HEAVY WEATHER

DEFINITION

What constitutes heavy weather depends on the type and size of boat and the experience of the crew. A small sailboat (20 -30 feet) can handle considerably more heavy weather than a small powerboat. Large boats (40-65 feet) generally fair better than smaller boats. Finally, in any given boat, the weather turns heavy when the winds increase five knots beyond any previously experienced by the crew.

Best Defence

The best defense against heavy weather is avoidance. Chapter Eight is devoted to understanding weather and using simple weather predicting techniques. If careful. there is rarely any need for the skipper of a recreational boat to place the boat and the crew in jeopardy by operating in inclement weather. It is much safer and certainly more enjoyable to spend another day securely in the harbor waiting for a better weather. Unfortunately, rarely is not the same as never. Even a prudent skipper will get caught in a sudden squall or engage in a passage longer than the weather predictions are accurate. On these occasions, the boat can be subjected to major danger and minor problems.

Major Dangers

The major dangers are **pitchpoling** (turning end-over-end); **broaching** (rolling over sideways); and **foundering** (taking on large quantities of water and sinking). Minor problems concern keeping the crew on board and free of injury, and handling any minor damage from breaking seas.

PROCEDURE

Disputed Subject

The "best" procedure for weathering a storm is a much disputed subject.[1] There are only a few tactics available, some, all or none of which may work at any one given time depending on the boat, the crew and the situation.

The adversaries

To understand and choose the correct evasive action, it is necessary to have a basic knowledge of the wind and the effects of its force on the boat and the water. The wind force acting on the water generates waves and acting on the boat moves the boat through the water. The effect on each depends on the magnitude of the wind force, which is in turn dependent on the velocity of the wind, and various other variables.

Wind Force

The equation for calculating the magnitude of this force has the general form shown in equation 1.

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[1]Coles, K. Adlard. Heavy Weather Sailing. Tuckahoe, NY: John de Graff, Inc., 1972. Page 265.

$$F = C\left(\frac{\rho V^2}{2}\right)A \qquad \textbf{Eq 1}$$

Where F is the desired force,

C is a coefficient that varies with the situation,

ρ is the density of the material (air in this case),

V is the velocity of the wind,

A is the contact exposed to the force of the wind.

The coefficient (C) and the area (A) depend on a great number of variables that are hard to define in any one specific case and even harder to generalize. For the purpose required here these difficulties can be ignored by moving the two offending terms to the other side of the equation.

$$\frac{F}{C\,A} = \frac{\rho V^2}{2}$$

Let $\frac{F}{C\,A}$ equal a thing called dynamic pressure (q) then;

$$q = \left(\frac{\rho V^2}{2}\right) \qquad \textbf{Eq 2}$$[2]

Even though ρ varies with temperature and atmospheric pressure enough to introduce a 20% error, this equation is useful to show the general trend and magnitude of the wind force. If standard atmospheric conditions are assumed, that is, 59° F and 14.7 psi, then q in pounds per square foot reduces to;

$q = 0.003391 \text{ (V in Knots)}^2$

$q = 0.002557 \text{ (V in Miles Per Hour)}^2$

$q = 0.001196 \text{ (V in Feet Per Second)}^2$

Equation 2 shows the pressure exerted by the wind increases relative to the square of the velocity. A plot of dynamic pressure (q) relative to wind velocity in knots is shown in Figure 1. Notice how this pressure increases very slowly below about 20 knots while above 20 knots the curve becomes steeper with each incremental change in wind velocity.

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[2]Marchaj, C.A. Aero-Hydrodynamics of Sailing. New York: Dodd, Mead & Co., 1979. Page 169.

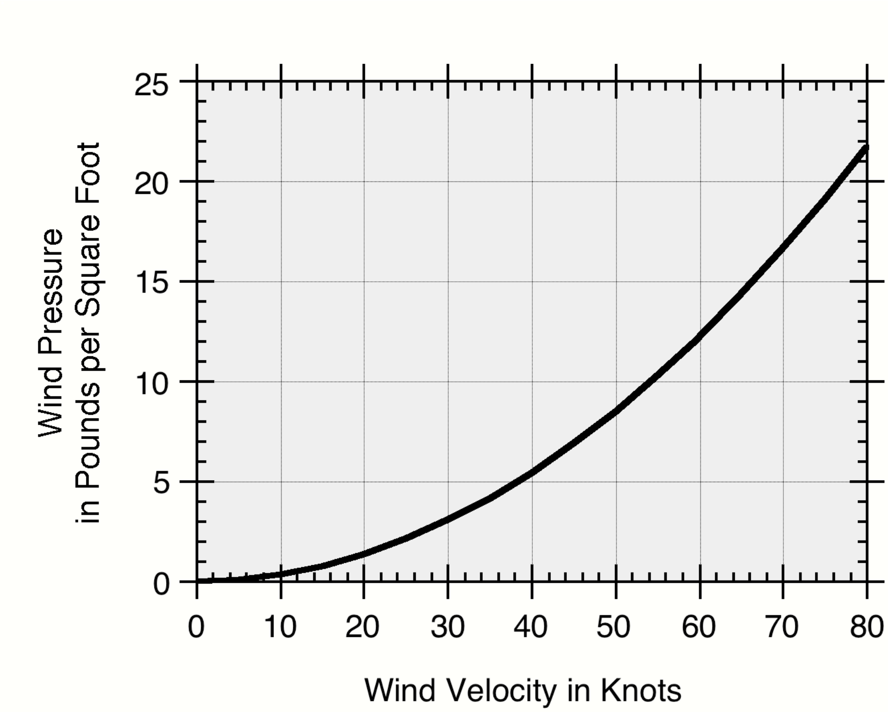

Figure 1 Wind Pressure

Effects on the Boat

Power boaters must overcome this force by engine power making winds much over ten knots an aggravation if not a problem. In winds with velocities of 20 knots or less sailboaters use this force as a power source to drive the boat. As the wind velocity increases, sailboaters can change a portion of the area of the boat exposed to this force, the sails, to reduce its effect. Powerboaters have very little of this luxury and winds over 15 knots become a problem. Eventually even the sailboat reaches a point where it cannot reduce the area exposed to the wind any further and must deal with the danger.

