identify those scenarios in which logistic support can be more economically provided by ground vehicles
4. Identify those scenarios that will require the BQR to be entirely self-sufficient

The scenarios that are used in this study coincide with those BQR operational roles that are considered to have the best potential market (Reference 26): logging; relief of port congestion; power transmission line erection; construction of power generators; pipeline construction.

In view of the prediction of the large market share in the logging industry, more attention is paid to that scenario.

Unless otherwise indicated, it is assumed that the land used for the mooring site is available free of charge.

2. LOGGING IN OREGON

a. General

The United States is the world's leading producer of forest products, and Oregon leads the nation in that category. Approximately one-half of the state is forest land, with 15 million acres classified as commercial. The average yearly harvest is over 700 million cubic feet of timber. Various species are rising in importance; however, Douglas fir continues to lead in production and constitutes about two-thirds of all the wood used by Oregon industry (Reference 27). The extent of the Douglas fir forests is shown in Figure 7-1.

Although the amount of timber harvested has remained constant for many years, the harvest has shifted from private lands near ports and other transportation centers to the more remote public lands (Reference 27). The specific study area

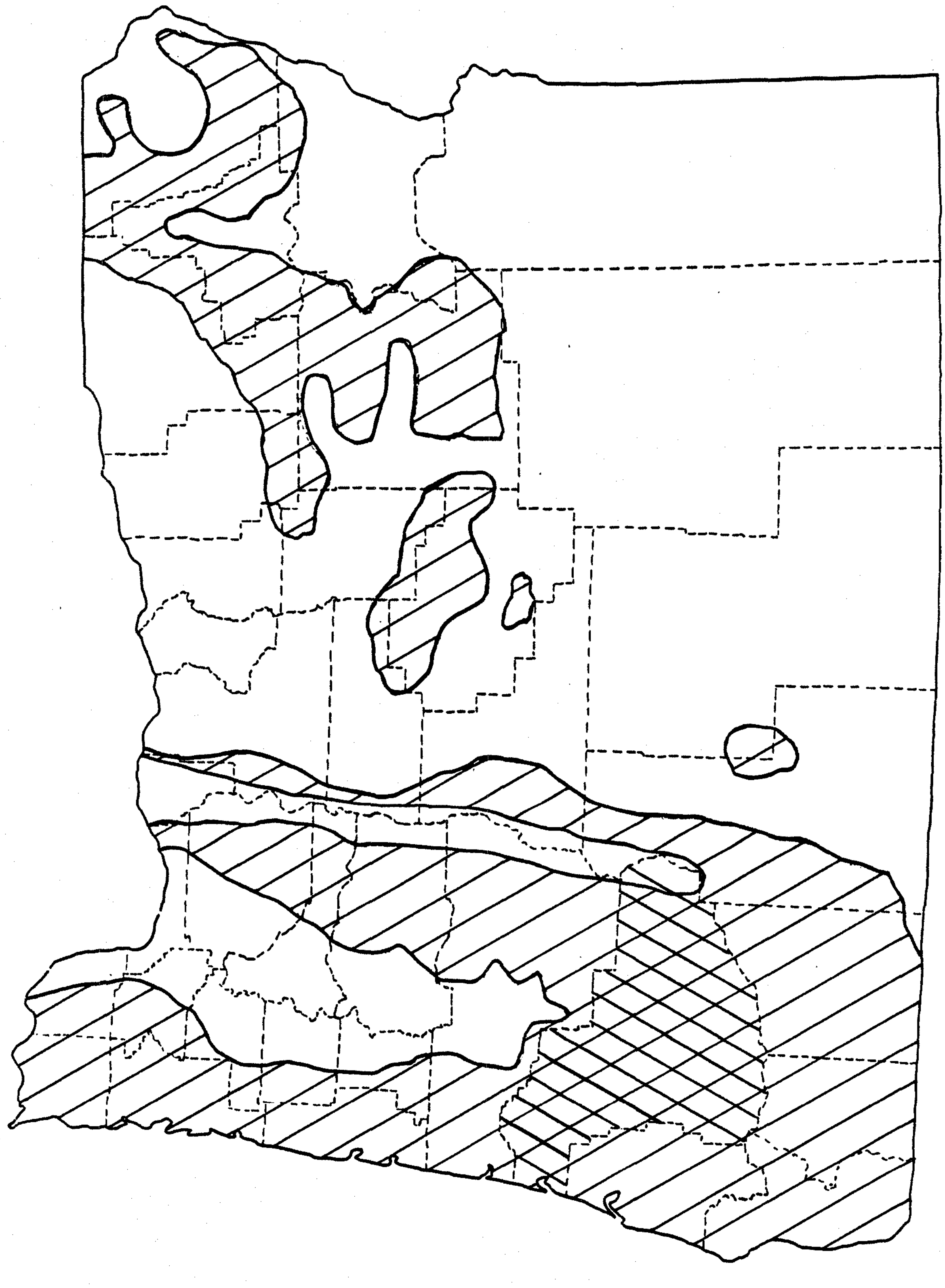


Figure 7-1 - Douglas Fir Forests of Commercial Significance under consideration is Douglas County in southwestern Oregon, which is identified by the cross-hatched area in Figure 7-1.

b. Climatic Overview

Oregon generally enjoys a mild, varied climate with only a rare occurrence of such devastating weather elements as cloudbursts, tornadoes, and hailstorms (Reference 28). The Pacific Ocean moderates temperatures and lessens the probability of extremes, while supplying an unlimited amount of moisture.

The main physical feature in this area is the coast range which extends the entire length of the state. With an overall crest height approaching 3,000 feet, it acts as a barrier to the moisture-laden clouds moving in from the coast. The result is heavy rainfall on the windward side. Normally, most of the rain falls from December through February. Coastal snowfall is usually only 1 to 3 inches per year, while in the study area it may range from 10 to 15 inches.

Over the state, there are a number of hailstorm occurrences each year, but they are usually light and localized. They cause several hundred thousand dollars in damages, mainly to crops, but sometimes buildings. Overall, this is insignificant (Reference 28). Thunderstorms occur in the average only about four or five days per year, and they are usually of little consequence. Although strong winds have been reported in the northern part of the state and along the coast, they seldom reach inland to the study area. Peak wind speeds of only 30 to 40 miles per hour are typical extremes.

Figures 7-2 through 7-5 illustrate the area's climatic thumbprint. The only city within Douglas County with official weather records is Roseburg. Its weather history is given in Table 7-2.

c. Typical BQR Operation

The harvesting of timber consists of a series of interrelated functions described below (Reference 25):

1. Felling

   Felling describes the process of cutting down the tree. In most cases this is accomplished with power saws or other mechanical equipment.

2. Bucking

   Bucking is the process used to cut a felled tree into segments. The segments of the tree after it has been bucked are called bolts or logs. If only the top of the tree is removed, it is called a tree-length log.

3. Measuring

   Prior to bucking, the tree is measured to insure proper length of the logs. The length is dependent upon the final use of the log and can vary from bolts of 100 in. to logs in excess of 50 ft in length.

4. Skidding or Yarding

   Once the trees have been bucked they have to be hauled to a landing area for further transportation to a lumber mill or pulp plant. This primary transportation from the stump to the landing area is called skidding. When cables, helicopters or other aerial systems are used, the skidding process is often referred to as yarding.

5. Loading

   Loading refers to the placing of the logs or bolts on a haul vehicle at the landing area to further transportation to a transfer point for reloading onto another mode of transportation or directly to the lumber mill or pulp plant. The loading at the landing area and the transfer points is normally accomplished with mechanized equipment.

This particular scenario examines the yarding of medium-sized Douglas fir logs with a tree length of 122 feet and an average weight of 14 tons. Assuming that an area with radius equal to two miles is yarded, the average yarding distance is 7500 feet. The BQR is assumed to be operating at 70 percent of its normal payload capability. Table 7-1 indicates potential operating capabilities based on these factors.

TABLE 7-1 - BQR OPERATIONAL CAPABILITIES*

Average flight speed (knots)	10	15	20	25	30
Average flying time per cycle (min)	14.8	9.9	7.4	5.9	4.9
Average cycle time (min)	16.8	11.9	9.4	7.9	6.9
Cycles per hour	3.3	4.6	5.9	7.0	8.0
Payload per hour (tons)	173	242	310	368	420

*Assumptions: The average yarding distance is 7500 feet. The average hookup plus release is 2 min. Five minutes each hour are required for refueling.

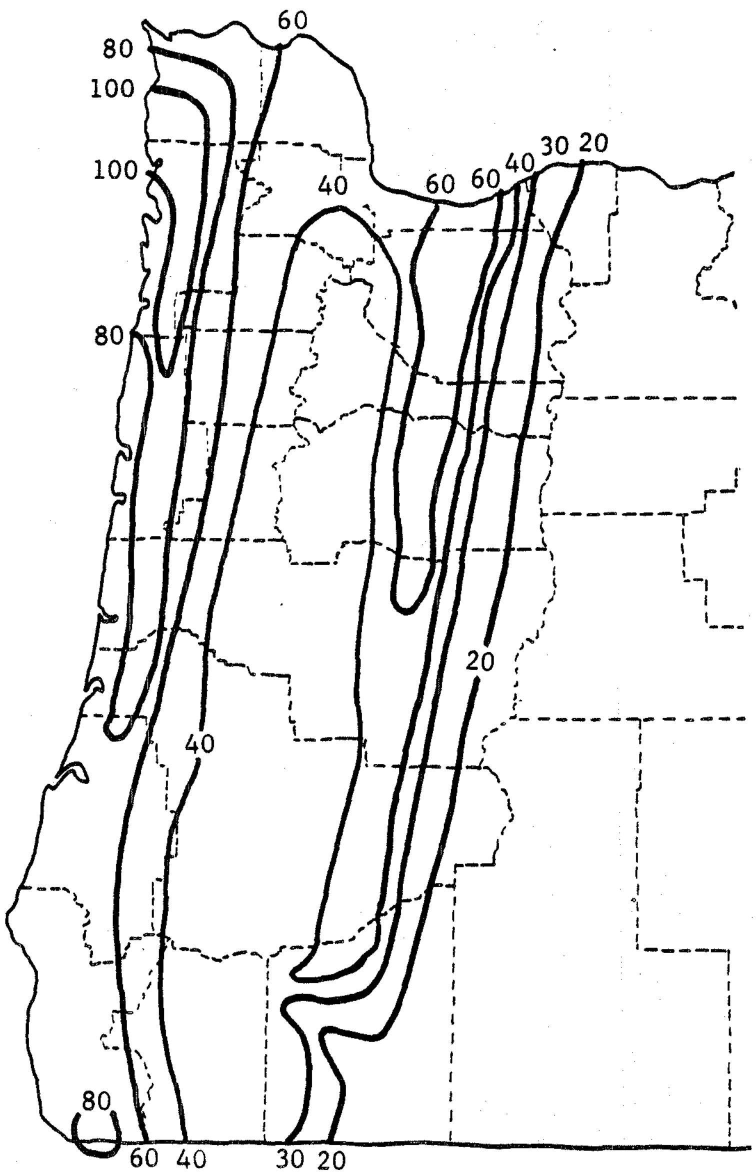


Figure 7-2 - Distribution of Precipitation (Average Annual Inches)

d. Limiting Mooring Conditions

As evidenced by the weather history for Roseburg, this area is not subject to extremes. The peak recorded wind speed is only 34 miles per hour (29.6 knots). In terms of peak mast loads, this would amount to an FMAST of 42,200 pounds, well below the design maximum (see Figure 4-9).

The native soil type is basically acidic clays that have a pronounced summer dry period. Certain areas may include some swelling clays. Based on the soil

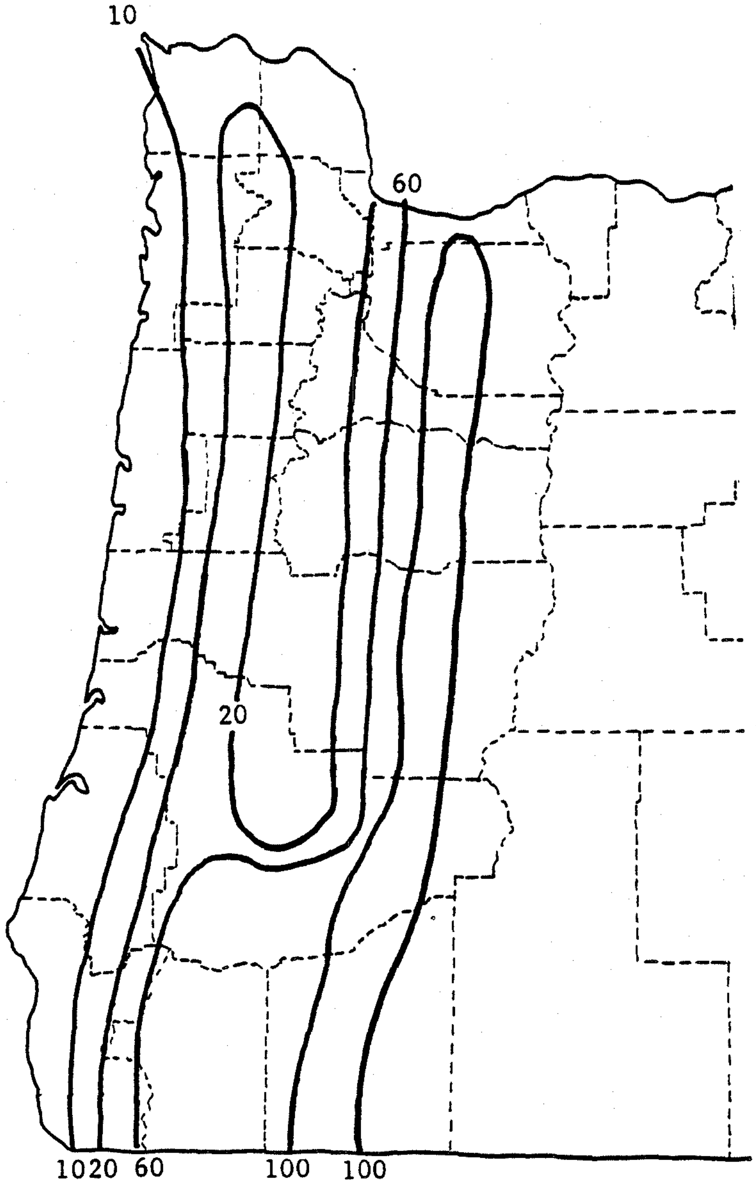


Figure 7-3 - Distribution of Snowfall (Average Annual Inches)

classification table developed for ground anchors (Table 5-2), it would appear that the appropriate class would be a 4 in the summer and a 5 in the winter. Ultimate load for the anchor would be 28,100 pounds. Therefore, a two-helix screw anchor would be satisfactory (Table 3-10).

e. Basing Requirements

The tradeoffs between having the airship moored at an existing prepared area such as an airport (level II basing), and commuting daily to the job site, versus on-site mooring (level III basing) must be considered.

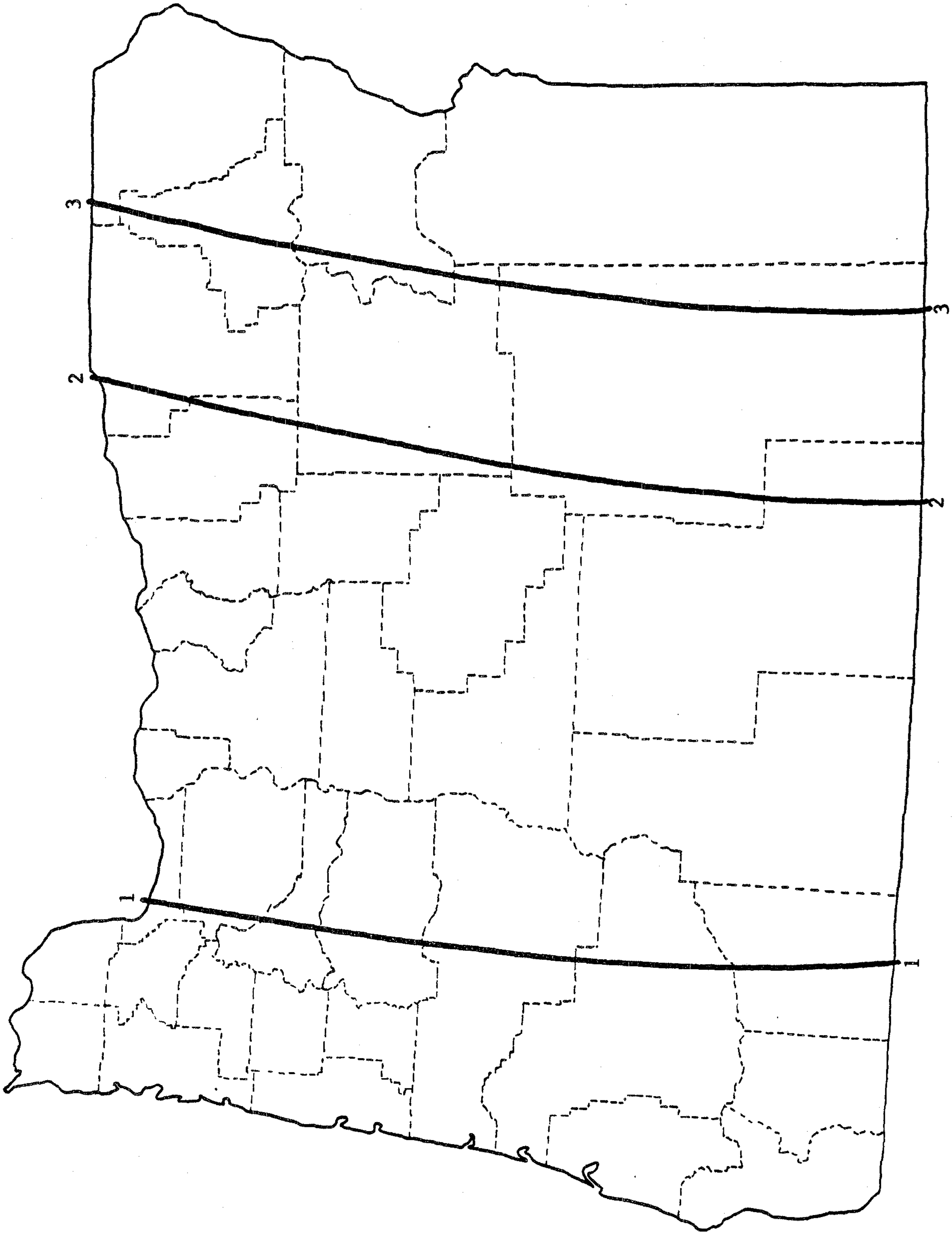


Figure 7-4 - Number of Days With Hail (Average Annual)

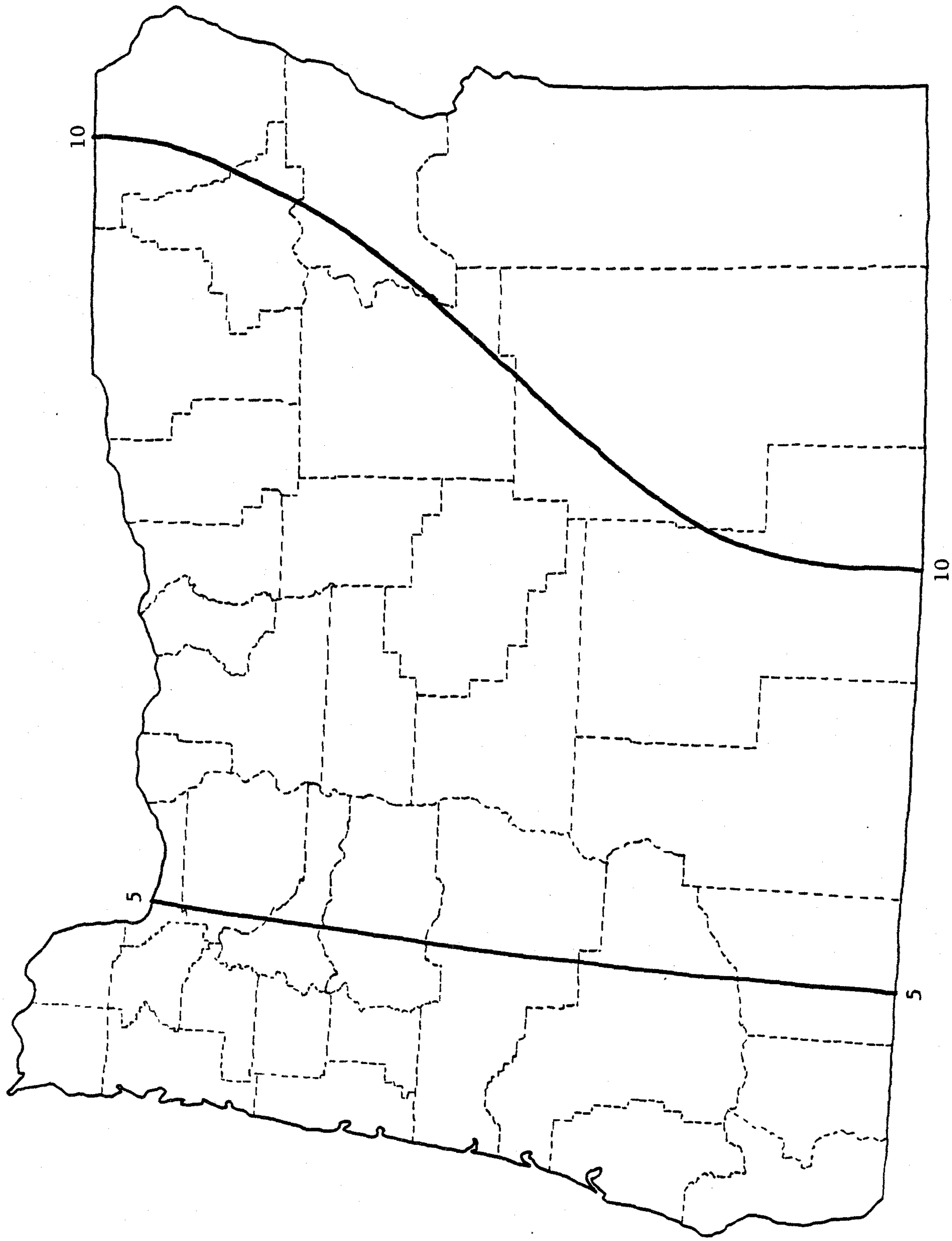


Figure 7-5 - Number of Days With Thunderstorms (Average Annual)

TABLE 7-2 - HISTORICAL WEATHER RECORD FOR ROSEBURG, OREGON (REFERENCE 28)

LATITUDE 43° 14' N
LONGITUDE 123° 22' W
ELEVATION (ground) 505 Feet

ROSEBURG, OREGON
MUNICIPAL AIRPORT

Month	Temperature – Normal – Daily maximum	Temperature – Normal – Daily minimum	Temperature – Normal – Monthly	Temperature – Extremes – Record highest	Year	Temperature – Extremes – Record lowest	Year	Normal degree days
(a)	(b)	(b)	(b)	5		5		(b)
J	47.1	31.8	39.5	65	1954	9	1957	791
F	51.9	34.3	43.1	66	1957	13	1956	613
M	57.7	36.1	46.9	79	1953	19	1956	581
A	64.0	38.9	51.5	90	1957+	27	1955	405
M	70.3	43.2	56.8	95	1956	26	1954	262
J	76.1	48.1	62.1	96	1955	34	1954	112
J	83.2	51.2	67.2	101	1956	40	1955+	29
A	82.9	50.7	66.8	99	1953	41	1956+	24
S	77.2	46.3	61.8	102	1955	32	1954	125
O	66.7	41.8	54.3	86	1953	26	1954	332
N	55.1	37.2	46.2	73	1955+	15	1955	564
D	48.6	33.8	41.2	68	1955	23	1955	738
Yr.	65.1	41.1	53.1	102	SEP. 1955	9	JAN. 1957	4556

Month	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet – Mean total	Snow, Sleet – Maximum monthly	Year	Snow, Sleet – Maximum in 24 hrs.	Year
(a)	(b)	5		5		5		5	5		5	
J	4.60	10.16	1953	2.42	1957	2.80	1956	5.4	13.3	1954	9.1	1954
F	3.76	7.07	1956	1.79	1955	3.24	1956	0.3	1.2	1956	0.9	1956
M	2.83	5.80	1957	2.23	1954	1.23	1956	1.6	7.0	1956	6.7	1956
A	2.13	3.41	1955	0.71	1956	0.84	1957	0.5	2.4	1953	2.4	1953
M	1.73	3.22	1953	0.30	1954	0.83	1956	0.0	0.0		0.0	
J	1.35	1.60	1953	0.23	1957	0.56	1956	0.0	0.0		0.0	
J	0.20	0.32	1957	T	1956+	0.30	1957	0.0	0.0		0.0	
A	0.32	1.29	1953	T	1955	0.61	1953	0.0	0.0		0.0	
S	1.11	1.98	1957	0.46	1956	0.98	1957	0.0	0.0		0.0	
O	2.93	7.00	1956	1.34	1954	2.16	1956	0.0	0.0		0.0	
N	4.51	8.44	1953	1.02	1956	3.71	1953	1.1	5.4	1955	3.3	1955
D	4.93	15.74	1955	3.30	1956	4.03	1955	0.3	0.8	1956	0.8	1956
Yr.	30.50	15.74	DEC. 1955	T	JUL. 1956+	4.03	DEC. 1955	9.2	13.3	JAN. 1954	9.1	JAN. 1954

Month	Relative humidity – 10:00 A. PST	Relative humidity – 4:00 P. PST	Wind – Mean hourly speed	Wind – Prevailing direction	Wind – Fastest mile – Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures – Max. – 90° and above	Max. – 32° and below	Min. – 32° and below	Min. – 0° and below
(a)	5	5	5		5	5		27	5	80	80	80	5	5	5	5	5	5	5	5
J	84	75	4.4		34	SW	1956	24	8.9	3	9	19	19	2	*	6	0	1	13	0
F	82	65	4.1		26	NW	1953	33	8.2	3	10	15	15	0	0	7	0	0	14	0
M	69	56	4.8		27	SW	1957+	40	7.8	5	11	15	15	1	*	3	0	0	11	0
A	62	50	4.9		27	S	1957	52	7.4	7	10	13	13	*	1	1	*	0	5	0
M	59	49	5.0		22	S	1957+	57	6.6	9	11	11	12	0	1	1	1	0	1	0
J	59	48	5.3		22	N	1956	60	6.2	11	10	9	9	0	1	1	1	0	0	0
J	54	36	6.1		25	NW	1954	78	3.2	19	9	3	1	0	*	0	4	0	0	0
A	57	39	5.5		25	N	1953	77	4.1	19	8	4	4	0	1	*	3	0	0	0
S	61	40	4.7		21	N	1956+	69	4.4	15	9	6	5	0	1	3	4	0	*	0
O	78	59	3.5		33	S	1954	41	7.3	8	12	11	12	0	*	11	0	0	2	0
N	85	74	3.5		26	SE	1953	28	8.5	4	10	16	14	*	0	12	0	*	8	0
D	87	80	4.0		31	SW	1954	17	8.9	2	9	20	18	0	0	10	0	0	12	0
Yr.	70	56	4.7		34	SW	JAN. 1956	51	6.8	105	118	142	137	3	6	55	13	1	66	0

There are many advantages to mooring the BQR at an airport. This option eliminates the need for performing civil engineering work since it is presumed that an adequately cleared area will be available on the airport property. Mooring at an airport provides ready access to aircraft services and fuels, thus precluding the need for large fuel storage tanks at the job site. Ready access to a townsite with provisions for crew's quarters and amenities is also an advantage to airport mooring. Also, the comparative ease of airship operation to and from a site that does not have limited clearances must be considered.

The major drawback to mooring at a site away from the job is the ferry cost incurred for the daily round trip. Estimated ferry costs for a 75 ton BQR with empennage with annual utilization of 2,000 hours and a production run of 25 is $858.80 per hour (Reference 25). Using 1980 dollars, this figure would increase to approximately $1000 per hour.

Available transportation infrastructure is, naturally, a prerequisite. Within 50 miles of Roseburg, there are eight airports, with an additional few just beyond the periphery as is shown in Figure 7-6. It is assumed that at least one such facility would be available as a level II mooring location.

Assuming a daily one-way ferry distance of 25 miles from an airport to the job site, and an average airship ferry speed of 50 knots, the daily commuting cost would be $868.

The next variable to determine is the number of days spent at a given site. At the present time, helicopters perform logging functions within one mile of a base. They typically can perform 30 tons per hour with a 14-ton payload. For a ten-hour day, this results in a daily harvest of 4,200 tons. Each site is normally cut for a two-week period; that is, ten working days. Based on this production rate, the average timber yield is, therefore, 13,370 tons per square mile.

An airship operation would typically harvest in a two-mile radius of the base. This results in a total yield of 168,000 tons. Assuming the BQR vehicle is capable of 7 turns per hour with a 70 percent load factor, it would take 46 working days to deplete the timber inventory.

The total ferry cost associated with mooring away from the job site would therefore be $39,928.

The cost factors of providing a mooring site at the job location (a level III base) include the following:

1. Site clearing costs

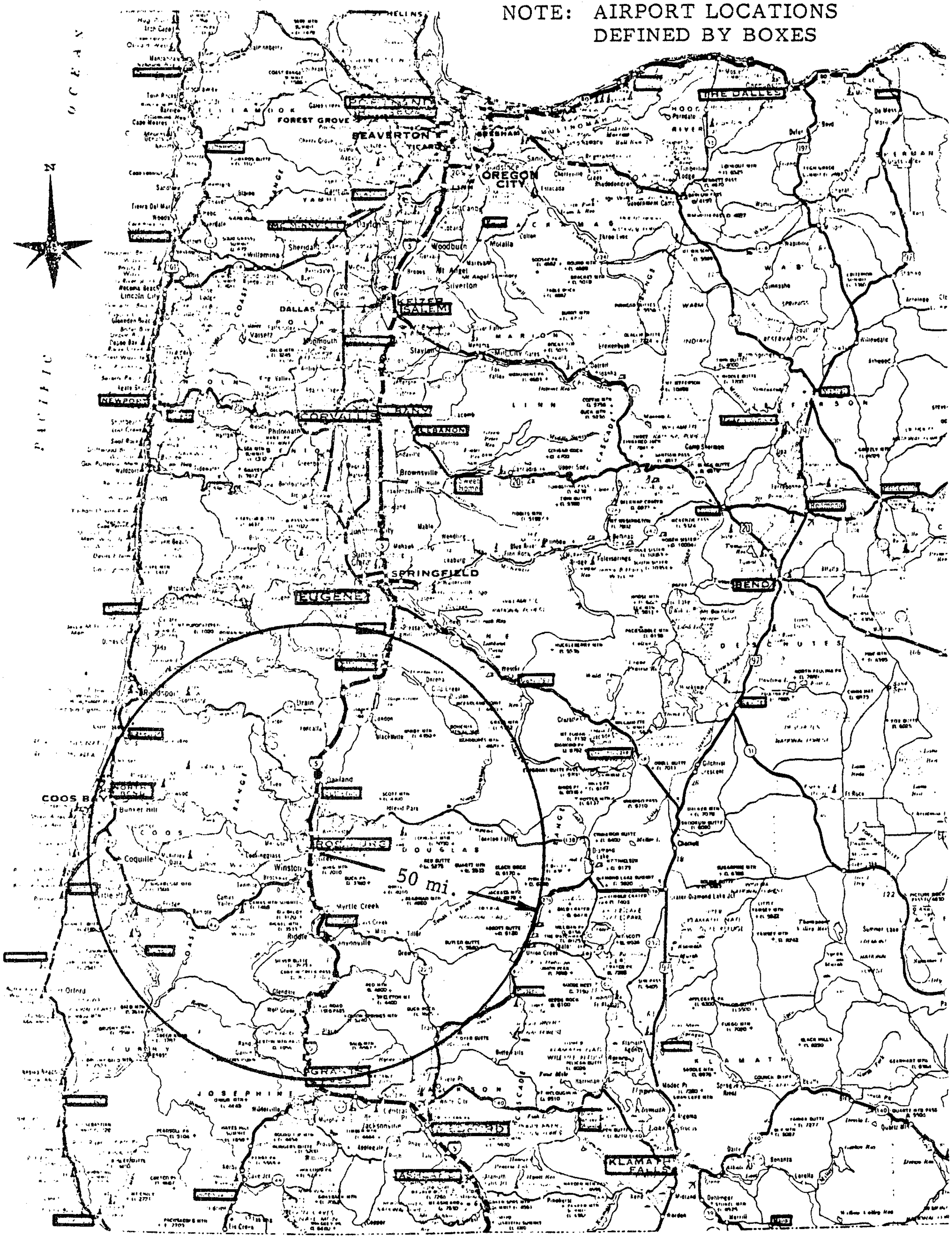


Figure 7-6 - Transportation Infrastructure

2. Site maintenance costs
3. Crew quarters

Once a suitable site has been chosen, men and equipment must be transported there to prepare a mooring area for the BQR. Clearing cost is composed of the vehicle rental, workmen's salaries, and provision of living quarters and food. Typical clearing costs are $500 per acre, while the cost to sustain a man, including salary, is approximately $50 per hour. At least fifteen men would be required for a three-week period. The total clearing cost would then be $99,000 for a bow mooring area.

Site maintenance, which can be accomplished by available logging personnel, would cost approximately $2500 for the 9-week period being considered.

Summarizing the above, the incremental cost for a level II base away from the job site and ferry daily is $39,928 as opposed to $101,500 for an on-site mooring area. The former number would be impacted by the cost of a remote fully restrained system that might be a requirement for emergency servicing or refueling at an estimated cost of $24,000. Even with this added expense, the level II base operation shows a clear advantage.

3. RELIEF OF PORT CONGESTION

a. General

Port congestion is a result of cargo throughput requirements exceeding port capacity and frequently occurs in areas with limited ground-site transportation infrastructure (Reference 26).

In recent years, several West African ports have become congested due to the rapid economic development of the countries in the area. Port expansion and improvements have not maintained the pace required by the demand for port services. The result is congestion. The scenario that is examined in this regard is Lagos, Nigeria.

b. Climatic Overview

Nigeria is situated just north of the equator in West Africa and enjoys a tropical climate. Lagos, on the coast, is impacted by tropical weather masses with the resulting rainfall.

Unfortunately, no specific wind data was available for this site. It is recognized, however, that the occurrence of hurricanes is inherent to this area, and appropriate steps to avoid those weather conditions should be implemented as required.

Available climatic data is provided in Table 7-3 (Reference 30). Maximum developable load restraint systems will be required.

TABLE 7-3 - CLIMATIC RECORD FOR LAGOS, NIGERIA

Latitude 6°27′N, longitude 3°24′E, elevation 3 m

Month	M.S.L. press. (mbar)	Temperature[1] (°C)				Dew point (°C)		Precipitation					Preval. wind direct.		Calm (%)		Averages		
		mean		extreme				mean (mm)	max. (mm)	min. (mm)	days >0.1 mm	max. in 24 h (mm)					cloudiness (oktas)		sunshine[1] (h/day)
		max.	min.	max.	min.	07h	16h						09h	15h	03h 21h	09h 15h	09h	15h	
Jan.	1,011	31	22	35	14	22.5	23.3	40	155	0	4	123	W	SW	60	3	5	2	5.9
Feb.	1,010	33	23	36	16	23.0	23.4	57	180	0	4	95	W	SW	54	2	5	3	6.8
Mar.	1,010	33	23	36	19	23.0	24.0	100	286	5	8	105	SW	S	48	1	6	4	6.4
Apr.	1,010	32	23	36	20	23.0	24.2	115	325	34	10	133	SW	S	55	4	7	4	6.3
May	1,012	31	22	35	20	22.0	24.1	215	549	90	18	158	W	S	53	4	7	5	5.6
June	1,014	29	22	32	18	22.0	23.7	336	763	138	23	254	W	SW	51	3	7	5	4.0
July	1,014	27	22	31	17	21.9	22.5	150	786	2	15	177	SSW	SSW	41	1	7	5	2.9
Aug.	1,014	27	21	31	16	21.0	22.1	59	580	2	10	108	SSW	SSW	40	0	7	5	3.0
Sept.	1,013	28	22	31	19	22.0	23.2	214	424	10	17	158	SSW	SW	44	2	7	5	3.1
Oct.	1,012	29	22	33	19	22.0	23.8	222	450	75	15	163	W	SW	59	2	7	5	4.9
Nov.	1,011	31	23	33	20	22.8	24.5	77	183	4	8	107	NW	S	53	3	6	4	6.5
Dec.	1,011	32	22	34	17	22.2	23.6	41	150	0	3	109	NW	S	56	2	6	2	6.6
Annual	1,012	30	22	36	14	22.2	23.5	1,625	2,934	1,039	135	254	—		51	2	6	4	5.2
Rec. (yrs.)	30	10	10	10	10	10	10	60	60	60	60	60	5	5	5	5	15	15	10

[1] Records from Ikeja (6°35′N 3°20′E, 35 m).

c. Typical BQR Operation

As defined in Reference 26, there are two potential applications for a BQR in a congested container port scenario.

1. As an interim solution to a long term congestion problem
2. As the only solution to the congestion problem

For the specified scenario, the former applies.

Due to a rapid rise in cargo flows and the absence of a corresponding growth in handling facilities, cargoes pile up in the warehouses and ships wait for extended periods at anchorage prior to berthing. The situation has resulted in the imposition of congestion surcharges for cargoes destined for the port and has prompted authorities to examine alternatives for lighterage of the ships.

A BQR that could accommodate three containers would transport its cargo between ship and shore.

d. Basing Requirements

The absence of available property at the port area is an integral part of the congestion problem. Therefore, it is inconceivable that a mooring site could be established at the port. Thus, the BQR would be required to commute to the job site from a distance that will not likely exceed 10 miles. Even at this, however, since frequent refueling will be necessary, there will be a significant ferry cost. Assuming refueling every two hours at the base, the total daily cost would be $1389.

4. POWER TRANSMISSION LINE ERECTION

a. General

Transmission towers are normally used for transmission lines in excess of 230 kv. The task of replacing complete towers for high voltage lines is beyond current capabilities for helicopters; therefore, the use of BQR vehicles has some considerable market potential.

The United States leads the world in tower installations. Historical and planned circuit miles are presented in Figure 7-7 (Reference 26). The study area presented herein is New Hampshire.

b. Climatic Overview

The principal attributes of this area's climate are: (1) frequent changes of the weather; (2) broad range of both daily and annual temperatures; (3) large seasonal weather changes in different years; (4) equable precipitation distribution; and (5) considerable diversity throughout the state (Reference 28).

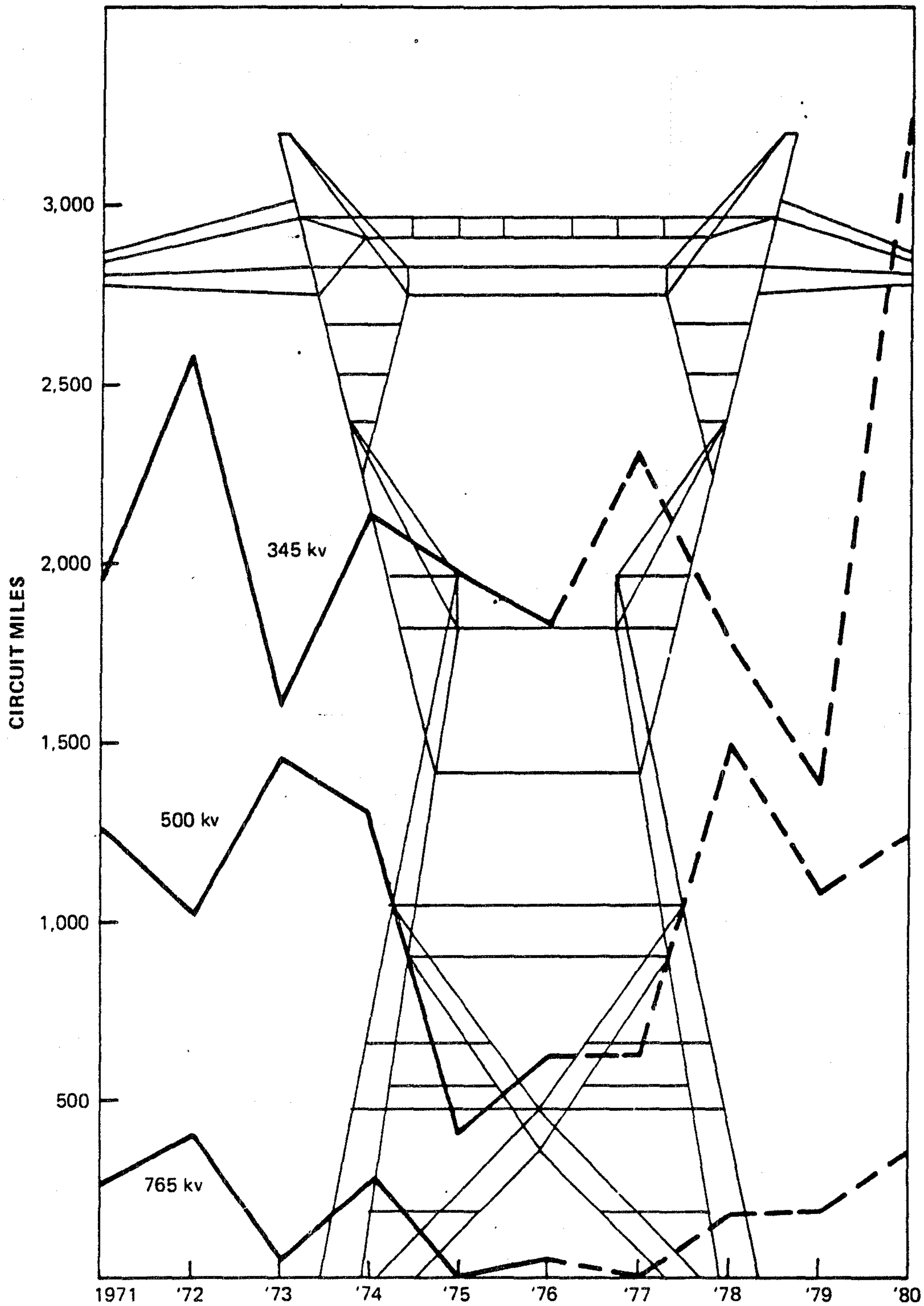
The mean annual temperature ranges from 41 deg F in the north to 46 deg F in the south. Summer temperatures are moderate, with few extremely hot days. Winter temperatures may frequently drop below zero at inland points.

Average annual snowfall varies from approximately 50 inches in the south near the coast to 80 inches inland and in excess of 100 inches at some higher elevations in the northern regions. The number of days with at least one inch of snow is between 30 and 40 for the study area. Ice storms have occurred.

Thunderstorm occurrence averages between 15 and 30 days per year. The more severe storms are often accompanied by hail which, although not widespread, can cause significant crop damage.

High winds can accompany major weather systems that pass through the area. Impacts from both hurricanes and tornadoes have been experienced in the area, but the probability of occurrence is slight.

The climatic record for Concord is given in Table 7-4 (Reference 28).



SOURCE: Electrical World, August 15,1977

Figure 7-7 - Circuit Miles of Overhead Transmission

TABLE 7-4 - CLIMATIC HISTORY OF CONCORD, NEW HAMPSHIRE

LATITUDE 43° 12' N
LONGITUDE 71° 30' W
ELEVATION (ground) 339 Feet

CONCORD, NEW HAMPSHIRE
MUNICIPAL AIRPORT

Month	Temperature							Normal degree days	Precipitation											
	Normal			Extremes												Snow, Sleet				
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year		Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	87		87		(b)	(b)	87		87		87		87	87		87	
J	31.6	6.6	20.1	72	1876	-35	1878	1392	2.91	5.87	1935	1.00	1871	2.10	1888	17.5	46.7	1935	19.0	1944
F	32.5	9.8	21.2	68	1880	-37	1943	1226	2.30	5.90	1896	0.40	1577	2.06	1937	17.0	59.0	1893	15.0	1929
M	42.9	20.7	31.8	85	1946	-16	1943	1029	3.04	9.80	1936	T	1915	2.59	1936	11.7	38.3	1956	12.9	1939
A	55.5	30.4	43.0	92	1941	7	1874	660	3.08	7.44	1904	0.42	1941	2.97	1923	4.4	35.0	1874	18.3	1933
M	68.8	40.7	54.8	98	1911	21	1947	316	3.04	8.26	1954	0.32	1899	3.05	1922	0.1	5.0	1945	5.0	1944
J	77.9	50.2	64.1	101	1919	32	1916	82	3.62	10.10	1944	0.10	1913	4.47	1944	0.0	0.0		0.0	
J	82.6	55.3	69.0	102	1911	38	1898	11	3.57	10.29	1915	0.91	1910	3.10	1887	0.0	0.0		0.0	
A	80.2	52.8	66.5	100	1955	33	1942	57	3.10	9.00	1892	0.35	1882	3.32	1908	0.0	0.0		0.0	
S	72.4	45.2	58.8	98	1953	20	1941	192	3.39	10.97	1888	0.21	1914	5.97	1932	0.0	0.0		0.0	
O	61.7	34.3	48.0	92	1879	18	1947	527	2.80	7.76	1890	0.05	1924	3.45	1877	0.1	3.0	1884	1.0	1925
N	47.5	25.8	36.7	80	1950	-17	1875	849	3.57	7.59	1937	0.50	1939	4.04	1927	5.5	25.0	1873	13.3	1938
D	34.3	13.0	24.0	65	1932	-24	1875	1271	2.81	7.64	1936	0.58	1943	2.79	1952	11.9	43.0	1876	14.6	1946
Year	57.3	32.3	44.8	102	July 1911	-37	Feb. 1943	7612	37.23	10.97	Sept. 1888	T	Mar. 1915	5.97	Sept. 1932	68.2	59.0	Feb. 1893	19.0	Jan. 1944

Month	Relative humidity				Wind					Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days										
							Fastest mile					Sunrise to sunset							Temperatures			
																			Max.		Min.	
	1:00 a.m., EST	7:00 a.m., EST	1:00 p.m., EST	7:00 p.m., EST	Mean hourly speed	Prevailing direction	Speed	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	90° and above	32° and below	32° and below	0° and below
(a)	17	17	17	17	50	26	20	20		42	48	55	55	55	55	15	55	20	55	55	55	55
J	79	78	60	69	6.2	NW	43	NW	1945	48	5.6	11	8	12	11	5	0	2	0	17	30	6
F	74	74	56	66	6.6	NW	42	N	1950	53	5.0	12	7	9	9	4	0	1	0	14	27	5
M	75	74	53	64	6.9	NW	71	NE	1950	55	5.0	13	8	10	10	4	1	2	0	5	25	1
A	76	72	47	61	6.9	NW	32	NW	1945	52	5.3	11	9	10	11	1	1	2	0	0	14	0
M	83	75	48	63	6.0	NW	48	NW	1945	51	5.3	12	9	10	10	0	3	3	1	0	1	0
J	87	76	49	66	5.3	NW	38	SW	1957	56	5.0	12	10	8	10	0	5	5	2	0	0	0
J	90	80	49	69	4.9	NW	37	NW	1944	56	4.7	12	12	7	10	0	6	7	3	0	0	0
A	91	85	53	71	4.6	NW	56	E	1954	58	4.8	13	11	7	10	0	5	10	2	0	0	0
S	91	88	53	76	4.8	NW	61	SE	1938	55	5.0	12	9	9	10	0	2	9	1	0	1	0
O	86	83	52	72	5.3	NW	39	NW	1944	51	5.3	12	8	11	9	0	1	7	0	0	8	0
N	82	84	59	75	5.9	NW	72	NE	1950	43	6.0	9	8	13	10	2	0	3	0	2	20	0
D	77	79	59	71	6.1	NW	51	NE	1944	43	5.9	10	7	14	10	4	0	2	0	12	28	3
Year	83	79	53	69	5.8	NW	72	NE	Nov. 1950	52	5.2	139	106	120	120	20	24	53	9	50	154	15

c. Airship Mooring Limitations

The extreme wind speed recorded at this site is 72 miles per hour (62.6 knots). This exceeds the design criteria for the bow mooring system; however, it is still well within the ultimate load limits of the structure. In those cases where predicted wind speeds are at or slightly in excess of 60 knots, some crew chief judgment will be required. It may prove necessary to leave the area until after the severe condition has subsided.