Typical Examples

As stated earlier, there are a great number of variables involved in determining the exact force applied to a boat by the wind, but it is useful to examine the range of this force by looking at some typical values. For a typical sailboat the hull area is around 100 square feet, for a typical power boat of the same length the hull area may be three times as much.

Sailboat

In 10 to 12 knots of wind the typical sailboat under full sail is designed to be driven along at hull speed by approximately 500 to 600 pounds of wind force. Any increase in this force overpowers the boat. As the wind velocity increases, the sail area is reduced until somewhere between 35 and 45 knots of wind the boat is completely overwhelmed by the wind and is capable of doing hull speed without any sail up at all.

> ***'…it is very unpleasant for sailboats to experience winds above 40 knots and power boats to experience winds above 25 knots…'***

Powerboat

A typical power boat on the other hand is overwhelmed at a much lower wind velocity due to its larger hull area. The force caused by 15 to 25 knots of wind makes handling a power boat difficult. The conclusion is that it is very unpleasant for sailboats to experience winds above 40 knots and power boats to experience winds above 25 knots. Although, it may be true that many commercial power boats deal with winds above these values, this book is only concerned with recreational boating. Commercial boats are constructed differently, are generally larger than the average recreational boat have professional crews and are out for profit not fun.

Boat's Mobility

Another point to consider is that because wind pressure is a function of the velocity; the boat's mobility can effect this velocity and the resulting force. For example, a boat traveling 6 knots into a wind with a true velocity of 20 knots passed a fixed object will feel an apparent wind velocity of 26 knots. It is this apparent wind velocity, not the true wind velocity, that exerts the force on the boat. The boat traveling into this wind experiences a pressure of about 2.25 pounds per square foot while the same boat traveling at the same speed with the wind feels only 0.66 pounds per square foot pressure or roughly 3 times less wind pressure.

WIND EFFECTS ON THE WATER

Waves

The effect of the wind's dynamic pressure on the water causes waves. The reason that waves form is that as the wind blows, the dynamic pressure of the wind on the surface of the water moves the surface layer of the water. Because the water at depth is not moving the surface layer is moved from one spot and piles up in another where it is unstable and gravity causes it to collapse. The forces of gravity and the wind pressure set up a harmonic motion on the surface called waves. Since gravity is relatively constant, the size of the waves depends on the wind forces.

Waves Effects on the Boat

Although the wind pressure on the boat is not to be discounted, once the wind velocity reaches 50 knots, it is the waves that cause most of the damage to a boat in a storm.[3] Waves in a major storm often exceed fifty feet in height. Consider the effects of a 50 foot wall of water on a small boat. The bad news is apparent. The good news is that waves greater than 8 ft high shield a major portion of the hull from the force of the wind much of the time.

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[3]Van Dorn, William G. Oceanography and Seamanship. New York: Dodd, Mead & Co., 1974. Page 187.

General Properties

Fortunately, all fifty foot waves are not walls of water. They have a shape that is defined by the height of the wave (H), its length (L). These two properties along with the waves velocity (C) are of general interest to the recreational boater and indicate the proper heavy weather tactic.

These properties are dependent on the wind velocity (V), the duration that the wind blows (T) and the distance over the water that the wind blows called the **fetch** (F). It is possible to predict a uniform wave shape and height given these values. Unfortunately, real waves are not uniform but look more like Figure 2.

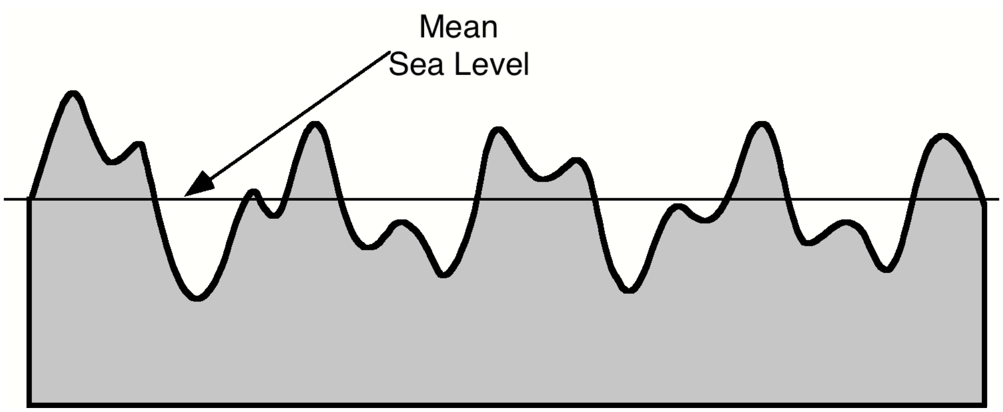


Figure 2 Typical Wave Pattern

A wave pattern such as this is best analyzed using statistical methods. By using such methods a table of useful wave parameters can be developed. It is helpful when analyzing or discussing wave theory to introduces the following concepts;

- ✷ Fully developed state (FDS),
- ✷ Minimum fetch (F_m) to establish a FDS,
- ✷ Minimum wind duration (t_m) to establish a FDS,
- ✷ Average wave period (T_a) in a FDS Spectrum,
- ✷ Average wave length (L_a) in a FDS spectrum,
- ✷ Most frequent probable wave height (H_f),
- ✷ Average height of all waves present (H_a),
- ✷ Average height of the highest 1/3 of the waves (H_3),
- ✷ Average height of the highest 1/10 of the waves (H_{10}).

Wave theroy

It can be shown that if a constant wind blows over an infinite stretch of calm water for an infinitely long time, waves will be generated. The waves will continue to increase their height and length until a limiting steady state condition is reached called a fully developed sea (FDS) state. If the stretch of calm water is limited by an upwind shore then a limiting steady state condition will be reached that may be less than a FDS depending on the relationship between that distance (fetch) and the steady wind. Therefore, each steady wind has a minimum fetch (F_m) needed to establish FDS.

'...no such thing as a steady wind exists in nature ...'

Since the waves increase with time, it follows that there exists a specific minimum length of time (t_m) that the steady wind must blow to produce a FDS. It can also be seen that because no such thing as a steady wind exists in nature, a true fully developed sea state never really exists either. However this fictitious term is still a very useful concept when dealing with waves, if you so desire you can alter the meaning of "F" from fully to fictitious. In a FDS the minimum time, the minimum fetch the wave period (T_a), length (L_a), and various heights as defined above are all related to the wind velocity. Table 1 list the various values of those parameters relative to wind veloctiy.

Table 1 Wave Parameters of Interest to Boaters

V in knots	**F_m** in na. mi	**t_m** in hrs	**T_a** in sec.	**L_a** in feet	**H_f** in feet	**H_a** in feet	**H_3** in feet	**H_{10}** in feet
5	2.5	0.5	1	7	0.2	0.3	0.5	0.6
10	10	2.5	3	28	1	1	2	4
15	30	6	4	63	2	3	4	5
20	75	10	6	112	4	5	8	9
25	150	16	7	175	6	8	12	15
30	275	23	9	252	9	11	17	21
35	450	32	10	343	12	15	24	29
40	700	42	12	448	15	19	31	37
45	1000	53	13	567	19	24	39	47
50	1400	70	15	700	24	30	48	58
55	1900	80	16	847	29	36	58	71
60	2500	95	17	1008	35	43	69	84
65	3200	110	19	1183	41	51	81	99
70	4000	130	20	1372	47	59	94	115
75	5000	150	22	1575	54	68	108	132
80	6000	170	23	1792	61	77	123	150

Table as a Guide

This table can be used as a guide to the general wave conditions that one could expect to encounter in any given wind. For example if a 30 knot wind has been blowing longer than 23 hours, and the nearest obstruction upwind is over 275 nautical miles away the average height of the highest 10 percent of the waves will be 21 feet. Or in other words, the waves will vary in height form 9 to 17 feet with an occasional 20 footer rolling through.

Shade Portion

The values given in the shaded portion of the table are only of general interest since the conditions necessary for the parameters to occur are extremely difficult to experience. For example, the possibility of a constant 60 knot wind blowing for 25 hours over a surface 850 miles long is remote. That is not to say that an 84 foot sea is impossible to encounter. First, this value is only the average of the highest 10 percent, not the maximum wave height; statistically it is possible to encounter a much larger wave. Second, not all waves are built from flat calm water. A 60 knot wind blowing across water that already has an established 30 foot sea would require considerably less time to establish FDS.

Real Waves

In fact, most of the fully developed sea conditions that get the attention of recreational boaters, get built on already established conditions. A five or ten knot wind builds gradually over a period of hours, typically three to twelve, until the full force of the storm hits. Then the maximum wind velocity generally last typically 12 to 24 hours, and gradually tapers off again. The result is that the waves are either forming or decaying for the largest part of the storm.

There are some major differences between a developing, mature and decaying wave system that are useful to boaters when confronted with heavy weather. It is convenient to begin with a mature system then discuss the developing system and finally say a few words about the decaying system.

Mature Wave System

The mature wave system occurs when all the available wind energy is used to maintain the wave motion. This condition occurs at FDS when the wind velocity and the wave velocity are equal. At this time the motion of a water particle in a mature wave is purely circular with no windward translation relative to surrounding water particles in the wave. There is of course windward movement relative to the bottom. As we have seen earlier when discussing ocean currents, the velocity of this wind driven current is 3 to 5 percent of the wind velocity. The center of the rotation is at mid wave height, as shown in Figure 3.