Soil types will typically be clayey. This will result in the use of twin anchors at each of the peripheral anchor points with either the three or four helix screw anchor models.

d. Airship Operation

The operating scenario as defined by Reference 26 is provided below. The BQR in this instance is limited to the transportation and emplacement of the towers. The towers, each weighing approximately 25 tons, are preassembled at staging areas. Upon completion of tower foundation work, the BQR is brought to the site to transport the towers to the foundations and emplace them. Crews of workers move from site to site following the progress of the BQR and securing the tower with bolts.

This procedure is based on the assumptions that the towers are fully assembled and rigged in the staging areas and that the average BQR travel distance from that area to a foundation is 2.5 miles.

In view of the activity level at a staging area, it is likely that a BQR would be moored at this site. This assumes that a suitable flat area will be available. Since the airship operation will be remotely centered, it must be self-reliant. However, since the staging area will be accessible by conventional transport means, necessary supplies can be obtained as required.

5. CONSTRUCTION OF POWER GENERATORS

a. General

Three basic types of power generation plants are nuclear plants, steam fossil fuel plants, and hydroelectric plants. Since each of these operations have different BQR requirements, only a steam generating fossile fuel plant will be examined in this report. A substantial number of steam plants will be coming on-stream in this decade as illustrated in Table 7-5 (source: Engineering News Record, Vol 204, No. 3, January 17, 1980).

TABLE 7-5 - FOSSIL POWER PROJECTS SCHEDULED FOR 1980-1989

		CAPAC (MW)	EST COST ($ MIL.)	% COMPL	EST COMPL
James H. Miller units 2-4	Alabama Power Co.	1,980	1,335	20	1987
Cholla Generating Station expansion Ariz.	Arizona Public Service	850	500	80	1981
Coronado Generating Station. St. John's, Ariz.	Salt River Project et. al.	1,050	990	99	1980
Craig Generating Station unit 3 Craig, Colo.	Colo.-Ute Elec. Assn.- Salt River Project	400	500	5	1983
Crystal River units 4,5, Fla.	Florida Power Corp.	1,280	840	10	1984
Martin Co. plant, units 1,2, Fla.	Florida Power & Light Co.	1,550	610	90	1981
Scherer plant units 1-4 Forsyth, Ga.	Georgia Power Co. et. al.	3,272	2,211	22	1989
Rockport plant Rockport, Ind.	Indiana-Michigan Elec. Co.	2,600	1,600	30	1983
Louisa plant Muscatine, Iowa	Iowa-Illinois Gas & Electric	650	600	5	1983
Jeffrey Energy Center units 1-4 Pottawatomie Co., Kan.	Kansas Power & Light Co. et. al.	2,720	1,200	46	1983
Brandon Shores plant, unit 1,2 Anne Arundel Co., Md.	Baltimore Gas & Electric Co.	1,240	844	36	1988
Bell River plant units 1,2 St. Clair, Mich	Detroit Edison Co.	1,200	1,300	5	1985
Campbell unit 3 Port Sheldon, Mich.	Consumers Power Co.	770	600	82	1980
Colstrip plant units 3,4 Colstrip, Mont.	Montana Power Co. et. al.	1,400	1,700	1	1984
Comstock plant unit 3 Comstock, Neb.	Nebraska Public Power District	650	650	1	1986
Gerald Generating plant unit 1,2 Sutherland, Neb.	Nebraska Public Power District	1,300	676	50	1981
Antelope Valley Station units 1,2 Beulah, N.D.	Basin Electric Power Cooperative	880	1,400	30	1983
San Juan units 3,4 Farmington, N.M.	Public Service of New Mexico	700	956	60	1982
Poston plant units 5,6 Athens, Ohio	Columbus & Southern Electric Co.	826	829	5	1990
Pebble Springs plant Pebble Springs, Ore.	Portland General Electric	530	525	65	1980
Bruce Mansfield plant unit 3 Shippingsport, Pa.	Pennsylvania Power Co. et al.	825	576	20	1980
W.A. Parish plant units 7,8 Fort Bend County, Tex.	Houston Lighting & Power Co.	1,200	658	75	1983
Mountaineer plant New Haven, W. Va.	Appalachian Power Co.	1,300	625	50	1980
Pleasants Station unit 2 St. Marys, W. Va.	Allegheny Power System	1,252	662	73.7	1980
Laramie River plant units 1-3 Wheatland, Wyo.	Basin Electric Power Co-operative et. al.	1,500	1,500	75	1982

The study location for this scenario is Forsyth, Georgia, which has a 3,272-mw plant due to be completed in 1989.

b. Climatic Overview (Reference 28)

The climate in Georgia is impacted by three main factors: its latitude, its proximity to major water bodies (Gulf of Mexico and Atlantic Ocean), and its altitude.

Average precipitation in the study area is 75 inches, with snow occurring at only the higher elevations where it seldom exceeds 5 inches per year.

The state averages 18 tornadoes per year, and while there have been occurrences in every month, the highest frequency is during the spring. Other more localized wind storms occur in spring and early summer, generally in connection with thunderstorms. The area will experience 50 to 60 days per year of thunderstorms, but only one or two of these will be accompanied by hail.

The closest location with recorded climatic information is Macon. This city's records are given in Table 7-6 (Reference 28).

c. Limiting Mooring Conditions

The extreme wind speed identified for this area is 70 miles per hour (60.9 knots), which is essentially the defined design limit for the bow mooring system. Since tornadoes are so prevalent, however, precautions should be taken during the season of highest probability. Evasive action may be appropriate.

The soils in this area generally fall into the 3-5 classification as previously defined by Table 5-2. Once again, the highest strength anchors in pairs at peripheral points would be mandated by this combination.

d. Airship Operations

There are three possible applications of a BQR in the construction of a power plant (Reference 26):

1. Transport the fully assembled turbine and shaft and the three pressure stages from the manufacturing plant to the construction site
2. Transport the heavy components from a lay-down area to the construction site and perform erection at the site
3. Lift fully assembled structural modules from the assembly yard and position them at the construction site

TABLE 7-6 - CLIMATIC RECORD OF MACON, GEORGIA

LATITUDE 32° 42' N
LONGITUDE 83° 39' W
ELEVATION (ground) 354 Feet

MACON, GEORGIA
LEWIS B. WILSON AIRPORT

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days
(a)	(b)	(b)	(b)	4		4		(b)
J	60.2	36.2	49.2	78	1967	3	1966	505
F	62.7	39.4	51.1	80	1965	14	1967	403
M	68.9	44.8	56.9	88	1967	22	1968	295
A	76.2	52.9	65.6	91	1968+	35	1966	63
M	86.5	61.2	73.9	99	1967	40	1968	0
J	92.6	68.7	80.7	98	1968	47	1966	0
J	92.6	71.0	81.9	101	1966	54	1967	0
A	92.2	70.3	81.3	104	1968	56	1967+	0
S	87.5	65.3	76.4	96	1966+	35	1967	0
O	78.6	53.8	66.2	89	1968+	29	1965	71
N	68.0	42.7	55.4	85	1964	22	1967	297
D	60.1	37.9	49.0	79	1967+	18	1968+	502
YR	77.4	53.9	65.6	104	AUG. 1968	3	JAN. 1966	2136

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	20		20		20		20	20		20	
J	3.37	8.30	1964	0.69	1954	4.44	1962	0.2	3.7	1955	3.7	1955
F	4.26	9.12	1949	1.39	1968	2.95	1952	0.2	2.9	1968	1.9	1968
M	4.94	9.69	1962	1.26	1968	3.45	1958	T	T	1969+	T	1968+
A	3.75	8.42	1964	0.97	1966	3.65	1955	0.0	0.0		0.0	
M	3.32	11.77	1957	0.32	1956	4.01	1957	0.0	0.0		0.0	
J	3.34	9.06	1965	0.99	1954	4.97	1965	0.0	0.0		0.0	
J	5.64	9.04	1953	1.21	1952	2.69	1965	0.0	0.0		0.0	
A	4.18	6.29	1959	1.39	1968	2.96	1959	0.0	0.0		0.0	
S	2.77	8.82	1953	0.64	1958	4.60	1956	0.0	0.0		0.0	
O	2.01	9.39	1959	0.00	1963+	4.63	1966	0.0	0.0		0.0	
N	2.45	5.89	1957	0.43	1956	1.63	1968	T	0.2	1950	0.2	1950
D	4.05	9.43	1953	0.58	1955	3.40	1956	T	0.5	1963	0.5	1963
YR	44.08	11.77	MAY 1957	0.00	OCT. 1963+	4.97	JUN. 1965	0.4	3.7	JAN. 1955	3.7	JAN. 1955

Month	Relative humidity: 1 AM	7 AM	1 PM	7 PM	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year
	Standard time used: EASTERN								
(a)	4	4	4	4	20	15	20	20	
J	80	84	57	65	8.5	WNW	47	SW	1959+
F	73	79	54	58	9.5	WNW	60	NE	1960
M	73	81	48	52	9.8	WNW	60	S	1954
A	76	84	49	53	9.5	WNW	57	SE	1957
M	80	85	49	55	8.0	NW	65	SE	1952
J	85	86	55	62	7.6	NW	56	NW	1954
J	88	89	59	69	7.2	SW	59	SW	1954
A	87	89	56	67	6.6	NE	70	S	1961
S	88	92	59	72	7.4	NE	40	NW	1956
O	84	87	52	68	7.1	NE	32	NW	1954+
N	80	84	50	65	7.6	WNW	54	SW	1957
D	78	82	54	64	7.9	NW	50	NW	1967
YR	81	85	53	62	8.1	WNW	70	S	AUG. 1961

Month	Pct. of possible sunshine	Mean sky cover, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max. 90 and above	Max. 32 and below	Min. 32 and below	Min. 0 and below
(a)	20	20	20	20	20	20	20	20	20	4	4	4	4
J	56	6.2	8	8	15	10	*	1	4	0	1	17	0
F	58	6.1	8	6	14	10	*	2	2	0	0	14	0
M	62	6.1	9	8	14	11	0	3	2	0	0	8	0
A	67	5.4	11	7	12	8	0	5	1	2	0	0	0
M	71	5.5	10	10	11	9	0	6	1	9	0	0	0
J	68	5.9	8	11	11	10	0	9	1	15	0	0	0
J	64	6.5	6	11	14	14	0	14	1	18	0	0	0
A	71	5.5	10	11	10	11	0	10	2	17	0	0	0
S	64	5.9	9	9	12	8	0	4	2	6	0	0	0
O	69	4.3	15	7	9	6	0	1	2	0	0	2	0
N	64	5.0	12	7	11	7	0	1	3	0	0	8	0
D	57	6.0	9	8	14	10	0	1	4	0	0	14	0
YR	63	5.7	115	103	147	112	*	56	23	66	1	63	0

Means and extremes in the above table are from the existing or comparable location(s). Annual extremes have been exceeded at other locations as follows: Highest temperature 106 in June 1954; maximum monthly precipitation 20.52 in August 1928; maximum precipitation in 24 hours 8.36 in August 1928; maximum monthly snowfall 6.9 in February 1914; maximum snowfall in 24 hours 6.9 in February 1914.

In each case, the airship would likely bow moor near the trip origin point where land space is likely to be available.

6. PIPELINE CONSTRUCTION

a. General

The building of oil and gas pipelines through wilderness areas is fundamental to accessing Alaskan petro reserves. The planned Alaska Highway pipeline through Canada to the United States is the selected scenario, with statistical reference to the Yukon territories for climatic data.

b. Climatic Overview

The severity of the winter months is of prime consideration in this area. Extreme temperatures necessitate appropriate cold weather procedures both for flight and mooring operations in order to protect personnel from the cold and wind chill effects. The average daily minimum temperature for the area is -20 deg F. Figure 7-8 shows the frequency of daily minimum temperatures at or below -30 deg F (Reference 25).

Mean annual measured snowfall for the area is 45 to 60 inches. Potentially more harmful, however, is freezing precipitation. This region has approximately five to ten hours per year of frozen precipitation, 45 percent of which falls as freezing rain.

In the summer months, an average of ten days will experience thunderstorm activity. Peak wind speeds will likely be in the realm of 40 to 50 knots. Further details are given in Table 7-7 (Reference 31).

c. Limiting Mooring Considerations

While the wind speeds that could be encountered are significant, there are other limiting features that are more germane to the analysis of this scenario.

1. The average annual snowfall, although not substantial, implies snow removal problems for a moored airship. As yet, no ideal solution exists.
2. The occurrence of freezing rain, with a higher density than snow, would be detrimental. The concern with respect to snow or freezing rain accumulation is that suspension system cables slacken due to increased load.

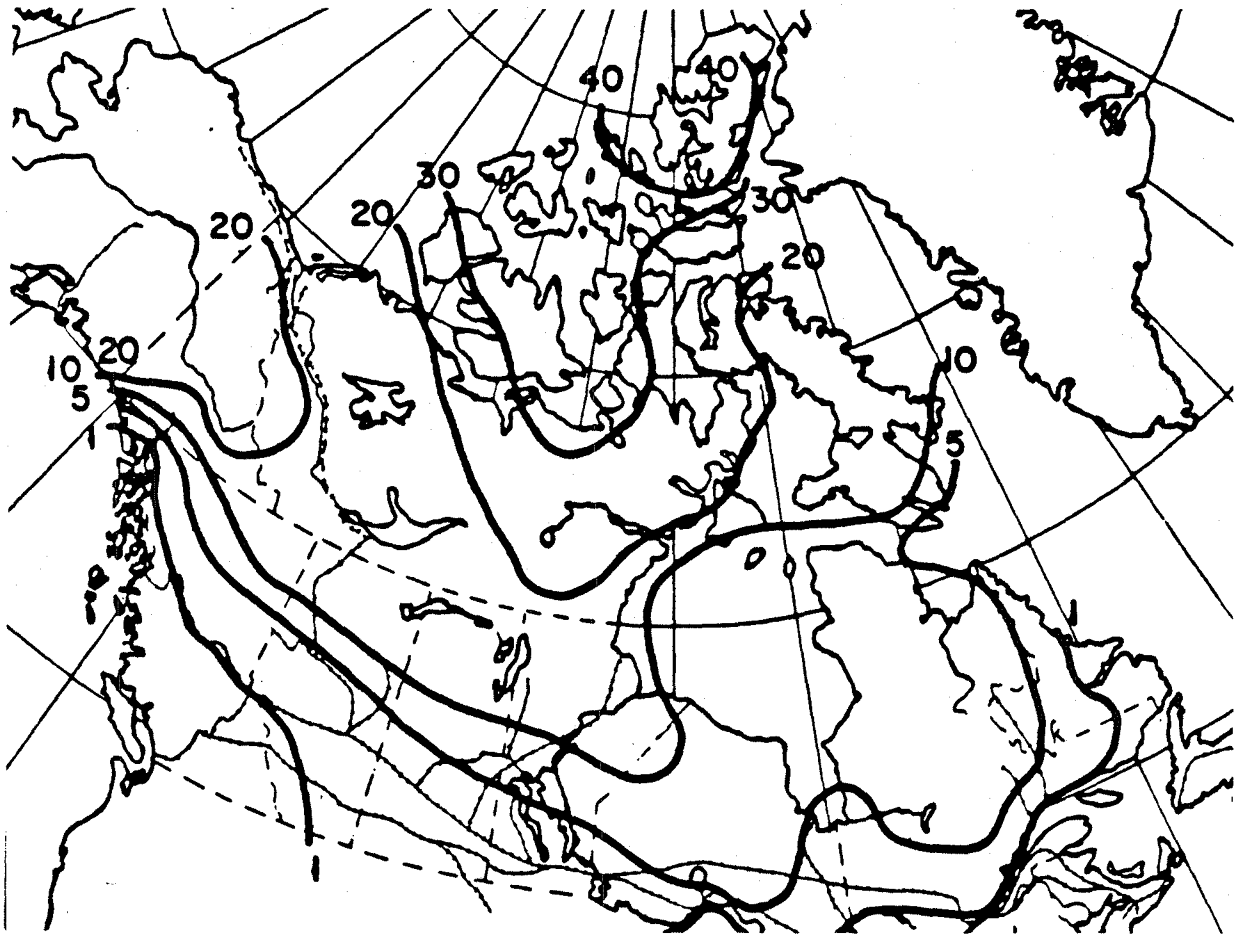


Figure 7-8 - Frequency of Daily Minimum Temperature At or Below -30 Deg F During the Winter

3. Permafrost, while not continuous in this zone, is a problem. It is unlikely that the prescribed anchors could be installed into frozen ground with standard procedures.
4. The winter season is long.

All of these limiting features could adversely impact any airship mooring system that relies on anchors. A modified approach or a total restraint system might be required.

d. Airship Operations

The BQR has the potential for transporting construction equipment to and from job sites in advance of the spring thaw in order to lengthen winter construction season; transporting equipment and personnel across natural obstructions; and transporting modularized compressor stations from a staging area near a railway

TABLE 7-7 - CLIMATIC RECORD OF WHITEHORSE, YUKON

Latitude 60°43′N, longitude 135°04′N, elevation 2,128 m

Month	Mean sta. press. (mbar)	Temperature (°C)				Mean vapor press. (mbar)	Precipitation (mm)		Snowfall (mm)
		mean daily	mean daily range	extremes			mean	max. in 24 h	
				max.	min.				
Jan.	929.1	−18.1	8.4	8	−52		18	9.4	178
Feb.	928.5	−14.1	9.5	10	−51		14	10.4	142
Mar.	926.7	−7.6	11.1	11	−38		15	20.3	150
Apr.	928.4	−0.2	10.5	21	−26		11	14.2	102
May	930.7	7.5	12.2	30	−8	5.8	13	12.2	20
June	931.3	12.6	12.9	32	−2	8.4	27	20.8	0
July	932.6	14.2	12.1	33	−2	9.8	35	21.1	0
Aug.	931.8	12.4	11.4	30	−8	9.4	37	30.7	tr.
Sept.	929.8	7.9	9.7	27	−10	7.5	25	21.6	33
Oct.	924.4	0.7	7.4	19	−24		19	11.9	119
Nov.	925.6	−8.2	6.7	11	−42		23	11.4	216
Dec.	924.6	−15.1	7.7	8	−48		20	10.9	198
Annual	928.6	−0.7	10.0	33	−52		257	30.7	1,158

Month	Number of days			Mean cloudiness (tenths)	Mean sunshine (h)	Wind		18°C degree-days
	precip. >0.25 mm	thunderstorm	heavy fog			most frequ. direct.	mean speed (m/sec)	
Jan.	12	0	3.7	6.7	48	S	3.9	1,130
Feb.	10	0	1.3	6.8	74	S	4,0	915
Mar.	8	0	1.1	6.4	164	S	4.0	804
Apr.	6	0	0.3	6.8	246	S	3.9	555
May	5	0.2	0.3	7.0	265	SE	3.9	336
June	8	2.2	0.9	7.1	295	SE	3.6	183
July	12	2.4	0.3	7.5	241	SE	3.3	133
Aug.	10	0.8	1.6	7.1	219	SE	3.5	184
Sept.	9	0	2.1	7.1	148	S,SE	4.1	312
Oct.	9	0	1.8	7.0	114	S	4.7	546
Nov.	12	0	2.2	7.7	56	S	4.1	797
Dec.	12	0	3.6	7.2	28	S	3.9	1,035
Annual	113	5.6	19.2	7.0	1,898	S	3.9	6,930

or highway. Each of these tasks entails specific origins and destinations that relate to a relatively short work period. Hence, it would be impractical to develop a mooring area that is local to any single task. Based on the predicted use of a BQR for pipeline construction, it would be more advantageous to identify a centrally located site that could service the system. Some ferry costs would be involved on all jobs, but a savings in prevention of mooring site duplication would accrue. At this site, a bow mooring approach would satisfy all needs.

SECTION VIII - SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

1. HISTORICAL REVIEW

The development of ground handling systems for lighter-than-air vehicles has evolved from man-handling to the mechanized state established for large non-rigid Navy airships in the 1950's. Throughout the nearly two hundred years since the Montgolfier brothers first ascended in a hot-air balloon, a plethora of mooring techniques have been attempted. Of all these efforts, however, the bow-mooring concept has consistently represented the optimum approach for securing airships on the ground.

2. VEHICLE CONCEPTS

Both vehicles presented have a predicted payload capability of 75 tons. The BQR without empennage was generated as part of the NASA Phase II study (Reference 24). It has a symmetrical envelope with a volume of 2.5 million cubic feet. This vehicle's power requirements were to be fulfilled by four modified heavy-lift helicopters tied together by an interconnecting structure.

Further investigation by Goodyear Aerospace, however, revealed certain operational inefficiencies in the cruise mode of this concept. The result of this study was to generate a second vehicle design that would have the same payload capability, but would exhibit improved flight characteristics. The 75-ton BQR with empennage was the outcome. It has the more conventional airship shape and is designed with an inverted "Y" tail configuration. Additional refinements include a rotor module that is designed specifically for the vehicle as well as a centrally located control car. The interconnecting structure design was retained from the BQR without tail.

3. STRUCTURAL ANALYSIS OF A FULLY RESTRAINED AIRSHIP

An investigation of airship empty weights versus wind velocity was undertaken for the two vehicle concepts, but was limited to a static condition in which envelope deformations were not considered. Previously defined aerodynamic coefficients that are based on experimental data for various airship models were found to have sufficient correlation to be applicable to the vehicles being considered herein. The coefficients appear to be insensitive to fineness ratio.

A static analysis of the mooring loads developed in a fully restrained airship was defined and coded for a computer program. Results indicate that the upward vertical loads are the most significant followed by lateral and longitudinal. The effect of buoyancy ratio on the vertical forces of a fully restrained airship is also assessed at various wind speeds. A lower β decreases the upward force and therefore lessens the impact of the vertical load.

When mooring, attempts are made to exclude ground handling loads from acting on the envelope and suspension system by transferring the loads to a mast. If this opportunity is not provided, however, the envelope and suspension system must be structurally capable of withstanding these forces. This results in a severe weight penalty due to increases in envelope fabric strength or increased size or quantity of catenary cables. Operationally, this would result in a serious degradation of airship performance efficiency.

4. DYNAMIC LOADS AND COMPUTER SIMULATION MODELS

In order to extend the results of the static analysis to encompass the dynamic effects of an airship rotating about a mast, a segmented approach was taken to determine the overall forces acting on the airship. For each segment, the various forces were computed, and then summed to yield results for the entire airship. Calculations were performed by a computer simulation model in which the airship physical properties, mooring mast location, and wind information were input. Results of this model, presented graphically, indicate that mast forces increase as the mast location moves from the airship nose toward the center point. For both bow- and belly-mooring concepts for the BQR with empennage, mast forces increase due to increased wind speeds and increased yaw angles. It was found that both concepts result in an airship equilibrium position colinear with the wind provided that the mast is no further than 140 feet from the nose.

For the center-point moored BQR without empennage, the equilibrium position is at right angles to the wind direction. Hence, the lateral force component is the most significant.

5. MOORING SITE CONSIDERATIONS

The main factors to consider in the establishment of a mooring site are the local topography, soil conditions, weather conditions, and the mooring concept. Only the mooring concept is a variable for any particular location.

The site topography will dictate the overall suitability of a mooring location. Significant relief would not be tolerable, and the site would require extensive renovation.

Soil conditions and bearing strength will ultimately define the operational limits of the mooring systems. The ability of the soil to withstand loads at landing gear contact points and to develop sufficient strength from anchors is of paramount importance. Similarly, the landing site's resistance to degradation through erosion caused by rotor downwash must be addressed.

The two weather factors that most severely affect airship mooring are wind and snow. This analysis has attempted to quantify wind loads and minimize their effects through the use of the appropriate mooring concept. Snow loads, however, present a significant problem since no effective means of snow removal has been developed.

6. MOORING SYSTEM ALTERNATIVES

Four mooring concepts were examined: bow-mooring; belly-mooring; center-point mooring; and total restraint.

Bow mooring, the most conventional, is designed to hold the airship at the nose, permitting it to rotate. Loads are transferred through the airship to the mast so that mooring loads do not act on the vehicle. Belly mooring, while it does permit the airship to rotate, results in significant loads due to the rolling moment that must be resisted. Some structural penalty would be involved with this concept. The retention of an airship on the ground by attachment to the interconnecting structure's center point was the basis of an investigation of the BQR without empennage. In this instance, the broadside of the vehicle is presented to the wind and results in severe wind loads. Similarly, total restraint mooring offers the same disadvantages. In both cases, extreme envelope and suspension system weight penalties would accrue, if a satisfactory means of attachment could be developed for high wind speeds.

Overall, the bow-mooring concept is preferred, even though it requires the largest land area. The attributes that are most attractive are: load transference to the mast, and hence no design impact on the airship; ability to withstand extreme wind speeds; transportability; and relative ease of installation.

In terms of permanent versus remote temporary basing, there exist three levels: (1) a permanent base which serves as the operator's operational headquarters; (2) a remote base from which the airship commutes on a daily basis to the job site; and (3) a remote base that is adjacent to the job site. Another advantage of the bow-mooring system is that it is applicable to all of the above without the need for any mooring equipment changes relative to base location. The only elements that would probably be required in (1) would be a paved mooring area with anchors permanently installed. Note that it is not anticipated that hangar facilities will be constructed by the operator.

7. OPERATIONAL SCENARIOS

Various scenarios were examined to assess the applicability and operational costs associated with ground handling.

Based on the weather extremes of these areas, it appears that the design criteria that were used in the study are appropriate. In terms of basing considerations, it seems that level II basing would satisfy a majority of applications.

8. RECOMMENDATIONS

As a result of the findings of this study, the following recommendations for additional study effort are suggested:

1. Future design studies should be aimed at the further development and enhancement of a transportable bow-mooring mast system. This shall include resolution of the weight impact as it relates to the ferry mode of the BQR.
2. Additional study of snow and ice removal as well as identification of critical operational limits in cold weather areas.
3. More detailed analysis of wind load effects that will examine the overall airship reactions to these forces - envelope deformation, landing gear deflections, other structural deflections.
4. Additional study of the dynamic effects on a moored airship including kiting effects.
5. Additional study of ground anchors and enhancement of their holding power capabilities.

LIST OF SYMBOLS

Symbol	Definition
C_l	Rolling moment coefficient
C_m	Pitching moment coefficient
C_n	Yawing moment coefficient
C_x	Axial force coefficient
C_y	Lateral force coefficient
C_z	Vertical force coefficient
C_{ws}	Suspension system weight coefficient
F_{latr}	Total lateral force
F_{long}	Total longitudinal force
F_{mast}	Total resultant force
I_{cg}	Moment of inertia about center of gravity, including virtual mass
I_y	Moment of inertia about mast, including virtual mass
$(KT)_D$	Design velocity, knots
$(KT)_W$	Wind velocity, knots
L_{cg}	Center of gravity location along X
L_m	Mast location along X
m	Mass of airship, including virtual mass
P'_s	Resultant force in suspension system
W_s	Suspension system weight
β	Buoyancy ratio
Θ	Airship heading
$\dot{\Theta}$	Angular velocity about the mast

LIST OF SYMBOLS (Continued)

Symbol	Definition
$\ddot{\Theta}$	Angular acceleration about the mast
λ	Length to diameter ratio
μ	Prismatic coefficient
ψ	Wind direction
ρ	Air density

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APPENDIX A

AIRSHIP MOORING LOADS ANALYSIS
SIMULATION MODEL OUTPUTS

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*****************************************
*                                       *
*    AIRSHIP MOORING LOADS ANALYSIS     *
*                                       *
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AIRSHIP CONFIGURATION DATA

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** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE.........:    203.8 FEET
```

MOORING STYLE

```
** BOW MOORED **
MAST LOCATION RELATIVE TO NOSE.......:       .0 FEET
HEIGHT OF MAST.......................:     65.0 FEET
MOMENT OF INERTIA ABOUT MAST.........: .560E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED...........................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     15.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

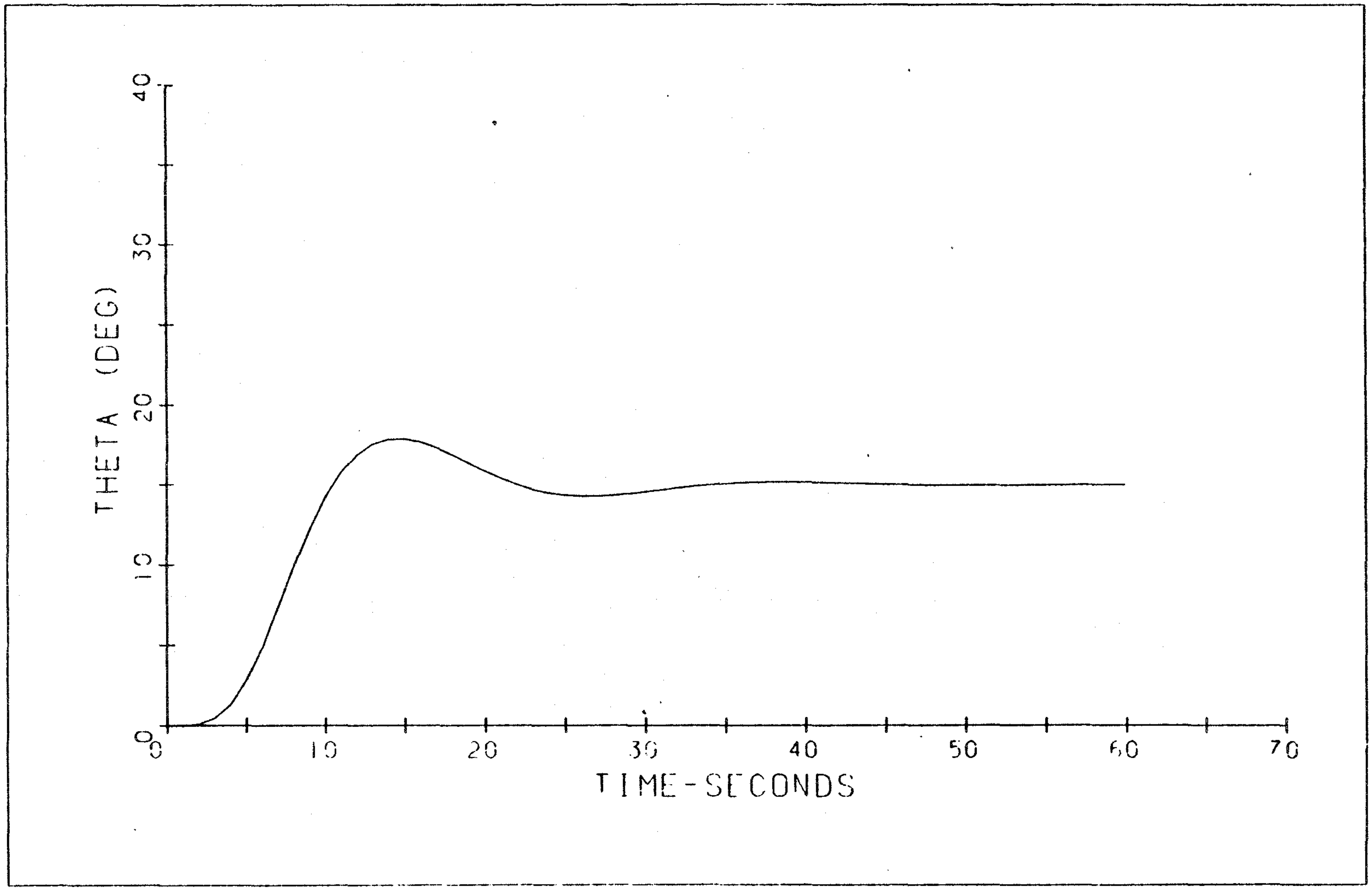
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.07	.02	.01	979	345	1039	0	0	0	0
2.0	.26	.19	.10	4128	1381	4353	0	0	0	0
3.0	.49	.57	.45	9799	3203	10309	0	0	0	0
4.0	.66	1.15	1.30	17729	6058	18736	0	0	0	0
5.0	.70	1.85	2.79	26872	10108	28710	0	0	0	0
6.0	.30	2.33	4.91	24997	11147	27370	0	0	0	0
7.0	.06	2.50	7.34	20349	11493	23371	0	0	0	0
8.0	-.14	2.45	9.83	15207	11212	18893	0	0	0	0
9.0	-.34	2.20	12.18	10773	10243	14866	0	0	0	0
10.0	-.44	1.80	14.19	6286	9008	10984	0	0	0	0
11.0	-.47	1.34	15.76	2205	8030	8327	0	0	0	0
12.0	-.44	.88	16.87	-1166	7332	7424	0	0	0	0
13.0	-.37	.48	17.54	-3690	6916	7840	0	0	0	0
14.0	-.29	.15	17.84	-5368	6719	8600	0	0	0	0
15.0	-.22	-.10	17.86	-6048	6643	8984	0	0	0	0
16.0	-.16	-.29	17.66	-5991	6613	8923	0	0	0	0
17.0	-.10	-.41	17.30	-5498	6586	8580	0	0	0	0
18.0	-.04	-.48	16.85	-4700	6541	8054	0	0	0	0
19.0	.00	-.50	16.35	-3719	6513	7501	0	0	0	0
20.0	.04	-.48	15.86	-2668	6467	6996	0	0	0	0
21.0	.07	-.42	15.41	-1637	6409	6615	0	0	0	0
22.0	.08	-.35	15.02	-701	6373	6411	0	0	0	0
23.0	.09	-.27	14.71	90	6363	6364	0	0	0	0
24.0	.09	-.18	14.49	709	6348	6388	0	0	0	0
25.0	.08	-.10	14.35	1146	6332	6435	0	0	0	0
26.0	.07	-.03	14.29	1406	6317	6471	0	0	0	0
27.0	.05	.03	14.30	1506	6300	6478	0	0	0	0
28.0	.04	.08	14.35	1473	6283	6454	0	0	0	0
29.0	.02	.11	14.45	1338	6264	6405	0	0	0	0
30.0	.01	.12	14.56	1131	6245	6346	0	0	0	0
31.0	-.00	.12	14.68	883	6236	6299	0	0	0	0
32.0	-.01	.12	14.80	622	6227	6258	0	0	0	0
33.0	-.02	.10	14.91	369	6220	6231	0	0	0	0
34.0	-.02	.08	15.01	141	6221	6222	0	0	0	0
35.0	-.02	.06	15.08	-48	6225	6225	0	0	0	0
36.0	-.02	.04	15.13	-194	6226	6229	0	0	0	0
37.0	-.02	.02	15.16	-296	6225	6232	0	0	0	0
38.0	-.02	.00	15.18	-354	6222	6232	0	0	0	0
39.0	-.01	-.01	15.17	-373	6218	6229	0	0	0	0
40.0	-.01	-.02	15.16	-360	6213	6223	0	0	0	0
41.0	-.00	-.03	15.13	-324	6208	6216	0	0	0	0
42.0	-.00	-.03	15.10	-270	6203	6208	0	0	0	0
43.0	.00	-.03	15.07	-208	6201	6204	0	0	0	0
44.0	.00	-.03	15.04	-143	6199	6200	0	0	0	0
45.0	.00	-.02	15.02	-81	6197	6198	0	0	0	0
46.0	.01	-.02	14.99	-26	6198	6199	0	0	0	0
47.0	.01	-.01	14.98	19	6200	6200	0	0	0	0

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	.01	-.01	14.97	53	6200	6201	0	0	0	0
49.0	.00	-.00	14.96	77	6200	6201	0	0	0	0
50.0	.00	-.00	14.96	90	6199	6200	0	0	0	0
51.0	.00	.00	14.96	93	6198	6199	0	0	0	0
52.0	.00	.01	14.96	89	6197	6198	0	0	0	0
53.0	.00	.01	14.97	79	6196	6196	0	0	0	0
54.0	.00	.01	14.98	65	6194	6195	0	0	0	0
55.0	-.00	.01	14.98	49	6194	6194	0	0	0	0
56.0	-.00	.01	14.99	33	6194	6194	0	0	0	0
57.0	-.00	.01	15.00	18	6193	6193	0	0	0	0
58.0	-.00	.00	15.00	5	6194	6194	0	0	0	0
59.0	-.00	.00	15.01	-5	6194	6194	0	0	0	0
60.0	-.00	.00	15.01	-13	6194	6194	0	0	0	0

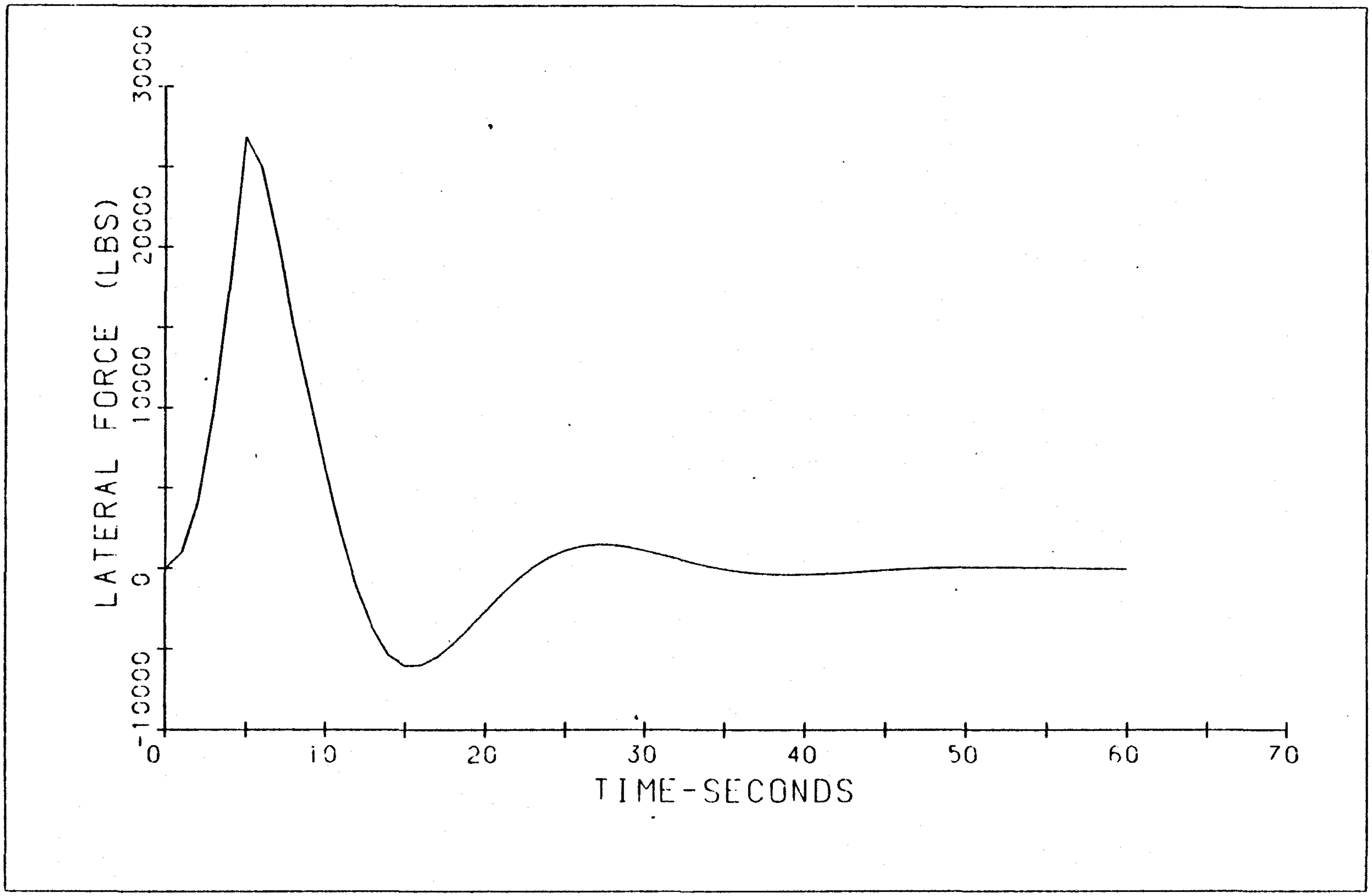
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 15°



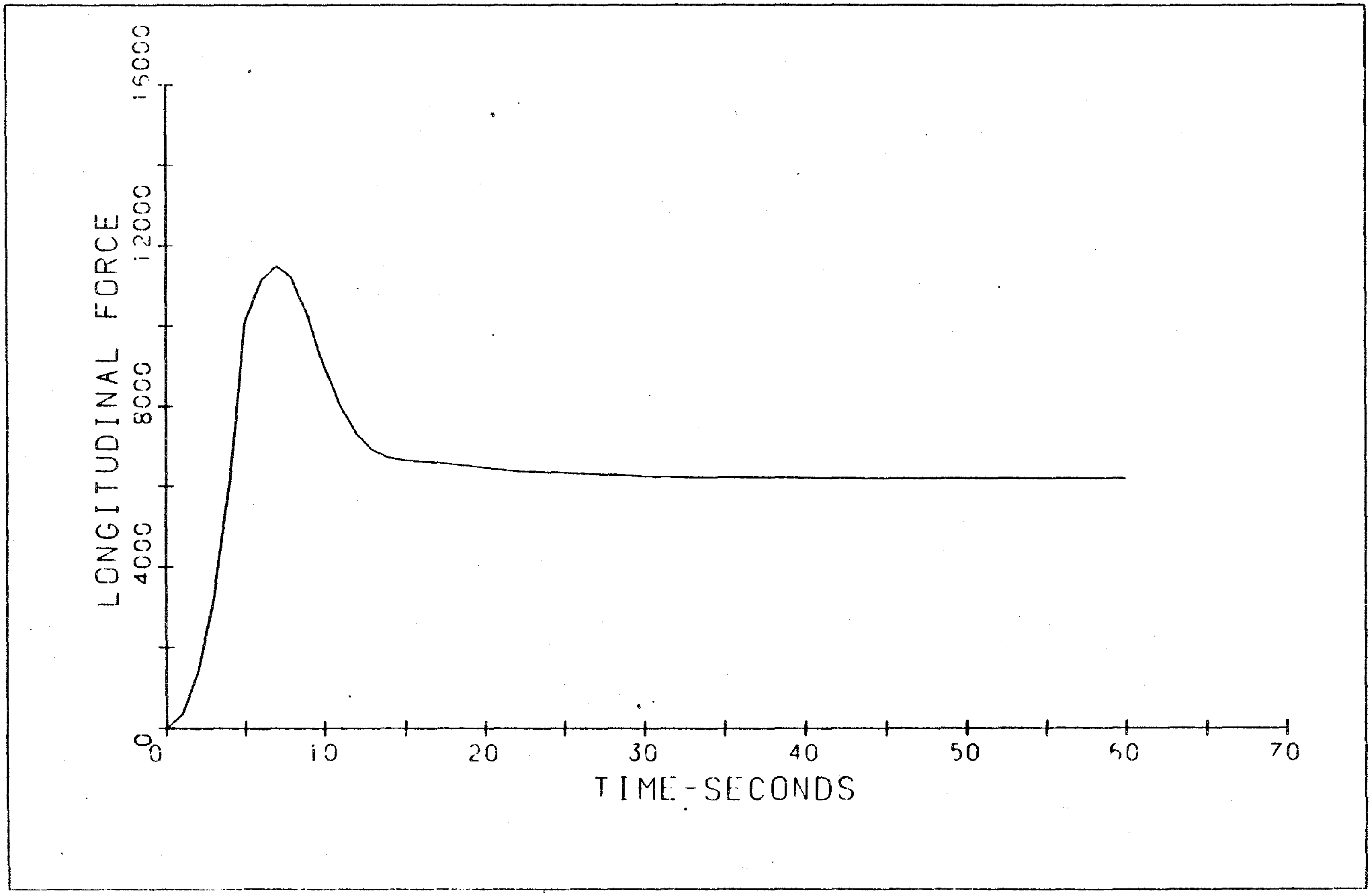
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 15°



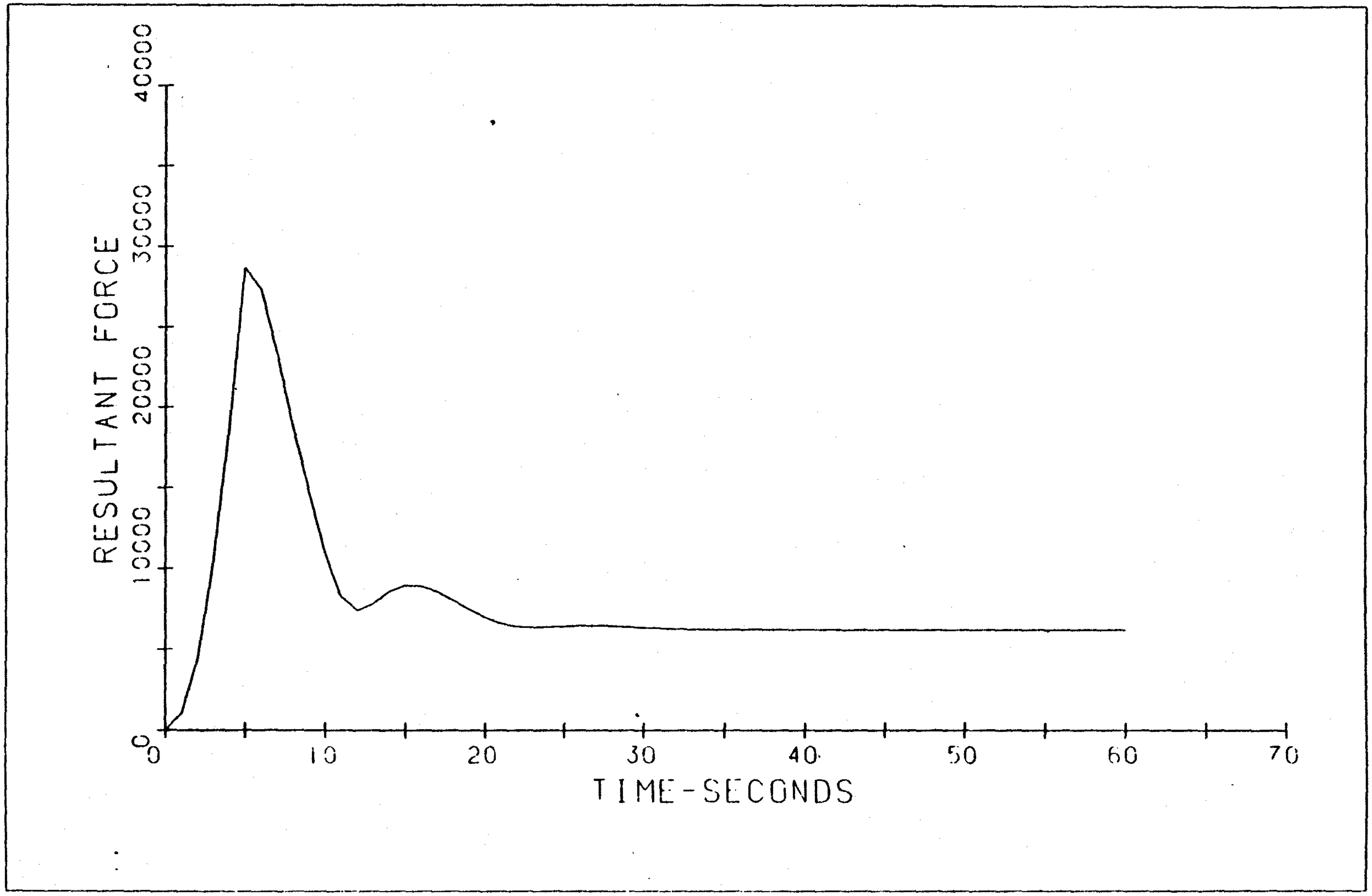
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 15°



** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 15°



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****************************************
*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
****************************************
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AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE.................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE..........:    203.8 FEET
```

MOORING STYLE

```
** BOW MOORED **
MAST LOCATION RELATIVE TO NOSE........:       .0 FEET
HEIGHT OF MAST........................:     65.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .560E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED............................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     30.0 DEGREES
THETA (DISPLACEMENT ANGLE)............:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY)..........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