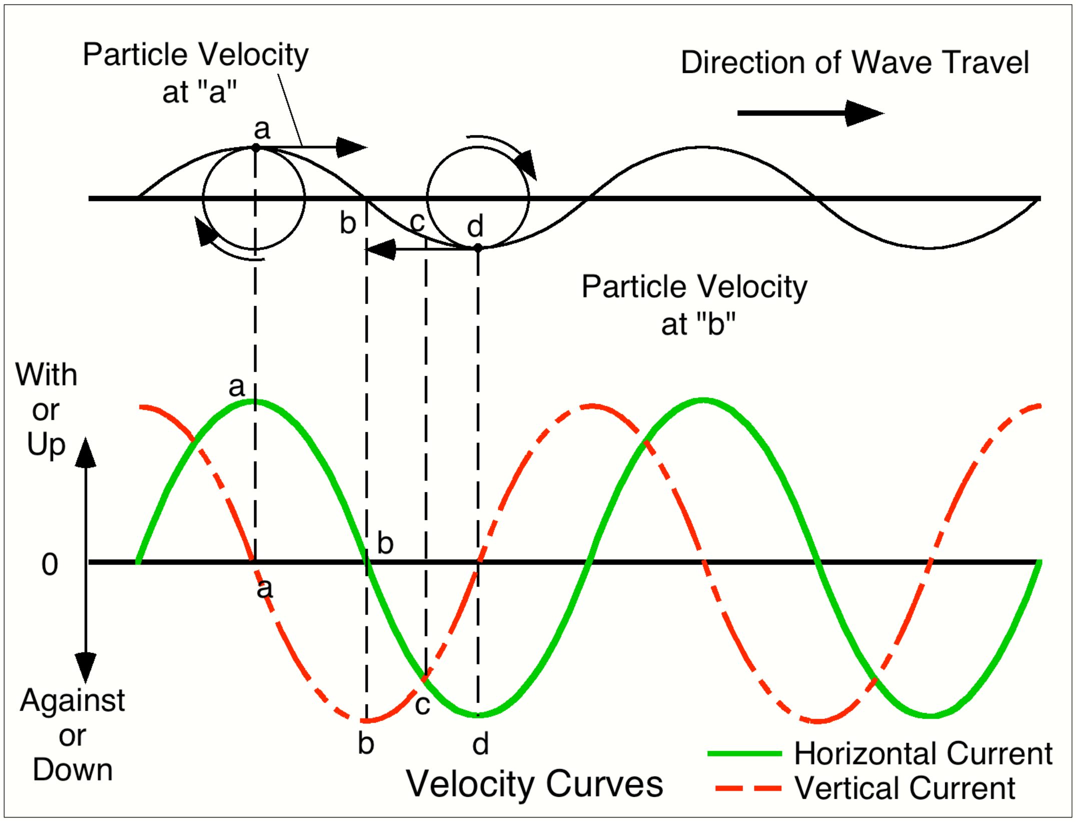


Figure 3 Typical path of an Individual Particle in a Sinusoidal Wave.

Sinusoidal

The relative circular particle motion produces a surface shape know as **Sinusoidal** wave. The solid curve is the current position of the sinusoidal surface. The dotted curve is the position of the water surface after a small period of time. The black dot is the current position of water particle "a or b." The open dot is the position of the same water particle after the change in time. The small circles describe the total paths of each water particle.

Surface Current

Because there is no net forward motion of the water, the result of this orbital flow is that a horizontal surface current is formed on the wave, first in one direction and then in the other. The horizontal velocity reaches a maximum at the crest and in the trough of the wave and is zero at two points midway down the face of each wave where the particle total particle velocity is completely vertically, either down or up. The maximum velocity (V_o) of this current is dependent on the wave height (H) and period (T).

$$V_o = 0.5921 \frac{\pi H}{T} \qquad \textbf{Eq 3}$$

Where: H is the height in Feet

T is the period in seconds
V_o is the orbital velocity in knots
0.5921 is the number of knots in a foot per second.

Orbital Velocity

Notice that the diameter of the circle is the wave height and therefore the larger the wave height, the greater the orbital velocity. This orbital velocity and its distribution along the wave materially affect a boat's handling in large waves. For example a 30 foot wave with a 10 second period has an orbital velocity of about 5.5 knots at the crest of the wave.

> ***'…This condition puts the stern of boat in water that is moving faster than the water surrounding the bow…'***

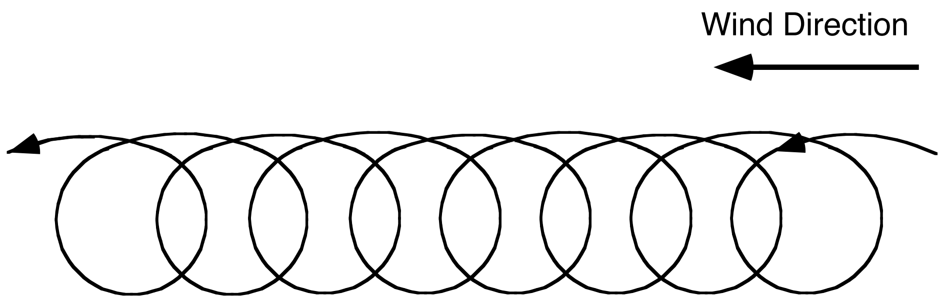
Effects of Orbital velocity on the Boat

The water accelerates from zero to maximum in 1/4 wave length. In the example that would be a little greater than 100 feet. If the boat is moving at 6 or seven knots when it enters this water it cannot accelerate as fast and steerage control is reduced as the boat surfs down the wave front. As shown in Figure 2.16, on the front side of the wave the orbital velocity of the water is decreasing from a maximum with the boat to a maximum against the boat in the trough. This condition puts the stern of boat in water that is moving faster than the water surrounding the bow. The result is a torque on the boat. This torque, the increase in speed and the decrease in steering ability all combine to produce conditions conducive to broaching. This is why in a mature system broaching is a real threat. Actions necessary to defend against broaching will be discussed later.

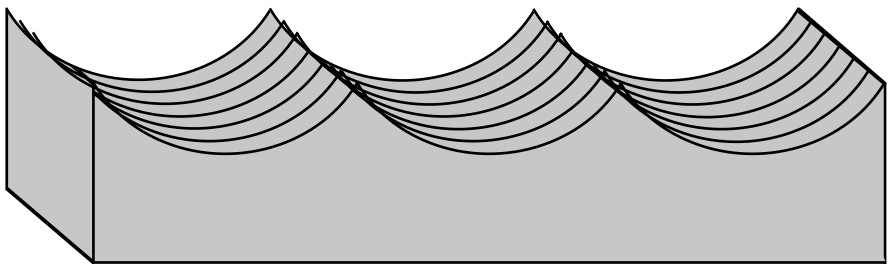
Developing Wave System

The developing wave system also poses some threats to boaters. To understand this phase of the life of a wave let's start from the very beginning. All waves systems at one time or another have developed from flat calm water. Before the wind begins to blow the particle of water is stationary both with respect to the bottom and the surrounding water. As the wind strikes the surface it moves the individual particle horizontally through the water a short distance in the direction of the wind and eventually the drag from the water below draws the particle down into the water.[4] Then the particle is submerged and rotates through a spiral and returns again to the surface and repeats the motion. As shown in Figure 4a.

[4]Smith, F.G. Walton. The Seas in Motion. New York: Thomas Y. Crowell Co., 1973. Page 16.



A. Path of a Water Particle in an Immature Wave



B. Cyclodial Immature Wave Surface

Figure 2.17 Typical Immature Wave.

Cycloidal Wave

The younger the wave the greater the proportion of the horizontal movement. The spiral starts out rather flat and then develops a more circular shape. As the force of the wind continues to work on the water, the excess energy increases the rotary motion until finally the mature rotary state described above is reached. As the wave height grows the particle motion is much harder to analyze than in a mature sinusoidal wave but it is apparent that the water moves faster in the crest of the wave than in the trough. This condition produces a water surface that is shaped into sharp peaks as shown in Figure 4b, and is called a **Cycloidal** wave.

Breaking Waves

Eventually, the transverse motion of the particle begins to cause the crest to travel faster than the wave itself. When this happens the water is flung forward ahead of the crest, the crest disintegrates and the wave breaks. This first manifests itself on the water surface as white caps. Early on, these small breaking waves are of no consequence to the recreational boater. As the wave height increases, this situation changes and larger breaking waves become a major danger to survival. The force of the water in a large breaking wave can be as much as one ton per square foot.[5] Considering the average recreational boat presents a couple of hundred square feet of surface area to the wave, 400,000

[5]Van Dorn, William G. Oceanography and Seamanship. New York: Dodd, Mead & Co., 1974. Page 187.

pounds of force is unleashed. Forces of this magnitude can crush hulls, break out ports and hatches or hurl the boat through the air. The possibility of encountering large breaking waves during heavy weather tends to interest most boaters.

Steepness

The ease at which a wave breaks has to do with the steepness of the forward face of the wave, which is in turn dependent on the wave's age, general shape, height and length. When a portion of the wave front exceeds about 30 degrees, the wave will break. This angle is difficult to measure in the real world. What is easy to measure is the wave height and length. Using these two parameters the steepness of a wave can be expressed by the steepness ratio. The steepness ratio (SR), is the ratio of the wave height (H) divided by the wave length (L).

$$SR = \frac{H}{L} \qquad \textbf{Eq. 4}$$

Steepness Ratio

The steepness ratio of a fully developed sinusoidal wave is about 1 to 15 or 0.067.[6] Because of this waves shape with a round top, the forward surface of the wave is much flatter than a cycloidal wave. To obtain the required 30 degree angle to cause a sinusoidal wave to break the SR needs to be about 1 to 5. The cycloidal wave on the other hand has a very steep wave front and therefore tends to break more easily. The SR of a breaking cycloidal wave is normally around 1:7.[7] Most of the breaking waves occur during the development of the system when it is around 40 percent mature or the wave velocity is about 40 percent of the wind velocity.[8]

Estimating Maturity

The velocity of a deep water wave (C) is related to the period (T) and the wave length (L).

$$C = \frac{gT}{2\pi} = 3.07T \text{ knots} \qquad \textbf{Eq. 5}$$

$$C = \sqrt{\frac{gL}{2\pi}} = 1.36\sqrt{L} \text{ knots} \qquad \textbf{Eq 6}$$

Where C is in knots

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[6]Marchaj, C. A. Sailing Theory and Practice. New York: Dodd, Mead & Co., 1964. Page 403.

[7]Gross, Grant M. Oceanography a View of the Earth. Englewood Cliffs, N.J...: Prentice-Hall, Inc., 1972. Page 205.

[8]Kinsman, Blair. Wind Waves, their Generation and Propagation on the Ocean Surface. Englewood, N.J.: Prentice-Hall, Inc., 1965. Page 307.

L is in feet.
And T is in seconds

It is much easier at sea to measure wave period than estimate wave length. Therefore Equation 5 is probably more useful. By timing the number of seconds and multiplying by three the boater can get the wave velocity. Comparing this with the wind velocity will give an idea of the maturity of the storm and the character of the waves to be encountered.

Decaying System

In a decaying wave system the water particle motion remains circular and so the shape of the wave remains sinusoidal as the storm dies. First, if there is enough energy in the wind to maintain the system, the wave height remains the same but the wave length continues to increase, thus the SR approaches 1:30. Under these conditions there are fewer breaking waves but the distribution of the wave height tends toward larger waves because time allows the probability of wave patterns combining to produce extremely large waves. The large long waves have correspondingly large lengths of wave front where the wave current is traveling with the boat. If the water and the boat are moving at the same rate the rudder force is lost and with it the ability to steer the boat and broaching again becomes a problem. It this situation where the waves are long and the possibility of plunging into the forward wave front is minimized, it is best to run fast and free in front of a very large wave to keep positive flow by the rudder. Finally as the wind velocity continues to drop, there is not enough energy available to maintain the wave height and the wave height drops along with the increase in wave length.