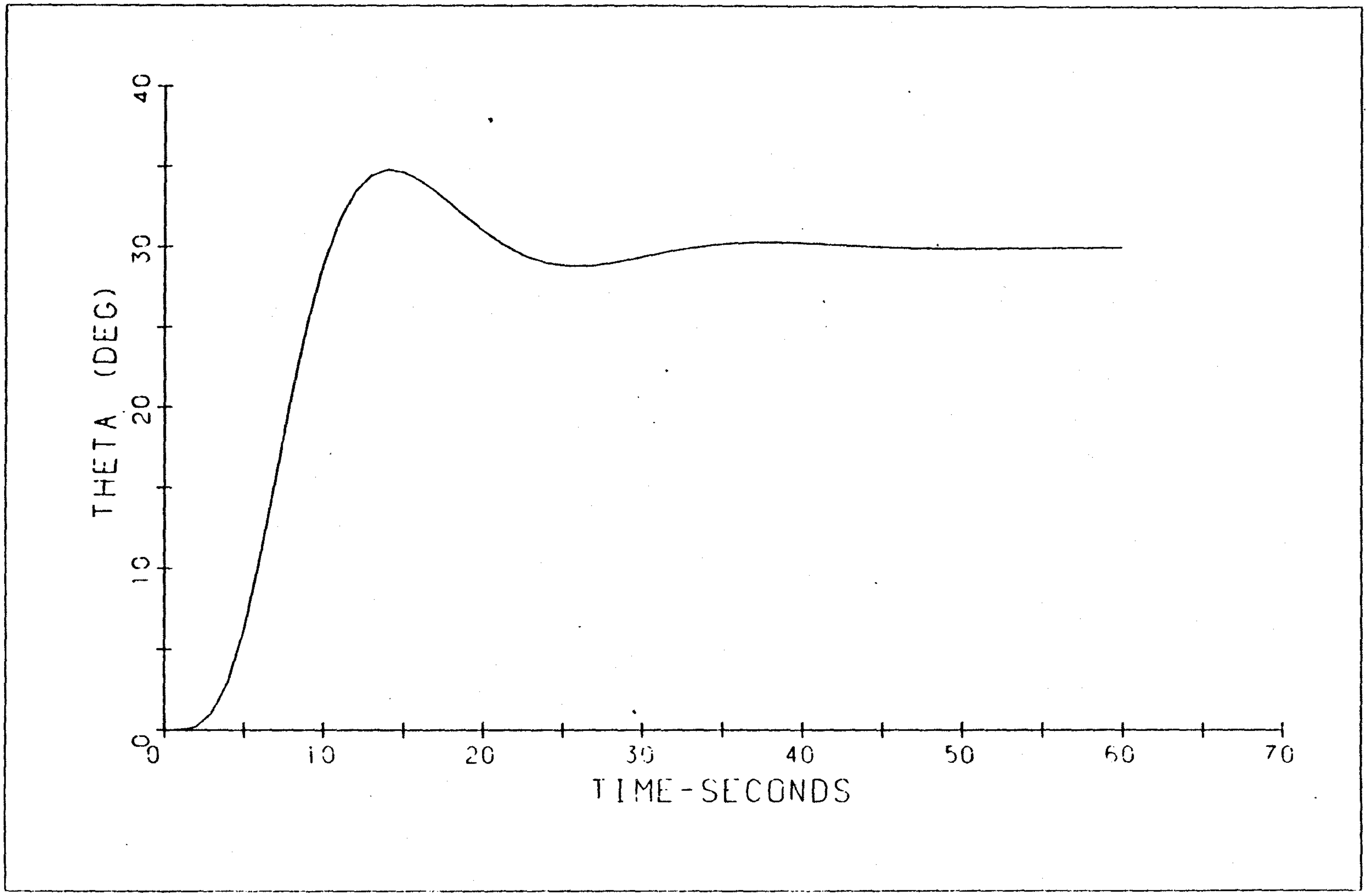
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.17	.06	.01	1565	276	1589	0	0	0	0
2.0	.60	.43	.22	6910	1324	7036	0	0	0	0
3.0	1.09	1.29	1.04	17148	3886	17583	0	0	0	0
4.0	1.40	2.55	2.94	32334	9631	33738	0	0	0	0
5.0	1.36	3.96	6.20	50735	19538	54367	0	0	0	0
6.0	.46	4.83	10.67	47984	24989	54101	0	0	0	0
7.0	.01	5.06	15.65	38467	26368	46636	0	0	0	0
8.0	-.49	4.81	20.63	30154	24386	38780	0	0	0	0
9.0	-.81	4.14	25.13	21200	19779	28994	0	0	0	0
10.0	-.95	3.24	28.83	12400	14812	19317	0	0	0	0
11.0	-.94	2.29	31.60	4635	11056	11989	0	0	0	0
12.0	-.83	1.40	33.44	-1533	8653	8787	0	0	0	0
13.0	-.67	.65	34.45	-5917	7437	9504	0	0	0	0
14.0	-.50	.06	34.79	-8616	7005	11104	0	0	0	0
15.0	-.33	-.35	34.63	-9890	6945	12085	0	0	0	0
16.0	-.21	-.61	34.14	-9633	6977	11895	0	0	0	0
17.0	-.11	-.76	33.45	-8507	6983	11006	0	0	0	0
18.0	-.03	-.83	32.64	-6985	6949	9853	0	0	0	0
19.0	.04	-.82	31.81	-5264	6892	8673	0	0	0	0
20.0	.09	-.75	31.02	-3512	6769	7626	0	0	0	0
21.0	.13	-.64	30.31	-1865	6637	6894	0	0	0	0
22.0	.14	-.51	29.73	-425	6566	6579	0	0	0	0
23.0	.15	-.36	29.30	745	6506	6548	0	0	0	0
24.0	.14	-.22	29.00	1614	6454	6653	0	0	0	0
25.0	.12	-.09	28.85	2181	6415	6776	0	0	0	0
26.0	.10	.01	28.81	2466	6385	6845	0	0	0	0
27.0	.07	.10	28.87	2507	6360	6837	0	0	0	0
28.0	.05	.16	29.00	2353	6334	6757	0	0	0	0
29.0	.02	.19	29.17	2056	6305	6632	0	0	0	0
30.0	.00	.21	29.38	1668	6284	6502	0	0	0	0
31.0	-.01	.20	29.58	1238	6270	6391	0	0	0	0
32.0	-.02	.18	29.78	805	6254	6305	0	0	0	0
33.0	-.03	.16	29.95	403	6244	6257	0	0	0	0
34.0	-.04	.12	30.08	56	6249	6249	0	0	0	0
35.0	-.04	.08	30.19	-222	6251	6255	0	0	0	0
36.0	-.03	.05	30.25	-426	6249	6264	0	0	0	0
37.0	-.03	.02	30.29	-555	6245	6270	0	0	0	0
38.0	-.02	-.01	30.29	-616	6239	6269	0	0	0	0
39.0	-.02	-.03	30.28	-618	6231	6262	0	0	0	0
40.0	-.01	-.04	30.24	-573	6223	6249	0	0	0	0
41.0	-.01	-.05	30.20	-495	6214	6233	0	0	0	0
42.0	-.00	-.05	30.15	-397	6209	6221	0	0	0	0
43.0	.00	-.05	30.10	-289	6205	6212	0	0	0	0
44.0	.01	-.04	30.05	-182	6202	6205	0	0	0	0
45.0	.01	-.04	30.01	-84	6202	6202	0	0	0	0
46.0	.01	-.03	29.97	-1	6204	6204	0	0	0	0
47.0	.01	-.02	29.95	65	6206	6206	0	0	0	0

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	.01	-.01	29.93	113	6206	6207	0	0	0	0
49.0	.01	-.00	29.93	142	6205	6207	0	0	0	0
50.0	.01	.00	29.93	155	6203	6205	0	0	0	0
51.0	.00	.01	29.93	153	6201	6203	0	0	0	0
52.0	.00	.01	29.94	140	6199	6201	0	0	0	0
53.0	.00	.01	29.95	120	6197	6198	0	0	0	0
54.0	-.00	.01	29.97	95	6196	6196	0	0	0	0
55.0	-.00	.01	29.98	68	6195	6195	0	0	0	0
56.0	-.00	.01	29.99	42	6194	6194	0	0	0	0
57.0	-.00	.01	30.00	18	6194	6194	0	0	0	0
58.0	-.00	.01	30.01	-1	6195	6195	0	0	0	0
59.0	-.00	.00	30.01	-17	6195	6195	0	0	0	0
60.0	-.00	.00	30.02	-28	6195	6195	0	0	0	0

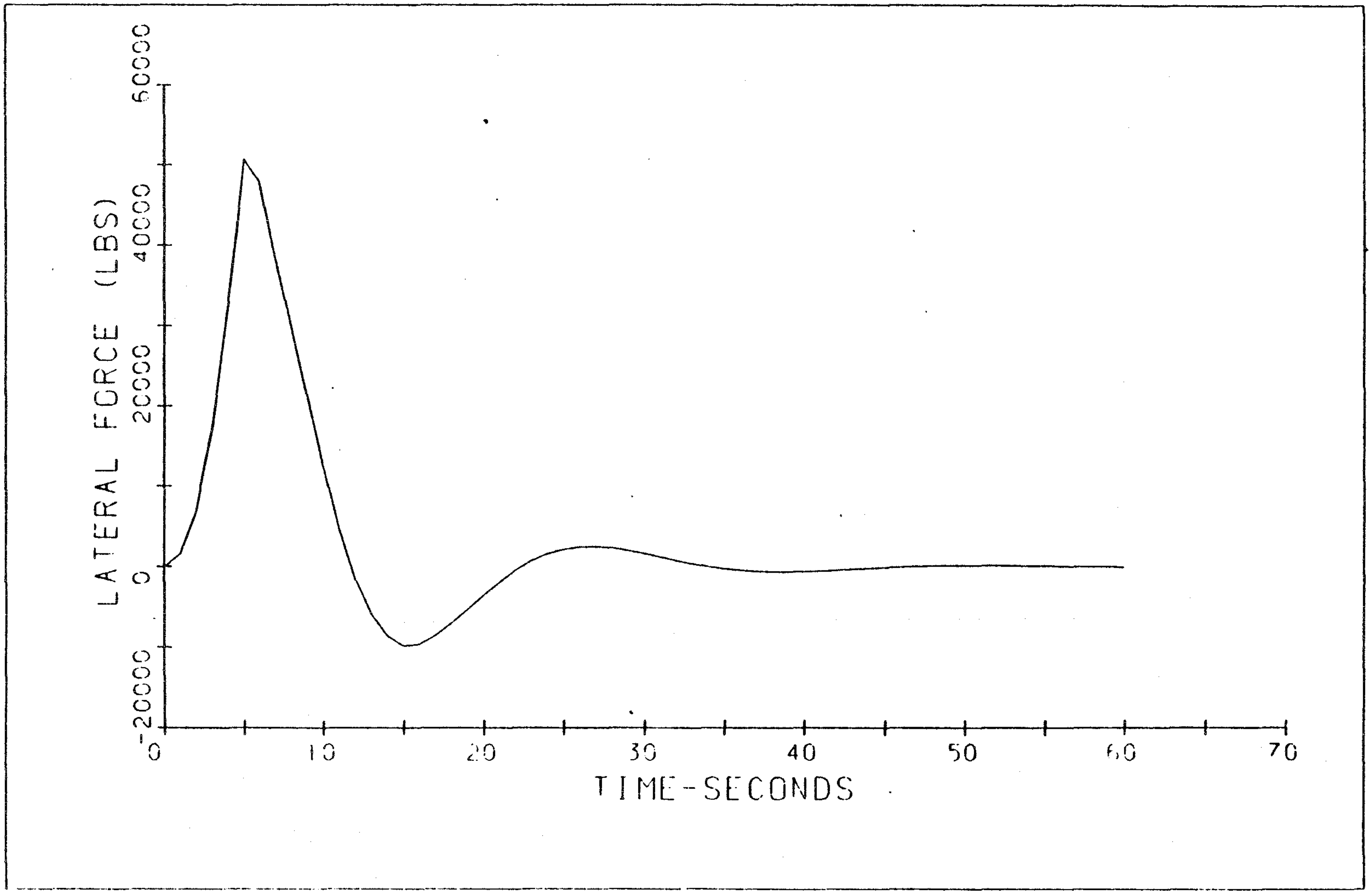
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 30°



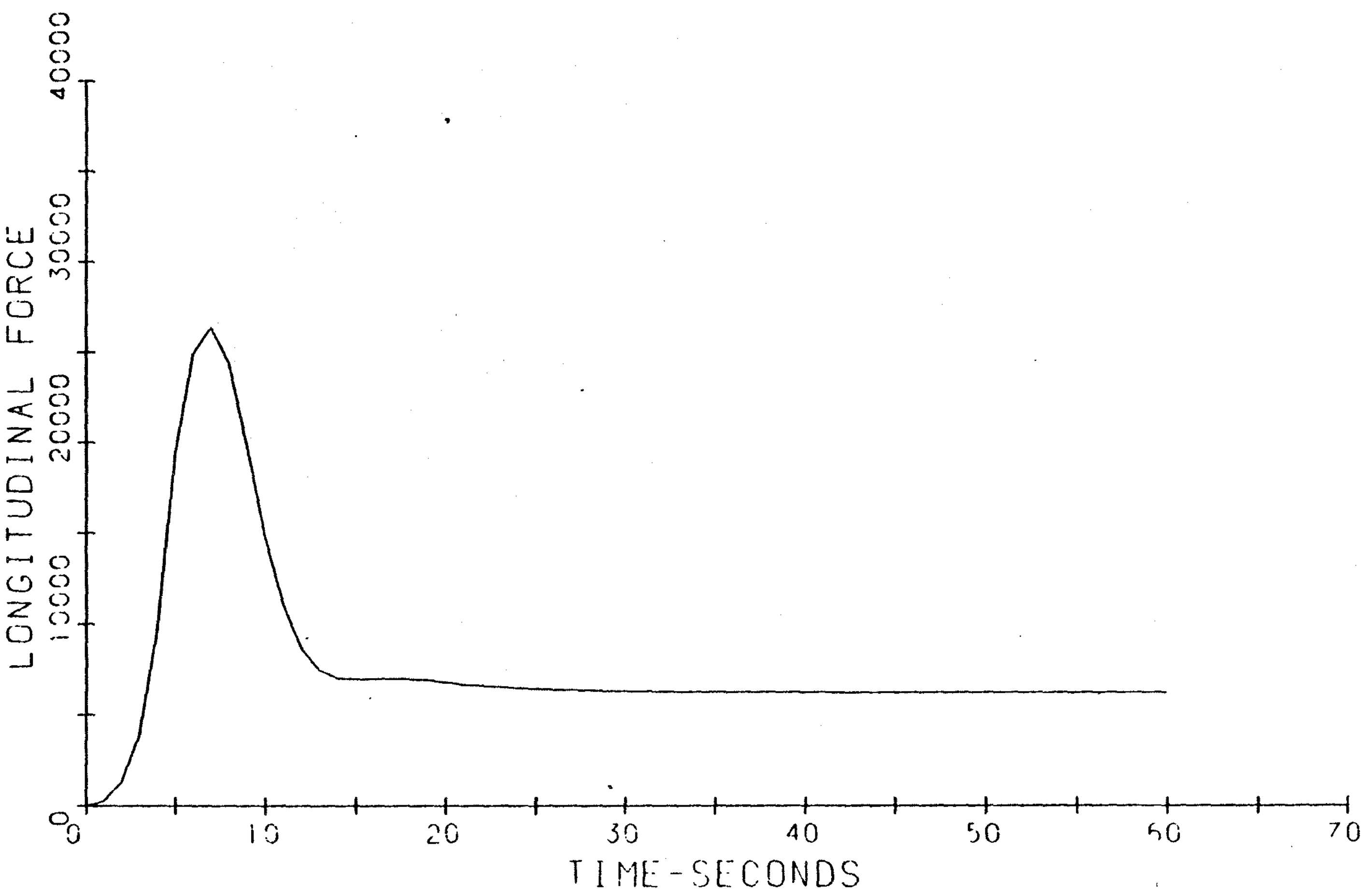
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 30°



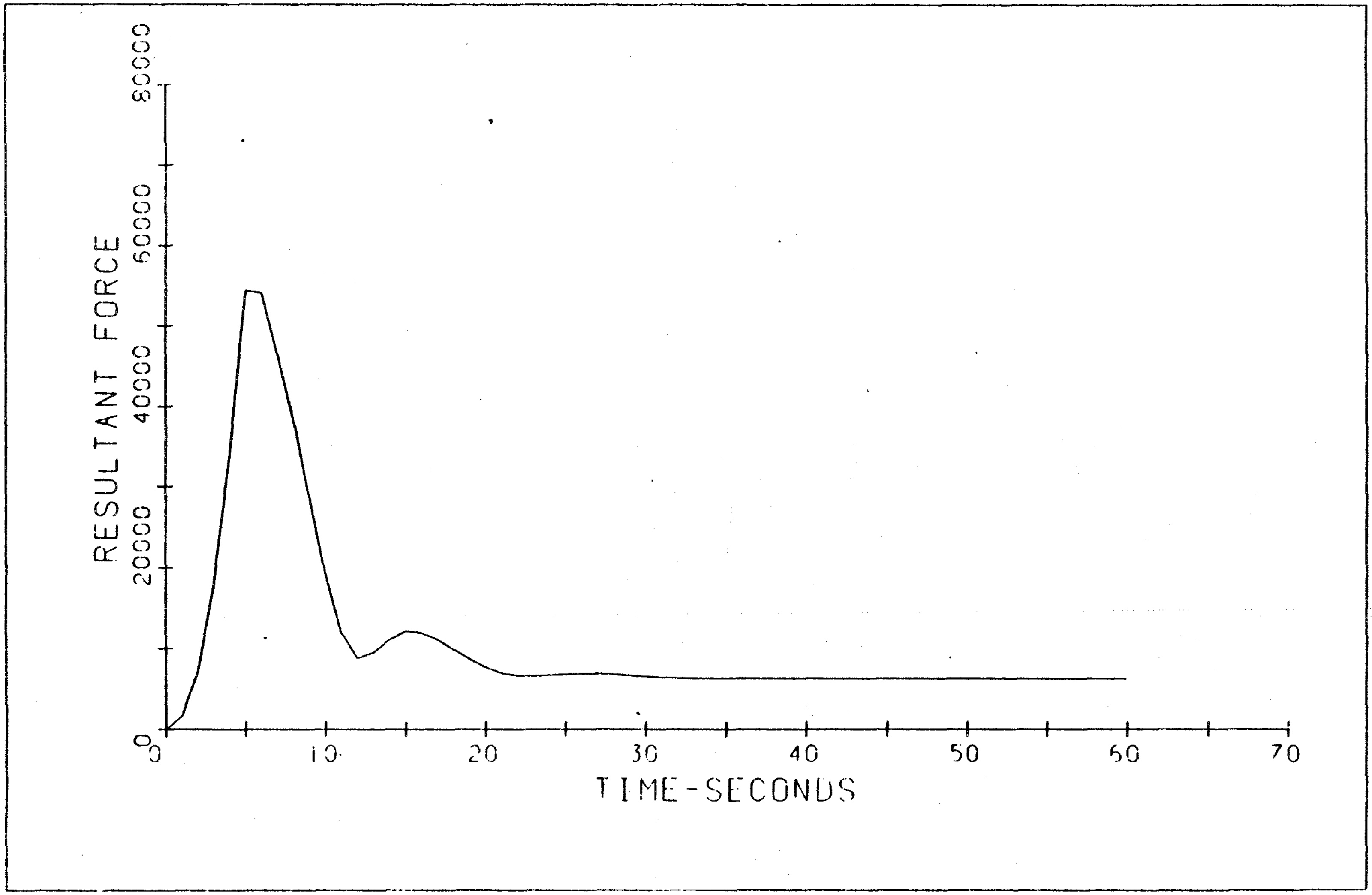
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 30°



** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 30°



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****************************************
*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
****************************************
```

AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE.........:    203.8 FEET
```

MOORING STYLE

```
** BOW MOORED **
MAST LOCATION RELATIVE TO NOSE.......:       .0 FEET
HEIGHT OF MAST.......................:     65.0 FEET
MOMENT OF INERTIA ABOUT MAST.........: .560E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED...........................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     45.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

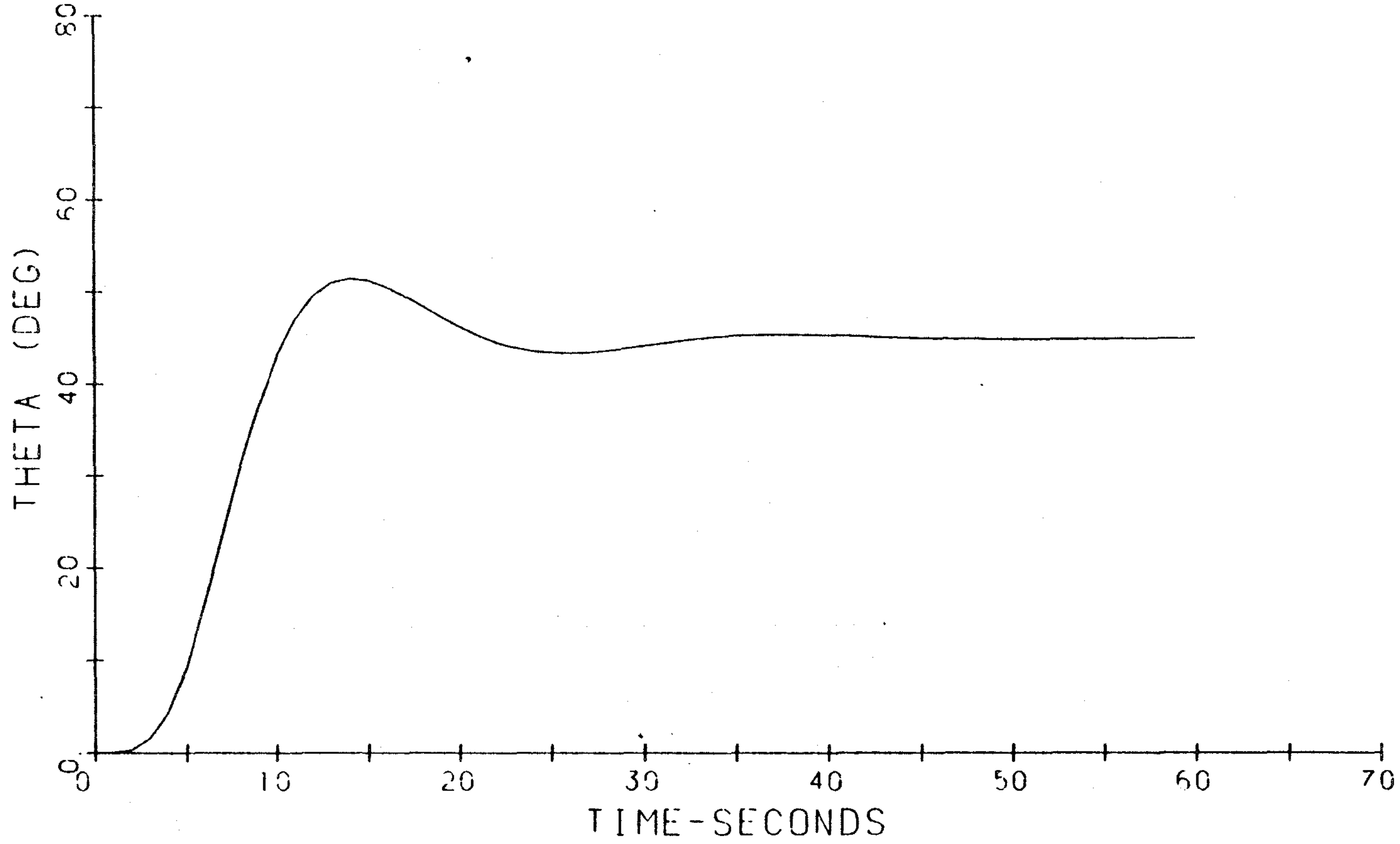
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.26	.09	.02	1850	-197	1861	0	0	0	0
2.0	.90	.65	.34	8714	-146	8715	0	0	0	0
3.0	1.60	1.91	1.56	22611	2868	22792	0	0	0	0
4.0	2.07	3.77	4.36	43476	12877	45343	0	0	0	0
5.0	2.08	5.90	9.20	68130	30927	74820	0	0	0	0
6.0	.71	7.23	15.88	65858	45243	79901	0	0	0	0
7.0	-.03	7.56	23.33	57479	50005	76186	0	0	0	0
8.0	-.76	7.14	30.75	45909	45563	64681	0	0	0	0
9.0	-1.24	6.12	37.42	33062	35321	48381	0	0	0	0
10.0	-1.43	4.76	42.87	20161	24257	31542	0	0	0	0
11.0	-1.40	3.33	46.92	8506	15825	17966	0	0	0	0
12.0	-1.22	2.02	49.58	-759	10639	10666	0	0	0	0
13.0	-.97	.92	51.03	-7231	8117	10870	0	0	0	0
14.0	-.72	.08	51.50	-11154	7295	13327	0	0	0	0
15.0	-.47	-.51	51.26	-12968	7266	14865	0	0	0	0
16.0	-.26	-.87	50.55	-13017	7415	14981	0	0	0	0
17.0	-.13	-1.07	49.57	-11379	7489	13623	0	0	0	0
18.0	-.02	-1.14	48.46	-9243	7482	11892	0	0	0	0
19.0	.07	-1.12	47.32	-6871	7379	10083	0	0	0	0
20.0	.13	-1.02	46.25	-4486	7161	8451	0	0	0	0
21.0	.18	-.86	45.31	-2265	6930	7291	0	0	0	0
22.0	.20	-.67	44.54	-340	6784	6792	0	0	0	0
23.0	.20	-.47	43.97	1206	6656	6765	0	0	0	0
24.0	.18	-.28	43.60	2339	6559	6963	0	0	0	0
25.0	.16	-.11	43.41	3059	6493	7178	0	0	0	0
26.0	.13	.04	43.37	3399	6452	7293	0	0	0	0
27.0	.09	.15	43.47	3415	6421	7273	0	0	0	0
28.0	.06	.23	43.66	3173	6391	7135	0	0	0	0
29.0	.03	.27	43.91	2745	6355	6922	0	0	0	0
30.0	.00	.28	44.19	2203	6332	6704	0	0	0	0
31.0	-.02	.27	44.47	1610	6310	6513	0	0	0	0
32.0	-.04	.25	44.73	1022	6285	6368	0	0	0	0
33.0	-.04	.21	44.96	481	6270	6289	0	0	0	0
34.0	-.05	.16	45.14	18	6275	6275	0	0	0	0
35.0	-.05	.11	45.27	-349	6275	6284	0	0	0	0
36.0	-.04	.06	45.36	-613	6271	6300	0	0	0	0
37.0	-.04	.02	45.40	-776	6264	6312	0	0	0	0
38.0	-.03	-.01	45.40	-847	6255	6312	0	0	0	0
39.0	-.02	-.04	45.37	-840	6244	6301	0	0	0	0
40.0	-.01	-.06	45.32	-772	6233	6280	0	0	0	0
41.0	-.01	-.07	45.26	-660	6221	6256	0	0	0	0
42.0	.00	-.07	45.19	-523	6215	6237	0	0	0	0
43.0	.01	-.07	45.12	-375	6210	6222	0	0	0	0
44.0	.01	-.06	45.06	-230	6206	6211	0	0	0	0
45.0	.01	-.05	45.00	-99	6206	6207	0	0	0	0
46.0	.01	-.04	44.96	12	6210	6210	0	0	0	0
47.0	.01	-.03	44.93	99	6211	6212	0	0	0	0

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	.01	-.01	44.91	160	6211	6213	0	0	0	0
49.0	.01	-.00	44.90	197	6209	6213	0	0	0	0
50.0	.01	.00	44.90	212	6207	6211	0	0	0	0
51.0	.01	.01	44.91	207	6204	6208	0	0	0	0
52.0	.00	.01	44.92	188	6201	6204	0	0	0	0
53.0	.00	.02	44.94	159	6198	6200	0	0	0	0
54.0	-.00	.02	44.96	125	6197	6198	0	0	0	0
55.0	-.00	.02	44.97	88	6196	6196	0	0	0	0
56.0	-.00	.01	44.99	52	6195	6195	0	0	0	0
57.0	-.00	.01	45.00	20	6195	6195	0	0	0	0
58.0	-.00	.01	45.01	-5	6196	6196	0	0	0	0
59.0	-.00	.01	45.02	-26	6197	6197	0	0	0	0
60.0	-.00	.00	45.02	-40	6197	6197	0	0	0	0

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

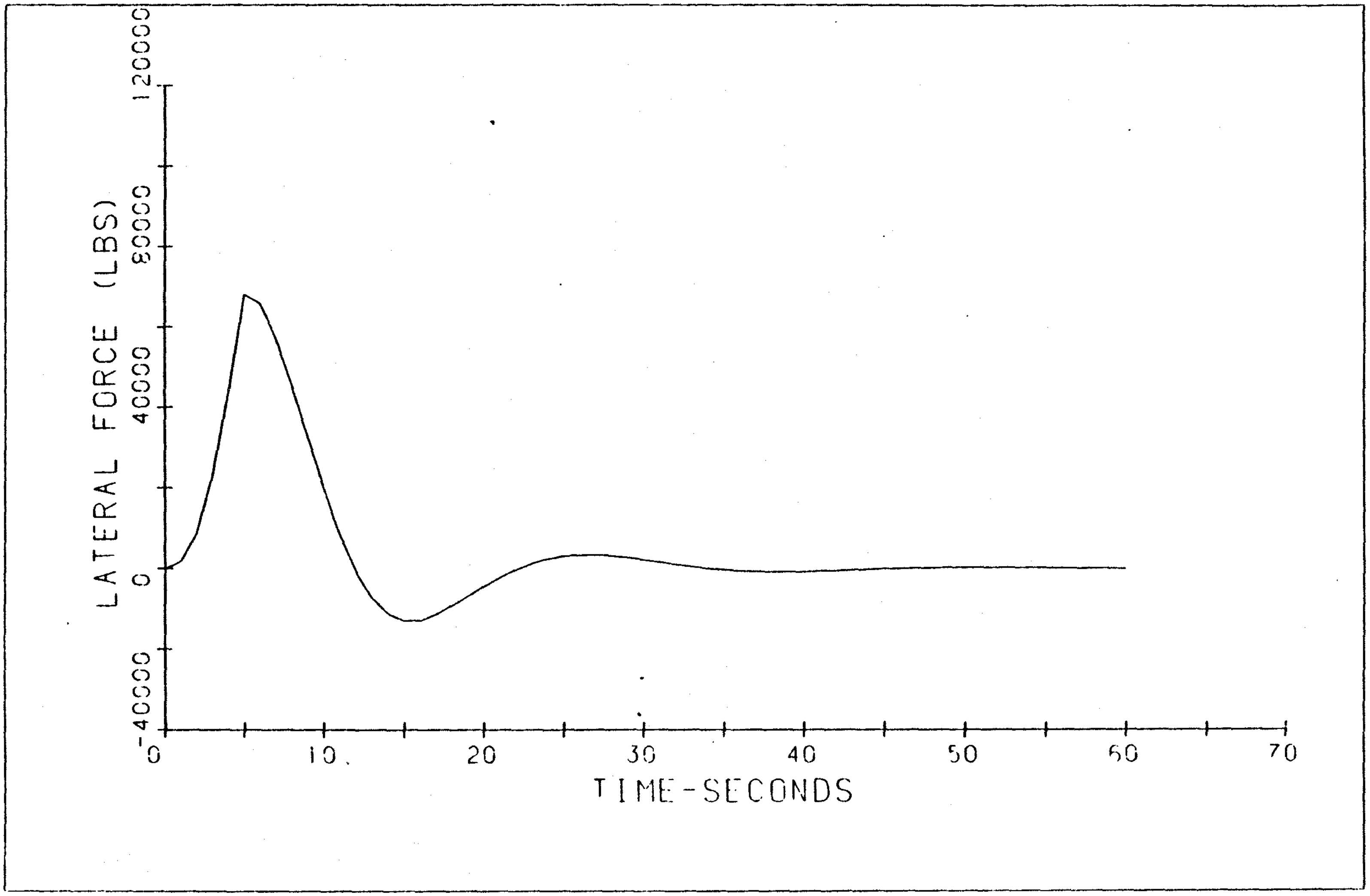
Wind = 60 Knots @ 45°



** 75 TON HLA *WITH* EMPENNAGE **

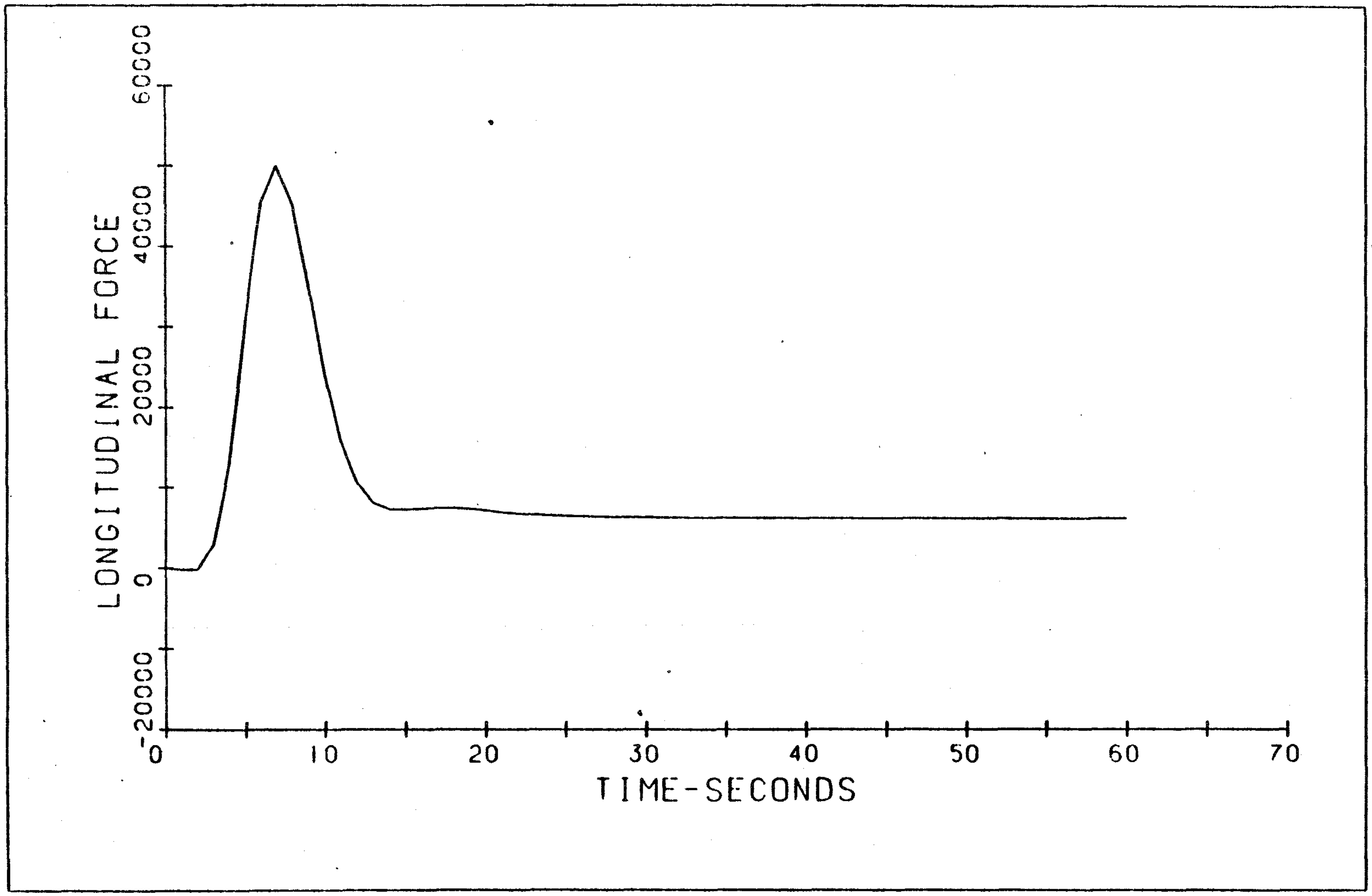
** BOW MOORED **

Wind = 60 Knots @ 45°



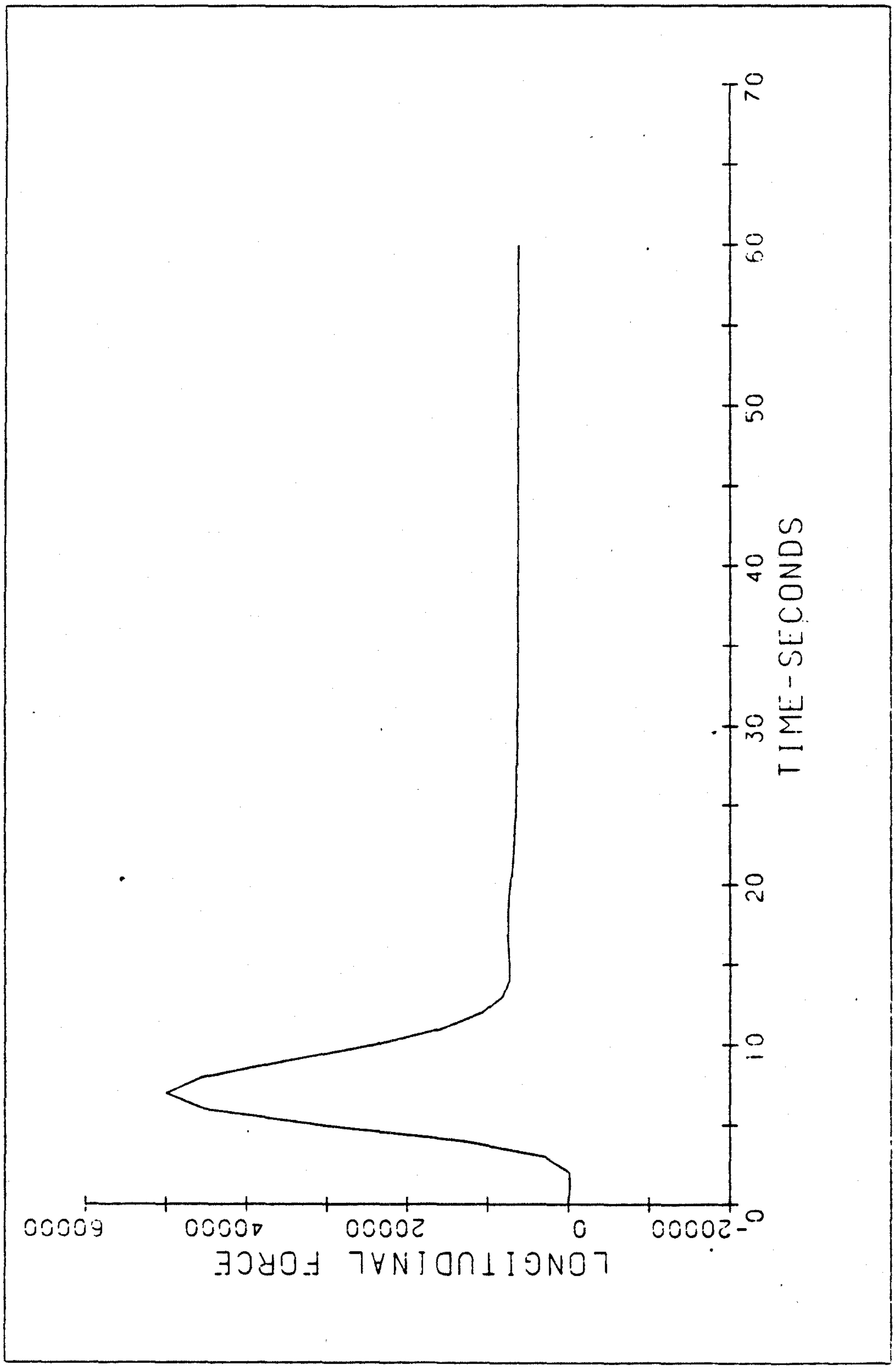
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 45°



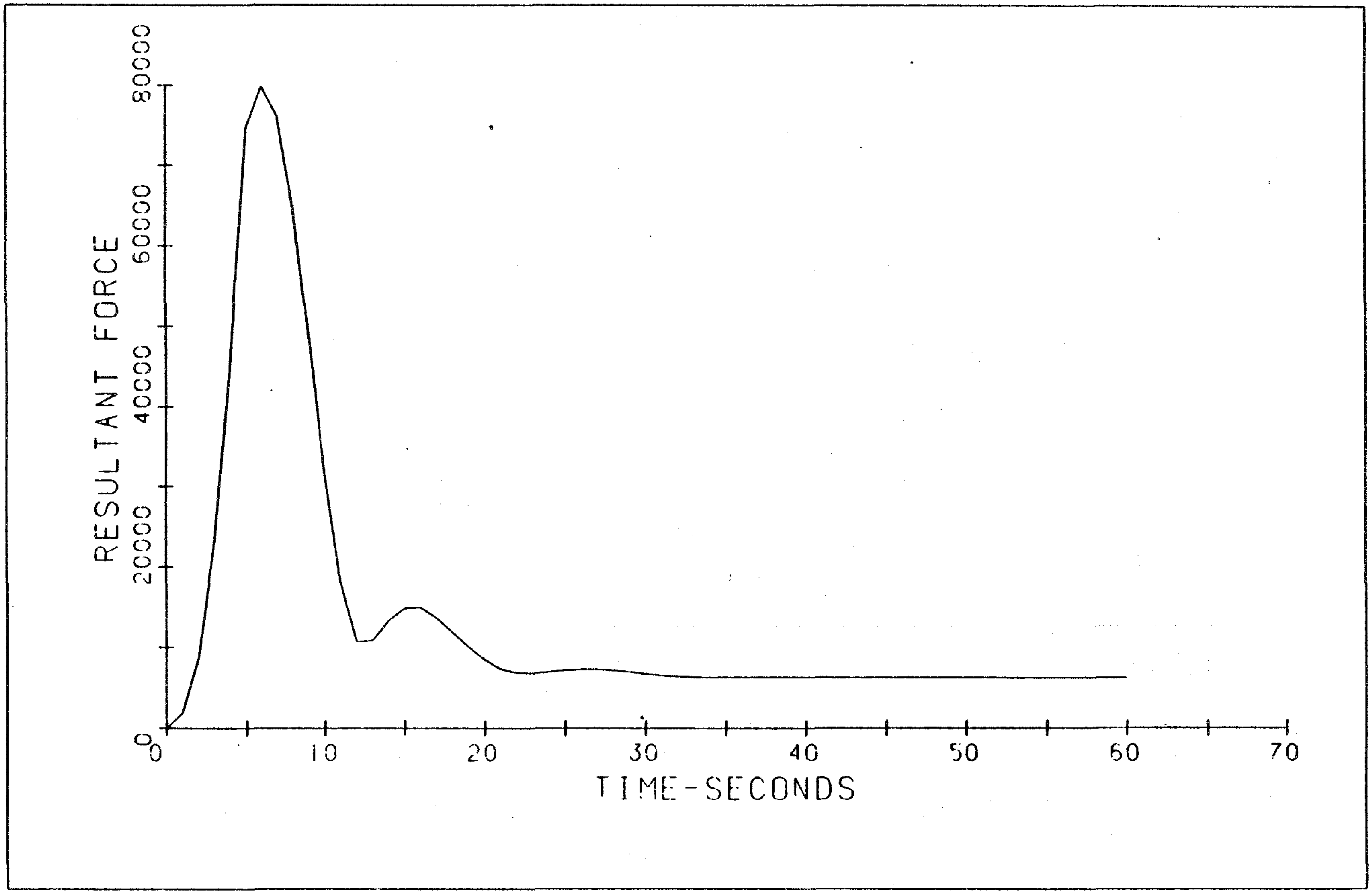
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 45°



** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 45°



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*                                      *
*     AIRSHIP MOORING LOADS ANALYSIS   *
*                                      *
****************************************
```

AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE.........:    203.8 FEET
```

MOORING STYLE

```
** BOW MOORED **
MAST LOCATION RELATIVE TO NOSE.......:       .0 FEET
HEIGHT OF MAST.......................:     65.0 FEET
MOMENT OF INERTIA ABOUT MAST.........: .560E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED...........................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     60.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **

** BOW MOORED **

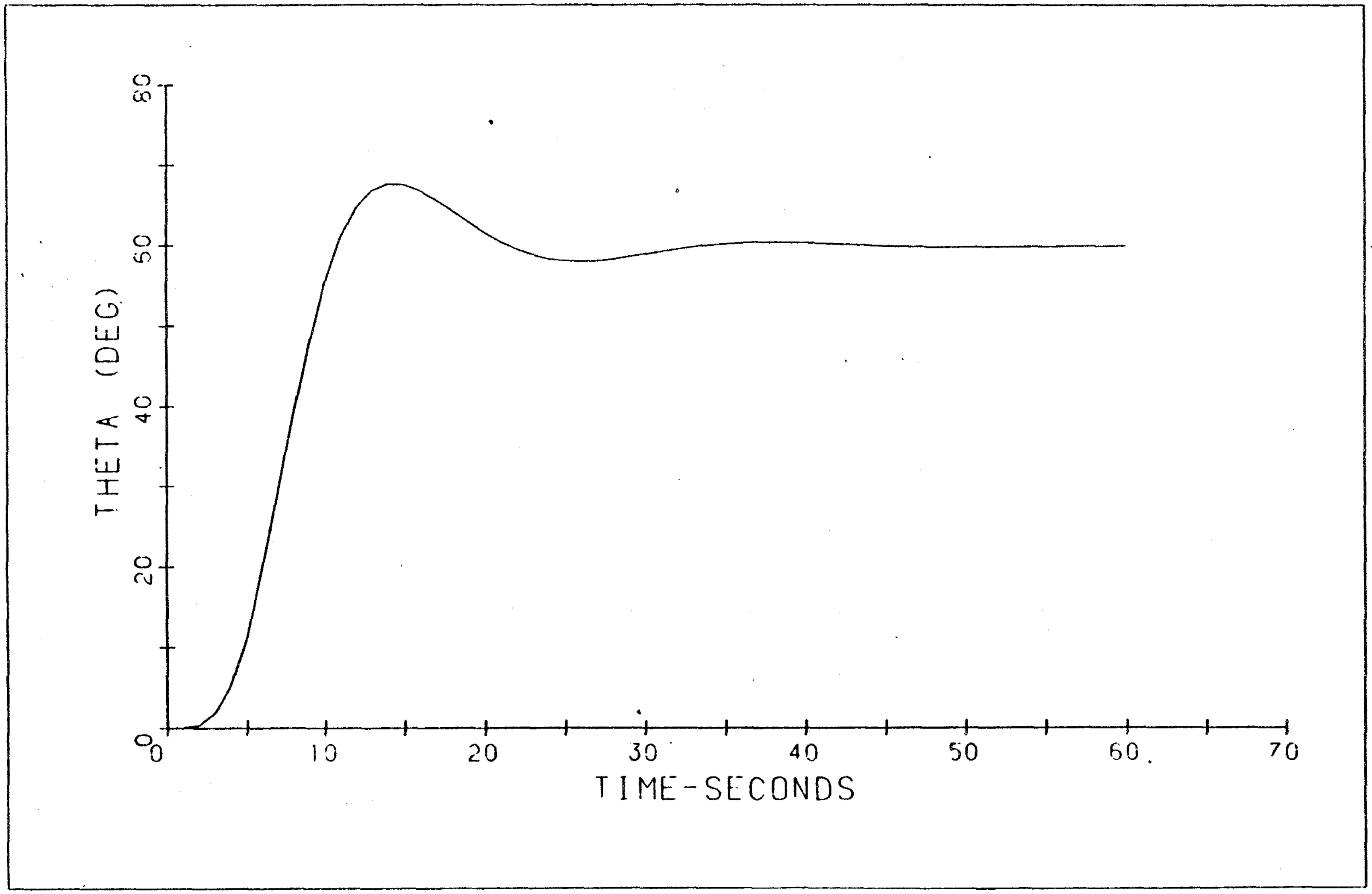
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.30	.10	.03	2071	-727	2195	0	0	0	0
2.0	1.06	.76	.40	9460	-1994	9668	0	0	0	0
3.0	1.95	2.27	1.84	24062	4	24062	0	0	0	0
4.0	2.59	4.58	5.20	49156	12256	50661	0	0	0	0
5.0	2.78	7.30	11.13	83515	40015	92607	0	0	0	0
6.0	1.18	9.25	19.53	81829	67010	105766	0	0	0	0
7.0	.14	9.86	29.16	72351	78416	106694	0	0	0	0
8.0	-.82	9.51	38.93	63846	75158	98615	0	0	0	0
9.0	-1.54	8.31	47.89	48476	59231	76539	0	0	0	0
10.0	-1.89	6.55	55.35	32013	39710	51007	0	0	0	0
11.0	-1.87	4.65	60.95	16150	23964	28898	0	0	0	0
12.0	-1.62	2.89	64.70	3054	14179	14504	0	0	0	0
13.0	-1.28	1.44	66.84	-6378	9354	11321	0	0	0	0
14.0	-.96	.32	67.69	-12012	7646	14240	0	0	0	0
15.0	-.64	-.48	67.58	-14836	7462	16607	0	0	0	0
16.0	-.37	-.98	66.83	-15527	7733	17347	0	0	0	0
17.0	-.19	-1.24	65.71	-14033	7922	16115	0	0	0	0
18.0	-.05	-1.36	64.39	-11559	7957	14033	0	0	0	0
19.0	.06	-1.35	63.03	-8752	7870	11770	0	0	0	0
20.0	.15	-1.24	61.72	-5882	7594	9606	0	0	0	0
21.0	.20	-1.06	60.56	-3174	7260	7923	0	0	0	0
22.0	.24	-.84	59.60	-885	7013	7068	0	0	0	0
23.0	.24	-.60	58.88	1094	6809	6896	0	0	0	0
24.0	.22	-.37	58.40	2578	6660	7141	0	0	0	0
25.0	.19	-.16	58.14	3514	6563	7445	0	0	0	0
26.0	.16	.02	58.07	3991	6507	7634	0	0	0	0
27.0	.12	.16	58.16	4073	6472	7647	0	0	0	0
28.0	.08	.25	58.36	3834	6442	7497	0	0	0	0
29.0	.04	.31	58.65	3360	6404	7233	0	0	0	0
30.0	.01	.34	58.97	2736	6374	6937	0	0	0	0
31.0	-.02	.33	59.31	2040	6351	6670	0	0	0	0
32.0	-.04	.30	59.62	1340	6319	6459	0	0	0	0
33.0	-.05	.25	59.90	688	6295	6332	0	0	0	0
34.0	-.06	.20	60.12	122	6295	6296	0	0	0	0
35.0	-.06	.14	60.29	-332	6293	6301	0	0	0	0
36.0	-.05	.08	60.40	-666	6287	6322	0	0	0	0
37.0	-.05	.03	60.46	-879	6278	6339	0	0	0	0
38.0	-.04	-.01	60.47	-980	6268	6344	0	0	0	0
39.0	-.03	-.04	60.44	-987	6256	6333	0	0	0	0
40.0	-.02	-.06	60.39	-918	6243	6310	0	0	0	0
41.0	-.01	-.08	60.32	-793	6229	6279	0	0	0	0
42.0	-.00	-.08	60.24	-637	6220	6253	0	0	0	0
43.0	.01	-.08	60.15	-464	6215	6232	0	0	0	0
44.0	.01	-.07	60.08	-293	6210	6216	0	0	0	0
45.0	.01	-.06	60.01	-136	6208	6210	0	0	0	0
46.0	.01	-.05	59.96	0	6212	6212	0	0	0	0
47.0	.01	-.03	59.92	106	6214	6215	0	0	0	0

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	.01	-.02	59.89	184	6214	6217	0	0	0	0
49.0	.01	-.01	59.88	232	6213	6217	0	0	0	0
50.0	.01	.00	59.88	254	6211	6216	0	0	0	0
51.0	.01	.01	59.89	252	6207	6213	0	0	0	0
52.0	.00	.02	59.90	233	6204	6208	0	0	0	0
53.0	.00	.02	59.92	201	6200	6203	0	0	0	0
54.0	-.00	.02	59.94	162	6198	6200	0	0	0	0
55.0	-.00	.02	59.96	121	6197	6198	0	0	0	0
56.0	-.00	.02	59.98	78	6196	6196	0	0	0	0
57.0	-.00	.02	60.00	39	6196	6196	0	0	0	0
58.0	-.00	.01	60.01	7	6197	6197	0	0	0	0
59.0	-.00	.01	60.02	-19	6197	6197	0	0	0	0
60.0	-.00	.01	60.02	-37	6197	6197	0	0	0	0

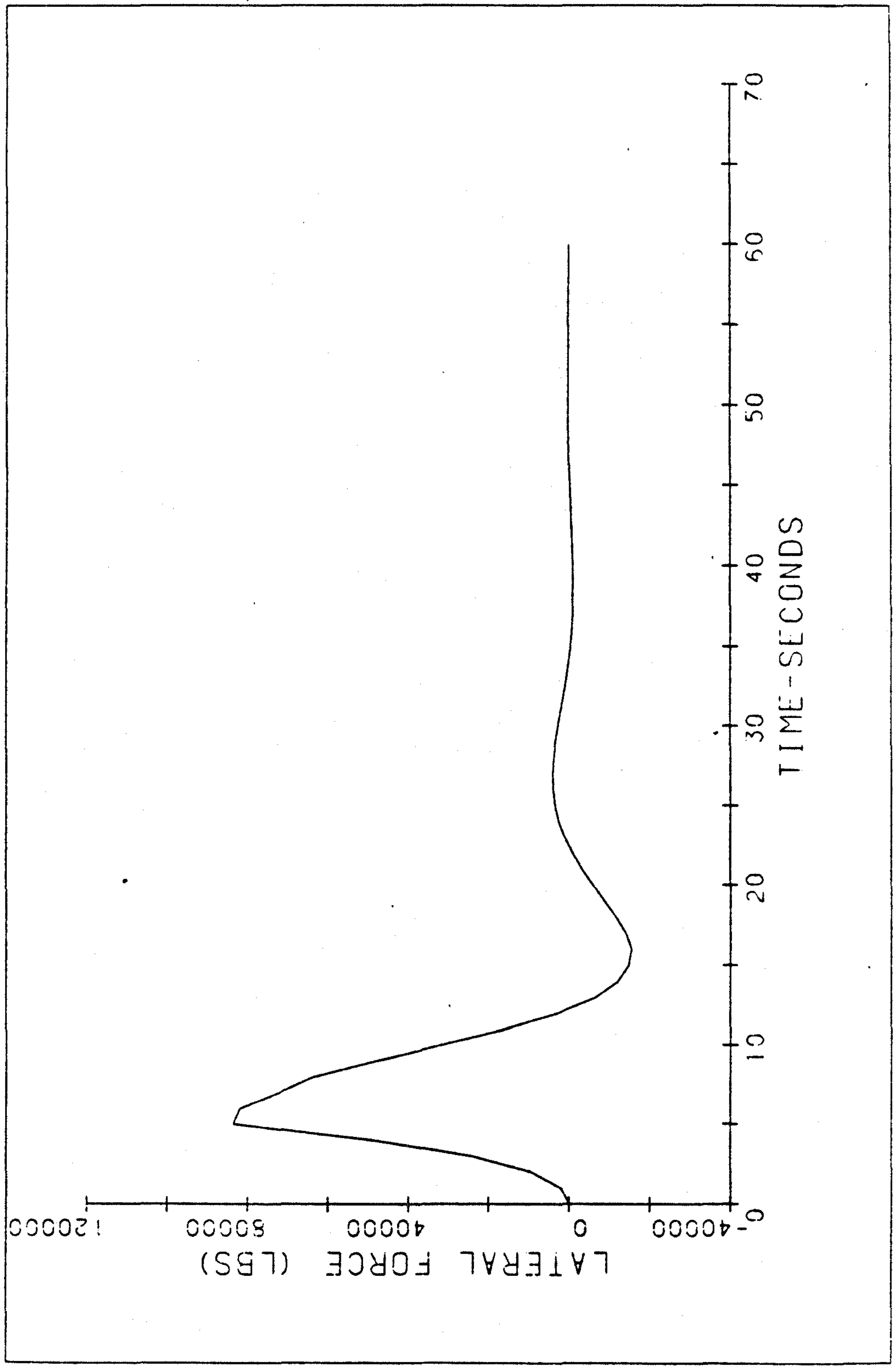
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 60°



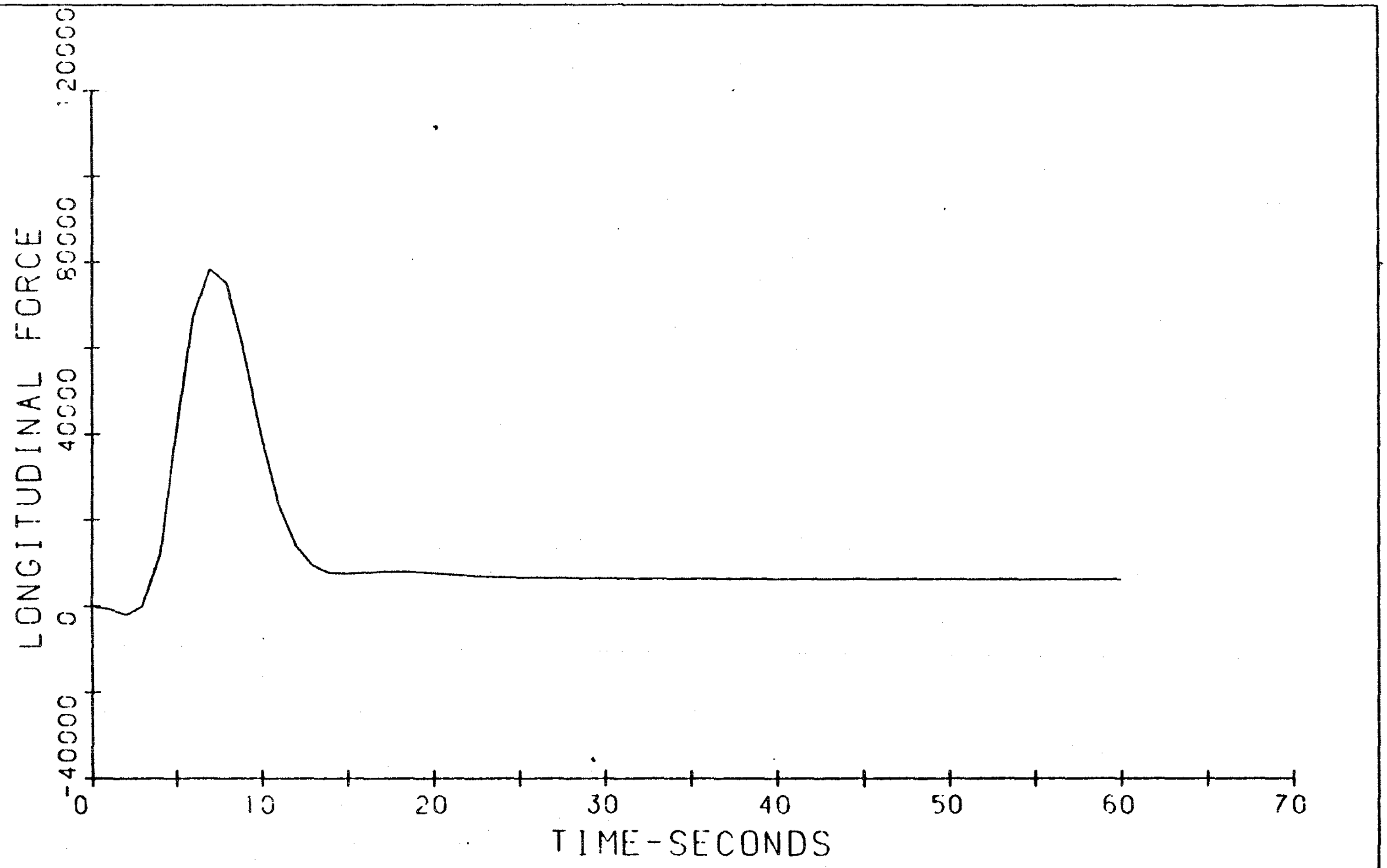
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 60°



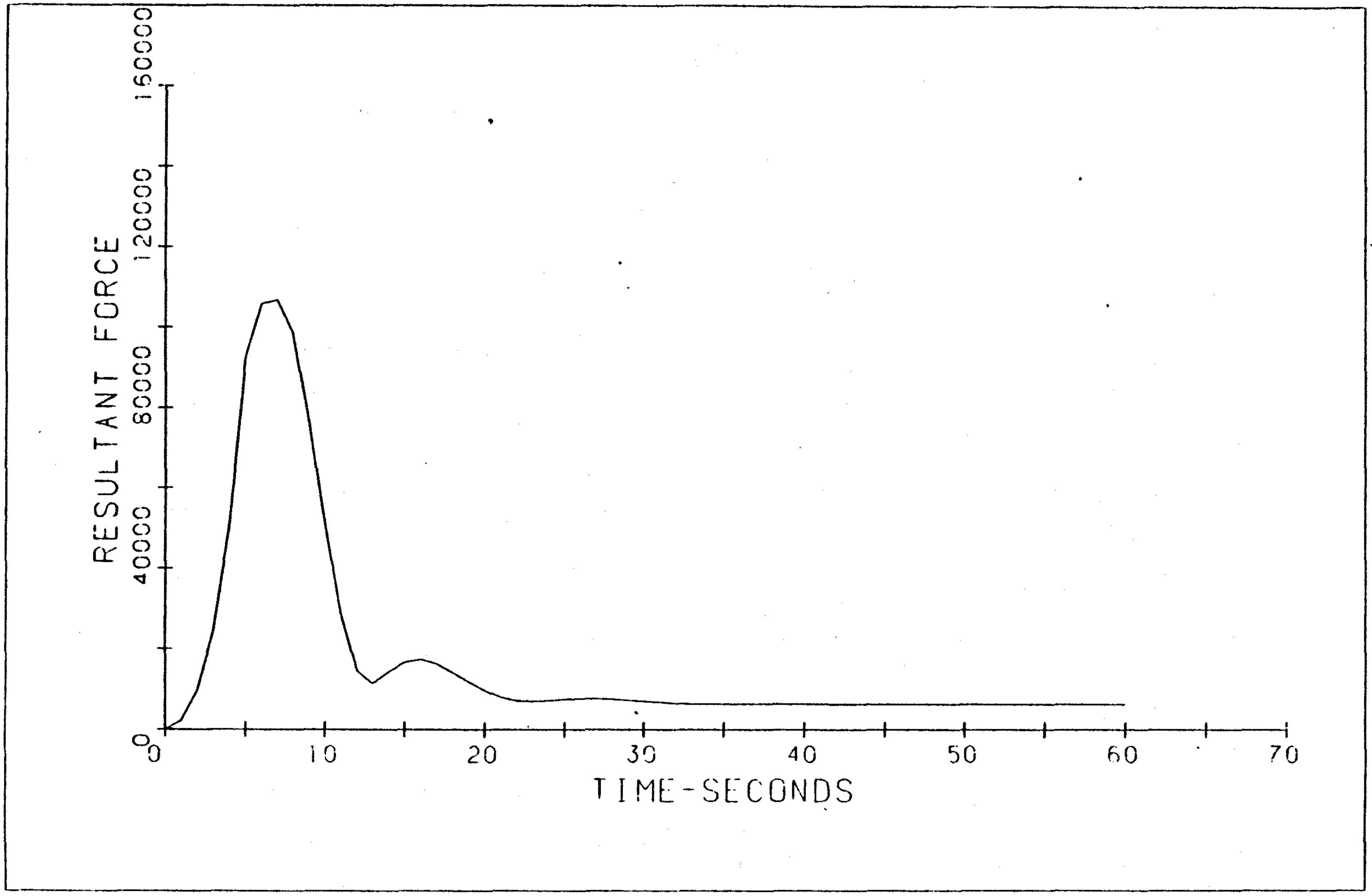
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 60°



** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 60°



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*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
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```

AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG...........: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE.........:    203.8 FEET
```

MOORING STYLE

```
** BOW MOORED **
MAST LOCATION RELATIVE TO NOSE.......:       .0 FEET
HEIGHT OF MAST.......................:     65.0 FEET
MOMENT OF INERTIA ABOUT MAST.........: .560E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED...........................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     90.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.37	.13	.03	-200	-1196	1213	0	0	0	0
2.0	1.24	.91	.47	1230	-3438	3652	0	0	0	0
3.0	2.17	2.62	2.16	8948	-2014	9172	0	0	0	0
4.0	2.88	5.16	5.99	28893	9971	30565	0	0	0	0
5.0	3.38	8.30	12.68	69039	39314	79448	0	0	0	0
6.0	2.16	11.04	22.45	87795	84461	121826	0	0	0	0
7.0	1.17	12.70	34.40	95220	118518	152030	0	0	0	0
8.0	.10	13.35	47.51	90654	135851	163321	0	0	0	0
9.0	-1.11	12.83	60.70	82663	129487	153623	0	0	0	0
10.0	-2.14	11.17	72.79	68347	101151	122076	0	0	0	0
11.0	-2.59	8.76	82.79	46827	65287	80344	0	0	0	0
12.0	-2.54	6.16	90.24	24963	36575	44282	0	0	0	0
13.0	-2.16	3.79	95.18	6837	19123	20308	0	0	0	0
14.0	-1.66	1.88	97.98	-5878	10815	12309	0	0	0	0
15.0	-1.19	.47	99.11	-13582	8021	15774	0	0	0	0
16.0	-.80	-.53	99.04	-17240	7718	18889	0	0	0	0
17.0	-.46	-1.16	98.17	-18210	8173	19960	0	0	0	0
18.0	-.22	-1.49	96.83	-16775	8517	18813	0	0	0	0
19.0	-.06	-1.62	95.26	-13823	8614	16288	0	0	0	0
20.0	.08	-1.61	93.62	-10474	8511	13496	0	0	0	0
21.0	.18	-1.49	92.06	-7050	8137	10767	0	0	0	0
22.0	.26	-1.26	90.68	-4076	7649	8668	0	0	0	0
23.0	.30	-.98	89.55	-1331	7252	7373	0	0	0	0
24.0	.29	-.68	88.72	1024	6942	7018	0	0	0	0
25.0	.26	-.41	88.17	2866	6732	7317	0	0	0	0
26.0	.22	-.17	87.89	4002	6611	7728	0	0	0	0
27.0	.18	.03	87.82	4523	6546	7957	0	0	0	0
28.0	.13	.18	87.92	4598	6510	7970	0	0	0	0
29.0	.09	.29	88.16	4316	6480	7786	0	0	0	0
30.0	.04	.36	88.49	3772	6441	7464	0	0	0	0
31.0	.01	.38	88.86	3062	6409	7103	0	0	0	0
32.0	-.02	.37	89.23	2274	6382	6775	0	0	0	0
33.0	-.04	.34	89.59	1483	6344	6515	0	0	0	0
34.0	-.06	.28	89.90	749	6314	6359	0	0	0	0
35.0	-.07	.22	90.15	113	6313	6314	0	0	0	0
36.0	-.07	.16	90.34	-396	6308	6320	0	0	0	0
37.0	-.06	.09	90.46	-768	6300	6346	0	0	0	0
38.0	-.05	.04	90.52	-1004	6289	6369	0	0	0	0
39.0	-.04	-.01	90.53	-1114	6277	6376	0	0	0	0
40.0	-.03	-.05	90.50	-1118	6264	6363	0	0	0	0
41.0	-.02	-.07	90.44	-1036	6249	6335	0	0	0	0
42.0	-.01	-.09	90.36	-893	6233	6297	0	0	0	0
43.0	-.00	-.09	90.26	-714	6224	6265	0	0	0	0
44.0	.01	-.09	90.17	-519	6218	6240	0	0	0	0
45.0	.01	-.08	90.09	-325	6212	6221	0	0	0	0
46.0	.01	-.07	90.01	-147	6211	6213	0	0	0	0
47.0	.02	-.05	89.95	4	6215	6215	0	0	0	0

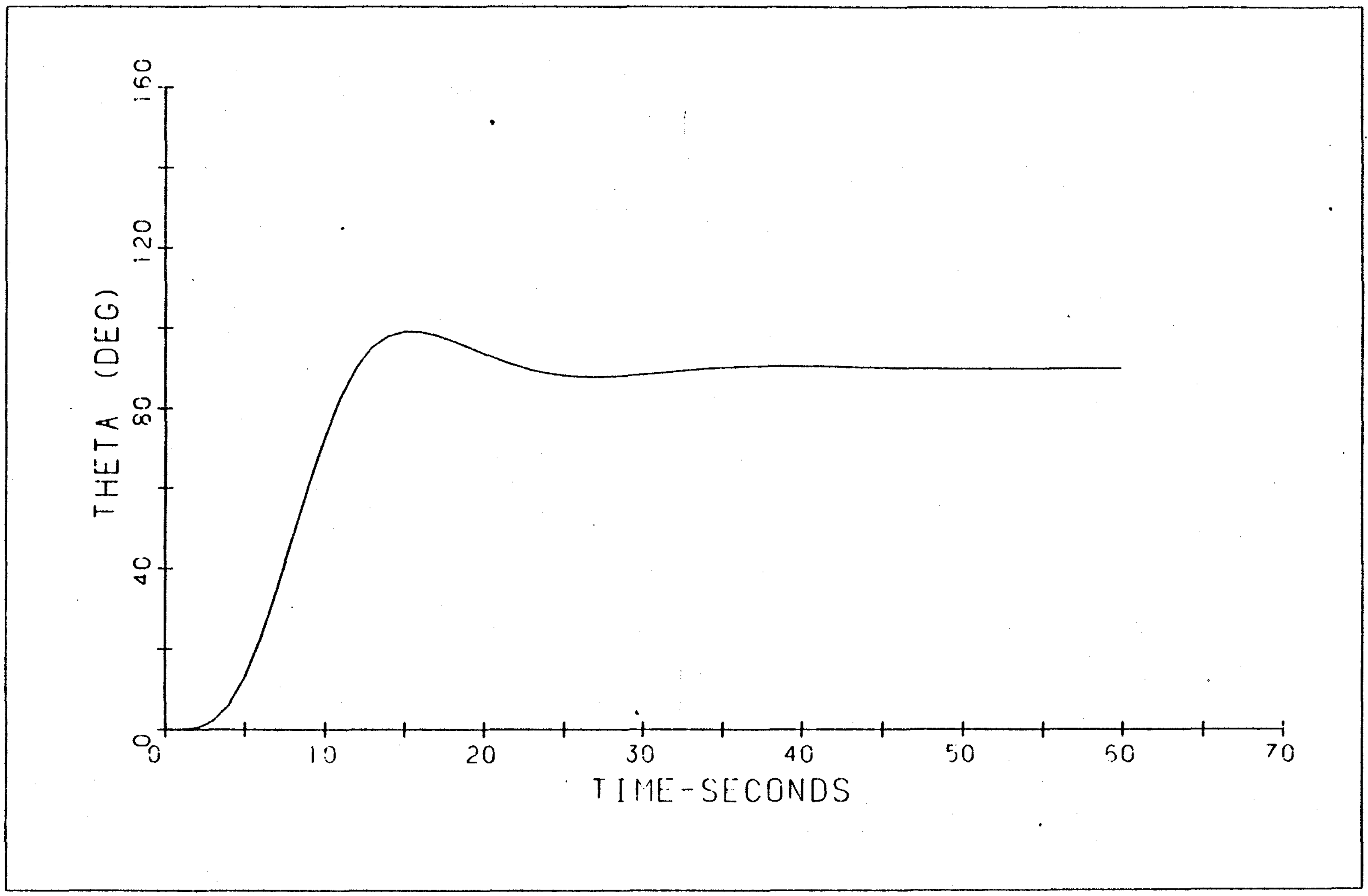
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	.02	-.03	89.91	124	6217	6219	0	0	0	0
49.0	.01	-.02	89.88	211	6217	6221	0	0	0	0
50.0	.01	-.01	89.87	264	6216	6221	0	0	0	0
51.0	.01	.01	89.86	287	6213	6220	0	0	0	0
52.0	.01	.01	89.87	285	6209	6216	0	0	0	0
53.0	.00	.02	89.89	262	6205	6211	0	0	0	0
54.0	.00	.02	89.91	225	6201	6205	0	0	0	0
55.0	-.00	.02	89.93	180	6199	6202	0	0	0	0
56.0	-.00	.02	89.96	131	6198	6199	0	0	0	0
57.0	-.00	.02	89.98	83	6196	6197	0	0	0	0
58.0	-.00	.02	90.00	40	6196	6196	0	0	0	0
59.0	-.00	.01	90.01	3	6197	6197	0	0	0	0
60.0	-.00	.01	90.02	-24	6198	6198	0	0	0	0

EXIT

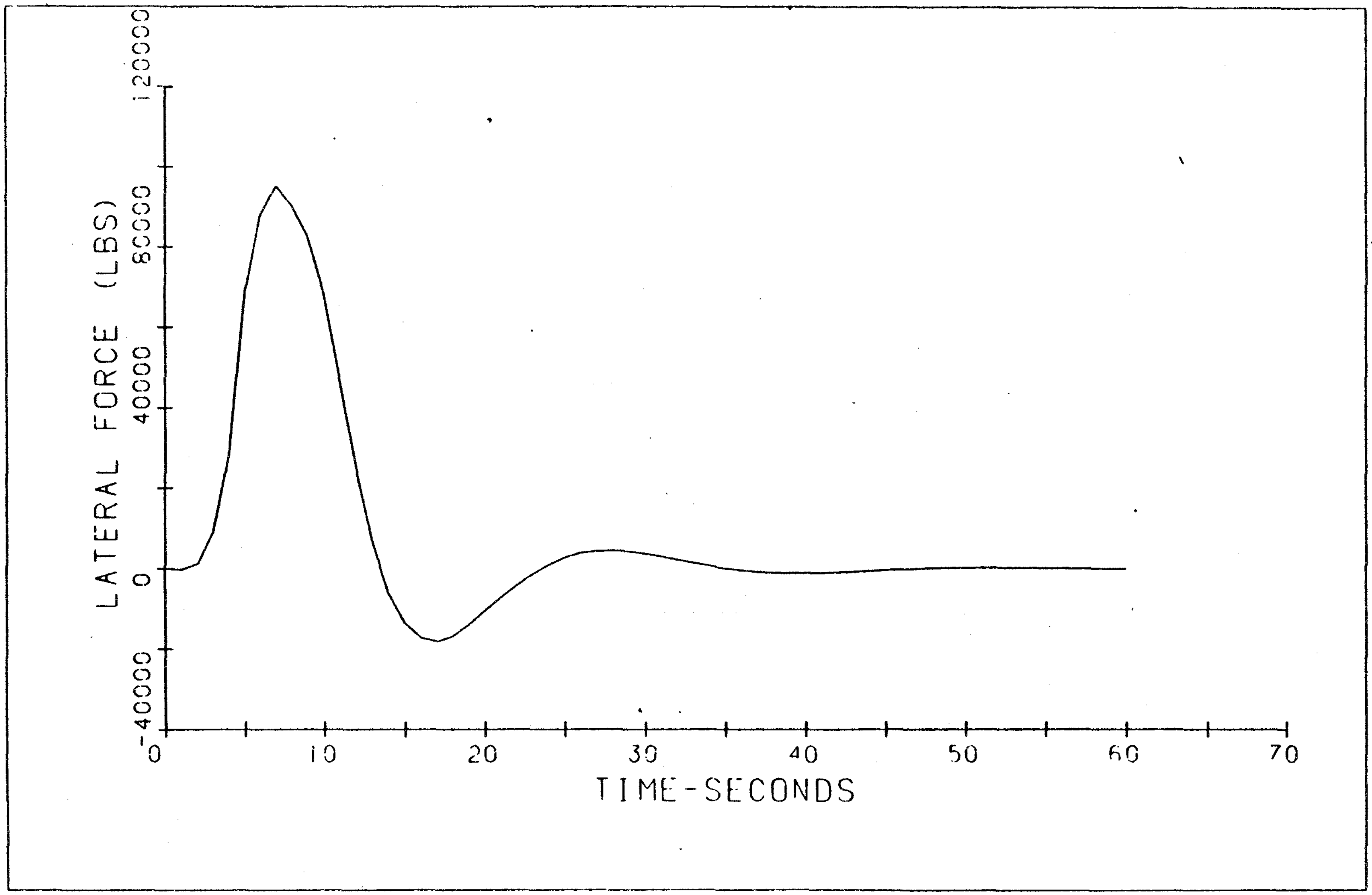
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 90°



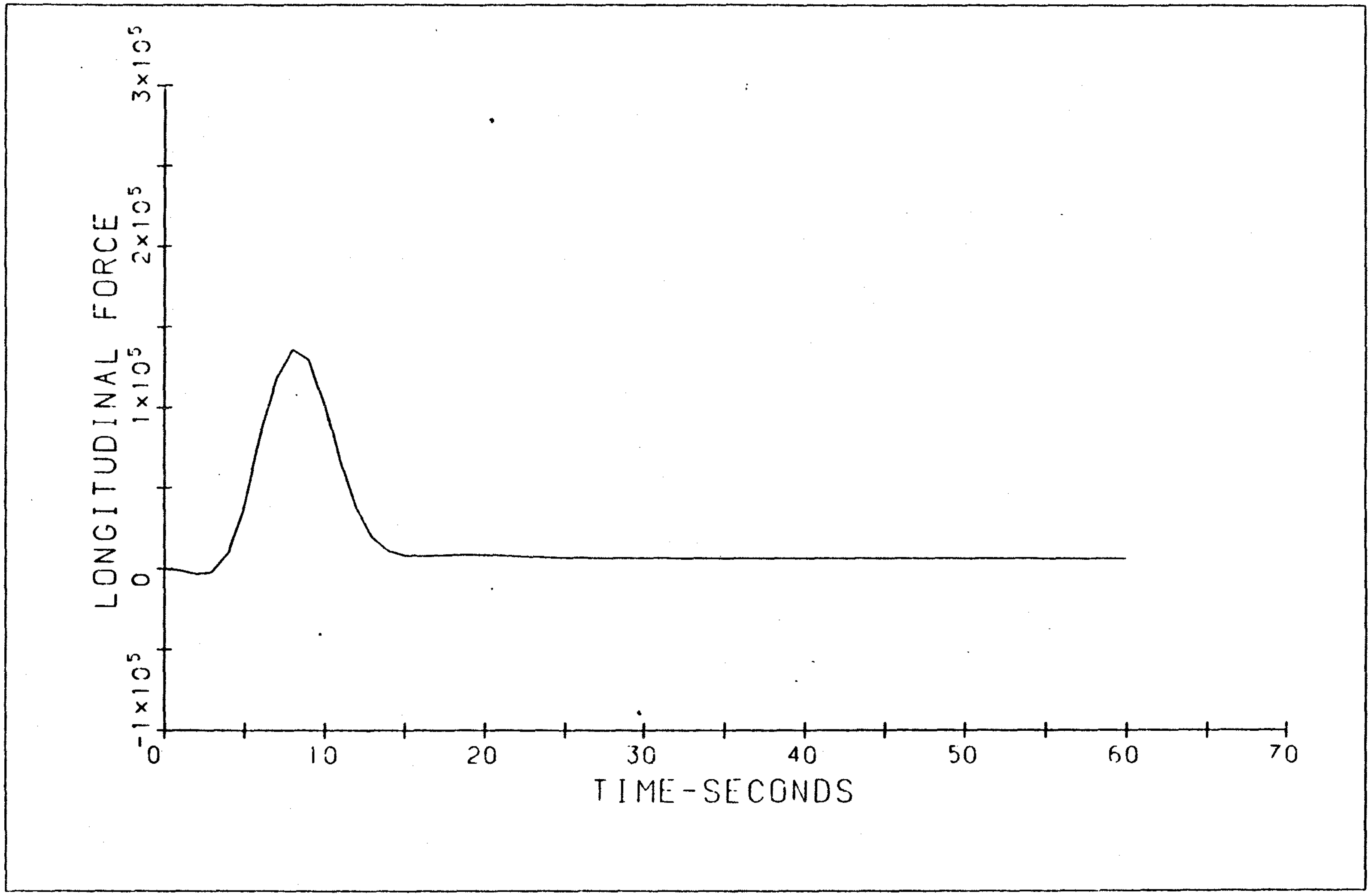
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 90°



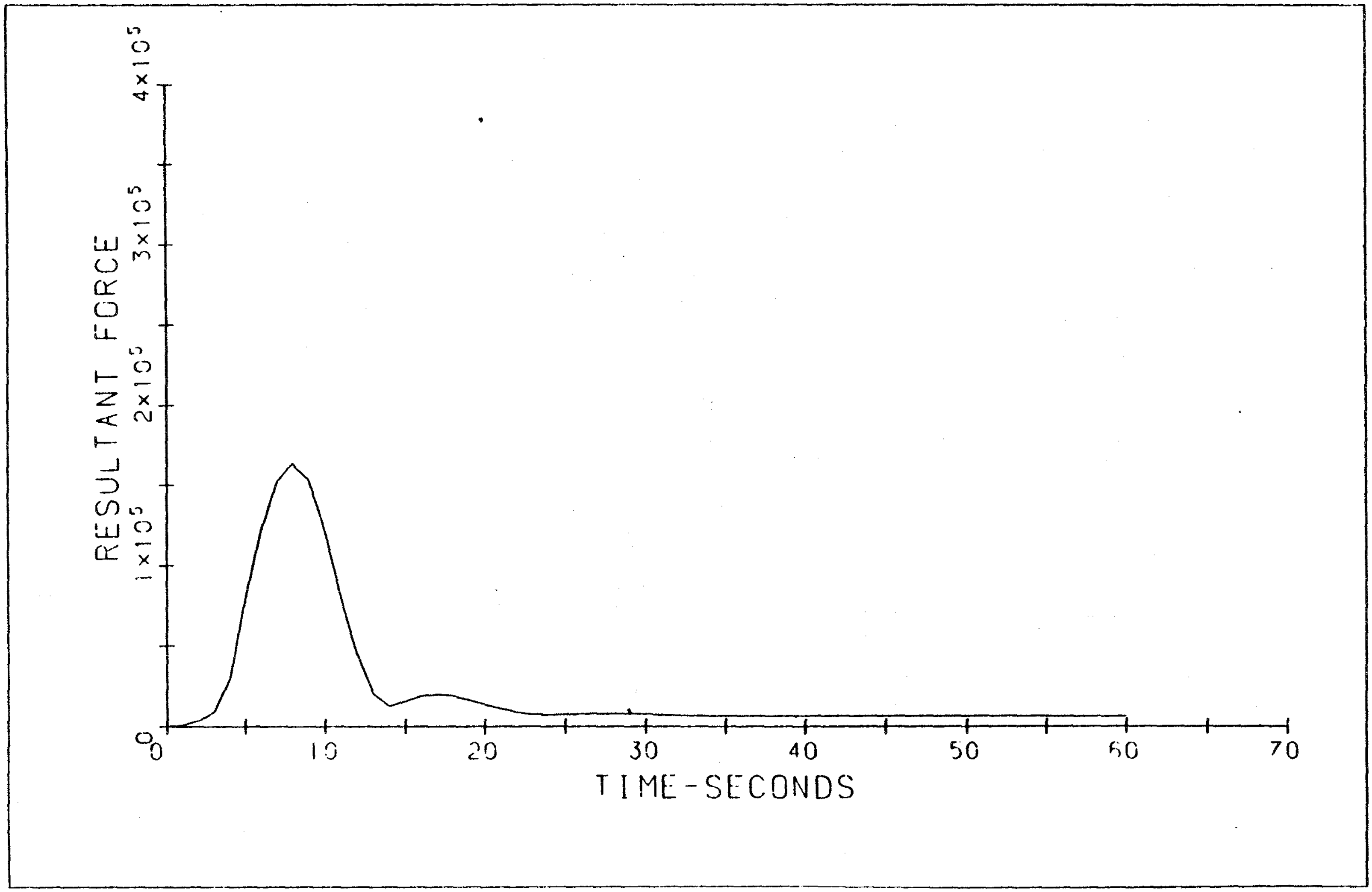
** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 90°



** 75 TON HLA *WITH* EMPENNAGE **
** BOW MOORED **

Wind = 60 Knots @ 90°



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*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
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AIRSHIP CONFIGURATION DATA

** 75 TON HLA *WITH* EMPENNAGE **

```
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE..................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE..........:    203.8 FEET
```

MOORING STYLE

** BELLY MOORED **

```
MAST LOCATION RELATIVE TO NOSE.......:    108.0 FEET
HEIGHT OF MAST.........................:     15.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .216E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED.............................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS...:     15.0 DEGREES
THETA (DISPLACEMENT ANGLE)............:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY)..........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

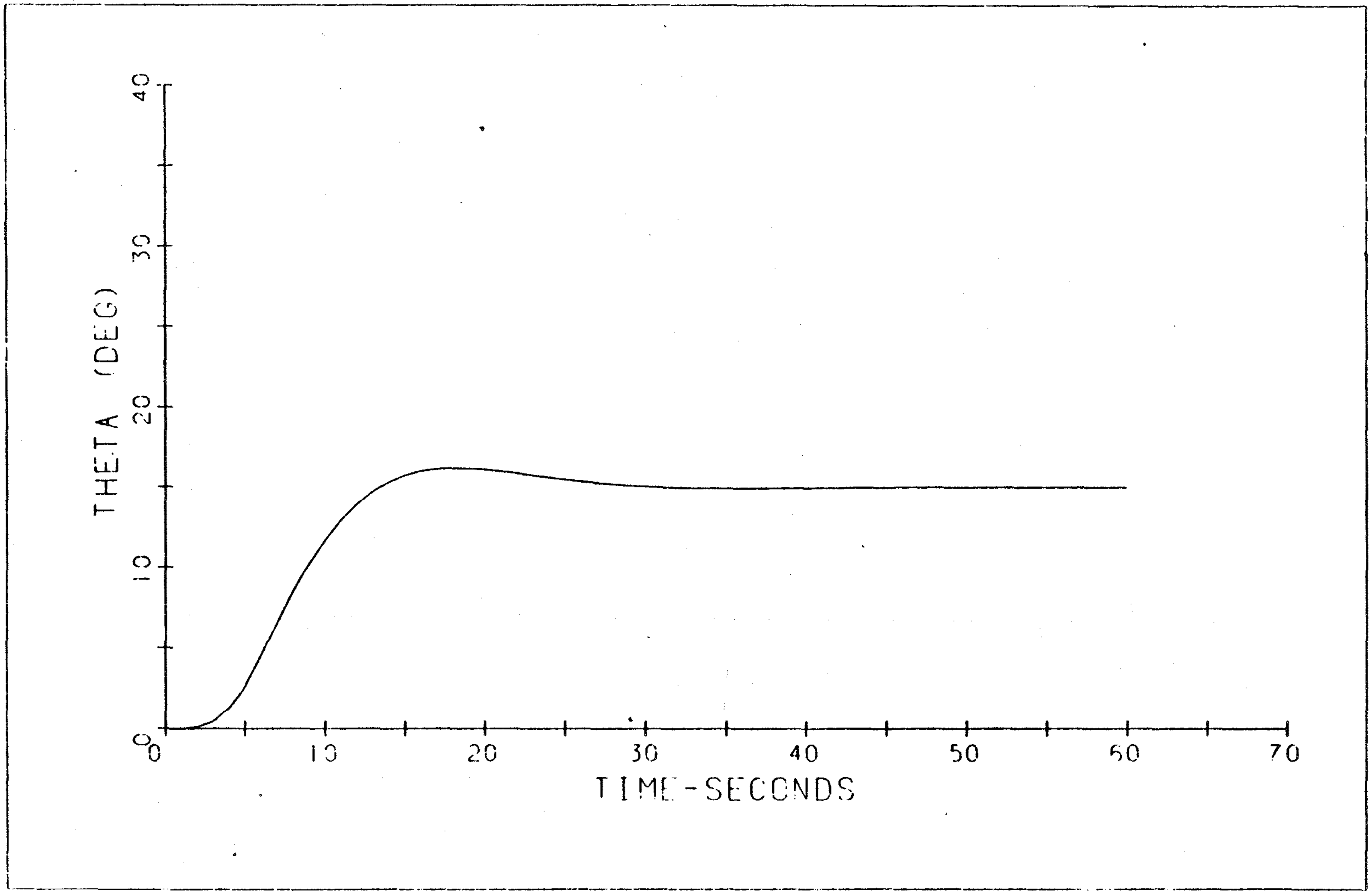
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.07	.02	.01	2203	346	2230	1219	0	1253	0
2.0	.26	.18	.10	9224	1389	9328	5099	0	5237	0
3.0	.47	.55	.45	21683	3189	21916	11981	0	12298	0
4.0	.58	1.08	1.25	38999	5845	39435	21556	0	22137	0
5.0	.55	1.66	2.63	58142	9301	58881	32175	0	33099	0
6.0	.16	2.00	4.49	54292	9547	55125	30101	0	31049	0
7.0	-.10	2.02	6.52	47276	9263	48175	26273	0	27193	0
8.0	-.21	1.84	8.46	38682	8660	39639	21568	0	22428	0
9.0	-.24	1.62	10.19	30026	8041	31084	16828	0	17626	0
10.0	-.25	1.37	11.68	22295	7506	23525	12596	0	13341	0
11.0	-.24	1.13	12.93	15598	7100	17138	8933	0	9638	0
12.0	-.22	.90	13.94	9968	6785	12058	5855	0	6529	0
13.0	-.20	.68	14.73	5384	6550	8479	3351	0	4002	0
14.0	-.17	.50	15.32	1784	6412	6655	1388	0	2025	87
15.0	-.15	.33	15.73	-925	6394	6461	0	920	550	1555
16.0	-.12	.20	16.00	-2854	6393	7001	0	1967	0	2602
17.0	-.09	.09	16.14	-4121	6393	7606	0	2655	0	3290
18.0	-.07	.01	16.19	-4844	6390	8019	0	3048	0	3682
19.0	-.05	-.05	16.17	-5135	6382	8192	0	3205	0	3839
20.0	-.03	-.09	16.10	-5098	6369	8158	0	3184	0	3817
21.0	-.02	-.12	15.99	-4823	6352	7976	0	3034	0	3665
22.0	-.01	-.13	15.87	-4389	6331	7704	0	2797	0	3426
23.0	.00	-.13	15.73	-3859	6310	7396	0	2507	0	3134
24.0	.01	-.13	15.60	-3285	6288	7094	0	2194	0	2819
25.0	.01	-.12	15.47	-2707	6267	6826	0	1879	0	2502
26.0	.01	-.11	15.36	-2154	6247	6609	0	1578	0	2198
27.0	.01	-.09	15.26	-1647	6231	6445	0	1301	131	1920
28.0	.02	-.08	15.17	-1197	6219	6333	0	1056	374	1674
29.0	.01	-.06	15.10	-810	6211	6264	0	846	582	1463
30.0	.01	-.05	15.04	-489	6205	6224	139	671	756	1287
31.0	.01	-.04	15.00	-231	6200	6204	279	531	895	1147
32.0	.01	-.03	14.97	-32	6200	6200	387	423	1003	1038
33.0	.01	-.02	14.95	114	6202	6204	467	343	1083	959
34.0	.01	-.01	14.93	216	6204	6208	523	288	1139	904
35.0	.01	-.00	14.93	279	6204	6211	557	253	1173	869
36.0	.00	.00	14.93	313	6204	6212	575	235	1191	851
37.0	.00	.00	14.93	322	6203	6212	580	230	1196	846
38.0	.00	.01	14.93	313	6202	6210	575	235	1191	851
39.0	.00	.01	14.94	291	6201	6208	563	247	1179	863
40.0	.00	.01	14.95	261	6200	6205	547	263	1163	879
41.0	-.00	.01	14.96	227	6198	6203	528	281	1144	897
42.0	-.00	.01	14.97	191	6197	6200	508	301	1124	916
43.0	-.00	.01	14.97	155	6196	6198	489	320	1105	935
44.0	-.00	.01	14.98	122	6195	6196	471	338	1087	953
45.0	-.00	.01	14.99	93	6194	6195	455	354	1070	969
46.0	-.00	.00	14.99	67	6193	6194	441	368	1056	983
47.0	-.00	.00	14.99	44	6193	6193	429	380	1044	995

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	-.00	.00	15.00	26	6193	6193	419	390	1034	1005
49.0	-.00	.00	15.00	12	6192	6192	411	398	1026	1013
50.0	-.00	.00	15.00	1	6192	6192	405	403	1020	1019
51.0	-.00	.00	15.00	-6	6193	6193	401	408	1016	1023
52.0	-.00	.00	15.00	-11	6193	6193	398	411	1013	1026
53.0	-.00	.00	15.00	-15	6193	6193	396	413	1011	1028
54.0	-.00	-.00	15.00	-16	6193	6193	395	414	1010	1029
55.0	-.00	-.00	15.00	-17	6193	6193	395	414	1010	1029
56.0	-.00	-.00	15.00	-16	6193	6193	395	413	1011	1028
57.0	-.00	-.00	15.00	-15	6193	6193	396	413	1011	1028
58.0	-.00	-.00	15.00	-13	6192	6192	397	412	1012	1027
59.0	.00	-.00	15.00	-10	6192	6192	398	410	1014	1025
60.0	.00	-.00	15.00	-8	6192	6192	400	409	1015	1024

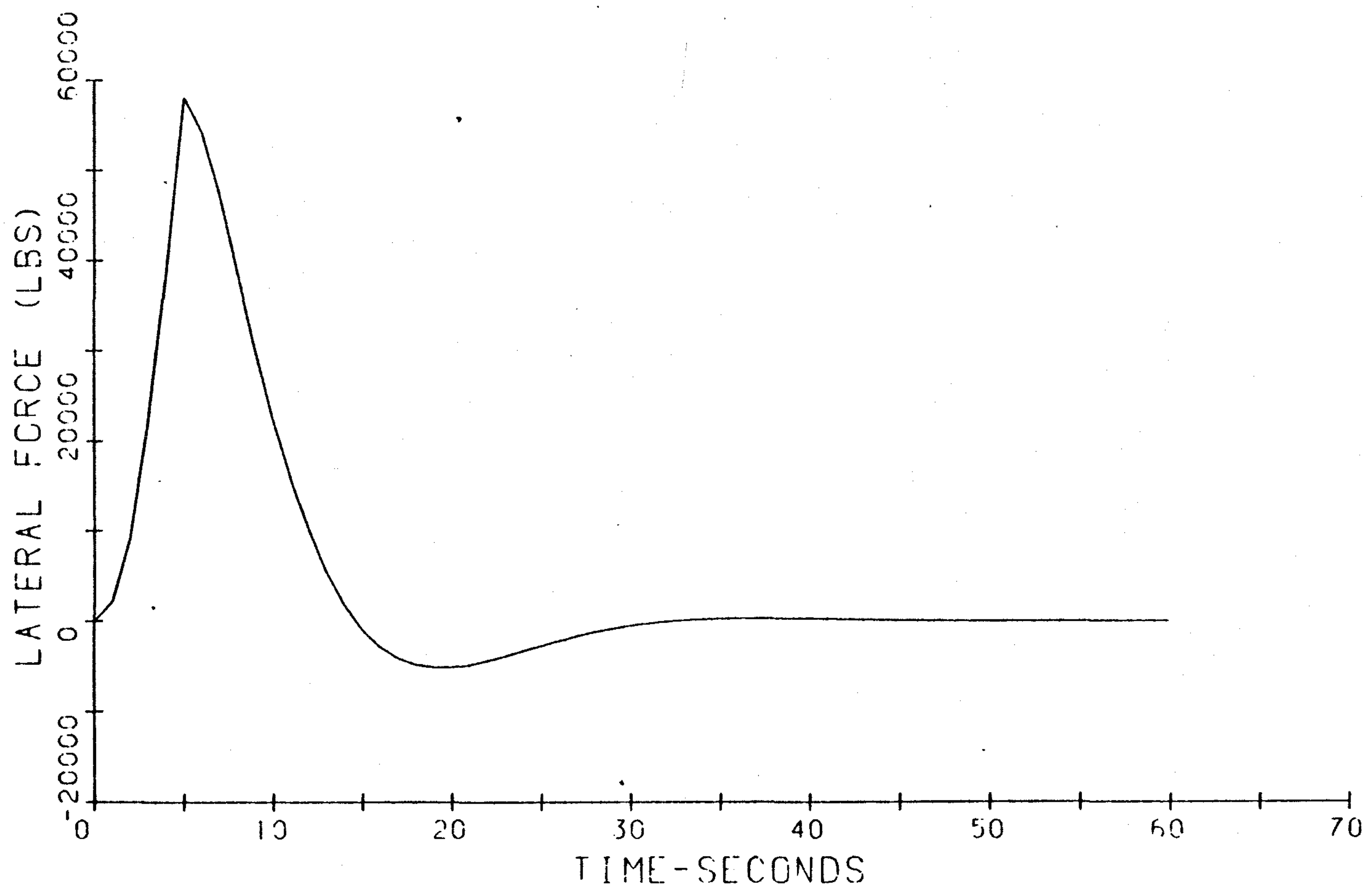
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 15°



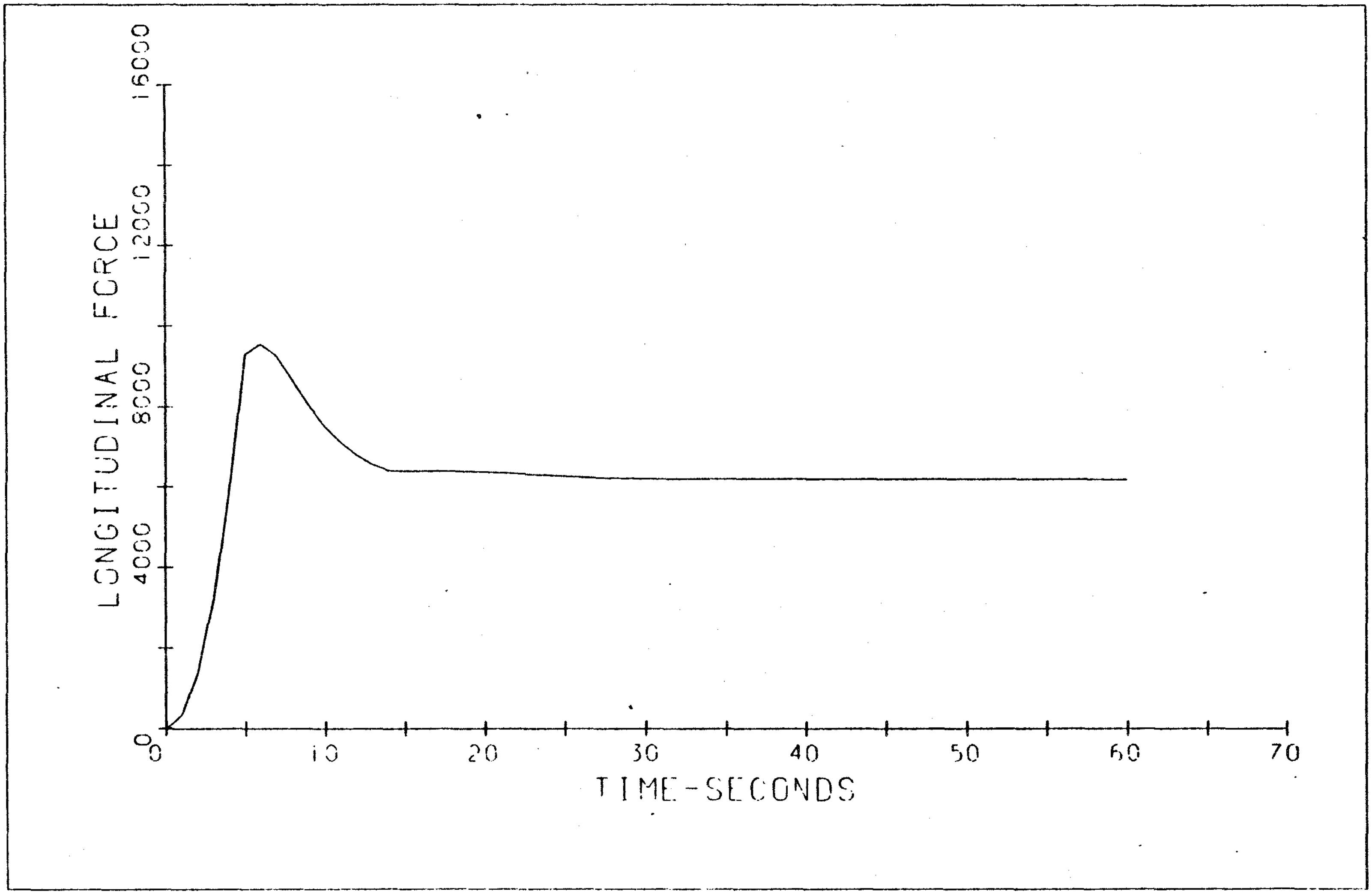
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 15°



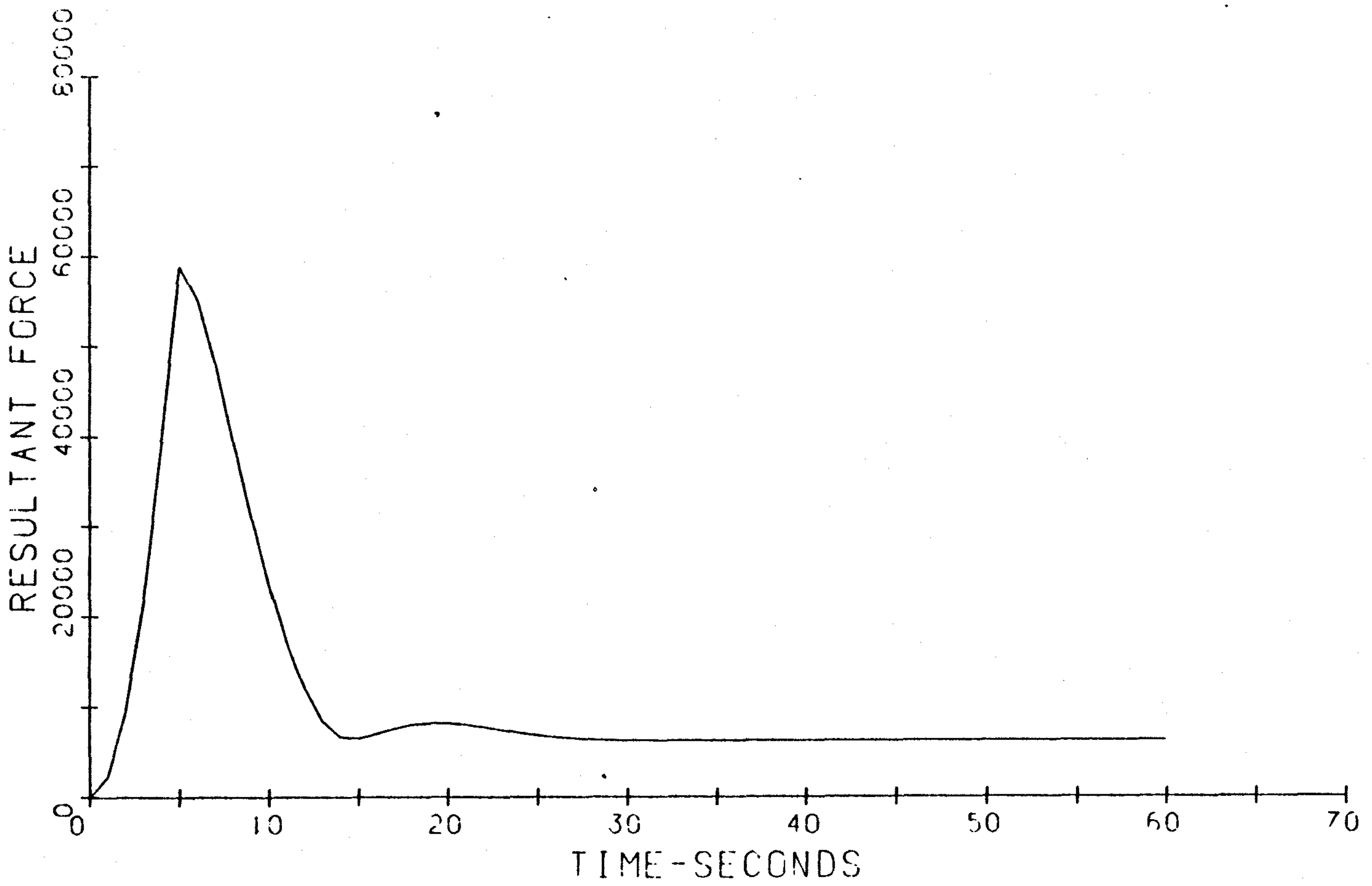
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 15°



** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 15°



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*                                       *
*    AIRSHIP MOORING LOADS ANALYSIS     *
*                                       *
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AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE.................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE..........:    203.8 FEET
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MOORING STYLE