Waves in Shallow Water

So far the discussion has been about waves in deep water, but the recreational boater when crossing a bar also occasional encounters waves influenced by current and shallow water. In a mature FDS, the orbital diameter decreases with depth to 0.04 of the wave height at a depth equal to the wave length.[9] Although, this circle is small, it is large enough so that a wave passing through water that is shallower than 1/2 the wave length begins to feel the bottom noticeably. The circular orbits of the water particles tend to flatten into ellipses and the speed of the wave decreases, while the period remains constant. Because the speed of the wave (C) is related to the period (T) and the wave length (L) by Equation 7, the wave length must also decrease.

$$C = \frac{L}{T}$$ **Eq 7**

[9]Coles, K. Adlard. Heavy Weather Sailing. Tuckahoe, NY: John de Graff, Inc., 1972. Page 269.

Waves in Current

As the length decreases, the steepness ratio increases because the wave height remains constant. When the steepness ration approaches 1:7, the wave becomes unstable and breaks. Current running against the wind and into the wave also slows the velocity of the wave with similar circumstances. A current running with the waves increases the wave speed and reverses the same process flattening the waves. Large waves in shallow water running against a foul current can be very dangerous causing very steep, violent breaking waves that can easily overwhelm a recreational boat and on occasion even a large commercial vessel.

PREPARATION FOR HEAVY WEATHER

Many times all that one can do when dealing with extreme weather is to prepare the boat and crew and take what comes. The amount of preparation depends on the boat, the crew, the skipper and the severity of the oncoming storm.

Information

First, get all information on the approaching storm that is available on the radio or using techniques described in Chapter Eight on Weather. Try to determine the wind strength and direction and the duration of the storm. Write the barometer reading and the time in the log and update the reading every hour.

Fix position

Next fix the boat's position on the chart, locate the nearest safe harbor and calculate a run time to the harbor. Also, locate the nearest lee shore, estimate the severity of the wind and the amount the boat will drift down wind. Note the locations of shallow water or adverse currents. Using this information, decide whether the boat should run for protection, sea room or continue on course. In making the decision to run for cover the skipper needs to judge the conditions that the boat will encounter at the harbor entrance. See the section on 'Crossing the Bar' at the end of this chapter.

> ***'...in many instances the boat has weathered the storm and the crew has perished...'***

Prepare the Crew

The crew should prepare by putting on the proper warm and waterproof clothing. Prepare quick snacks. High energy foods like candy and a thermos or two of hot soup are needed to keep the crew efficient. Any drugs needed to suppress seasickness symptoms should be taken early enough to become effective. Seasickness in a storm is not only a discomfort, it is dangerous because it reduces the strength of the crew when strength is needed for survival. Handling a boat in a storm is exhausting work. In many instances, even though the boat has weathered the storm, the crew has perished due to exhaustion from cold, hunger and exposure. A tired brain makes bad decisions.

Safety Harnesses

Safety harnesses should be worn by any crew on deck. In a storm-tossed sea without help nearby any individual lost overboard is lost, if they cannot be recovered within a couple of minutes. The possibility of being recovered without a life line is minimal. Sailboats often run a line fore and aft along the deck to which a safety harness can be attached. Power boaters are very seldom as well rigged or even equipped with safety harnesses. Although most power boat crews may expect to spend most of their time in the shelter of the cabin, if a crew member needs to go forward to rig a sea anchor or make emergency repairs, they need to be tied off.

The most dangerous time for the crew is immediately after exiting the cabin. Emerging from the relative calm of the cabin into all the motion and fury is startling. Once on deck the individual can adjust to the force of the wind, the flying spray and brace against any oncoming seas. If a wave hits before they make the adjustment there is a good chance they will lose their balance.

Life Jackets

Life jackets are debatable. Unfortunately the conditions where a life vest will actually saved a life are limited.[10] If the water is cold, the life expectancy can be a matter of minutes. The extra bulk of a life vest makes working more exhausting as well as awkward. It is entirely possible than wearing a life preserver will reduce the chances of survival by tiring the crew unnecessarily or upsetting their balance and pitching them overboard. These two objections do not apply to passengers or once the loss of the ship becomes unavoidable.

Survival Suits

Survival suits will preserve life for an extended time even in cold water but they are also impossible to work in. If they are available, they should be positioned where they can be distributed quickly in case the ship needs to be abandoned. Any other survival gear like extra water and food for the life raft should also be moved to an accessible location.

Prepare Emergency Equipment

Emergency equipment like flares, EPRIBS and the first aid kit should be located and moved to accessible, secure positions. Those rarely used pieces of equipment like drogues, sea anchors, warps, cable cutters, and panels to cover the windows need to be located and positioned before the sea conditions makes rummaging around in the lower reaches of the vessel uncomfortable. All large windows not needed for navigation should be covered early.

Secure Equipment

The properly dressed and tethered crew should secure all equipment on deck. Everything that can be stowed below should be stowed in lockers. Equipment that must be left on deck should be lashed tightly. The force of wind

[10] Andrews, Howard L. and Russel, Alexander L. Basic Boating Piloting and Seamanship. First U. S. ed. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1964. Page 237.

and waves in the center of a severe storm is hard to imagine. Shock cord is woefully inadequate. Larger items should be attached with extra lashings.