```
** BELLY MOORED **
MAST LOCATION RELATIVE TO NOSE........:    108.0 FEET
HEIGHT OF MAST........................:     15.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .216E 09 SLUG-FTSQ
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INITIAL CONDITIONS

```
WIND SPEED............................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS...:     30.0 DEGREES
THETA (DISPLACEMENT ANGLE)............:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY)..........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

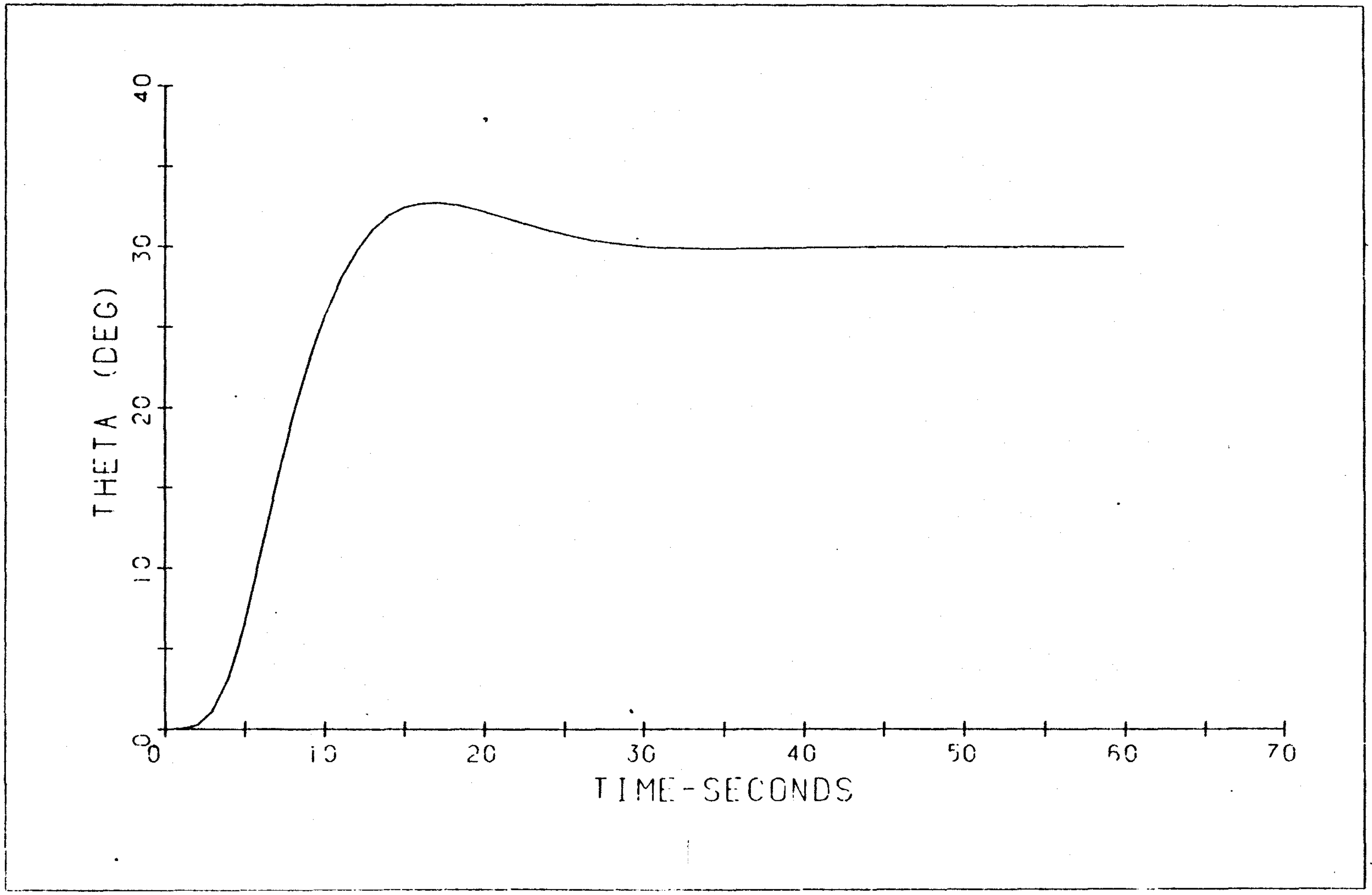
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.19	.07	.02	3893	272	3903	2131	0	2159	0
2.0	.66	.48	.25	16812	1259	16859	9210	0	9335	0
3.0	1.15	1.40	1.15	40675	3493	40825	22312	0	22659	0
4.0	1.37	2.69	3.17	74453	8015	74883	40947	0	41743	0
5.0	1.12	3.97	6.53	112159	15056	113165	61880	0	63375	0
6.0	.07	4.53	10.86	104901	17737	106389	58114	0	59876	0
7.0	-.44	4.31	15.33	87922	16718	89497	48829	0	50490	0
8.0	-.60	3.76	19.38	68143	14097	69585	37919	0	39319	0
9.0	-.60	3.16	22.84	49617	11765	50992	27708	0	28876	0
10.0	-.57	2.57	25.70	33925	9958	35357	19070	0	20059	0
11.0	-.53	2.02	28.00	20942	8566	22626	11930	0	12781	0
12.0	-.48	1.52	29.77	10615	7574	13040	6258	0	7011	0
13.0	-.43	1.06	31.06	2611	6989	7461	1874	0	2568	0
14.0	-.35	.67	31.92	-3406	6781	7589	0	2293	0	2966
15.0	-.27	.36	32.43	-7586	6688	10113	0	4556	0	5220
16.0	-.19	.13	32.67	-10178	6653	12159	0	5961	0	6621
17.0	-.14	-.04	32.71	-11407	6637	13197	0	6627	0	7286
18.0	-.10	-.16	32.61	-11748	6620	13484	0	6811	0	7468
19.0	-.06	-.24	32.41	-11424	6594	13191	0	6634	0	7289
20.0	-.03	-.28	32.15	-10634	6558	12494	0	6202	0	6853
21.0	-.01	-.30	31.85	-9541	6513	11553	0	5606	0	6253
22.0	.01	-.30	31.55	-8282	6463	10505	0	4919	0	5561
23.0	.02	-.29	31.25	-6962	6412	9465	0	4199	0	4836
24.0	.03	-.26	30.97	-5662	6362	8517	0	3490	0	4122
25.0	.03	-.23	30.72	-4440	6316	7721	0	2823	0	3451
26.0	.03	-.20	30.51	-3334	6279	7109	0	2220	0	2844
27.0	.03	-.17	30.32	-2365	6253	6686	0	1693	0	2314
28.0	.03	-.13	30.17	-1545	6234	6422	0	1246	187	1865
29.0	.03	-.10	30.06	-871	6219	6279	0	879	550	1497
30.0	.03	-.07	29.97	-338	6209	6218	222	589	838	1206
31.0	.02	-.05	29.91	66	6213	6213	442	370	1059	987
32.0	.02	-.03	29.87	358	6217	6228	601	211	1218	829
33.0	.01	-.02	29.84	554	6220	6244	707	105	1325	723
34.0	.01	-.00	29.83	670	6220	6256	770	42	1388	660
35.0	.01	.01	29.83	722	6219	6261	798	14	1416	632
36.0	.01	.01	29.84	725	6217	6259	800	12	1417	630
37.0	.00	.02	29.86	692	6214	6253	782	30	1399	647
38.0	.00	.02	29.87	634	6211	6244	750	61	1367	678
39.0	.00	.02	29.89	562	6208	6234	711	100	1327	717
40.0	-.00	.02	29.91	481	6205	6224	667	144	1283	760
41.0	-.00	.02	29.93	400	6202	6215	622	188	1239	804
42.0	-.00	.02	29.95	321	6200	6208	580	230	1195	846
43.0	-.00	.01	29.96	249	6198	6203	540	269	1156	885
44.0	-.00	.01	29.97	184	6196	6199	505	305	1120	920
45.0	-.00	.01	29.98	127	6195	6196	474	335	1089	950
46.0	-.00	.01	29.99	81	6194	6194	448	360	1064	976
47.0	-.00	.01	30.00	43	6193	6193	428	381	1043	996

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	-.00	.00	30.00	13	6193	6193	412	397	1027	1012
49.0	-.00	.00	30.01	-8	6193	6193	400	409	1015	1024
50.0	-.00	.00	30.01	-24	6194	6194	391	418	1007	1033
51.0	-.00	.00	30.01	-33	6194	6194	386	423	1001	1038
52.0	-.00	.00	30.01	-39	6194	6194	383	426	998	1041
53.0	-.00	-.00	30.01	-41	6194	6194	382	427	997	1042
54.0	-.00	-.00	30.01	-40	6193	6194	382	427	997	1042
55.0	-.00	-.00	30.01	-38	6193	6193	384	425	999	1040
56.0	-.00	-.00	30.01	-34	6193	6193	386	423	1001	1038
57.0	.00	-.00	30.01	-30	6193	6193	388	421	1003	1036
58.0	.00	-.00	30.00	-25	6193	6193	391	418	1006	1033
59.0	.00	-.00	30.00	-20	6193	6193	393	416	1008	1031
60.0	.00	-.00	30.00	-16	6192	6192	396	413	1011	1028

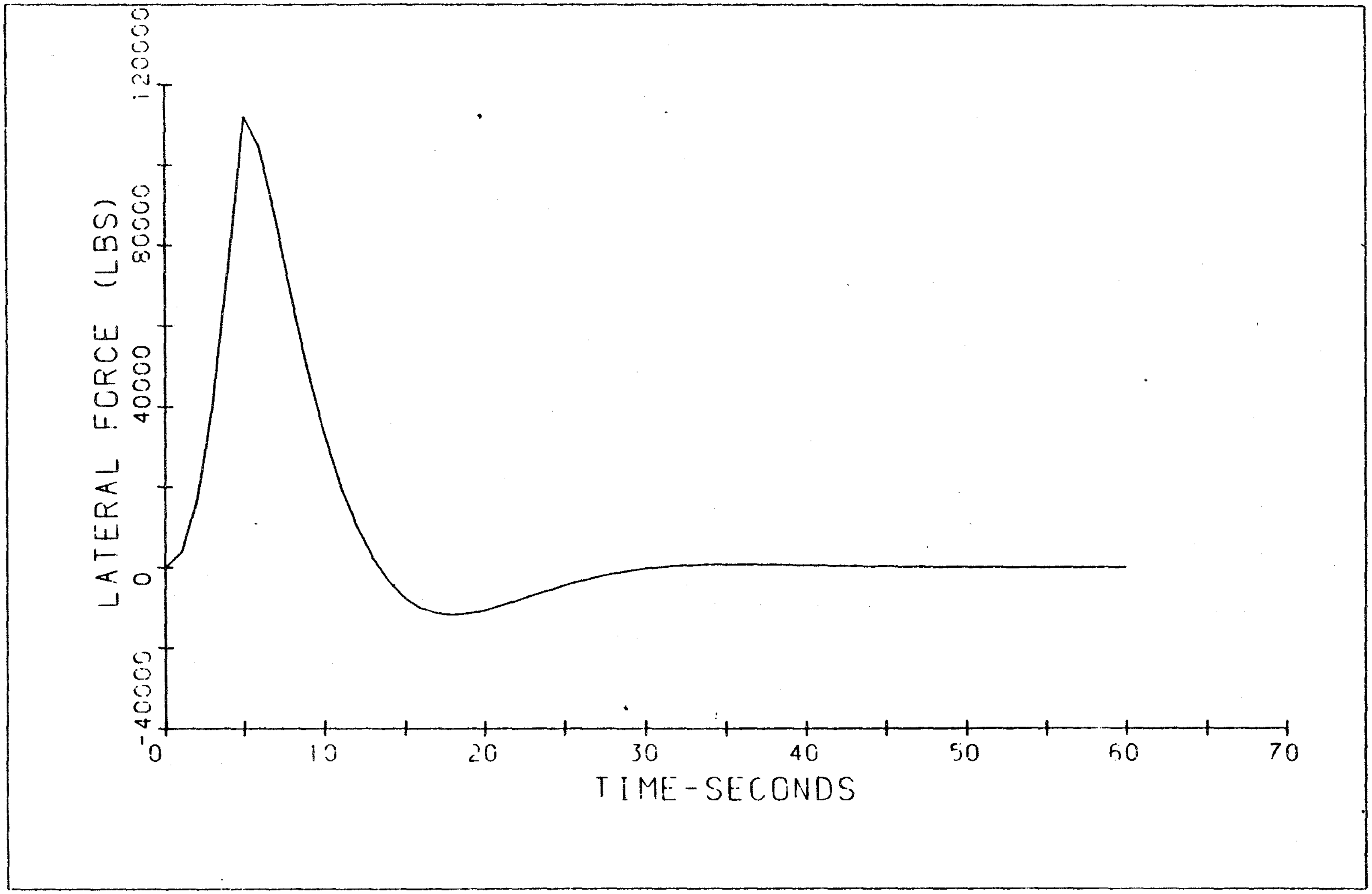
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 30°



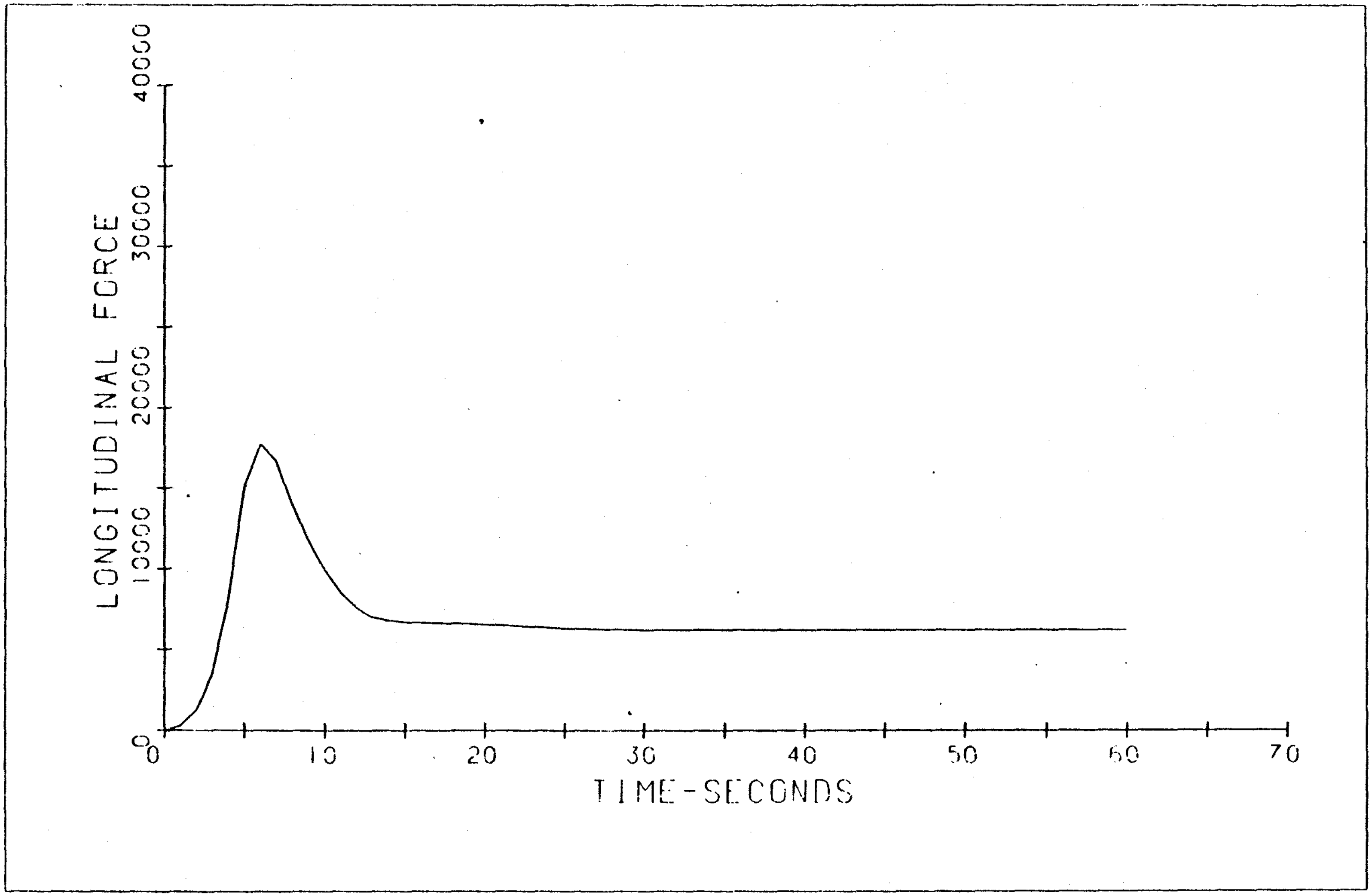
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 30°



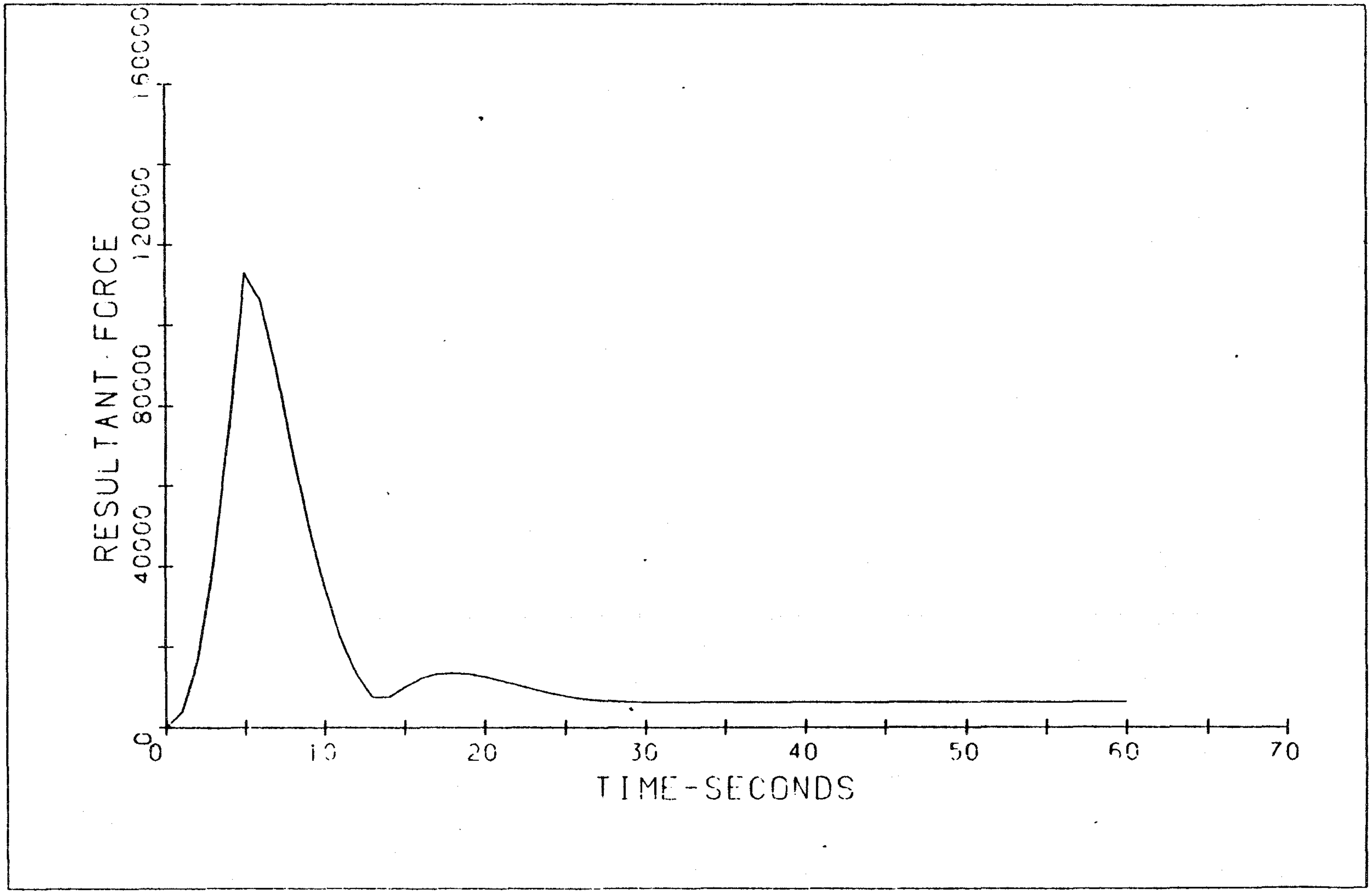
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 30°



** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 30°



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*****************************************
*                                       *
*     AIRSHIP MOORING LOADS ANALYSIS    *
*                                       *
*****************************************
```

AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE.................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE..........:    203.8 FEET
```

MOORING STYLE

```
** BELLY MOORED **
MAST LOCATION RELATIVE TO NOSE.......:    108.0 FEET
HEIGHT OF MAST........................:     15.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .216E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED............................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     45.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

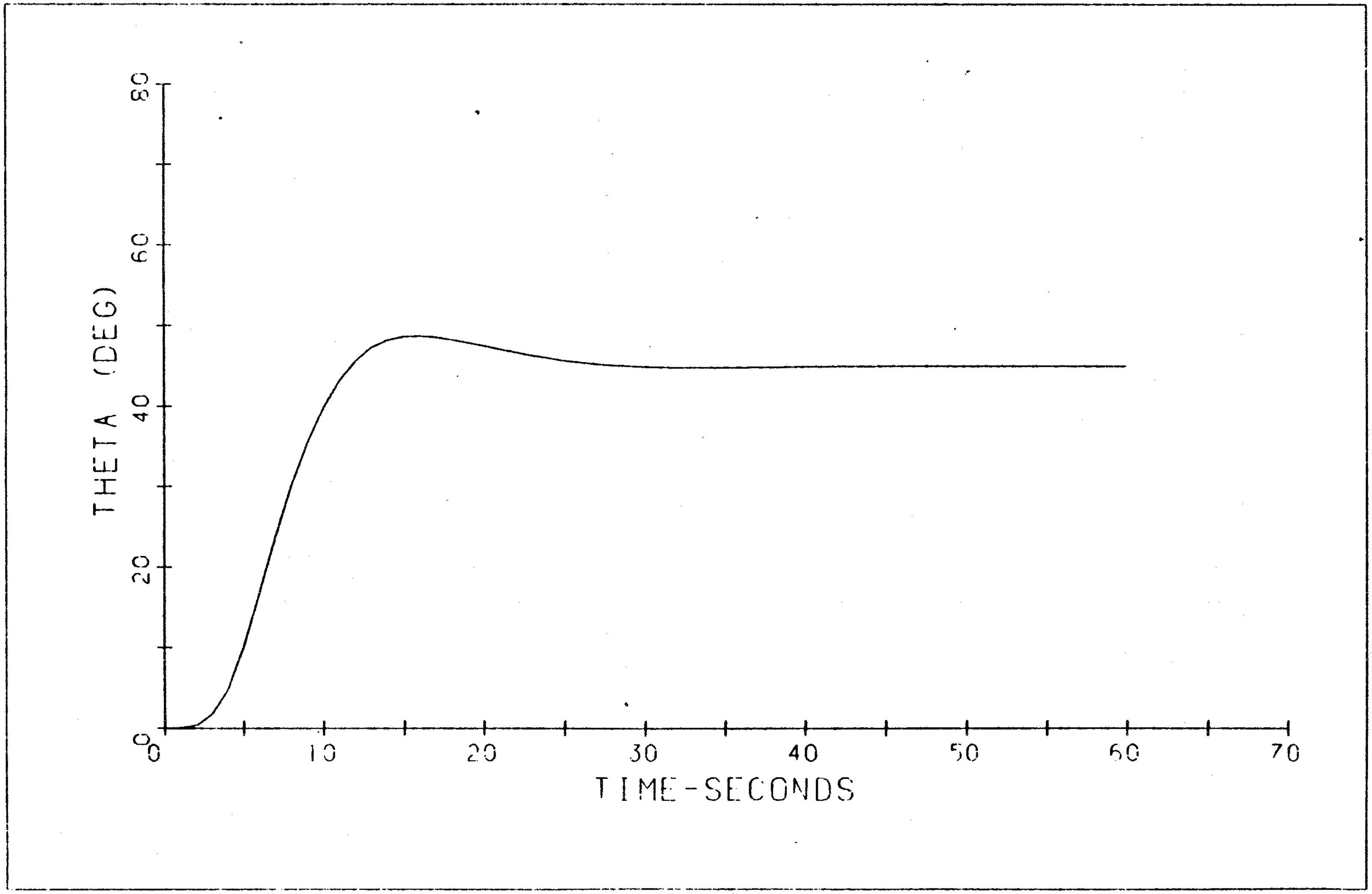
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.31	.11	.03	5028	-209	5032	2716	0	2695	0
2.0	1.03	.76	.40	22689	-357	22692	12295	0	12260	0
3.0	1.73	2.16	1.80	56956	1655	56979	31031	0	31196	0
4.0	2.07	4.10	4.90	106399	9068	106784	58361	0	59261	0
5.0	1.86	6.11	10.03	162377	21626	163811	89574	0	91722	0
6.0	.21	7.08	16.76	150063	29158	152869	83381	0	86277	0
7.0	-.70	6.78	23.77	126948	28726	130157	70803	0	73656	0
8.0	-1.04	5.85	30.11	100299	23808	103086	56013	0	58377	0
9.0	-1.00	4.83	35.44	70467	18335	72813	39458	0	41279	0
10.0	-.96	3.86	39.78	46252	14062	48342	26031	0	27428	0
11.0	-.94	2.90	43.16	27000	10730	29054	15361	0	16427	0
12.0	-.83	2.01	45.61	11636	8485	14401	6872	0	7715	0
13.0	-.67	1.26	47.23	160	7423	7424	572	398	1309	1135
14.0	-.51	.67	48.18	-7762	6992	10446	0	4671	0	5365
15.0	-.36	.23	48.62	-12683	6839	14409	0	7333	0	8012
16.0	-.23	-.06	48.70	-15246	6799	16693	0	8722	0	9397
17.0	-.13	-.24	48.54	-16088	6780	17458	0	9178	0	9851
18.0	-.08	-.34	48.25	-15525	6749	16928	0	8870	0	9540
19.0	-.04	-.40	47.88	-14356	6703	15843	0	8232	0	8898
20.0	-.01	-.42	47.47	-12807	6642	14427	0	7387	0	8047
21.0	.01	-.41	47.05	-11057	6573	12863	0	6433	0	7086
22.0	.03	-.39	46.65	-9246	6500	11302	0	5445	0	6090
23.0	.04	-.36	46.27	-7477	6430	9861	0	4480	0	5118
24.0	.05	-.31	45.94	-5825	6365	8628	0	3579	0	4211
25.0	.05	-.27	45.65	-4339	6313	7660	0	2768	0	3395
26.0	.05	-.22	45.41	-3044	6277	6976	0	2063	0	2687
27.0	.04	-.17	45.21	-1953	6249	6548	0	1469	0	2090
28.0	.04	-.13	45.06	-1063	6228	6318	0	984	448	1603
29.0	.03	-.10	44.94	-363	6217	6227	209	603	826	1221
30.0	.03	-.07	44.86	165	6223	6225	496	317	1114	935
31.0	.02	-.04	44.81	542	6228	6251	701	112	1320	731
32.0	.02	-.02	44.78	791	6230	6280	836	0	1455	596
33.0	.01	-.00	44.77	934	6230	6300	914	0	1533	519
34.0	.01	.01	44.77	992	6229	6307	946	0	1565	486
35.0	.01	.02	44.79	987	6226	6304	943	0	1561	489
36.0	.00	.02	44.81	936	6222	6292	915	0	1533	516
37.0	.00	.03	44.83	853	6218	6276	869	0	1487	560
38.0	-.00	.03	44.86	751	6214	6259	814	0	1431	615
39.0	-.00	.03	44.88	641	6210	6243	754	57	1370	674
40.0	-.00	.02	44.91	529	6206	6228	693	118	1309	734
41.0	-.00	.02	44.93	422	6202	6216	635	175	1251	791
42.0	-.00	.02	44.95	324	6199	6208	581	229	1197	844
43.0	-.00	.02	44.97	237	6197	6201	534	276	1149	891
44.0	-.00	.01	44.98	162	6196	6198	493	316	1108	932
45.0	-.00	.01	44.99	100	6194	6195	459	350	1074	965
46.0	-.00	.01	45.00	50	6194	6194	432	377	1047	992
47.0	-.00	.01	45.01	11	6193	6193	411	398	1026	1013

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	-.00	.00	45.01	-17	6194	6194	395	414	1010	1029
49.0	-.00	.00	45.01	-37	6194	6194	384	425	1000	1040
50.0	-.00	.00	45.01	-49	6194	6194	378	431	993	1047
51.0	-.00	-.00	45.01	-56	6194	6195	374	435	989	1050
52.0	-.00	-.00	45.01	-57	6194	6194	373	436	988	1051
53.0	-.00	-.00	45.01	-56	6194	6194	374	435	989	1050
54.0	-.00	-.00	45.01	-52	6194	6194	376	433	991	1048
55.0	-.00	-.00	45.01	-47	6193	6194	379	430	994	1045
56.0	.00	-.00	45.01	-41	6193	6193	382	427	997	1042
57.0	.00	-.00	45.01	-34	6193	6193	386	423	1001	1038
58.0	.00	-.00	45.00	-27	6193	6193	389	420	1004	1035
59.0	.00	-.00	45.00	-21	6193	6193	393	416	1008	1031
60.0	.00	-.00	45.00	-15	6192	6192	396	413	1011	1028

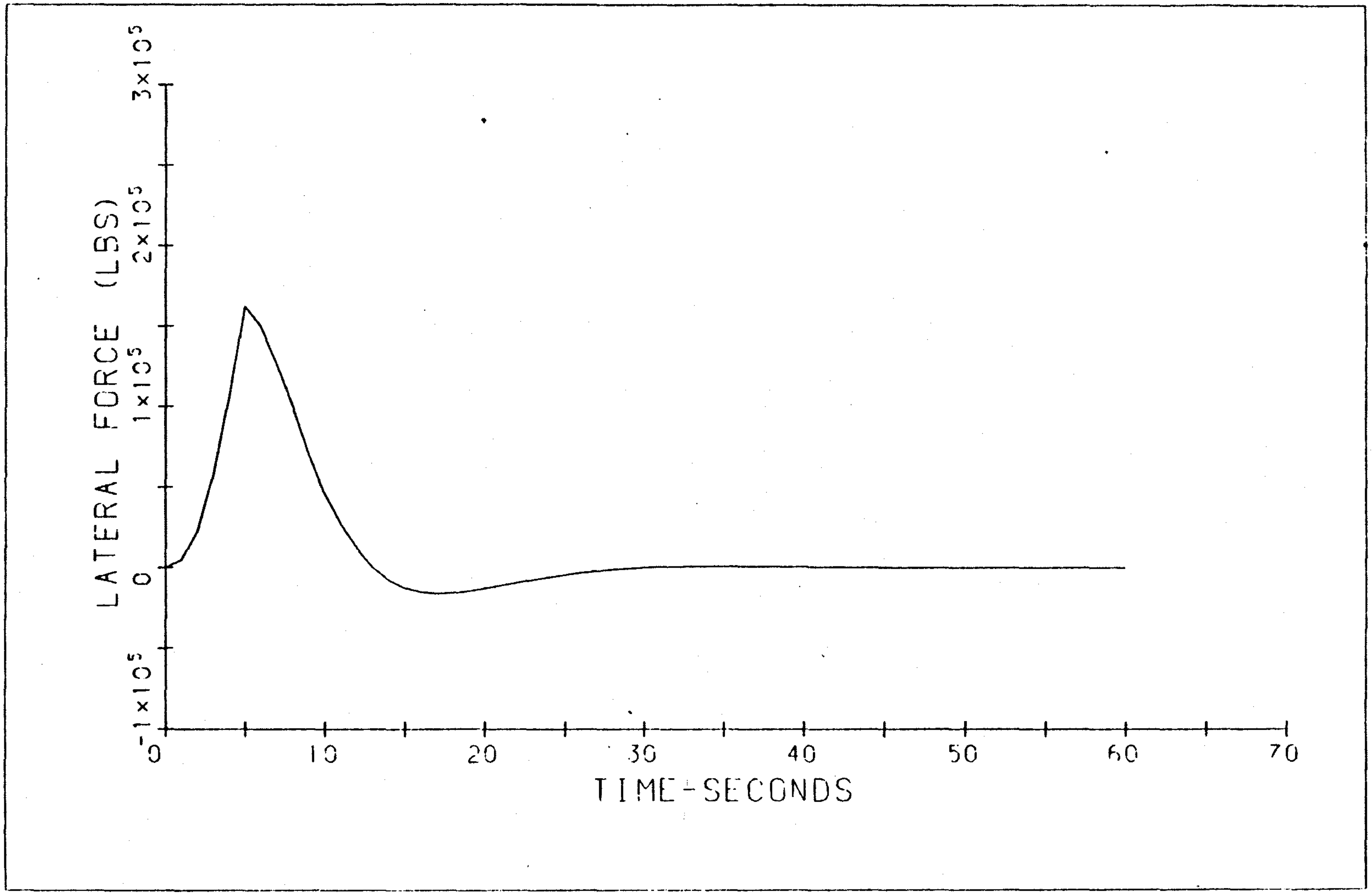
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

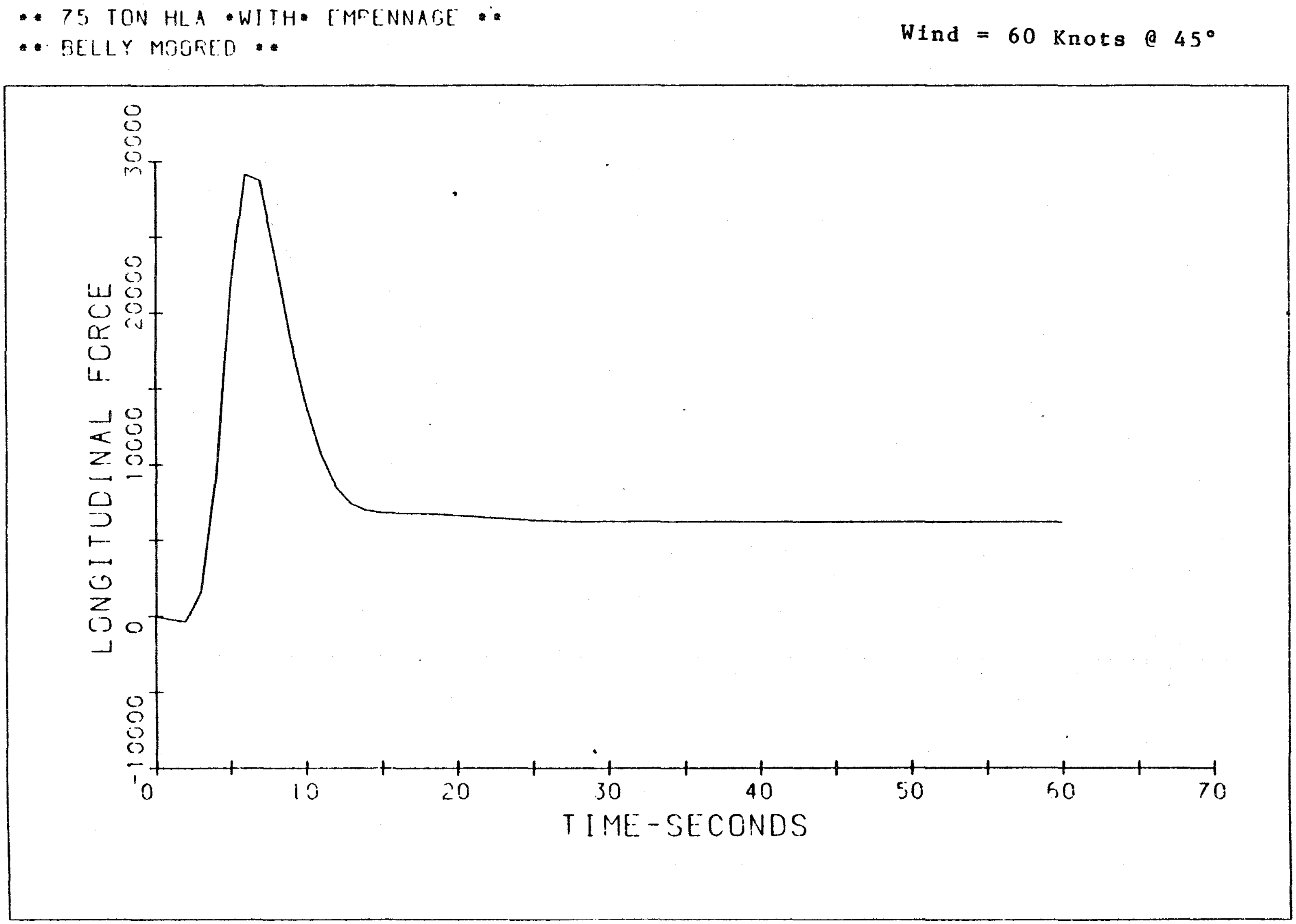
Wind = 60 Knots @ 45°



** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 45°

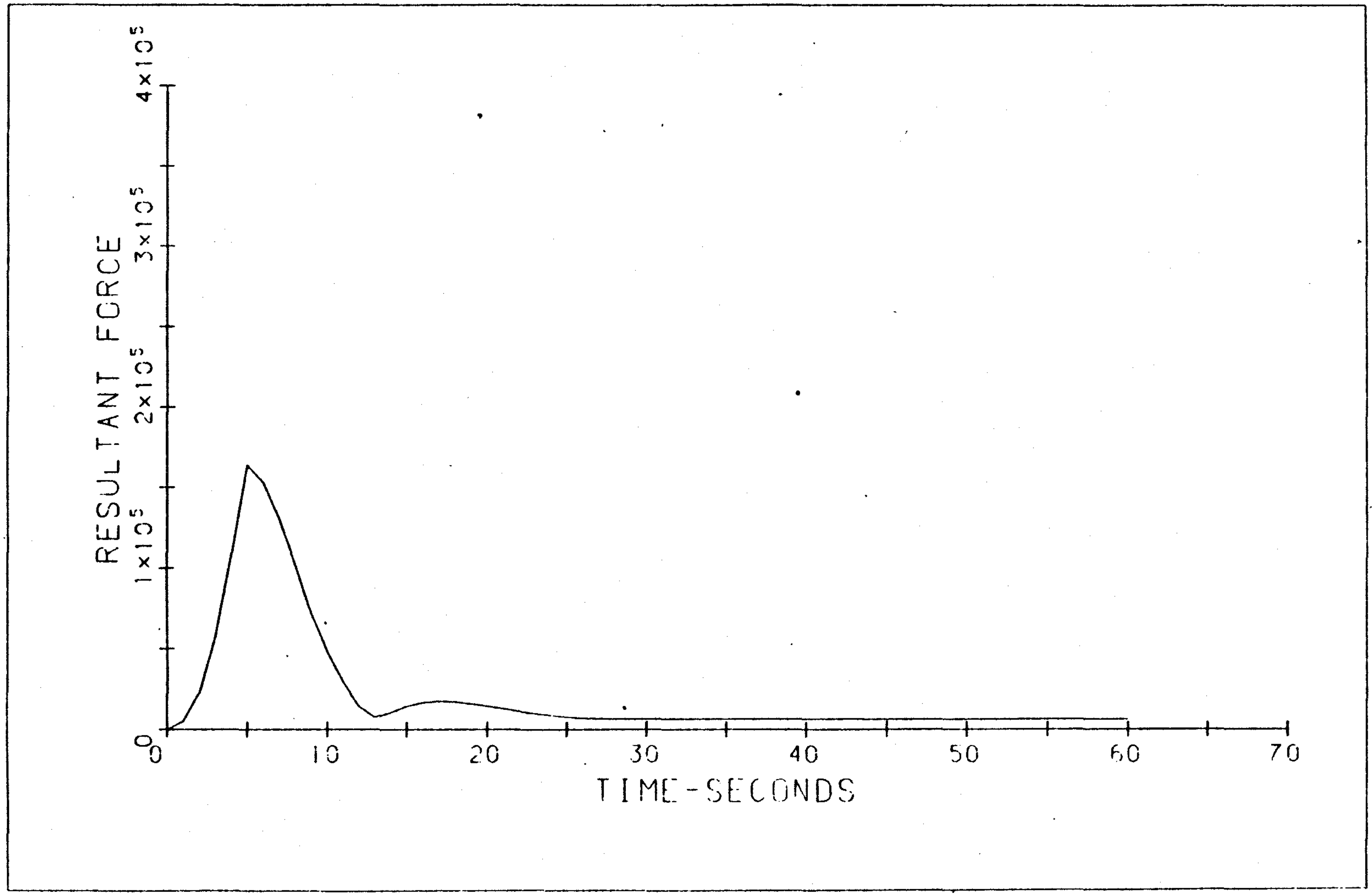




** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **
Wind = 60 Knots @ 45°
LONGITUDINAL FORCE
30000
20000
10000
0
-10000
0
10
20
30
40
50
60
70
TIME-SECONDS

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 45°



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****************************************
*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
****************************************
```

AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE.................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE..........:    203.8 FEET
```

MOORING STYLE

```
** BELLY MOORED **
MAST LOCATION RELATIVE TO NOSE........:    108.0 FEET
HEIGHT OF MAST........................:     15.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .216E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED............................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS...:     60.0 DEGREES
THETA (DISPLACEMENT ANGLE)............:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY)..........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

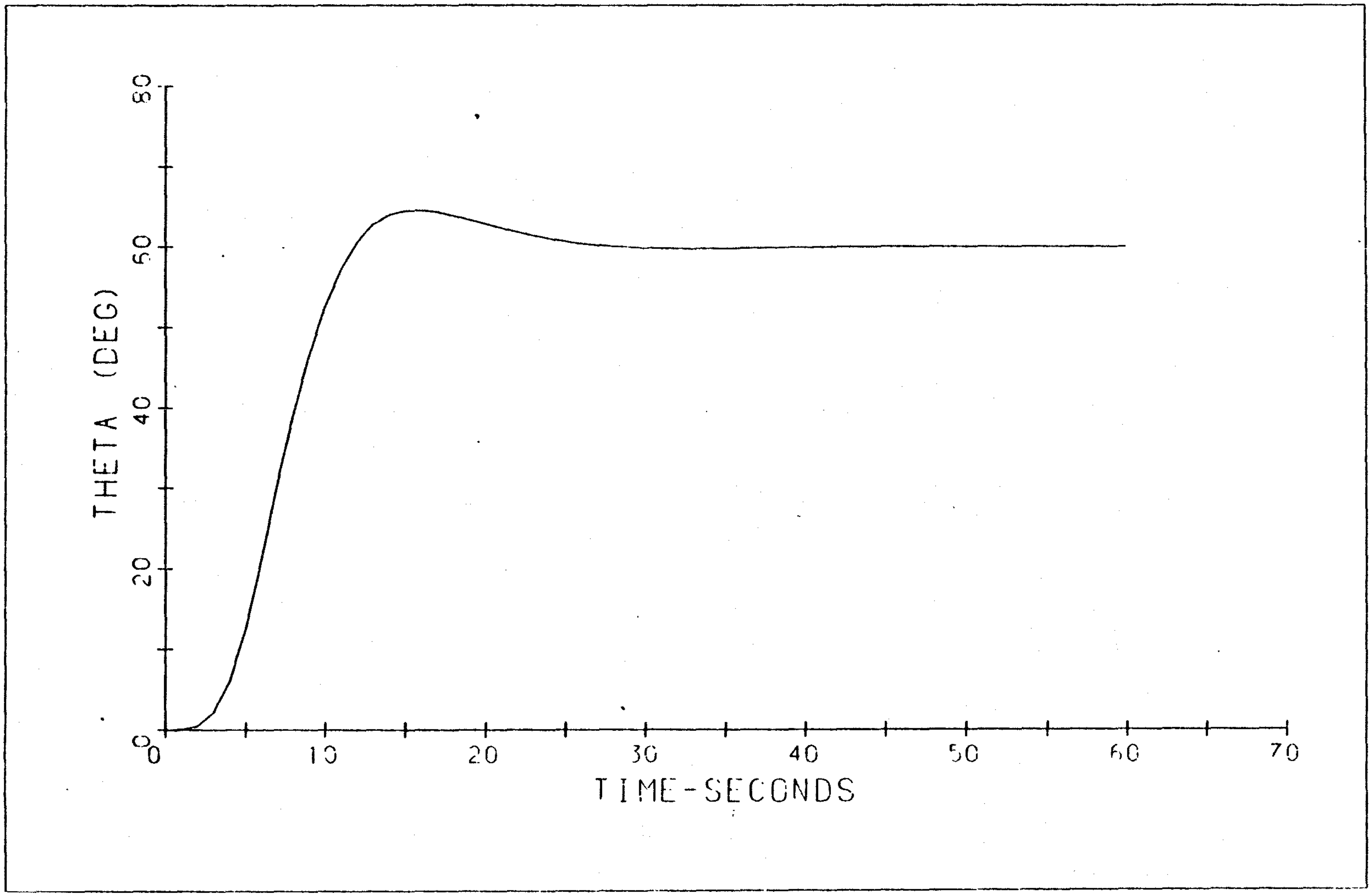
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.36	.12	.03	5697	-744	5745	3044	0	2970	0
2.0	1.24	.90	.47	25334	-2285	25436	13605	0	13378	0
3.0	2.19	2.62	2.15	63412	-1618	63433	34323	0	34162	0
4.0	2.76	5.16	5.99	123555	6804	123742	67527	0	68203	0
5.0	2.44	7.81	12.50	205699	25853	207317	113372	0	115940	0
6.0	.59	9.23	21.17	199380	41526	203658	110966	0	115090	0
7.0	-.69	9.15	30.47	170124	43876	175690	95235	0	99593	0
8.0	-1.32	8.09	39.15	134848	37551	139978	75669	0	79399	0
9.0	-1.39	6.71	46.55	99694	28890	103794	56016	0	58886	0
10.0	-1.39	5.33	52.57	65829	20715	69010	37095	0	39152	0
11.0	-1.33	3.96	57.21	38702	14359	41280	21951	0	23378	0
12.0	-1.16	2.71	60.54	17434	10170	20183	10130	0	11140	0
13.0	-.93	1.67	62.71	1758	8099	8287	1484	0	2288	379
14.0	-.70	.85	63.95	-8911	7270	11500	0	5313	0	6035
15.0	-.48	.26	64.48	-15408	6992	16920	0	8822	0	9517
16.0	-.30	-.13	64.53	-18665	6936	19912	0	10587	0	11276
17.0	-.16	-.36	64.28	-19589	6923	20776	0	11088	0	11776
18.0	-.07	-.47	63.86	-18857	6885	20074	0	10688	0	11372
19.0	-.03	-.52	63.36	-17101	6821	18411	0	9731	0	10408
20.0	.01	-.53	62.83	-14993	6739	16438	0	8581	0	9250
21.0	.03	-.51	62.31	-12729	6647	14360	0	7345	0	8006
22.0	.05	-.47	61.82	-10460	6553	12343	0	6107	0	6758
23.0	.05	-.42	61.37	-8297	6464	10518	0	4927	0	5569
24.0	.06	-.36	60.98	-6317	6384	8981	0	3847	0	4481
25.0	.06	-.30	60.65	-4566	6326	7802	0	2892	0	3521
26.0	.06	-.25	60.37	-3065	6285	6993	0	2075	0	2699
27.0	.05	-.19	60.15	-1822	6252	6512	0	1398	40	2019
28.0	.05	-.14	59.98	-824	6229	6284	0	855	578	1473
29.0	.04	-.10	59.86	-56	6228	6228	376	437	995	1056
30.0	.03	-.06	59.78	507	6236	6256	683	131	1302	751
31.0	.03	-.03	59.73	895	6240	6304	894	0	1514	541
32.0	.02	-.01	59.71	1137	6241	6344	1025	0	1645	410
33.0	.01	.01	59.70	1258	6240	6366	1091	0	1711	344
34.0	.01	.02	59.72	1287	6237	6369	1107	0	1726	328
35.0	.01	.03	59.74	1248	6233	6357	1085	0	1704	348
36.0	.00	.03	59.77	1160	6228	6335	1037	0	1655	395
37.0	.00	.03	59.80	1040	6223	6309	971	0	1590	459
38.0	-.00	.03	59.83	904	6218	6283	897	0	1515	533
39.0	-.00	.03	59.86	762	6212	6259	820	0	1437	609
40.0	-.00	.03	59.89	624	6208	6239	744	67	1361	683
41.0	-.00	.03	59.92	493	6204	6223	673	137	1290	753
42.0	-.00	.02	59.94	376	6200	6211	609	200	1225	816
43.0	-.00	.02	59.96	274	6198	6204	554	256	1170	871
44.0	-.00	.01	59.98	188	6196	6199	507	302	1122	918
45.0	-.00	.01	59.99	118	6195	6196	469	340	1084	956
46.0	-.00	.01	60.00	61	6194	6194	438	371	1053	986
47.0	-.00	.01	60.00	20	6193	6193	415	394	1031	1009

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	-.00	.00	60.01	-10	6194	6194	399	410	1014	1025
49.0	-.00	.00	60.01	-29	6194	6194	388	421	1004	1036
50.0	-.00	.00	60.01	-40	6194	6194	383	426	998	1042
51.0	-.00	.00	60.01	-46	6194	6194	379	430	995	1045
52.0	-.00	-.00	60.01	-48	6194	6194	378	431	994	1046
53.0	-.00	-.00	60.01	-41	6193	6194	382	427	997	1042
54.0	-.00	-.00	60.01	-34	6193	6193	386	423	1001	1038
55.0	.00	-.00	60.00	-25	6193	6193	391	418	1006	1033
56.0	.00	-.00	60.00	-15	6192	6192	396	413	1011	1028
57.0	.00	-.00	60.00	-5	6192	6192	401	407	1016	1023
58.0	.00	-.00	60.00	4	6192	6192	407	402	1022	1017
59.0	.00	-.00	60.00	15	6193	6193	413	396	1028	1011
60.0	.00	.00	60.00	18	6193	6193	415	394	1030	1009

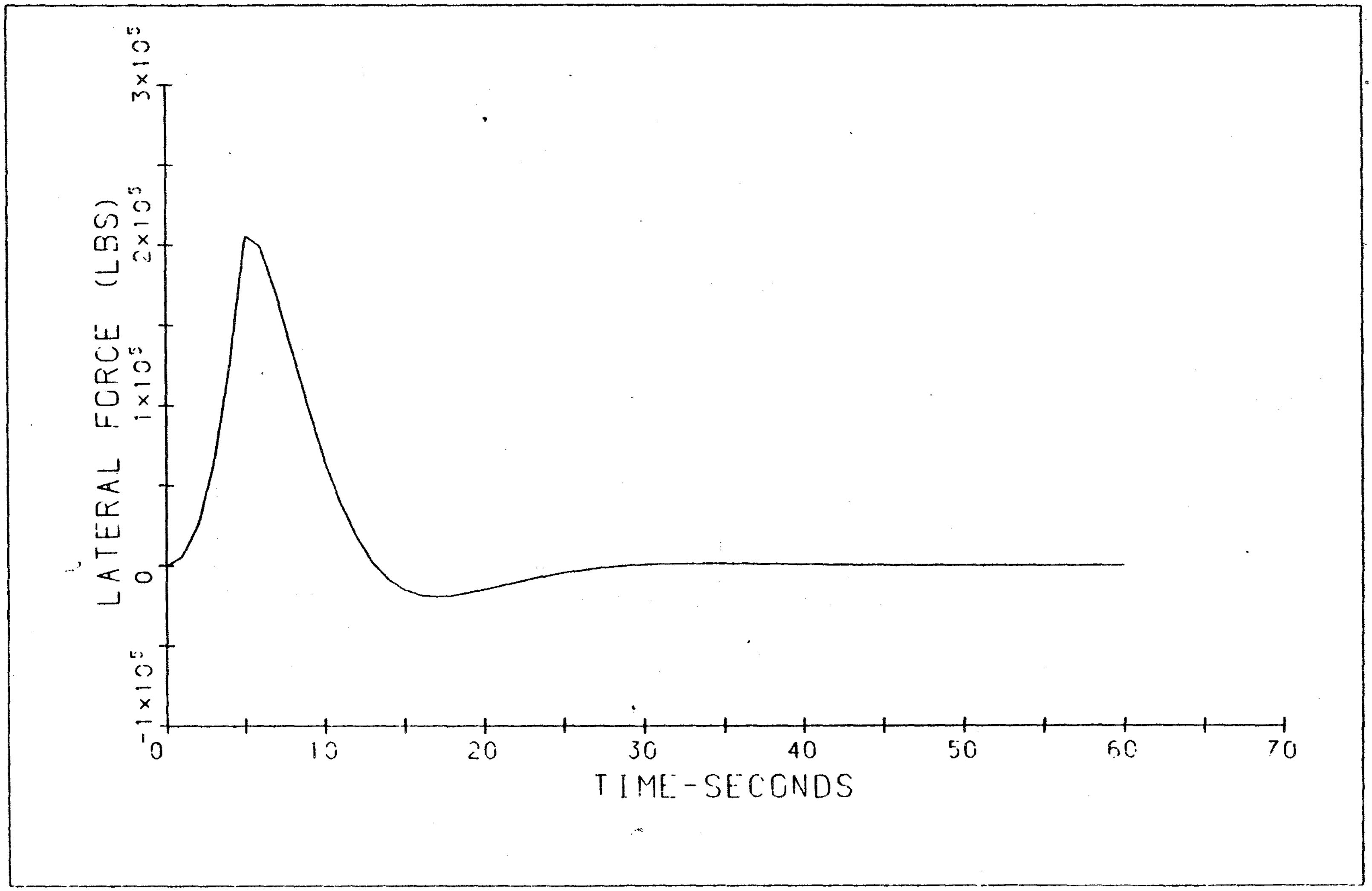
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

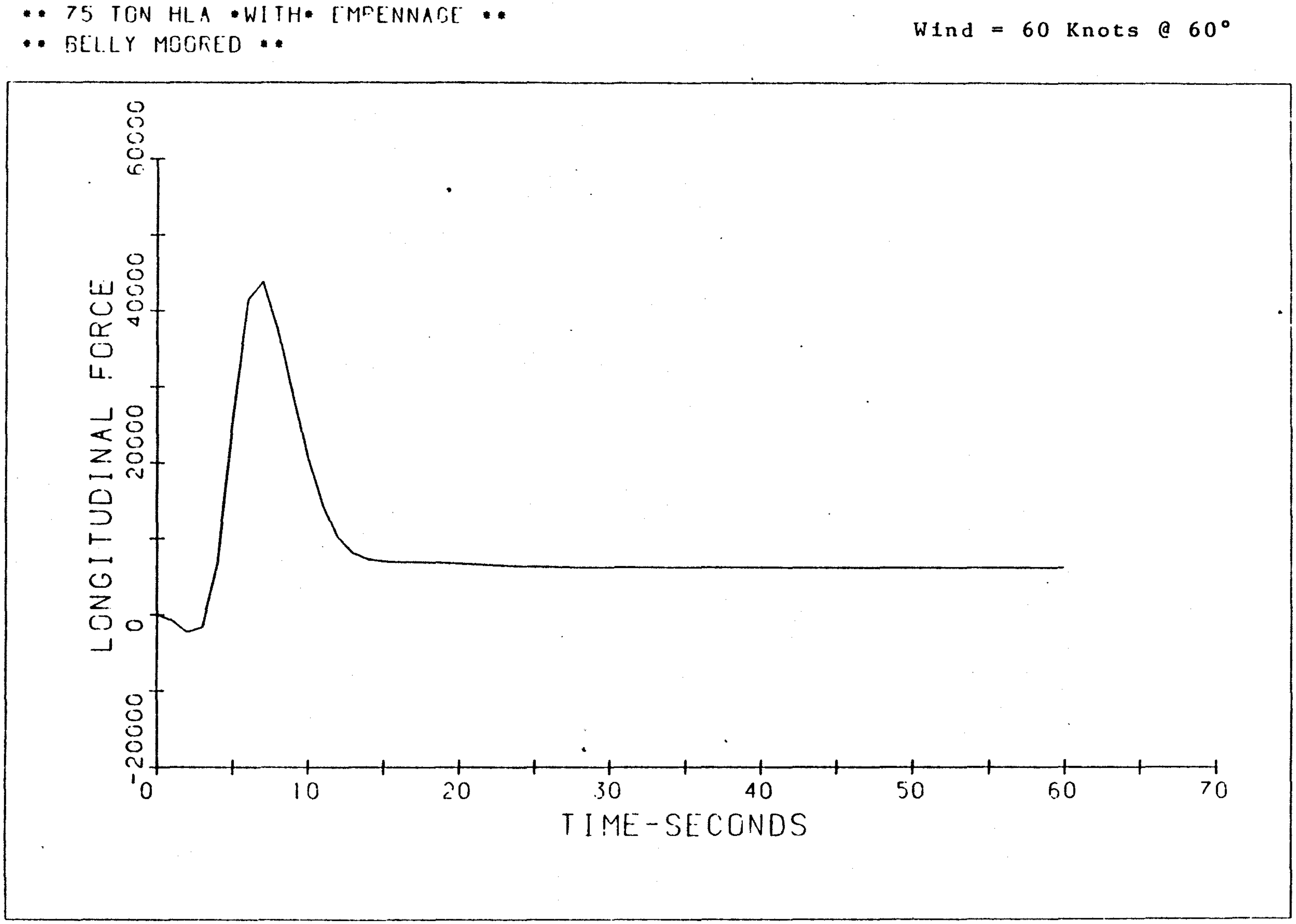
Wind = 60 Knots @ 60°



** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

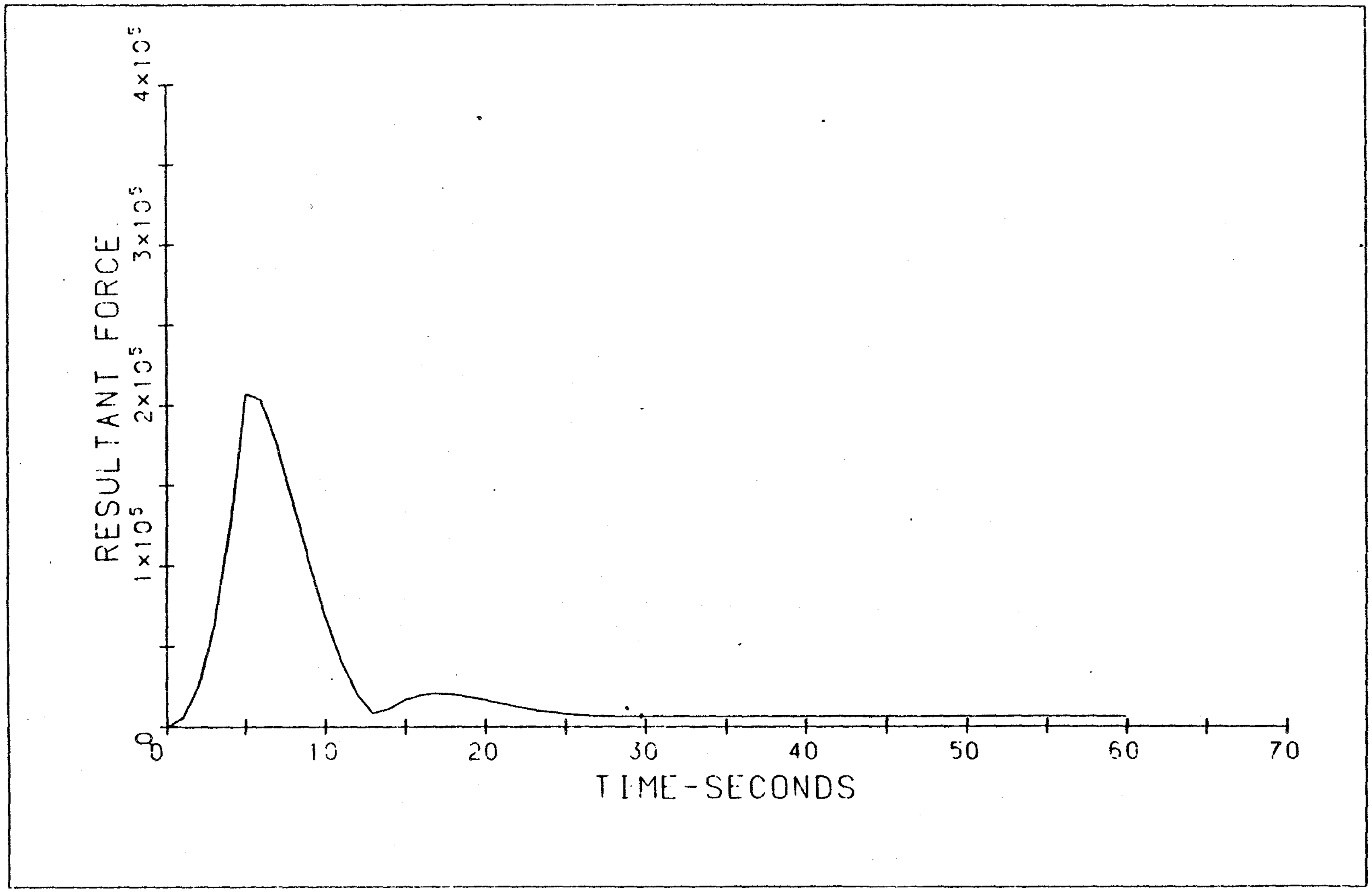
Wind = 60 Knots @ 60°




** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **
Wind = 60 Knots @ 60°
LONGITUDINAL FORCE
60000
40000
20000
0
-20000
0
10
20
30
40
50
60
70
TIME-SECONDS

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 60°



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*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
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AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITH* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .119E 09 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  10632.0 SLUGS
HEIGHT OF CENTER LINE.................:     65.0 FEET
CG LOCATION RELATIVE TO NOSE..........:    203.8 FEET
```

MOORING STYLE

```
** BELLY MOORED **
MAST LOCATION RELATIVE TO NOSE........:    108.0 FEET
HEIGHT OF MAST........................:     15.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .216E 09 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED............................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     90.0 DEGREES
THETA (DISPLACEMENT ANGLE)............:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY)..........:       .0 DEG/SEC
```

** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
.0	.00	.00	.00	0	0	0	0	0	0	0
1.0	.51	.18	.04	2102	-1203	2422	1062	0	943	0
2.0	1.70	1.25	.66	12007	-3462	12497	6293	0	5949	0
3.0	2.84	3.55	2.97	39051	-1939	39099	21075	0	20883	0
4.0	3.43	6.75	8.07	97766	9147	98192	53679	0	54587	0
5.0	3.29	10.16	16.53	207754	32141	210226	114899	0	118091	0
6.0	1.32	12.35	27.95	244352	60644	251763	136633	0	142656	0
7.0	-.12	12.92	40.70	245160	73924	256060	137939	0	145282	0
8.0	-1.23	12.20	53.35	216823	71070	228172	122368	0	129427	0
9.0	-1.80	10.60	64.80	165681	57891	175503	93739	0	99489	0
10.0	-1.99	8.71	74.46	121269	43160	128720	68663	0	72950	0
11.0	-2.00	6.69	82.16	78406	28548	83441	44436	0	47271	0
12.0	-1.81	4.77	87.87	43018	17771	46544	24518	0	26283	0
13.0	-1.51	3.10	91.78	16368	11347	19917	9629	0	10756	0
14.0	-1.17	1.76	94.17	-2470	8508	8859	0	1897	59	2742
15.0	-.84	.76	95.40	-14636	7433	16416	0	8432	0	9171
16.0	-.56	.06	95.79	-21458	7157	22620	0	12118	0	12829
17.0	-.33	-.37	95.61	-24295	7145	25324	0	13657	0	14367
18.0	-.15	-.60	95.11	-24388	7144	25413	0	13708	0	14418
19.0	-.03	-.69	94.45	-22713	7080	23791	0	12794	0	13498
20.0	.01	-.70	93.75	-19880	6972	21067	0	11249	0	11942
21.0	.04	-.68	93.06	-16854	6846	18192	0	9598	0	10278
22.0	.06	-.62	92.40	-13831	6713	15374	0	7948	0	8615
23.0	.07	-.56	91.81	-10957	6585	12784	0	6379	0	7033
24.0	.08	-.48	91.29	-8329	6470	10547	0	4945	0	5588
25.0	.08	-.40	90.85	-6008	6387	8769	0	3680	0	4314
26.0	.08	-.32	90.48	-4024	6327	7498	0	2598	0	3226
27.0	.07	-.25	90.19	-2380	6278	6714	0	1702	0	2326
28.0	.06	-.19	89.97	-1064	6245	6335	0	986	450	1606
29.0	.05	-.13	89.81	-51	6242	6242	379	436	999	1056
30.0	.04	-.08	89.71	690	6251	6289	783	33	1404	654
31.0	.03	-.04	89.64	1199	6256	6370	1060	0	1681	379
32.0	.03	-.01	89.61	1513	6258	6438	1231	0	1852	208
33.0	.02	.01	89.61	1670	6256	6475	1315	0	1937	123
34.0	.01	.03	89.63	1705	6252	6480	1334	0	1955	104
35.0	.01	.04	89.65	1649	6247	6461	1303	0	1924	133
36.0	.00	.04	89.69	1530	6240	6425	1238	0	1858	196
37.0	.00	.04	89.74	1370	6233	6382	1151	0	1770	282
38.0	-.00	.04	89.78	1187	6226	6338	1051	0	1670	380
39.0	-.00	.04	89.82	999	6219	6299	949	0	1566	481
40.0	-.00	.04	89.86	814	6213	6266	848	0	1465	580
41.0	-.00	.03	89.90	642	6207	6240	754	57	1371	673
42.0	-.00	.03	89.93	486	6202	6221	669	141	1285	757
43.0	-.00	.02	89.95	350	6199	6209	595	214	1211	830
44.0	-.00	.02	89.97	236	6197	6202	533	276	1149	892
45.0	-.00	.02	89.99	143	6196	6197	483	327	1098	942
46.0	-.00	.01	90.00	70	6194	6195	443	366	1058	982
47.0	-.00	.01	90.01	15	6194	6194	413	396	1028	1011

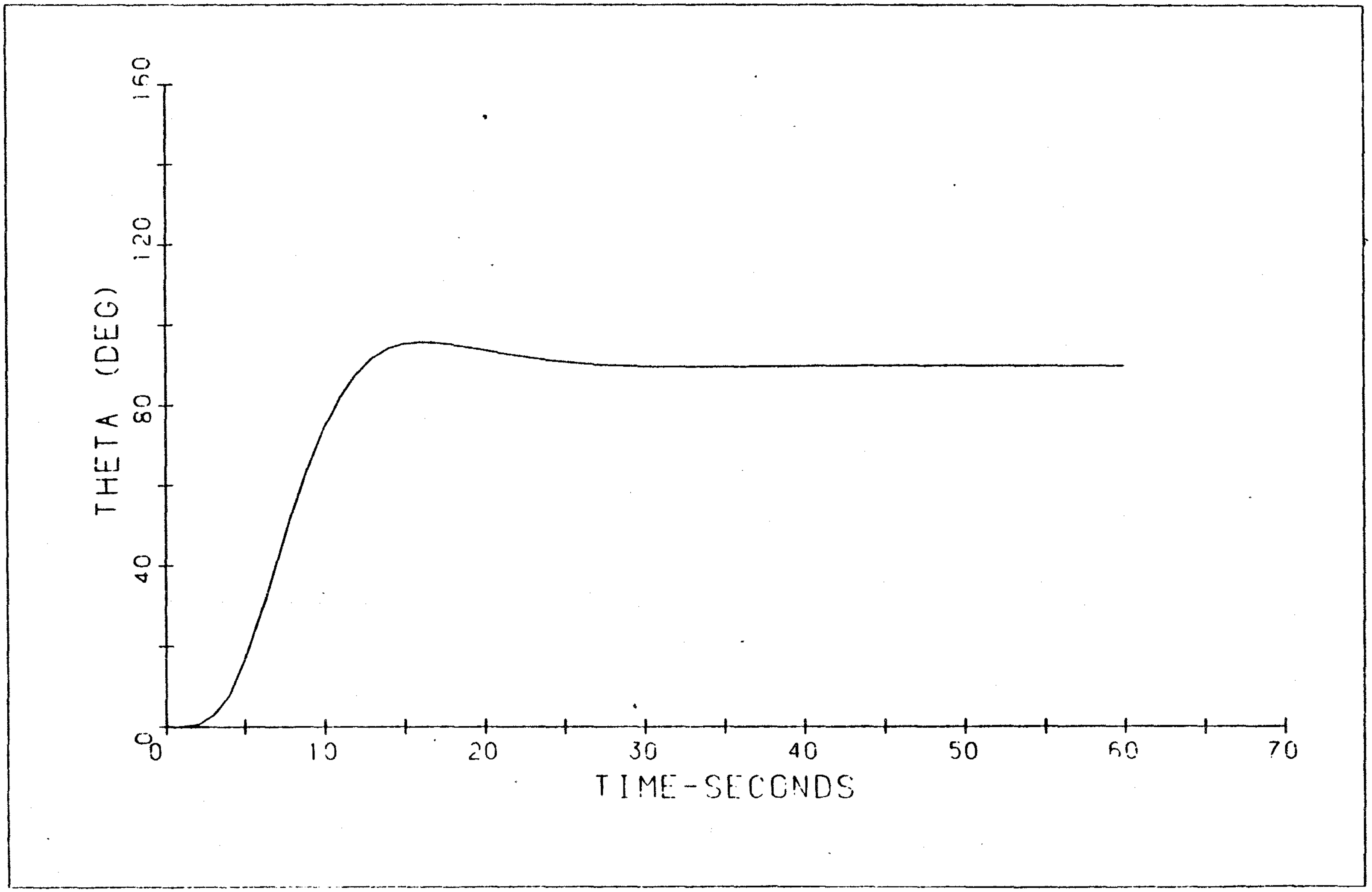
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS	FLGA1 LBS	FLGA2 LBS	FLGB1 LBS	FLGB2 LBS
48.0	-.00	.01	90.01	-24	6195	6195	391	418	1007	1033
49.0	-.00	.00	90.02	-50	6195	6195	377	432	993	1047
50.0	-.00	.00	90.02	-65	6195	6195	369	440	985	1055
51.0	-.00	.00	90.02	-72	6195	6195	365	444	980	1059
52.0	-.00	-.00	90.02	-71	6195	6195	366	443	981	1059
53.0	-.00	-.00	90.01	-65	6194	6195	369	440	984	1056
54.0	-.00	-.00	90.01	-58	6194	6194	373	436	988	1052
55.0	-.00	-.00	90.01	-50	6194	6194	377	432	992	1047
56.0	.00	-.00	90.01	-41	6193	6193	382	427	997	1042
57.0	.00	-.00	90.01	-31	6193	6193	387	421	1003	1036
58.0	.00	-.00	90.00	-20	6192	6192	393	416	1008	1031
59.0	.00	-.00	90.00	-10	6192	6192	399	410	1014	1025
60.0	.00	-.00	90.00	0	6192	6192	405	404	1020	1019

EXIT

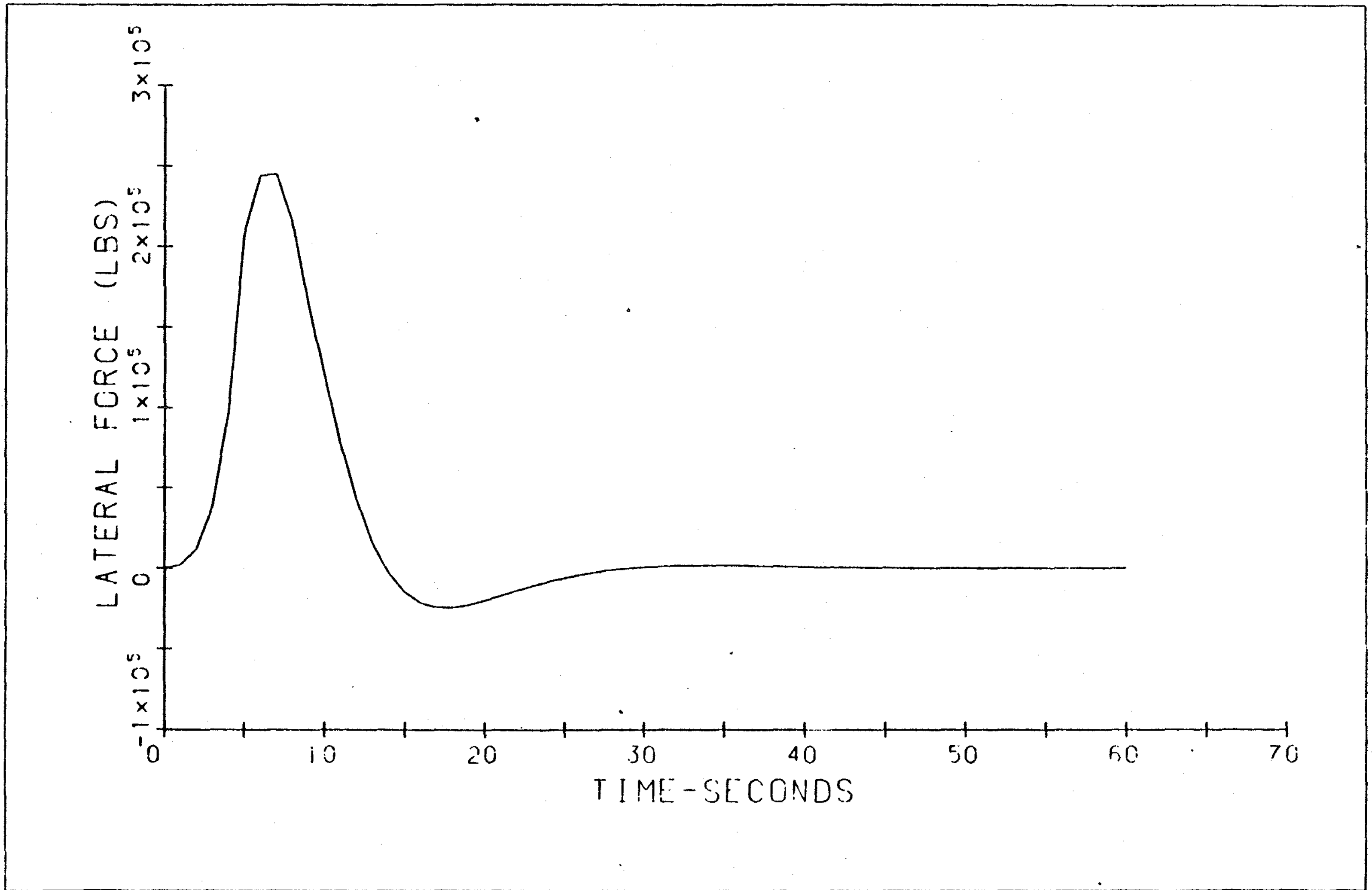
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 90 Knots @ 90°



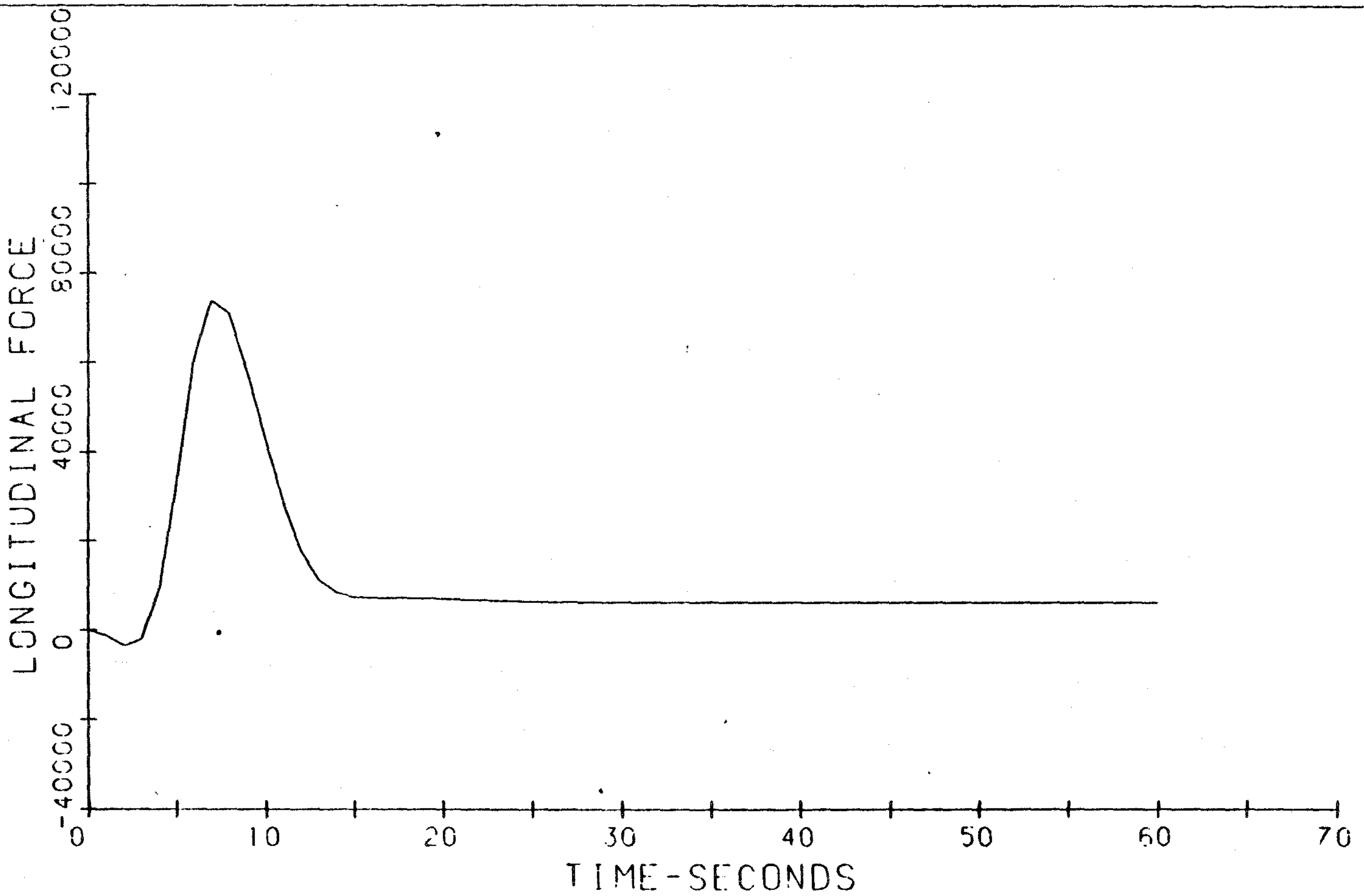
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 90 Knots @ 90°



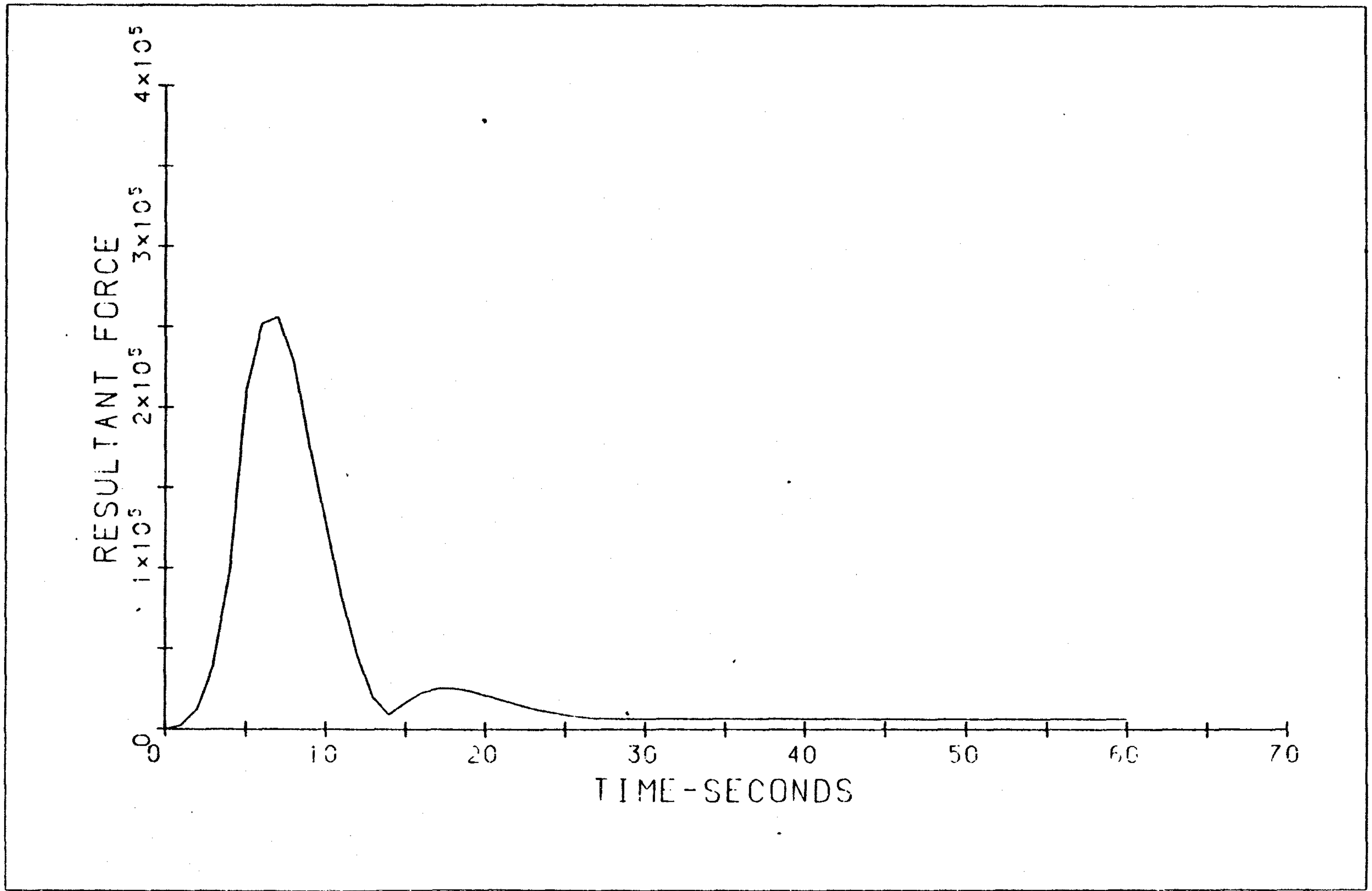
** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 90 Knots @ 90°



** 75 TON HLA *WITH* EMPENNAGE **
** BELLY MOORED **

Wind = 60 Knots @ 90°



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*************************************** 
*                                     *
*    AIRSHIP MOORING LOADS ANALYSIS   *
*                                     *
***************************************

AIRSHIP CONFIGURATION DATA
--------------------------

** 75 TON HLA *WITHOUT* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG...........: .916E 08 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  11365.0 SLUGS
HEIGHT OF CENTER LINE................:     64.5 FEET
CG LOCATION RELATIVE TO NOSE.........:    171.0 FEET

MOORING STYLE
-------------

** CENTER MOORED **
MAST LOCATION RELATIVE TO NOSE.......:    171.0 FEET
HEIGHT OF MAST.......................:     11.0 FEET
MOMENT OF INERTIA ABOUT MAST.........: .916E 08 SLUG-FTSQ

INITIAL CONDITIONS
------------------

WIND SPEED...........................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     15.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

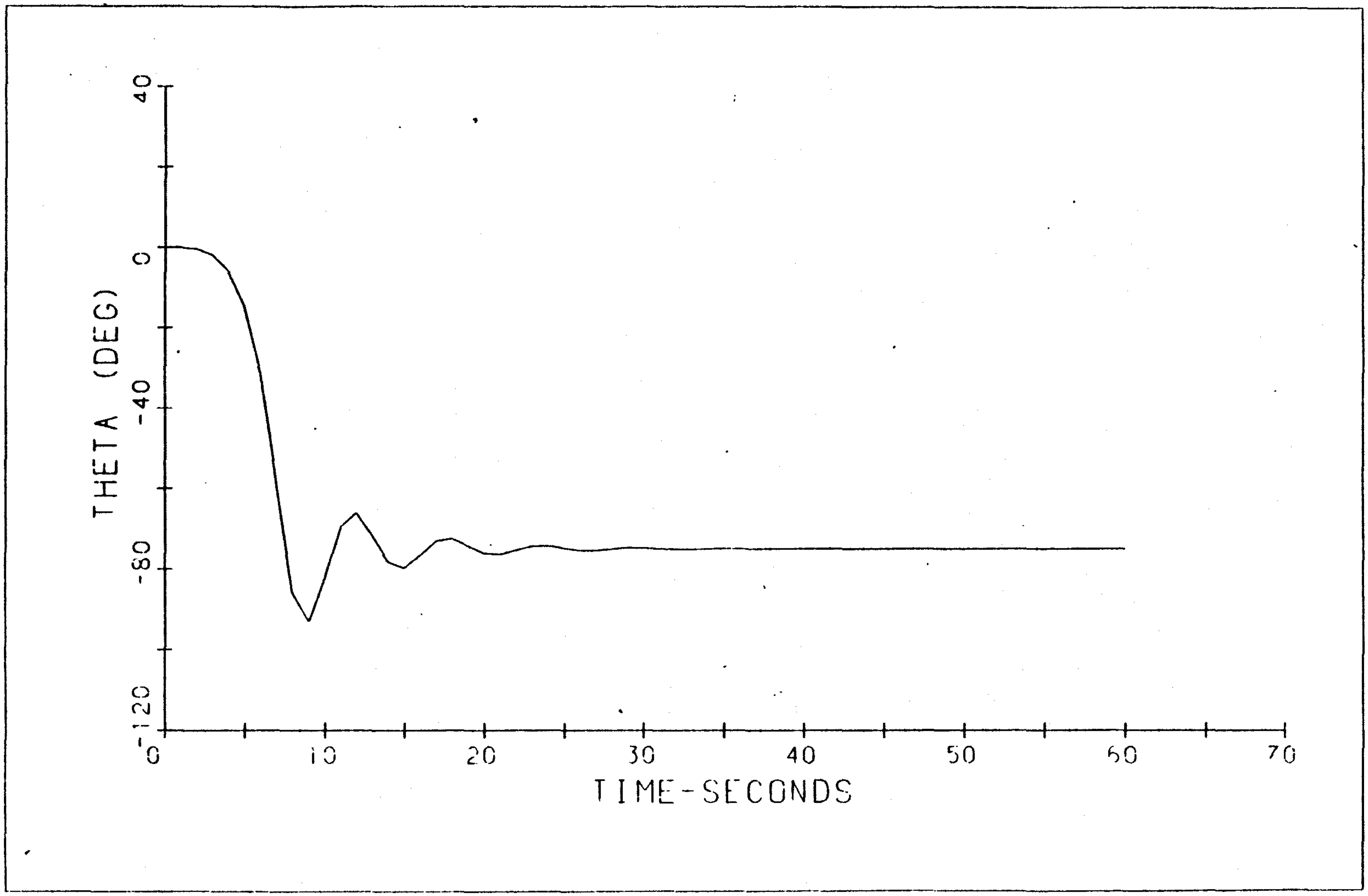
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
.0	.00	.00	.00	0	0	0
1.0	-.31	-.11	-.03	9453	348	9459
2.0	-1.12	-.79	-.41	33954	1563	33990
3.0	-2.33	-2.47	-1.93	69369	5015	69549
4.0	-4.47	-5.76	-5.87	122550	15864	123572
5.0	-9.04	-12.21	-14.48	218316	51501	224307
6.0	-12.35	-22.80	-31.69	221146	149380	266870
7.0	-.00	-30.05	-59.19	260529	237733	352691
8.0	22.83	-19.21	-85.83	52376	65552	83906
9.0	18.78	4.13	-92.97	25381	-25309	35843
10.0	1.75	14.33	-82.30	316157	39467	318610
11.0	-11.00	9.27	-69.41	585848	-985	585844
12.0	-9.61	-2.28	-66.05	536808	-30858	537692
13.0	-.72	-7.52	-71.71	373376	-18641	373840
14.0	5.84	-4.54	-78.30	267536	-29046	269107
15.0	4.96	1.46	-79.76	276674	-31045	278408
16.0	.20	4.09	-76.58	359148	-24784	359999
17.0	-3.26	2.31	-73.08	424110	-29161	425110
18.0	-2.65	-.96	-72.46	411335	-32232	412594
19.0	.08	-2.28	-74.31	361353	-31863	362753
20.0	1.85	-1.15	-76.18	331047	-32597	332646
21.0	1.38	.63	-76.39	338738	-31837	340231
22.0	-.13	1.27	-75.31	364802	-31014	366115
23.0	-1.06	.57	-74.31	382022	-31729	383335
24.0	-.73	-.41	-74.25	376013	-32333	377398
25.0	.14	-.71	-74.89	359830	-32461	361290
26.0	.60	-.28	-75.42	351918	-32391	353405
27.0	.38	.26	-75.41	355836	-32079	357276
28.0	-.11	.39	-75.04	364152	-31945	365550
29.0	-.35	.13	-74.75	368670	-32114	370062
30.0	-.20	-.17	-74.78	365942	-32284	367361
31.0	.08	-.22	-75.00	360754	-32327	362197
32.0	.20	-.06	-75.15	358875	-32262	360319
33.0	.10	.10	-75.12	360550	-32165	361981
34.0	-.05	.12	-74.99	363170	-32142	364587
35.0	-.11	.02	-74.92	364286	-32194	365703
36.0	-.05	-.06	-74.94	363169	-32245	364596
37.0	.04	-.07	-75.01	361564	-32254	362997
38.0	.06	-.01	-75.05	361150	-32226	362583
39.0	.02	.03	-75.03	361804	-32198	363232
40.0	-.02	.03	-74.99	362616	-32195	364041
41.0	-.03	.00	-74.97	362852	-32212	364275
42.0	-.01	-.02	-74.98	362430	-32227	363857
43.0	.01	-.02	-75.01	361957	-32228	363387
44.0	.02	-.00	-75.01	361896	-32218	363325
45.0	.01	.01	-75.01	362122	-32210	363550
46.0	-.01	.01	-75.00	362350	-32210	363779
47.0	-.01	-.00	-74.99	362387	-32216	363813