> ***'…Getting hit in the head with a flying one pound can of tomatoes will do more than get your attention…'***

All equipment below should likewise be stowed and secured. All locker hatches should be secured both above and below decks. Those above deck, if they come open, will lose their contents into the sea and take in water. Those below will empty their contents into the cabin. Heavy flying objects are a hazard to your health. Getting hit in the head with a flying one pound can of tomatoes will do more than get your attention.

Securing Hull Openings

Secure ports, cowls and hatches as it becomes necessary. Stale air in the cabin can add to seasickness keep as much ventilation as possible without endangering the safety of the vessel. Large quantities of water can get below through these openings and jeopardize the safety of thevessel. Check the bilge for excess water and debris, clean and pump if necessary. Check the bilge pump intake screen to see that it is not clogged. Close all through hulls. An overturned boat will remain floating as long as air remains inside the boat. Closing the through hulls will prevent air from leaking out of the cabin.[11]

Hang On

Once preparations are complete there is very little left to do except hang on solve problems as they arise and persevere. Better times will come, even though that may not seem possible during the din and confusion, which is unbelievable and difficult to imagine without the questionable benefit of experience.

POWER BOATS

A power boat in heavy weather is vulnerable because the high freeboard exposes a large surface area to the force of the wind and seas. Most power boats also have large windows, which if broken can allow large quantities of water below. Exposed to heavy weather, the powerboat's options are limited, to running for cover, defensive course selection, or station keeping.

Running for Cover

A power boat's main defense, especially the smaller boats, is speed and vigilance. The probability of sucessfully riding out a severe storm at sea is considerably less for a small power boat than a small sailboat. The sooner a storm can be predicted the better chance the boat has to make it to safety. Boat speed places a limitation on how far a small power boat can prudently get from sheltered conditions. In setting this limit the skipper should be aware that a boat

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[11]Sleightholme, Des. Better Boat Handling. Newport, RI: Seven Seas Press, Inc., 1983. Page 112.

that can do 20 knots in flat water cannot do 20 knots once wind generated waves are present, especially if the course is into those waves.

Forced Speed Reduction

As the wind rise, a boat heading into the wind will have to reduce its speed or change its course to prevent pounding. If the waves are short and steep the screws may come out of the water as well. Changing course so that the boat is running 45 degrees into the weather extends the boat's path on the wave and reduces the pounding. This course is very uncomfortable due to the part roll and part pitch motion of the boat and lengthens the run for cover. Turning the boat down wind reduces the apparent wind on the boat by the speed of the boat and the motion is more comfortable. Down wind is the best direction to run for cover.

> ***'…the most vulnerable position for a boat in severe conditions is beam on to the wind…'***

Beam Seas

If the desired course of the boat places it beam to the seas, it may become necessary for the power boat to tack towards its destination, running first 45 degrees into the wind then 135 degrees off the wind. It should be pointed out that the most vulnerable position for a boat in severe conditions is beam on to the wind and seas.

Defensive Course Selection

If it becomes necessary to ride out a storm in a powerboat, the major decision is whether to run into the waves or with them. Each skipper must judge the storm conditions and the behavior of the boat in choosing which course they think is best. The question of whether to run into or away from the storm is hotly contested and I am sure depends on the individual vessel, storm and skipper. The right choice early in the storm with steep short seas may be different later in the same storm when the seas lengthen and flatten.

Downwind

Running downwind away from the storm, decreases the velocity of the wind by the speed of the boat and increases the length of the waves which in turn reduces the forces the boat and crew must resist. For example, it is possible for a power boat going twelve knots to run with a six or seven foot wave using the two knot orbital current on the crest to keep them on a single wave. This is not necessarily as good an idea as it sounds; because the boat will tend to surf down the wave front. When surfing, the water and the boat are moving at the same speed, helm control is reduced and the tendency to broach is increased. It is better to lose a little distance on the wave and regain helm control.

Sea State

In this manner, it may be possible to handle very large seas successfully, especially early in a storm when the waves are moving slower or late in the storm when the seas are sinusoidal in shape and the slope of the wave is more gentle. The general guidelines are that in short steep seas it is best to slow the boat down and let the waves run under the boat. If the waves are high and long, hold as much speed as possible and run away from them.

> ***'...Towing warps to slow a power boat should be avoided....***
> ***'***

Pitchpoling & Broaching

Running downwind the skipper should be mindful of the increased chance of pitchpoling, broaching or being pooped by a following sea, especially early in a storm. The seas are cycloidal in the early stages of a storm and their steep faces and sharp crests can cause considerable trouble. Negotiating short, steep seas safely requires the boat speed to be carefully controlled. The speed needs to be slow enough so the bow does not plunge into the trough or wave ahead causing the boat to be flipped by the wave coming from behind, yet fast enough to maintain steerage control and avoid broaching or being pooped by a following sea. Slowing a power boat running downwind may not be an easy task. The wind force on the superstructure alone will drive it at surprisingly high speeds. Towing warps to slow a power boat should be avoided. Any lines strung out behind a power boat may become fouled on the prop with disastrous consequences.

Boat Control

If the skipper cannot control the speed of the boat it may be best to take the more uncomfortable but safer course and power into the wind. This presents the bow, which is better designed to take the force of the storm, to the elements. If the seas are sinusoidal, control of the boat is seldom a problem and running directly into the seas produces a fairly smooth up and down motion around the long axis of the boat. If the seas are cycloidal, heading into the wind requires the boat speed to be progressively reduced as the conditions get worse. Eventually the boat may be moving so slowly that it is barely keeping steerage. This is called station keeping.