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
48.0	-.00	-.01	-75.00	362249	-32220	363676
49.0	.00	-.01	-75.00	362122	-32219	363551
50.0	.01	-.00	-75.00	362116	-32216	363543
51.0	.00	.00	-75.00	362190	-32214	363619
52.0	-.00	.00	-75.00	362260	-32214	363687
53.0	-.00	-.00	-75.00	362259	-32216	363688
54.0	-.00	-.00	-75.00	362208	-32217	363638
55.0	.00	-.00	-75.00	362170	-32217	363600
56.0	.00	-.00	-75.00	362182	-32216	363611
57.0	-.00	.00	-75.00	362212	-32215	363642
58.0	-.00	-.00	-75.00	362222	-32216	363649
59.0	-.00	-.00	-75.00	362217	-32216	363646
60.0	-.00	-.00	-75.00	362213	-32216	363642

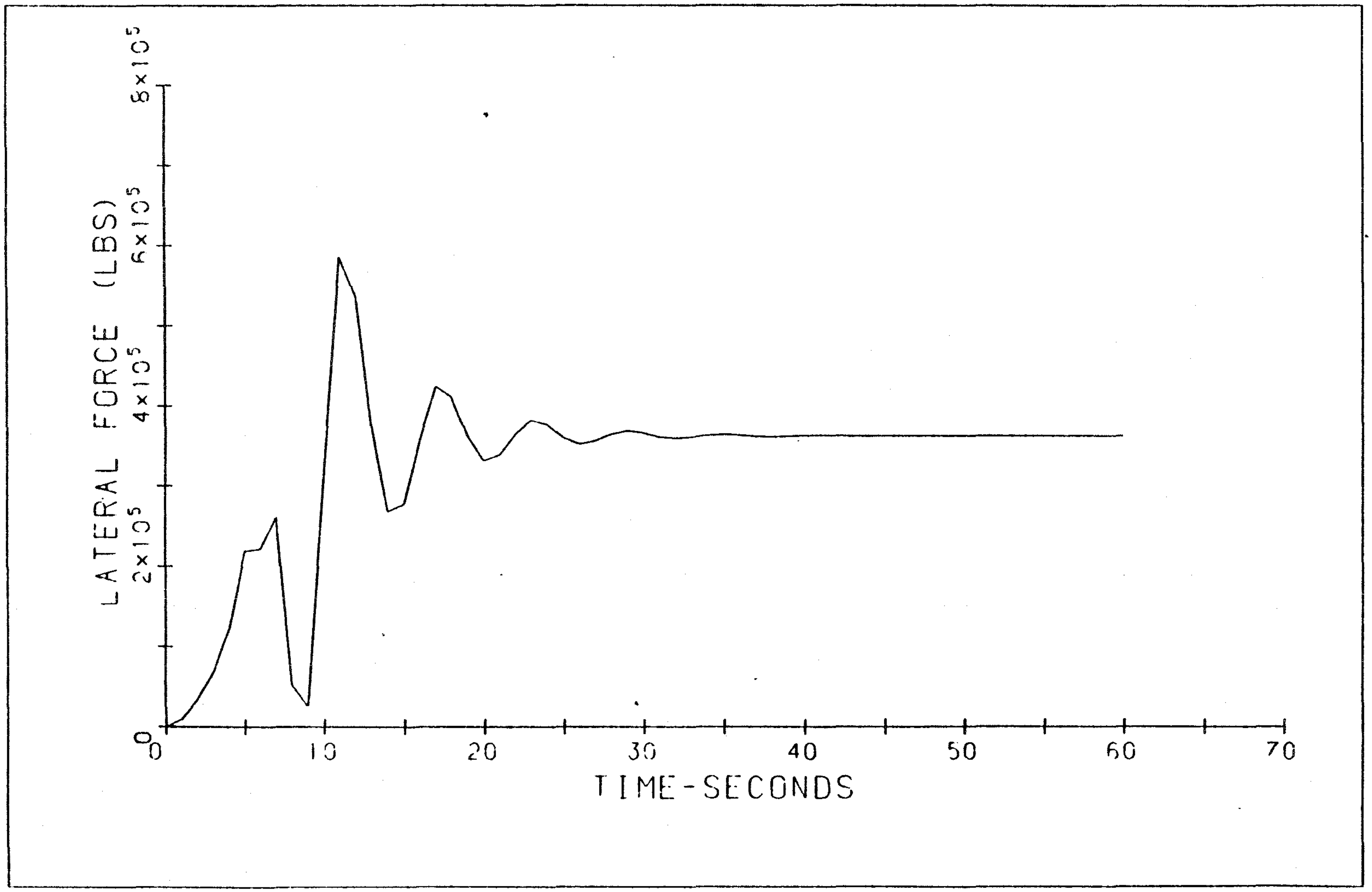
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 15°



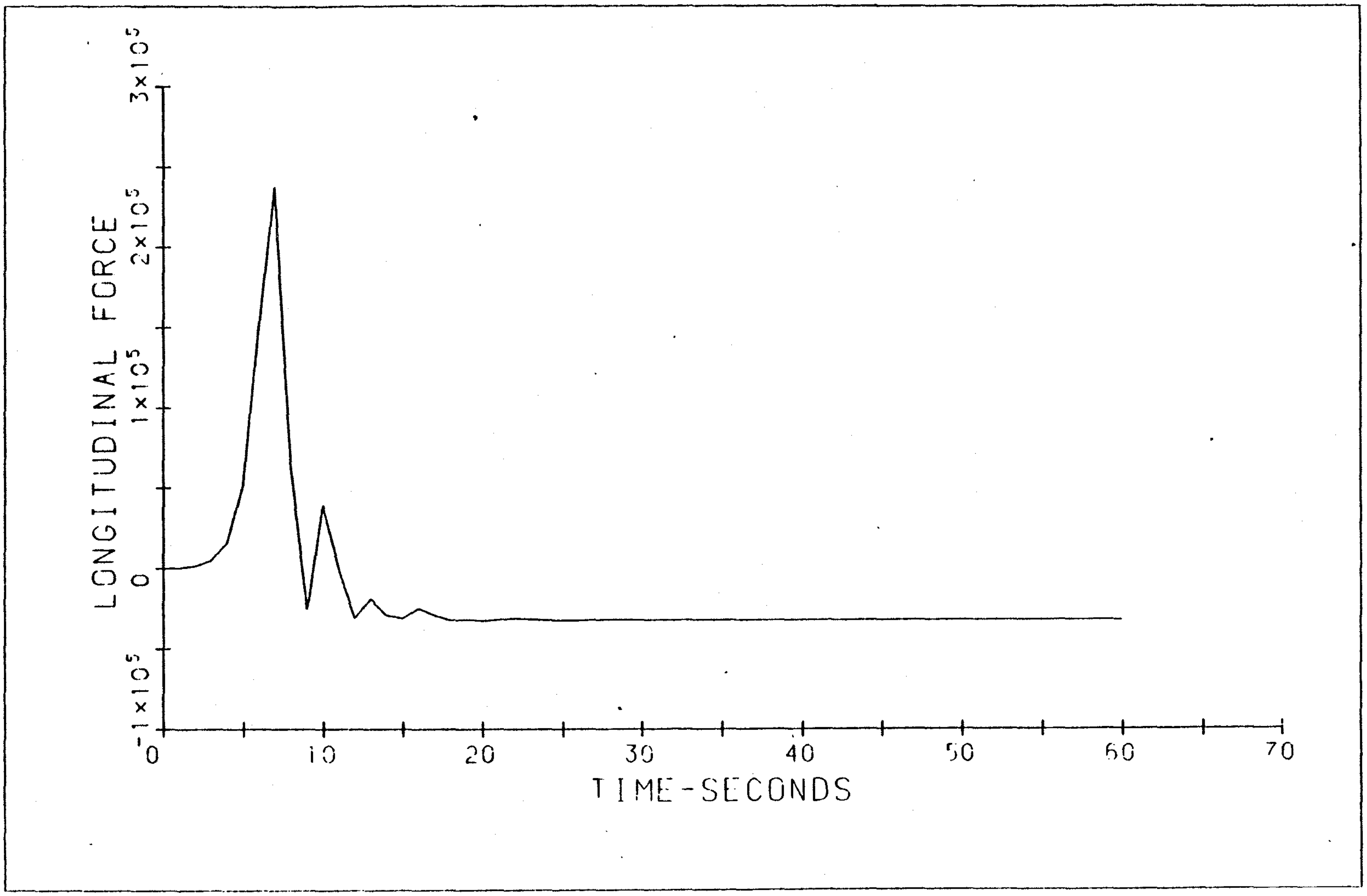
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 15°



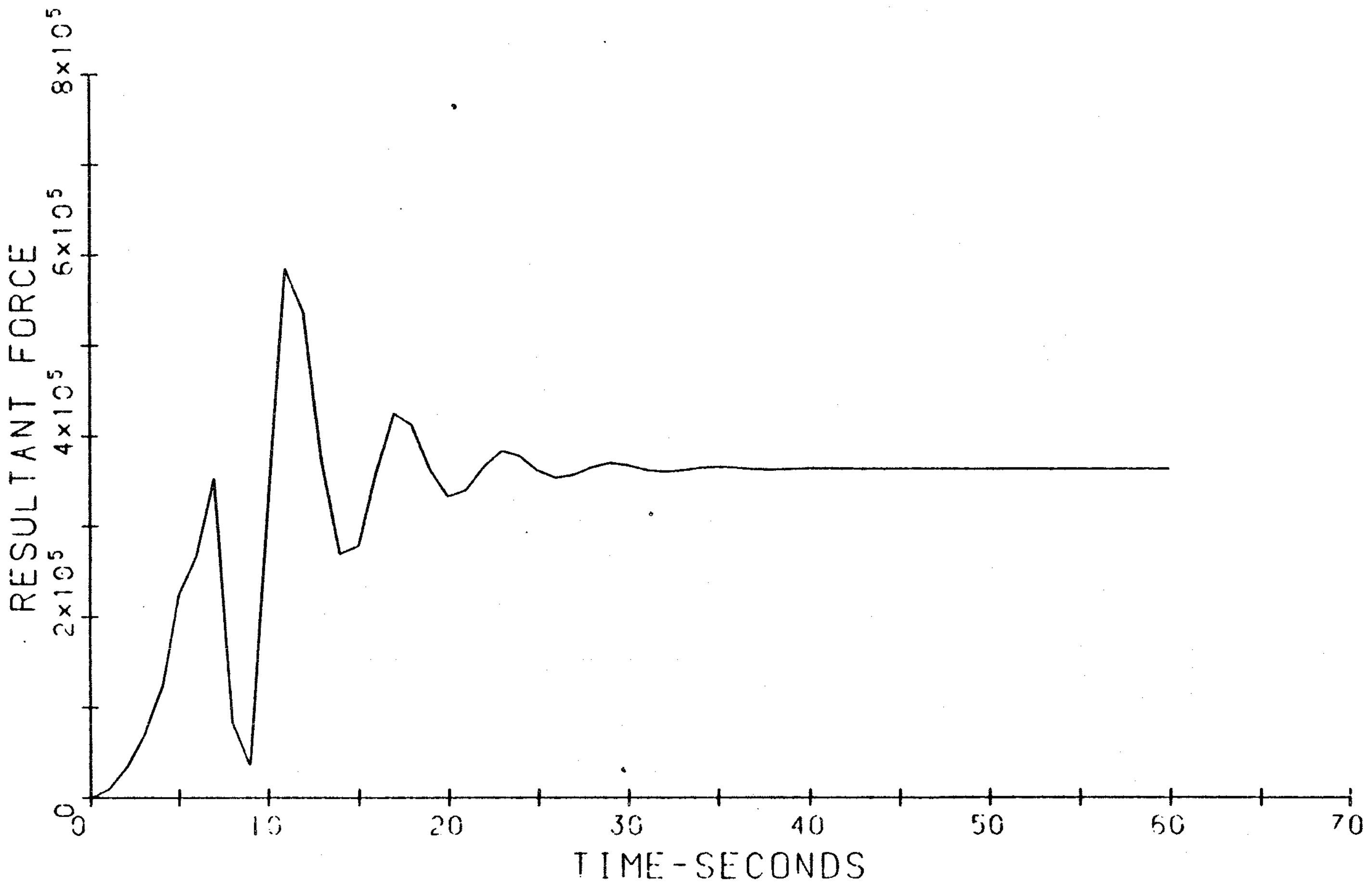
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 15°



** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 15°



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*                                       *
*     AIRSHIP MOORING LOADS ANALYSIS    *
*                                       *
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AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITHOUT* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .916E 08 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  11365.0 SLUGS
HEIGHT OF CENTER LINE.................:     64.5 FEET
CG LOCATION RELATIVE TO NOSE..........:    171.0 FEET
```

MOORING STYLE

```
** CENTER MOORED **
MAST LOCATION RELATIVE TO NOSE........:    171.0 FEET
HEIGHT OF MAST........................:     11.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .916E 08 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED............................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     30.0 DEGREES
THETA (DISPLACEMENT ANGLE)............:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY)..........:       .0 DEG/SEC
```

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

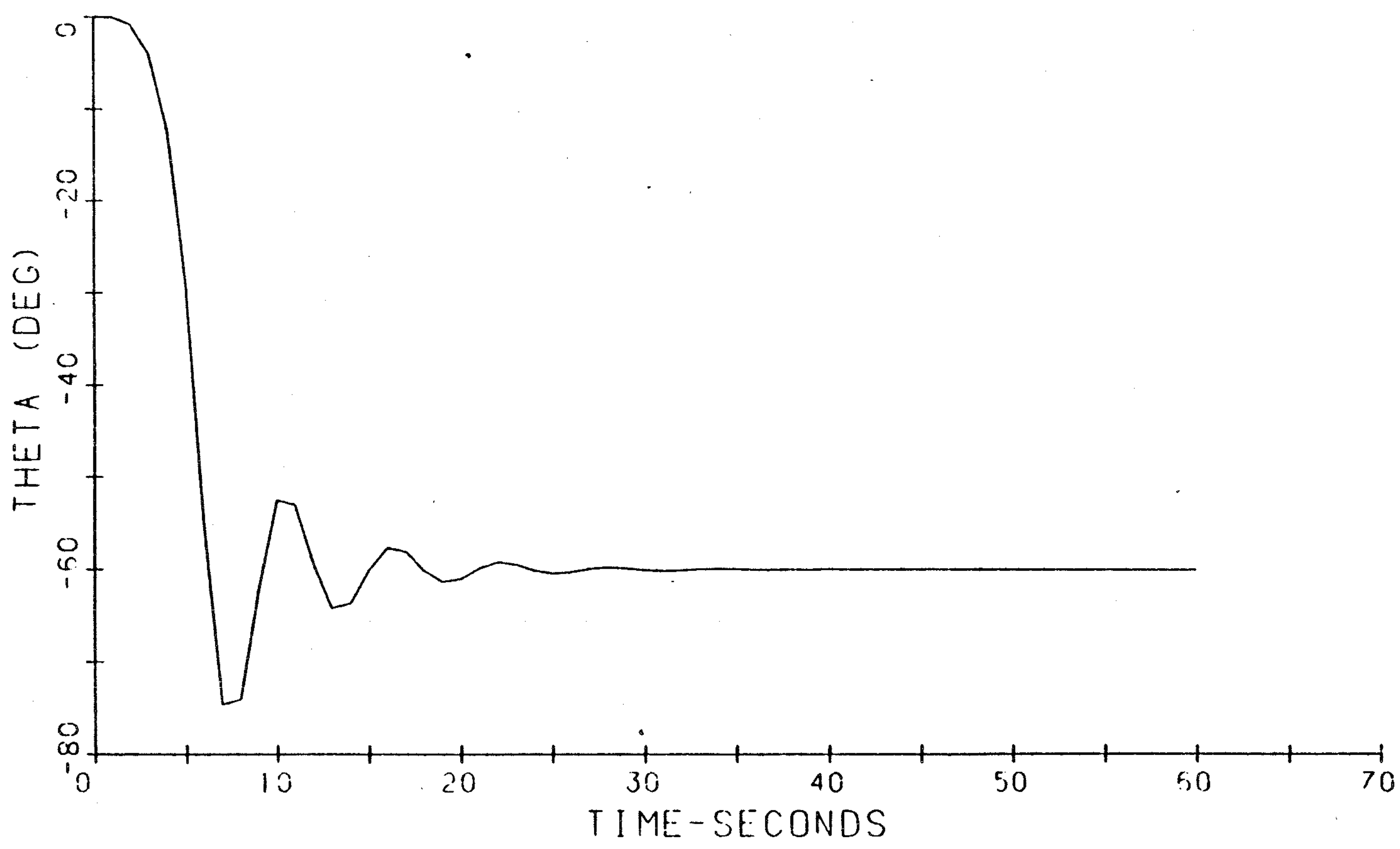
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
.0	.00	.00	.00	0	0	0
1.0	-.65	-.22	-.06	18993	279	18995
2.0	-2.31	-1.63	-.84	66019	1818	66044
3.0	-4.81	-5.11	-4.01	128336	9381	128679
4.0	-8.94	-11.79	-12.11	208460	40006	212263
5.0	-10.92	-22.95	-29.26	301054	139470	331791
6.0	5.99	-26.13	-55.19	255926	163173	303517
7.0	22.69	-9.66	-74.63	21920	-12381	25175
8.0	11.75	8.83	-74.09	133664	-2981	133696
9.0	-2.93	12.85	-62.01	416853	25729	417644
10.0	-11.25	4.64	-52.53	583120	-22839	583564
11.0	-6.10	-4.76	-53.03	468859	-26953	469631
12.0	1.95	-6.68	-59.43	329268	-22345	330025
13.0	5.87	-2.14	-64.18	265108	-32539	267097
14.0	3.12	2.73	-63.65	307627	-28551	308948
15.0	-1.24	3.58	-60.12	385032	-26235	385922
16.0	-3.23	1.00	-57.66	423109	-31168	424252
17.0	-1.60	-1.62	-58.11	391919	-32139	393231
18.0	.87	-1.94	-60.10	347134	-32200	348625
19.0	1.77	-.43	-61.36	332252	-32533	333841
20.0	.80	.96	-61.00	348732	-31452	350147
21.0	-.55	1.05	-59.88	372248	-31263	373558
22.0	-1.00	.17	-59.23	380814	-32042	382159
23.0	-.40	-.58	-59.48	369726	-32398	371141
24.0	.36	-.57	-60.12	355949	-32456	357422
25.0	.55	-.06	-60.45	352919	-32286	354391
26.0	.19	.34	-60.27	359101	-32007	360523
27.0	-.22	.31	-59.91	366295	-32004	367687
28.0	-.31	.01	-59.75	367930	-32189	369336
29.0	-.09	-.20	-59.86	363885	-32308	365314
30.0	.14	-.16	-60.06	359794	-32308	361239
31.0	.17	.01	-60.14	359389	-32224	360830
32.0	.04	.12	-60.07	361599	-32151	363026
33.0	-.08	.09	-59.96	363748	-32160	365167
34.0	-.09	-.01	-59.92	363942	-32216	365363
35.0	-.01	-.07	-59.97	362507	-32251	363939
36.0	.05	-.05	-60.03	361334	-32244	362768
37.0	.05	.01	-60.05	361367	-32214	362799
38.0	.00	.04	-60.02	362134	-32195	363560
39.0	-.03	.02	-59.98	362753	-32201	364179
40.0	-.03	-.01	-59.97	362712	-32218	364138
41.0	-.00	-.02	-59.99	362226	-32228	363654
42.0	.02	-.01	-60.01	361912	-32224	363341
43.0	.01	.00	-60.01	361977	-32215	363405
44.0	-.00	.01	-60.00	362211	-32210	363637
45.0	-.01	.00	-59.99	362376	-32212	363802
46.0	-.01	-.00	-59.99	362343	-32217	363772
47.0	.00	-.01	-60.00	362194	-32220	363623

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
48.0	.01	-.00	-60.00	362112	-32218	363543
49.0	.00	.00	-60.00	362143	-32215	363569
50.0	-.00	.00	-60.00	362224	-32214	363653
51.0	-.00	.00	-60.00	362267	-32215	363695
52.0	-.00	-.00	-60.00	362241	-32217	363669
53.0	.00	-.00	-60.00	362189	-32217	363619
54.0	.00	-.00	-60.00	362178	-32216	363608
55.0	.00	.00	-60.00	362187	-32216	363615
56.0	-.00	.00	-60.00	362223	-32215	363649
57.0	-.00	-.00	-60.00	362218	-32216	363646
58.0	-.00	-.00	-60.00	362214	-32216	363642
59.0	-.00	-.00	-60.00	362211	-32216	363638
60.0	-.00	-.00	-60.00	362210	-32217	363638

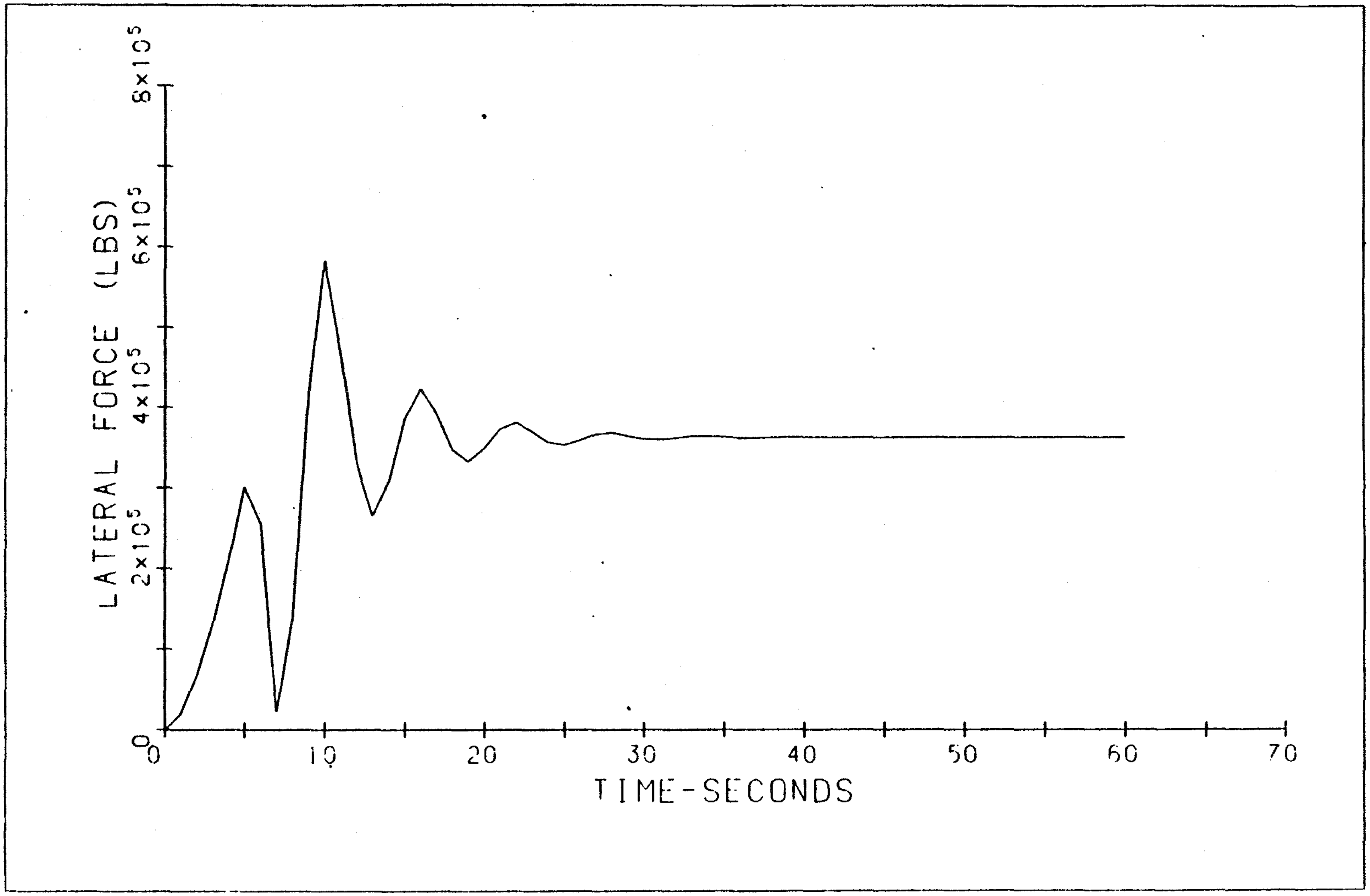
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 30°



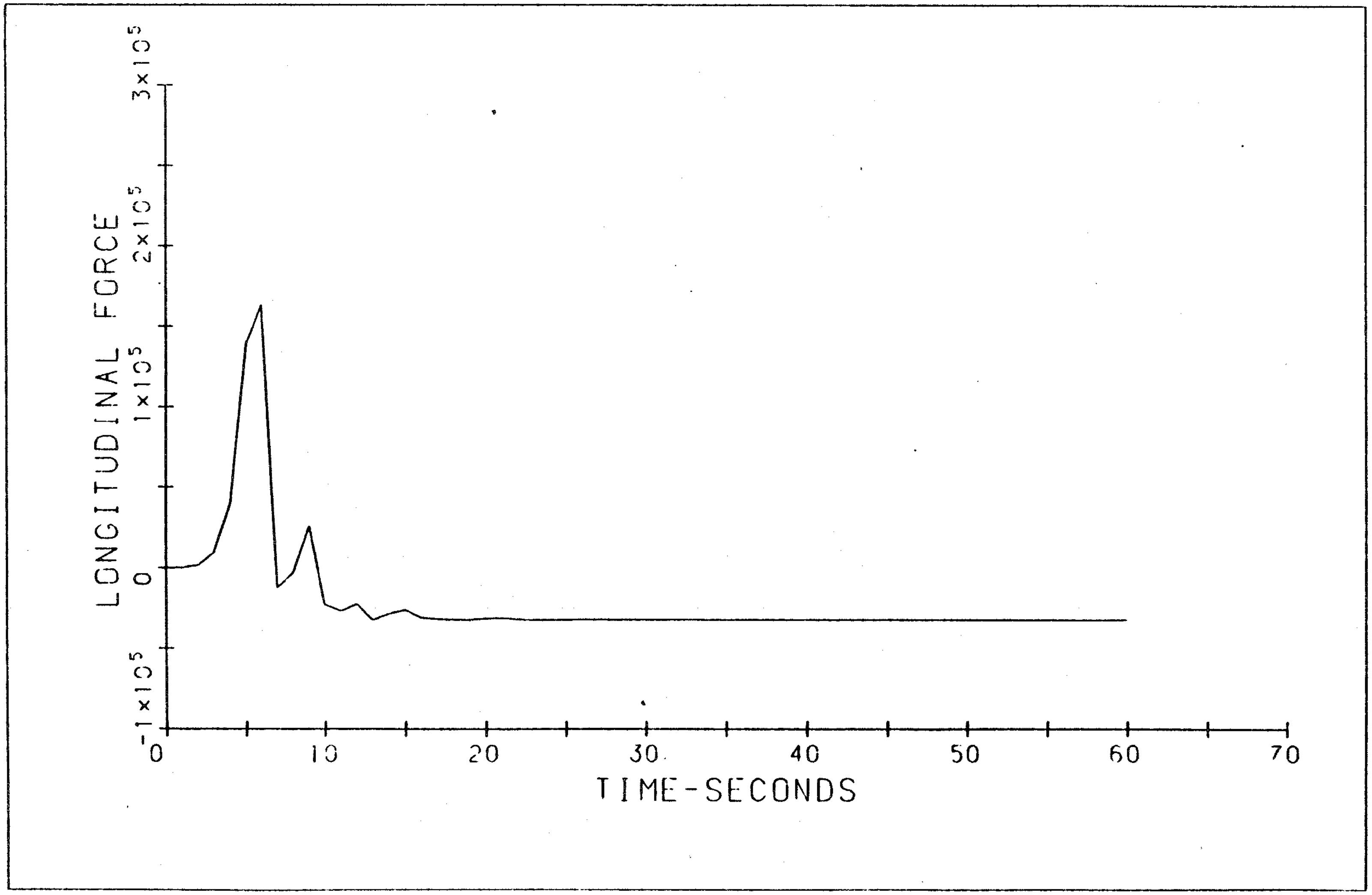
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 30°



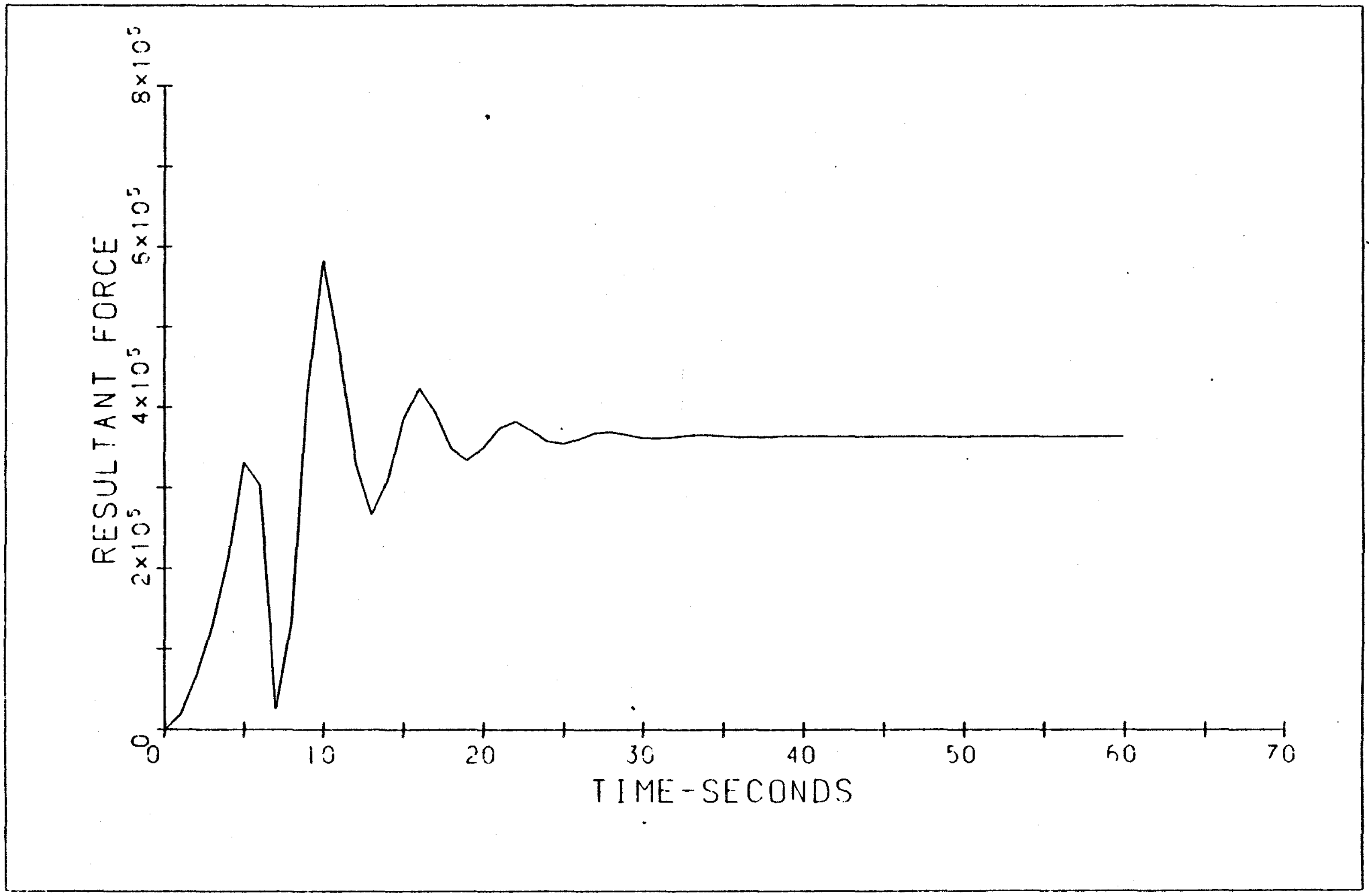
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 30°



** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 30°



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*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
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AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITHOUT* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG............: .916E 08 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  11365.0 SLUGS
HEIGHT OF CENTER LINE.................:    64.5 FEET
CG LOCATION RELATIVE TO NOSE..........:   171.0 FEET
```

MOORING STYLE

```
** CENTER MOORED **
MAST LOCATION RELATIVE TO NOSE........:   171.0 FEET
HEIGHT OF MAST........................:    11.0 FEET
MOMENT OF INERTIA ABOUT MAST..........: .916E 08 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED............................:    60.0 KNOTS
WIND.ANGLE RELATIVE TO AIRSHIP AXIS..:     45.0 DEGREES
THETA (DISPLACEMENT ANGLE)............:      .0 DEGREES
THETA-DOT (ANGULAR VELOCITY)..........:      .0 DEG/SEC
```

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

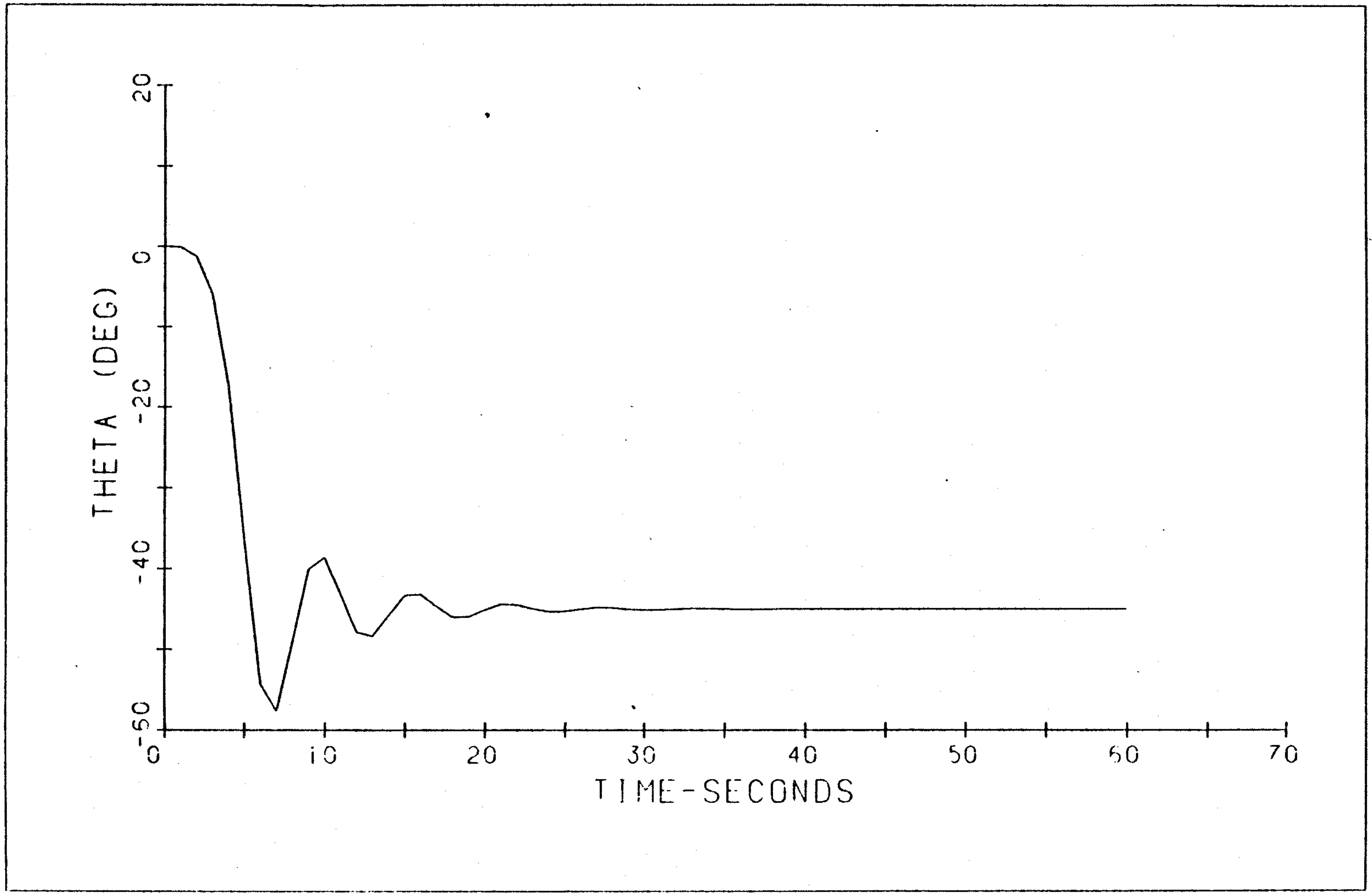
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
.0	.00	.00	.00	0	0	0
1.0	-.98	-.34	-.08	28279	-203	28280
2.0	-3.41	-2.44	-1.27	93704	684	93706
3.0	-6.83	-7.47	-5.94	169202	12767	169681
4.0	-8.19	-15.45	-17.29	256623	57798	263050
5.0	.02	-21.14	-36.22	335012	95636	348394
6.0	16.95	-11.95	-54.26	112945	2173	112966
7.0	12.56	4.37	-57.65	135520	-24232	137668
8.0	.13	10.65	-49.08	356080	8804	356186
9.0	-8.60	5.87	-40.06	532178	-18334	532492
10.0	-6.55	-2.52	-38.57	480823	-30933	481813
11.0	.23	-5.69	-43.25	358490	-25321	359382
12.0	4.64	-2.86	-47.90	285789	-31743	287545
13.0	3.39	1.56	-48.44	303823	-30800	305377
14.0	-.30	3.11	-45.80	368028	-27496	369053
15.0	-2.60	1.43	-43.33	411251	-30655	412391
16.0	-1.79	-.98	-43.17	395605	-32303	396918
17.0	.32	-1.72	-44.70	356887	-32271	358340
18.0	1.46	-.69	-46.01	337461	-32565	339025
19.0	.93	.62	-46.00	346549	-31819	348005
20.0	-.24	.95	-45.11	366617	-31395	367955
21.0	-.84	.33	-44.41	377797	-31941	379144
22.0	-.48	-.39	-44.47	371334	-32344	372737
23.0	.19	-.53	-44.99	358920	-32434	360380
24.0	.47	-.15	-45.35	354212	-32327	355683
25.0	.24	.24	-45.29	358122	-32085	359555
26.0	-.12	.29	-44.99	364426	-32021	365829
27.0	-.27	.07	-44.80	367201	-32158	368605
28.0	-.12	-.15	-44.85	364567	-32280	365990
29.0	.08	-.16	-45.02	360716	-32301	362157
30.0	.15	-.03	-45.12	359670	-32241	361112
31.0	.06	.09	-45.08	361208	-32170	362636
32.0	-.05	.09	-44.98	363180	-32162	364600
33.0	-.08	.01	-44.93	363779	-32205	365201
34.0	-.03	-.05	-44.96	362767	-32241	364194
35.0	.03	-.05	-45.01	361609	-32243	363042
36.0	.05	-.00	-45.04	361421	-32220	362853
37.0	.01	.03	-45.02	361990	-32199	363419
38.0	-.02	.03	-44.99	362592	-32200	364018
39.0	-.03	-.00	-44.98	362689	-32214	364115
40.0	-.01	-.02	-44.99	362319	-32225	363746
41.0	.01	-.01	-45.01	361982	-32224	363414
42.0	.01	.00	-45.01	361970	-32216	363398
43.0	.00	.01	-45.01	362171	-32210	363599
44.0	-.01	.01	-45.00	362349	-32211	363775
45.0	-.01	-.00	-44.99	362351	-32216	363779
46.0	-.00	-.01	-45.00	362221	-32219	363650
47.0	.00	-.00	-45.00	362125	-32218	363554

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
48.0	.00	.00	-45.00	362136	-32215	363565
49.0	.00	.00	-45.00	362206	-32214	363634
50.0	-.00	.00	-45.00	362256	-32214	363684
51.0	-.00	-.00	-45.00	362247	-32216	363676
52.0	.00	-.00	-45.00	362204	-32217	363630
53.0	.00	-.00	-45.00	362179	-32216	363608
54.0	.00	.00	-45.00	362187	-32215	363615
55.0	-.00	.00	-45.00	362208	-32215	363634
56.0	-.00	.00	-45.00	362222	-32215	363649
57.0	-.00	-.00	-45.00	362216	-32216	363646
58.0	.00	-.00	-45.00	362204	-32216	363630
59.0	.00	-.00	-45.00	362197	-32216	363627
60.0	.00	.00	-45.00	362200	-32215	363627

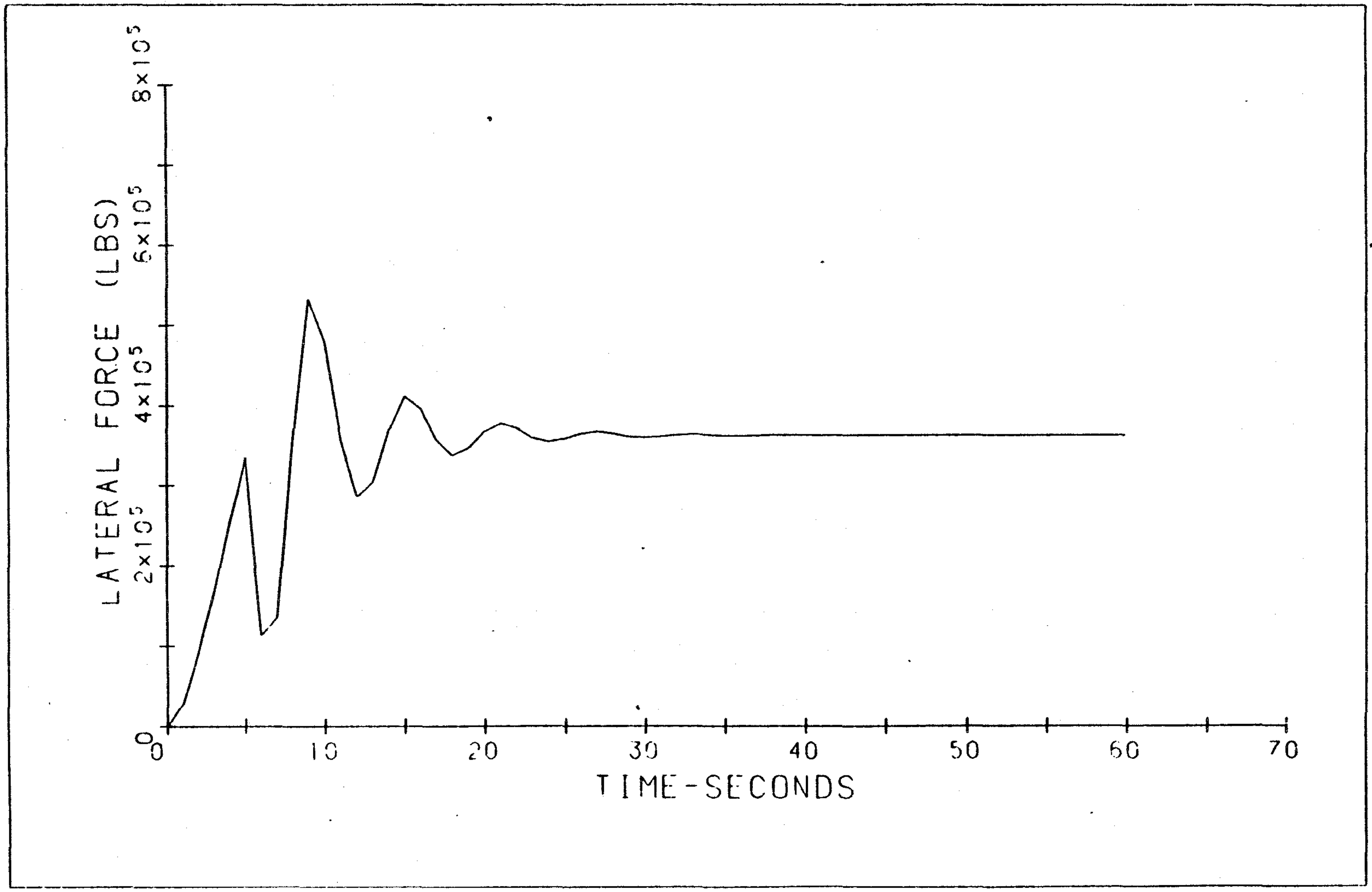
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 45°



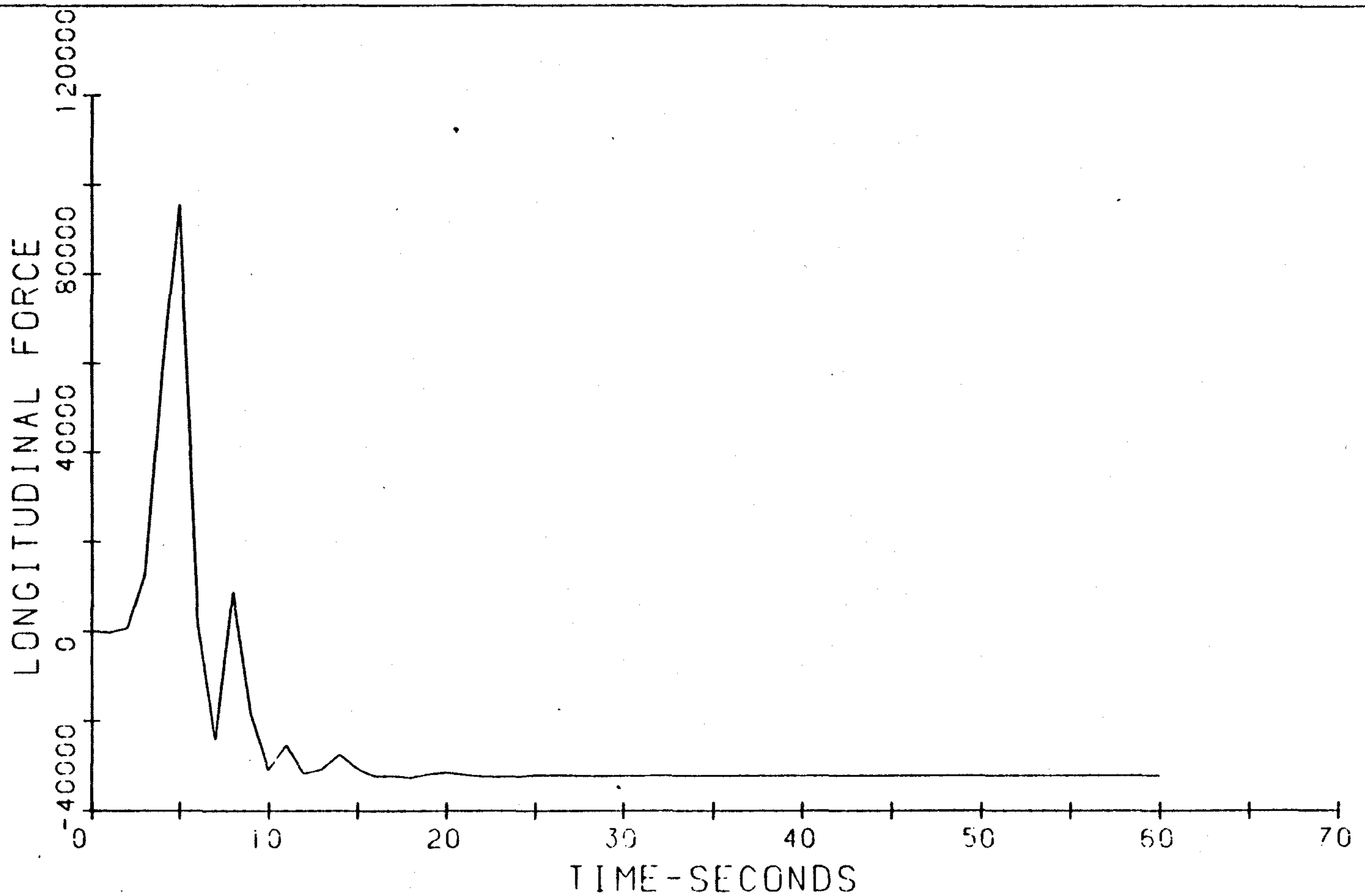
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 45°



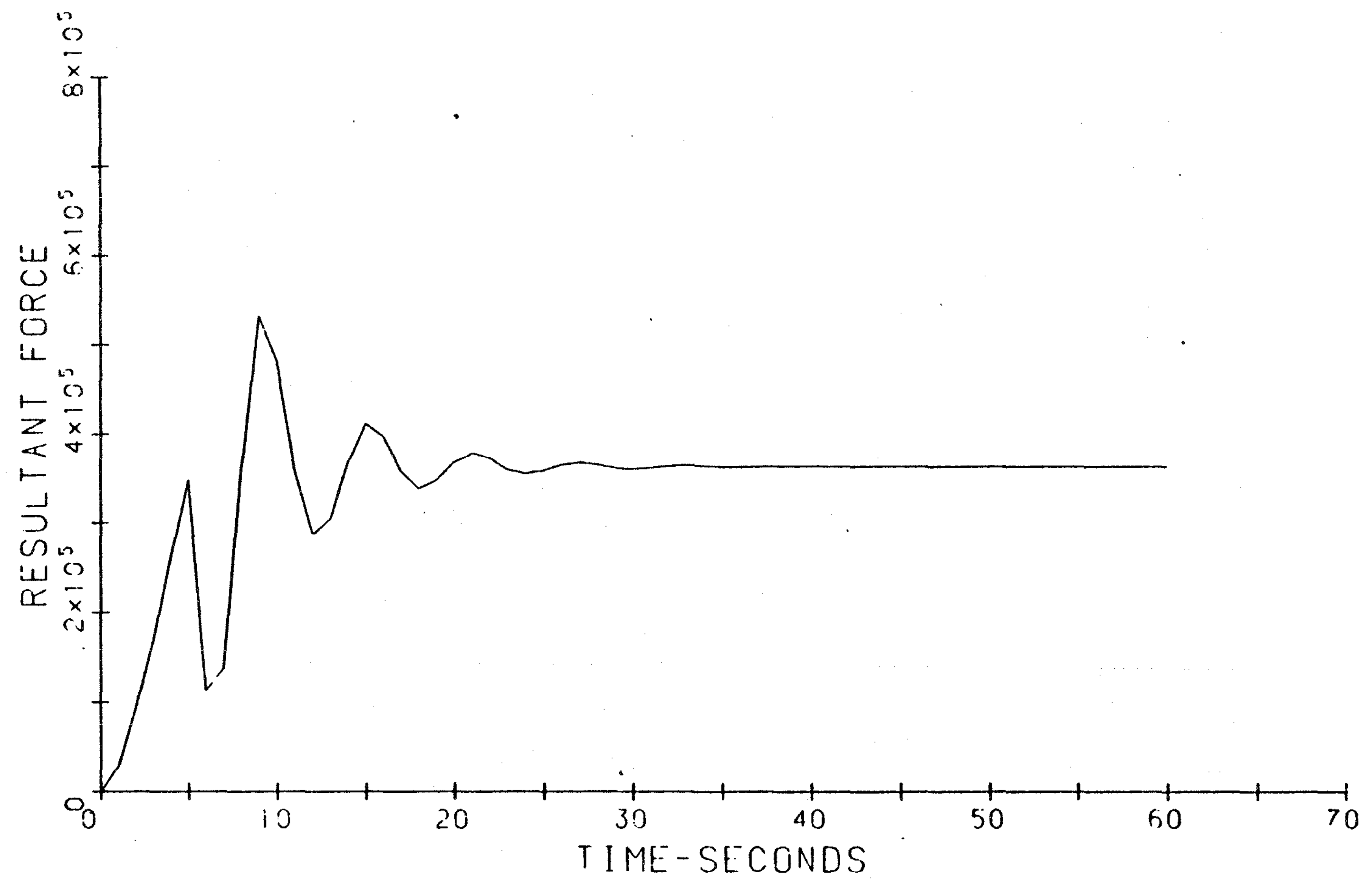
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 45°



** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 45°



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****************************************
*                                      *
*    AIRSHIP MOORING LOADS ANALYSIS    *
*                                      *
****************************************
```

AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITHOUT* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG...........: .916E 08 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  11365.0 SLUGS
HEIGHT OF CENTER LINE................:     64.5 FEET
CG LOCATION RELATIVE TO NOSE.........:    171.0 FEET
```

MOORING STYLE

```
** CENTER MOORED **
MAST LOCATION RELATIVE TO NOSE.......:    171.0 FEET
HEIGHT OF MAST.......................:     11.0 FEET
MOMENT OF INERTIA ABOUT MAST.........: .916E 08 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED...........................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     60.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

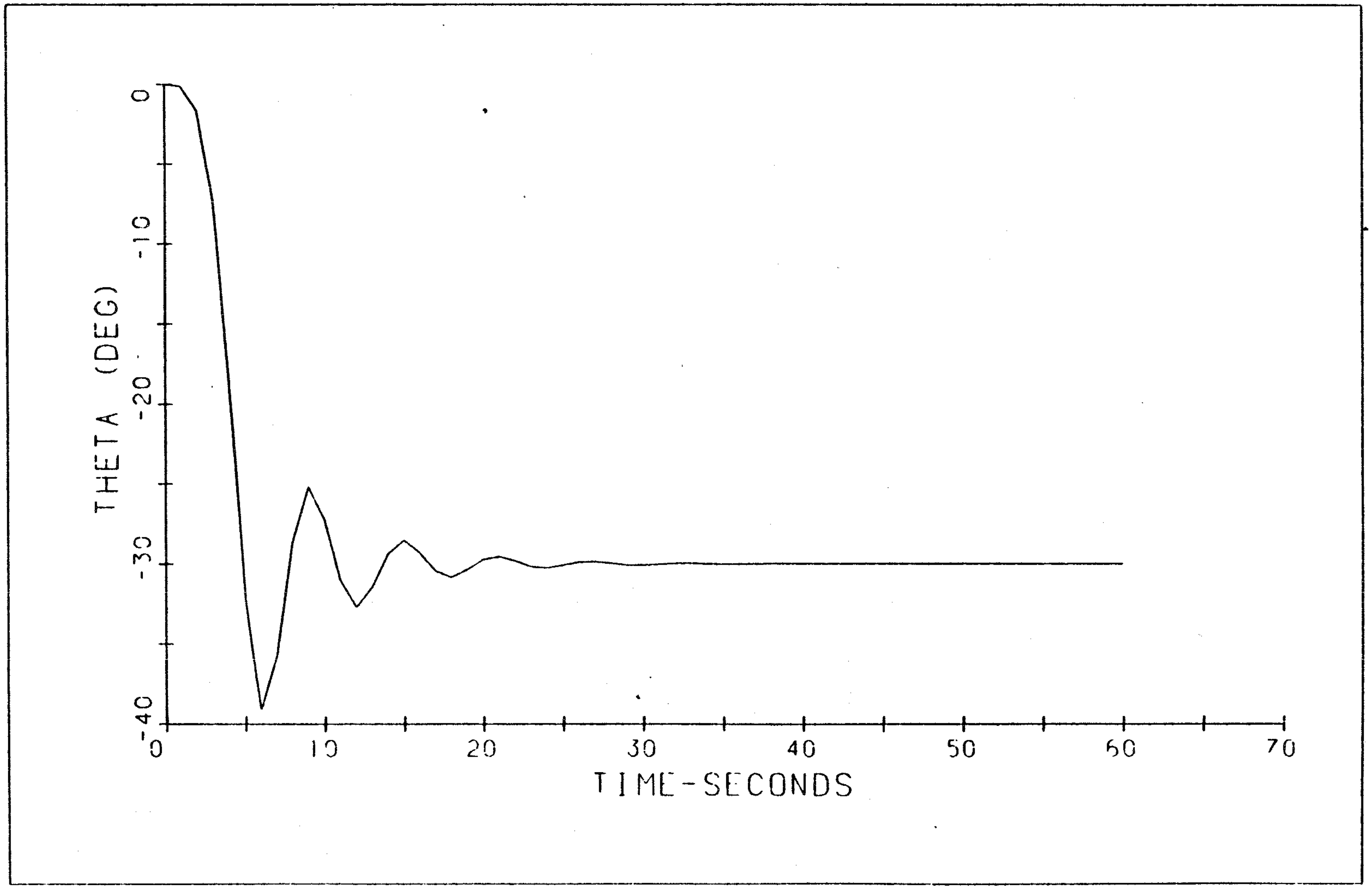
TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
.0	.00	.00	.00	0	0	0
1.0	-1.28	-.45	-.11	37126	-727	37133
2.0	-4.00	-3.05	-1.63	118359	-569	118360
3.0	-6.08	-8.24	-7.10	211803	10993	212088
4.0	-3.19	-13.63	-18.27	265691	33002	267733
5.0	7.44	-12.18	-32.04	247851	5482	247911
6.0	11.37	-1.29	-39.09	173067	-33399	176260
7.0	3.72	6.65	-35.75	291923	-14848	292300
8.0	-4.14	6.24	-28.66	442186	-16766	442501
9.0	-6.01	.43	-25.17	475123	-31521	476167
10.0	-1.82	-3.72	-27.17	395041	-29743	396159
11.0	2.47	-3.23	-31.00	320844	-31037	322339
12.0	3.19	-.03	-32.69	308273	-32469	309976
13.0	.86	2.11	-31.45	347691	-29719	348957
14.0	-1.46	1.71	-29.35	389463	-30299	390638
15.0	-1.75	-.09	-28.52	394885	-32136	396188
16.0	-.37	-1.22	-29.29	369414	-32391	370829
17.0	.88	-.89	-30.45	347192	-32532	348710
18.0	.94	.12	-30.84	346329	-32211	347822
19.0	.15	.70	-30.36	359829	-31692	361218
20.0	-.52	.47	-29.72	371867	-31854	373228
21.0	-.51	-.11	-29.54	371851	-32233	373245
22.0	-.05	-.40	-29.83	363208	-32382	364646
23.0	.31	-.24	-30.18	356902	-32353	358363
24.0	.27	.08	-30.26	357587	-32188	359033
25.0	.01	.23	-30.08	362147	-32075	363564
26.0	-.18	.12	-29.89	365579	-32129	366985
27.0	-.15	-.06	-29.86	364999	-32235	366417
28.0	.01	-.13	-29.97	362094	-32282	363529
29.0	.11	-.06	-30.07	360390	-32256	361830
30.0	.08	.04	-30.08	360900	-32199	362330
31.0	-.01	.07	-30.02	362404	-32173	363829
32.0	-.06	.03	-29.96	363352	-32194	364775
33.0	-.04	-.03	-29.96	362987	-32226	364414
34.0	.01	-.04	-30.00	362035	-32238	363465
35.0	.04	-.01	-30.03	361602	-32226	363033
36.0	.02	.02	-30.02	361851	-32208	363279
37.0	-.01	.02	-30.00	362336	-32202	363763
38.0	-.02	.01	-29.99	362584	-32210	364012
39.0	-.01	-.01	-29.99	362413	-32220	363841
40.0	.01	-.01	-30.00	362111	-32223	363539
41.0	.01	-.00	-30.01	362010	-32218	363440
42.0	.01	.01	-30.01	362115	-32213	363542
43.0	-.00	.01	-30.00	362267	-32212	363695
44.0	-.01	.00	-30.00	362327	-32214	363756
45.0	-.00	-.00	-30.00	362258	-32217	363688
46.0	.00	-.00	-30.00	362165	-32218	363592
47.0	.00	-.00	-30.00	362144	-32216	363573

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
48.0	.00	.00	-30.00	362185	-32214	363615
49.0	-.00	.00	-30.00	362231	-32214	363661
50.0	-.00	.00	-30.00	362243	-32215	363672
51.0	-.00	-.00	-30.00	362217	-32216	363646
52.0	.00	-.00	-30.00	362190	-32216	363619
53.0	.00	-.00	-30.00	362188	-32216	363615
54.0	.00	.00	-30.00	362201	-32215	363630
55.0	-.00	.00	-30.00	362214	-32215	363642
56.0	-.00	-.00	-30.00	362216	-32216	363646
57.0	-.00	-.00	-30.00	362207	-32216	363634
58.0	.00	-.00	-30.00	362201	-32216	363630
59.0	.00	-.00	-30.00	362200	-32216	363627
60.0	.00	.00	-30.00	362206	-32215	363634

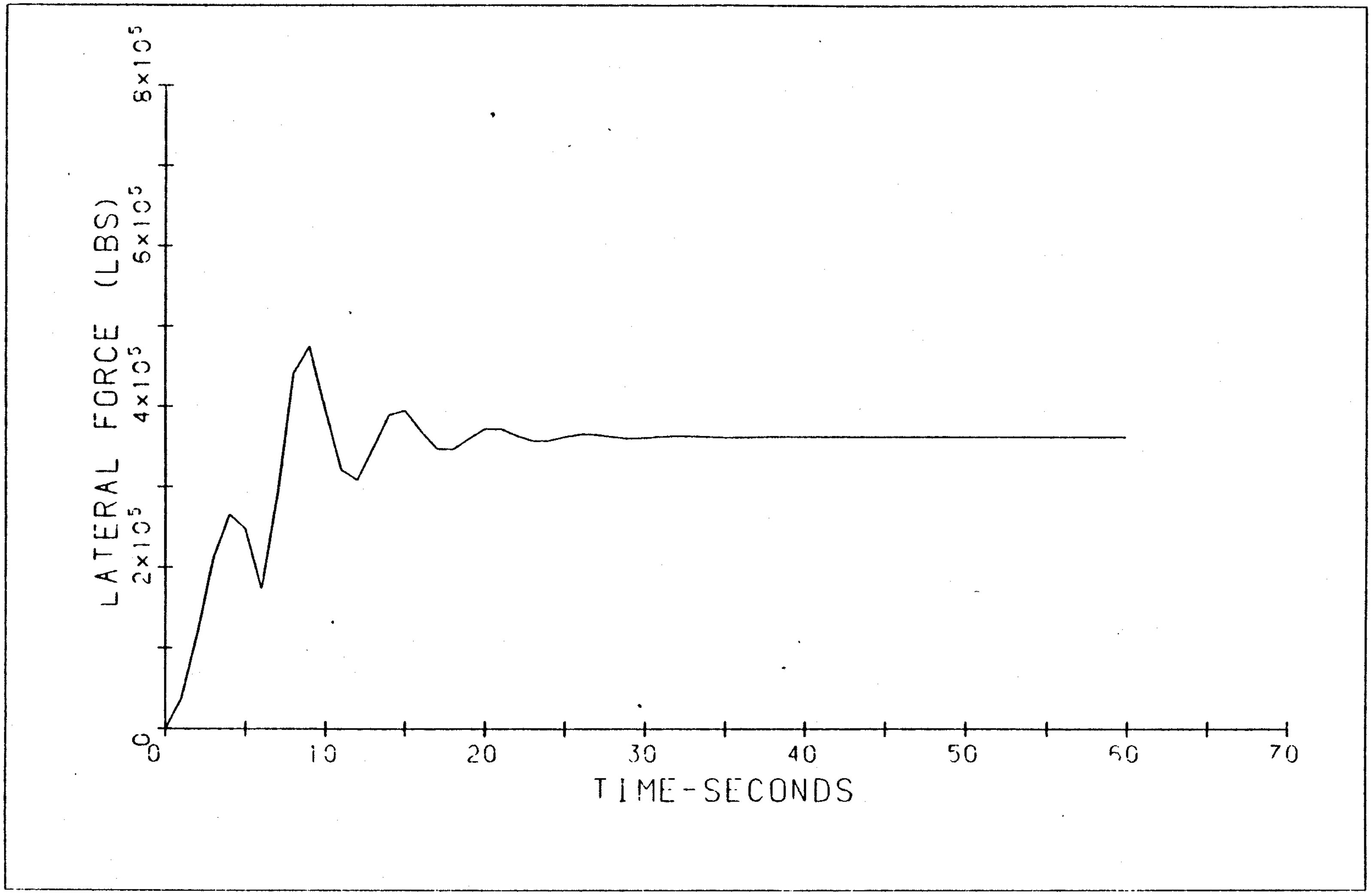
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 60°



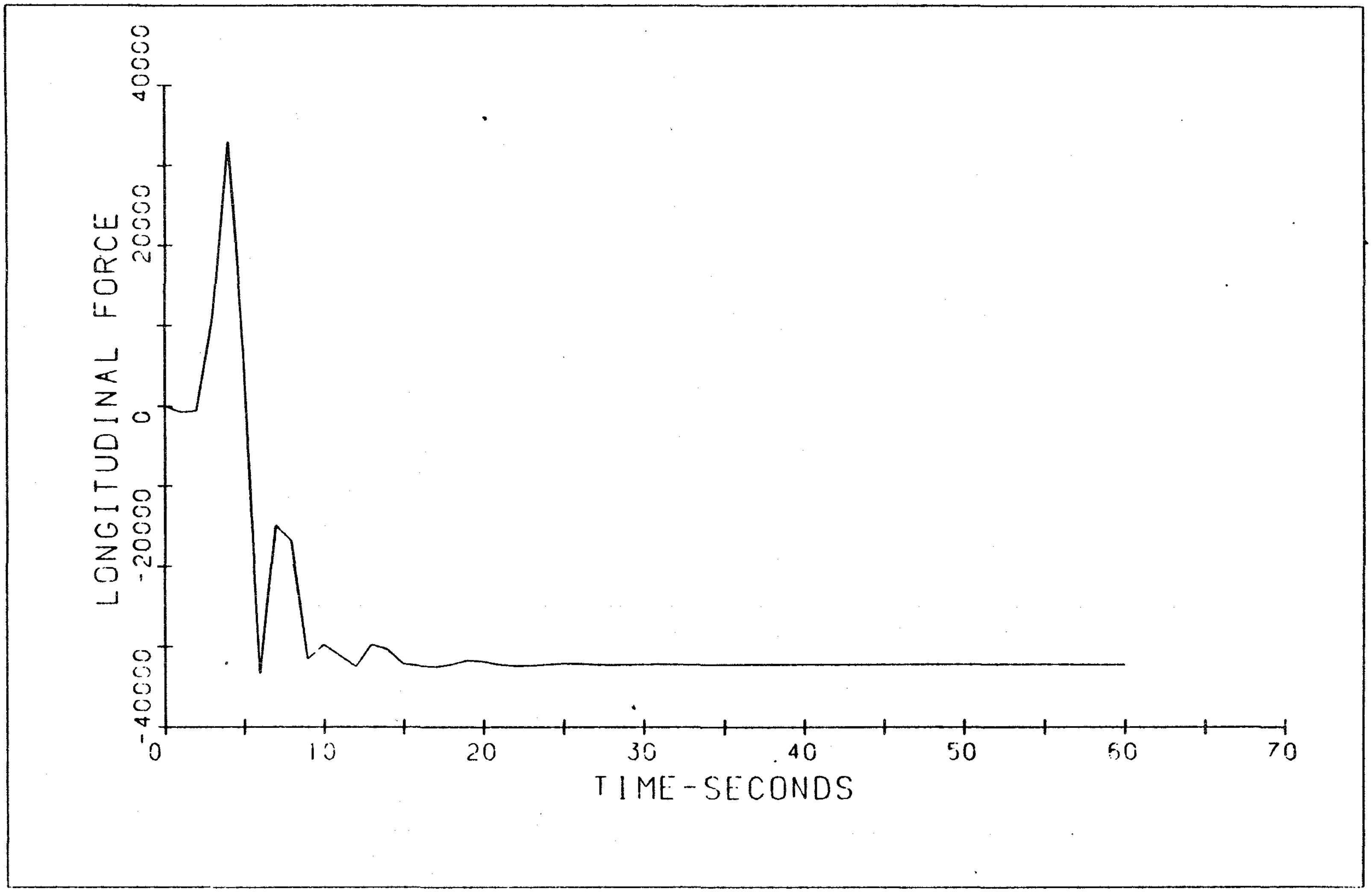
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 60°



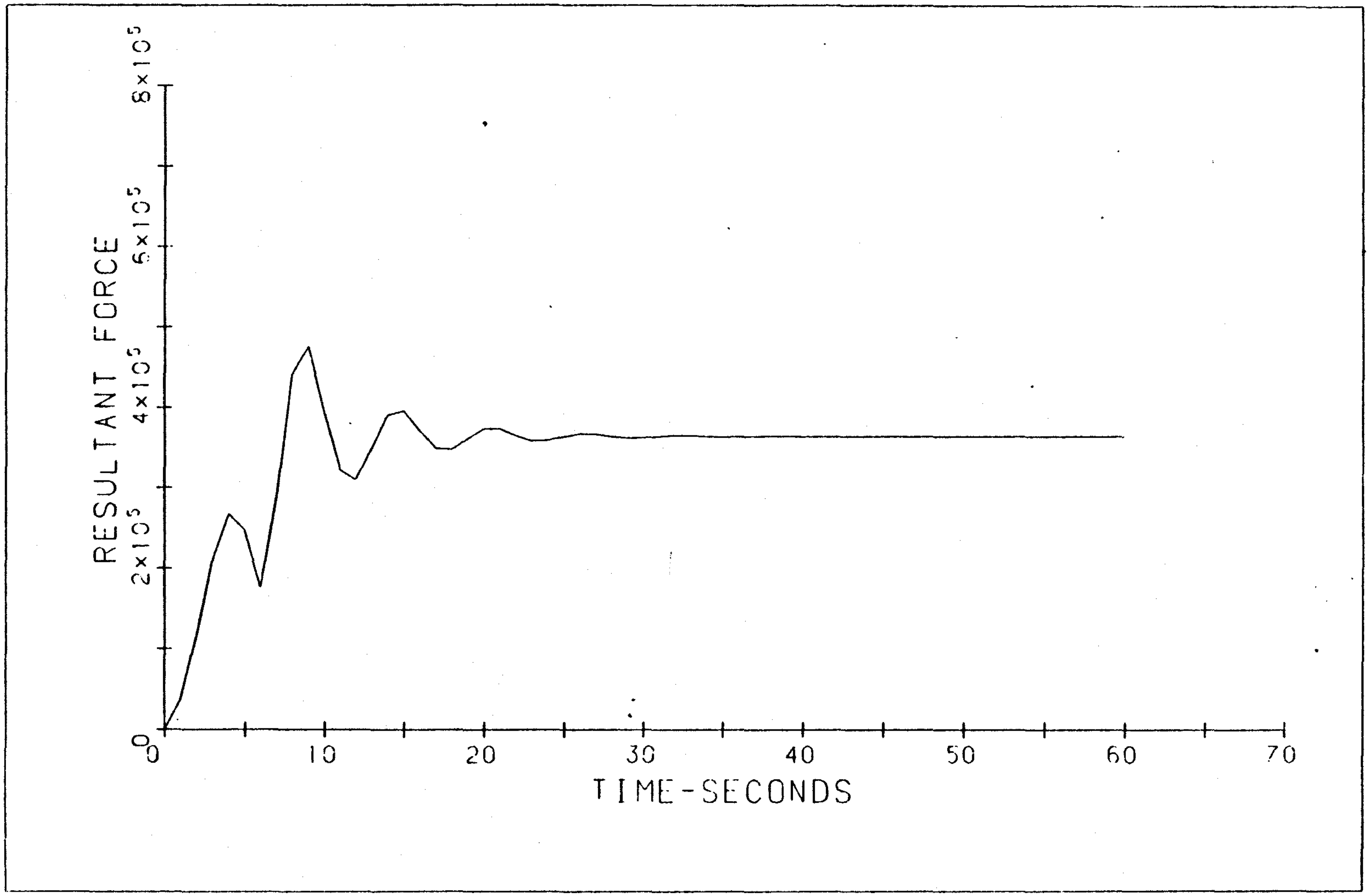
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 60°



** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 60°



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***************************************
*                                     *
*    AIRSHIP MOORING LOADS ANALYSIS   *
*                                     *
***************************************
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AIRSHIP CONFIGURATION DATA

```
** 75 TON HLA *WITHOUT* EMPENNAGE **
MOMENT OF INERTIA ABOUT CG...........: .916E 08 SLUG-FTSQ
AIRSHIP MASS (INCLUDES VIRTUAL MASS).:  11365.0 SLUGS
HEIGHT OF CENTER LINE................:     64.5 FEET
CG LOCATION RELATIVE TO NOSE.........:    171.0 FEET
```

MOORING STYLE

```
** CENTER MOORED **
MAST LOCATION RELATIVE TO NOSE.......:    171.0 FEET
HEIGHT OF MAST.......................:     11.0 FEET
MOMENT OF INERTIA ABOUT MAST.........: .916E 08 SLUG-FTSQ
```

INITIAL CONDITIONS

```
WIND SPEED...........................:     60.0 KNOTS
WIND ANGLE RELATIVE TO AIRSHIP AXIS..:     90.0 DEGREES
THETA (DISPLACEMENT ANGLE)...........:       .0 DEGREES
THETA-DOT (ANGULAR VELOCITY).........:       .0 DEG/SEC
```

** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
.0	.00	.00	.00	0	0	0
1.0	-.00	-.00	-.00	14488	-1288	14545
2.0	-.00	-.00	-.00	57952	-5154	58180
3.0	-.00	-.00	-.00	130391	-11597	130905
4.0	-.00	-.00	-.00	231806	-20617	232720
5.0	.00	-.00	-.00	362196	-32215	363623
6.0	.00	.00	-.00	362204	-32216	363634
7.0	-.00	.00	-.00	362206	-32216	363634
8.0	-.00	.00	-.00	362206	-32216	363634
9.0	-.00	.00	-.00	362206	-32216	363634
10.0	-.00	.00	-.00	362206	-32216	363634
11.0	-.00	.00	-.00	362206	-32216	363634
12.0	-.00	-.00	-.00	362206	-32216	363634
13.0	.00	-.00	-.00	362206	-32216	363634
14.0	.00	-.00	-.00	362206	-32216	363634
15.0	.00	-.00	-.00	362206	-32216	363634
16.0	.00	-.00	-.00	362206	-32216	363634
17.0	.00	-.00	-.00	362206	-32216	363634
18.0	.00	-.00	-.00	362206	-32216	363634
19.0	.00	-.00	-.00	362206	-32216	363634
20.0	.00	-.00	-.00	362206	-32216	363634
21.0	.00	-.00	-.00	362206	-32216	363634
22.0	.00	-.00	-.00	362206	-32216	363634
23.0	.00	-.00	-.00	362206	-32216	363634
24.0	.00	-.00	-.00	362206	-32216	363634
25.0	.00	-.00	-.00	362206	-32216	363634
26.0	.00	-.00	-.00	362206	-32216	363634
27.0	.00	-.00	-.00	362206	-32216	363634
28.0	.00	-.00	-.00	362206	-32216	363634
29.0	.00	-.00	-.00	362206	-32216	363634
30.0	.00	-.00	-.00	362206	-32216	363634
31.0	.00	-.00	-.00	362206	-32216	363634
32.0	.00	-.00	-.00	362206	-32216	363634
33.0	.00	-.00	-.00	362206	-32216	363634
34.0	.00	-.00	-.00	362206	-32216	363634
35.0	.00	-.00	-.00	362206	-32216	363634
36.0	.00	-.00	-.00	362206	-32216	363634
37.0	.00	-.00	-.00	362206	-32216	363634
38.0	.00	-.00	-.00	362206	-32216	363634
39.0	.00	-.00	-.00	362206	-32216	363634
40.0	.00	-.00	-.00	362206	-32216	363634
41.0	.00	-.00	-.00	362206	-32216	363634
42.0	.00	-.00	-.00	362206	-32216	363634
43.0	.00	-.00	-.00	362206	-32216	363634
44.0	.00	-.00	-.00	362206	-32216	363634
45.0	.00	-.00	-.00	362206	-32216	363634
46.0	.00	-.00	-.00	362206	-32216	363634
47.0	.00	-.00	-.00	362206	-32216	363634

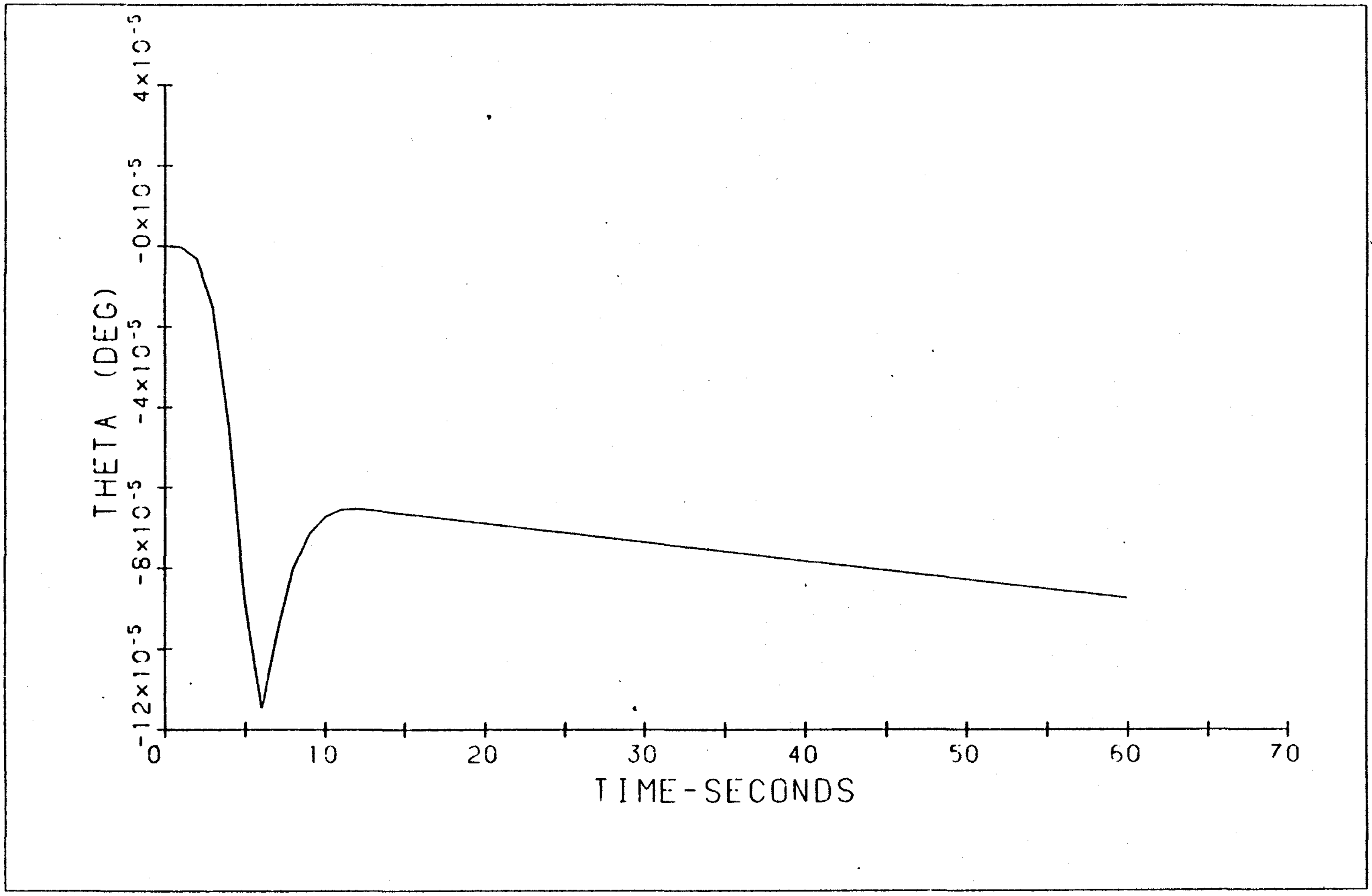
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

TIME SEC	THEDD D/S/S	THD D/S	TH DEG	FLATR LBS	FLONG LBS	FMAST LBS
48.0	.00	-.00	-.00	362206	-32216	363634
49.0	.00	-.00	-.00	362206	-32216	363634
50.0	.00	-.00	-.00	362206	-32216	363634
51.0	.00	-.00	-.00	362206	-32216	363634
52.0	.00	-.00	-.00	362206	-32216	363634
53.0	.00	-.00	-.00	362206	-32216	363634
54.0	.00	-.00	-.00	362206	-32216	363634
55.0	.00	-.00	-.00	362206	-32216	363634
56.0	.00	-.00	-.00	362206	-32216	363634
57.0	.00	-.00	-.00	362206	-32216	363634
58.0	.00	-.00	-.00	362206	-32216	363634
59.0	.00	-.00	-.00	362206	-32216	363634
60.0	.00	-.00	-.00	362206	-32216	363634

EXIT

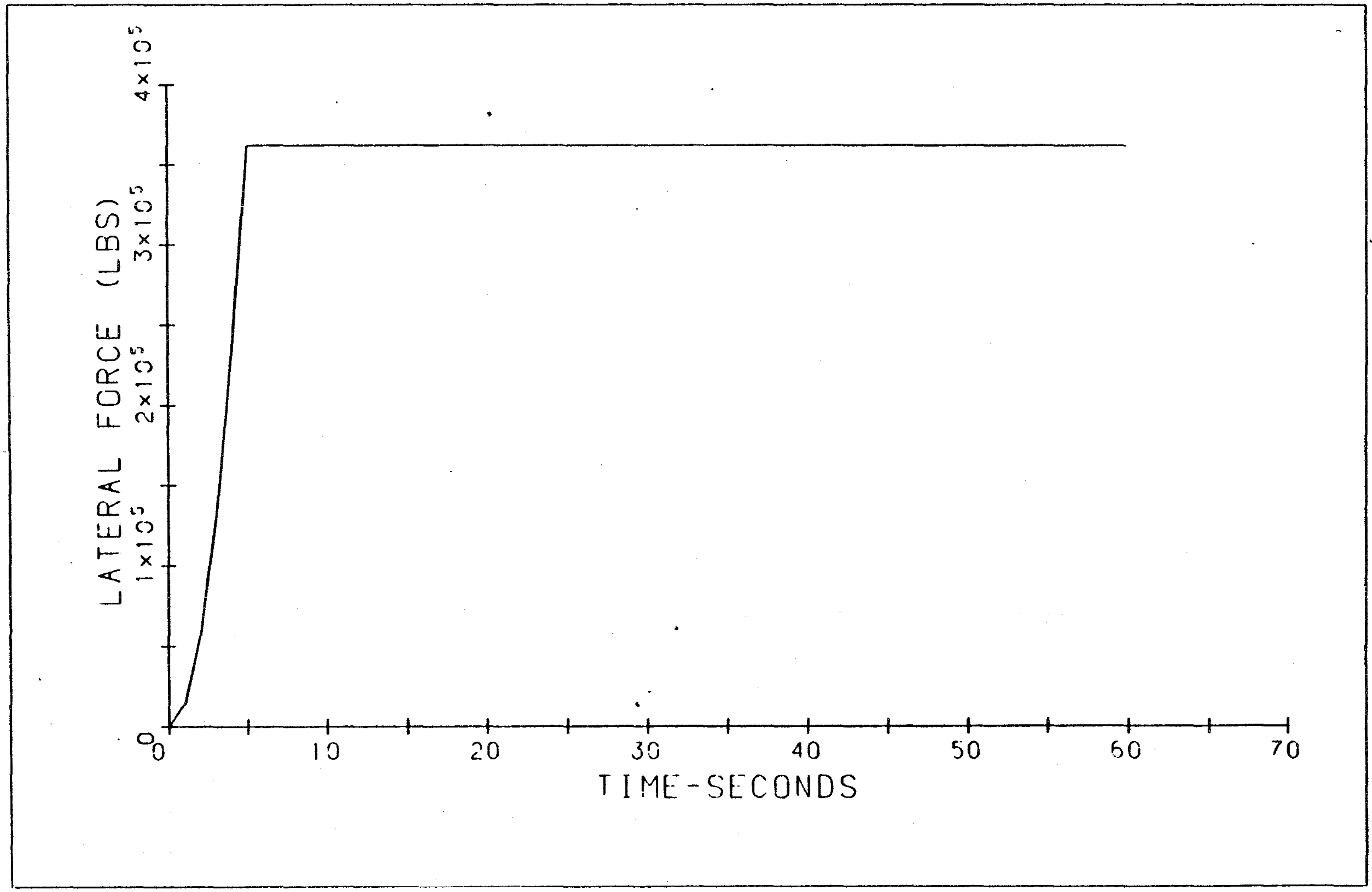
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 90°



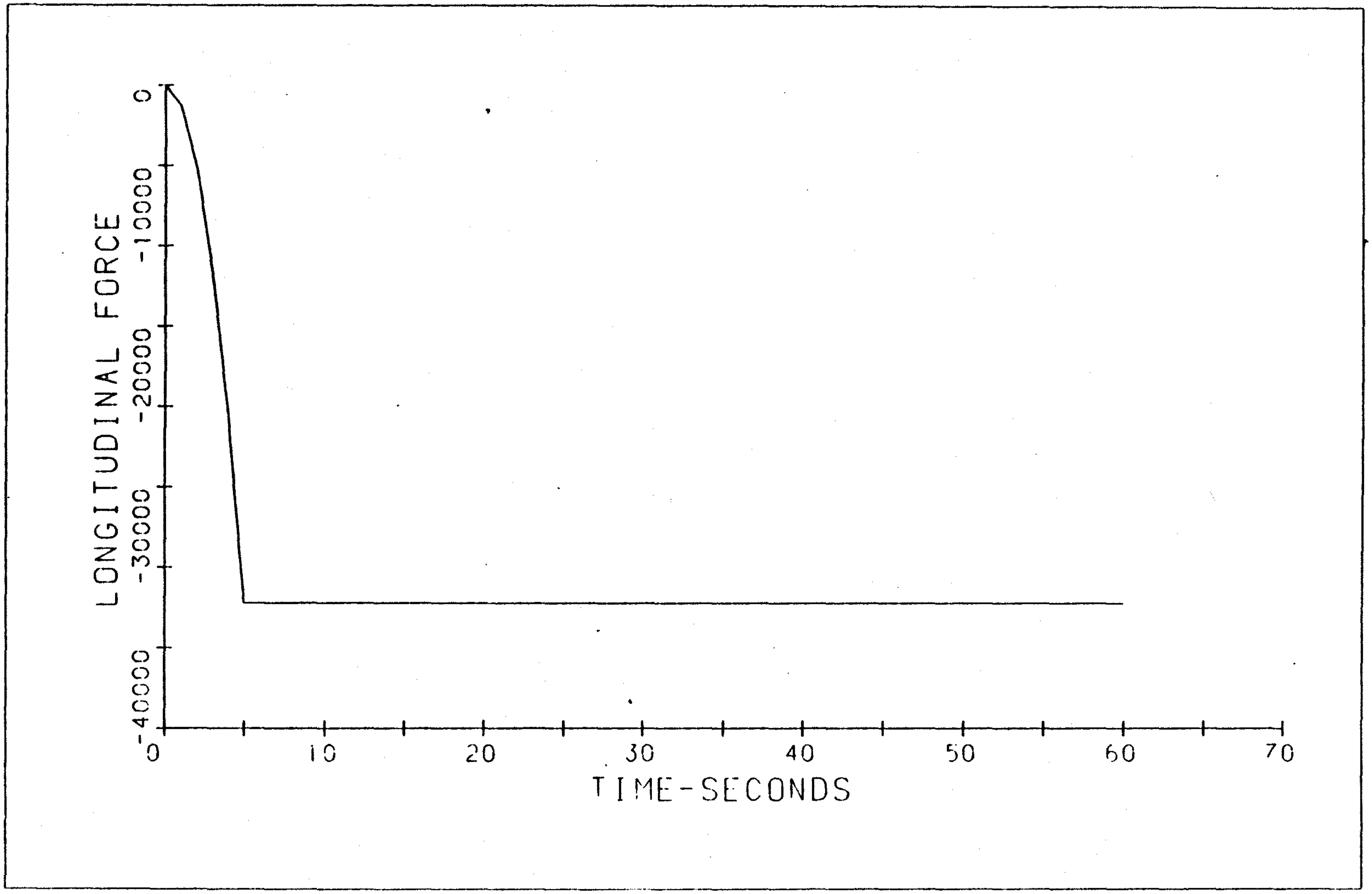
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 90°



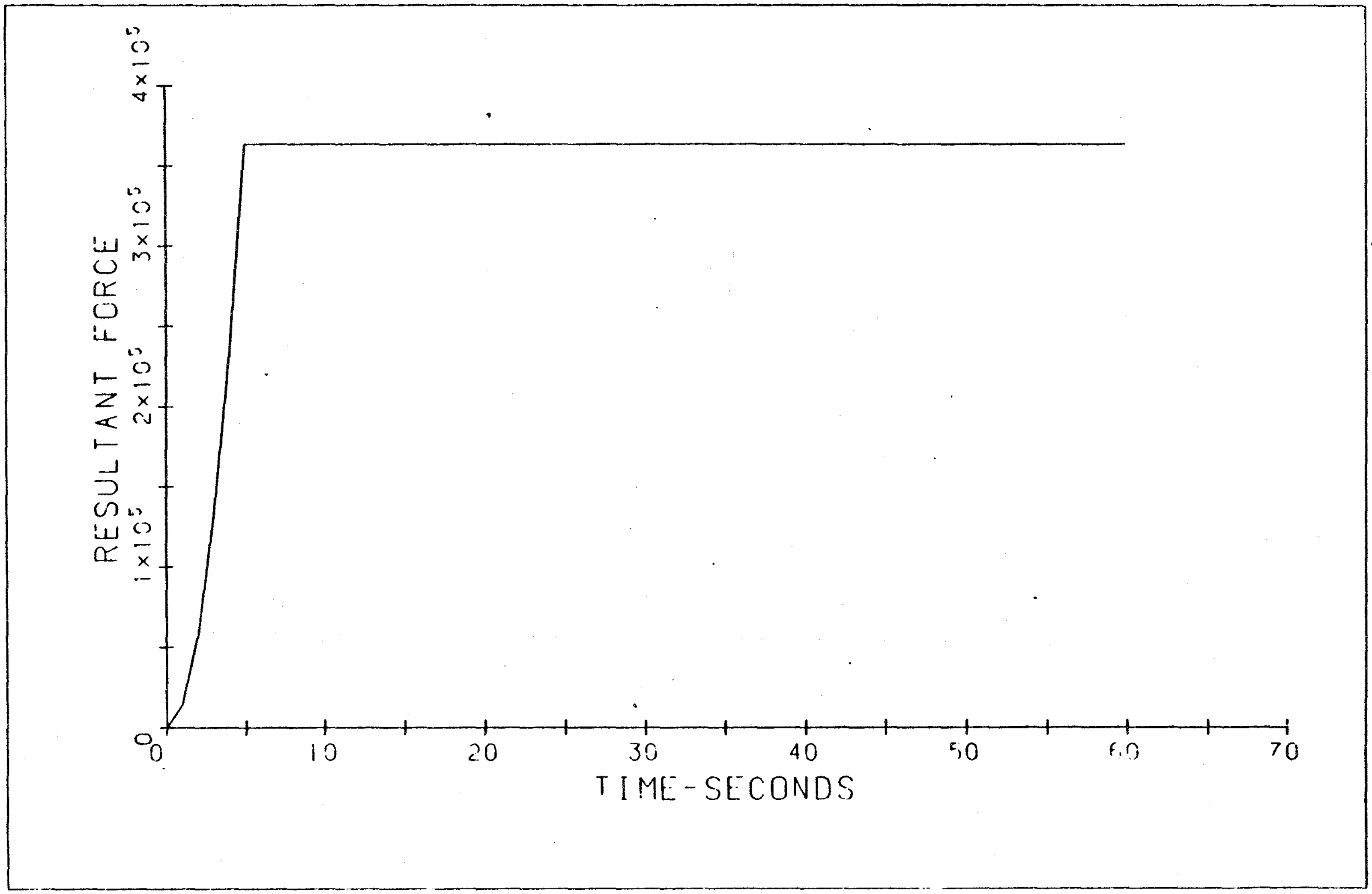
** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 90°



** 75 TON HLA *WITHOUT* EMPENNAGE **
** CENTER MOORED **

Wind = 60 Knots @ 90°



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NASA CR-166130		

4. Title and Subtitle	5. Report Date
Preliminary Study of Ground Handling Characteristics of Buoyant Quad Rotor (BQR) Vehicles	July 1980
	6. Performing Organization Code
7. Author(s) Ronald G.E. Browning	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address Goodyear Aerospace Corporation Akron, Ohio 44305	11. Contract or Grant No. NAS2-10448
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	13. Type of Report and Period Covered Contractor Report-Final
	14. Sponsoring Agency Code

15. Supplementary Notes

Technical Monitor: Peter D. Talbot, Mail Stop 237-11, NASA Ames Research Center, Moffett Field, CA 94035 (415) 965-5887 FTS 448-5887

16. Abstract

A preliminary investigation of mooring concepts appropriate for heavy lift buoyant quad rotor (BQR) vehicles has been performed.

A review of the evolution of ground handling systems and procedures for all airship types is presented to ensure that appropriate consideration is given to past experiences. Two buoyant quad rotor designs are identified and described. An analysis of wind loads on a moored airship and the effects of these loads on vehicle design is provided. Four mooring concepts are assessed with respect to the airship design, wind loads, and mooring site considerations. Basing requirements and applicability of expeditionary mooring at various operational scenarios are also addressed.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Lighter-than-Air Vehicles Buoyant Quad Rotor (BQR) Vehicles Ground handling characterisitcs	Unclassified - Unlimited Subject Category - 01

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	252	

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End of Document