Station Keeping

Station keeping is very similar to hoving to with a sailboat. Enough power is maintained to keep the boat heading between 50 degrees off and directly into the wind. Just slightly off the wind is generally a little more comfortable where the motion is mostly pitch. The more off the wind the more power that can be applied, but the greater the danger of being caught by a gust and forcibly turned sideways to the wind and waves. In this position the boat is very susceptible to broaching.

Drogues and Sea Anchors

Holding the head into the wind by using a drogue, sea anchor or trailing warps off the bow may or may not work. The experience of sailboats using this method is poor.[12] Certainly the sea anchor will keep the head into the seas and places the bow in a position to split the waves. However, the boat can no longer be powered forward with the engine or it will over run the lines. This is not a method to consider in a powerboat unless no other options are available

> ***'…the object is to slow the boat and stabilize its path and not stop it…'***

Trailing Warps

If warps or sea anchors are to be set it is best to attach them using a harness that is attached just aft of amidships rather than to the bow. Heavy loads on the bow will tend to depress it and increase the possibility of taking green water over the bow. The lines need to be protected from chafe and long enough to reach several wave lengths ahead of the boat. The amount of drag is important, the object is to slow and stabilize the boat not stop it. Too much drag will stop the boat and subject it to the full force of the breaking waves. The boat must be allowed to fall back with the wave so that the immense force of the wave will be dissipated and less damage will occur. This necessary backward movement places abnormal loads on the rudder and may damage it.

Changing Tactics

Changing course or removing warps in mid storm is difficult. Recovering any warps in the midst of a storm is practically impossible and if it becomes necessary will probably require the warps to be cut loose. Radical course changes that require the vessel to pass beam to the weather are difficult and dangerous, especially if the crest of a wave hits the boat while it is beam to the weather. Try to make any turns beam to the weather on the back side of waves. It may not be possible to time the maneuver so that the boat can turn a full 180 degrees before the crest of the next wave hits. The exposure can be reduced by breaking the turn into two segments. First, turn the boat 45 or 50 degrees off the wind and hold this course until a suitable sea approaches. Then, as the crest passes, make the remaining portion of the turn.

SAILBOATS

Caught out in open water in a sailboat is a much safer than in a power boat. The hull shape, the deep, heavy keel, the lower freeboard and the smaller openings are all better designed to take the forces of the weather and increase the chances for survival. Because of their construction sailboats may have a few different options than a power boat in severe conditions, but their options are still limited to lying a hull, heaving to or running before the storm with or without warps.

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[12]Coles, K. Adlard. Heavy Weather Sailing. Tuckahoe, NY: John de Graff, Inc., 1972. Page 259.

Shortening Sail

As the wind rises, a sailboat progressively shortens sail and maintains course until minimum sail is set. This condition, which is somewhat boat and weather dependent, for most sailboats is around 40 to 50 knots of wind. When the wind reaches this velocity, the wind is not as much a danger as the accompanying seas. The options now become similar to a powerboats with the addition of lying a-hull, or hulling, and heaving-to which is similar to the process of station keeping for powerboaters.

Defensive Course Selection

Once minimum sail is set the boat can further reduce the wind pressure by changing course to alter the apparent wind. The farther off the wind, the less the apparent wind and its accompanying pressure. As the wind increases eventually the boat is forced to run directly down wind. Running before the storm in a sailboat is very similar to running before a storm in a power boat, except that it requires at least one person at the helm exposed in the cockpit to the fury of the storm. All the advantages and disadvantages are similar, except that with no turning propeller, towing warps behind the boat to slow its progress is an expectable practice. The advice on towing warps given above is applicable here, except that the warps attached to the stern will now depress the stern and increase the chances of swamping the cockpit and should again be attached amidships.

Lying a-hull

Lying a-hull is literally casting your fate to the wind. All sail is stowed, the helm is lashed to weather and the crew goes below letting the boat fend for itself. The crew is relatively more comfortable below where they are warmer and drier. Their only tasks are to hang on, keep the bilge dry, listen to the din and fight panic. One crew member should remain dressed properly for deck duty just in case changing conditions or an emergency top side requires instant attention.

> ***'...Many boats have suffered 360 degree rolls using this strategy....'***

Sea Room

The success of lying a-hull requires sea room as the boat will drift down wind. If the boat lies too much beam to the weather the heeling of the boat may expose a considerable portion of the undersides of the hull to the force of the waves. If this exposed surface is essentially perpendicular to the waves such as in a round bottom or canoe shaped hull the waves will slap violently against the bottom. Also, since there is no one at the helm, the boat may come beam on to the seas more often and take large rolls. If these rolls become too frequent or severe it may be more prudent to change tactics. Many boats have suffered 360 degree rolls using this strategy.

Heaving-to

Heaving to is the traditional way for sailboats to ride out a gale. It is very similar to lying a hull but requires a small sail to be set and the boat balanced so that it rides closer to the wind than a boat that is lying a hull. When heading close to the wind, most of the force from the wind and waves is off the boat and it is surprising how well it will ride the storm. A boat hoved-to is much more comfortable below than one lying a-hull. Some of the difficulties encountered when hoved-to can be attributed to carrying too little sail rather than too much.[13] There is a limit however to what sail cloth and fastenings can take and again the skipper may be required to change tactics. Lying to a sea anchor is not recommended for sailboats because of their exposed rudders and the lack of documented success.

[13]Coles, K. Adlard. Heavy Weather Sailing. Tuckahoe, NY: John de Graff, Inc., 1972. Page 256.