

EXHIBIT 1010



THE ART AND SCIENCE OF

SAILS

A GUIDE TO
MODERN MATERIALS,
CONSTRUCTION, AERODYNAMICS,
UPKEEP, AND USE

TOM WHIDDEN AND MICHAEL LEVITT



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popular on cruising boats (see Figure 7.2); however, their use is sometimes restricted by class or rating rules, in particular the IOR. They conform to the rules of the International Measurement System (IMS), Performance Handicap Racing Fleet (PHRF), and Midget Ocean Racing Club (MORC).

So direct is the connection of batten length to leech support that a full-battened polyester/Mylar mainsail may well be faster than a considerably lighter and lower-stretch Kevlar mainsail (with short "IOR-style" battens). Full-battened Dacron cruising mainsails are faster than Dacron racing mainsails before the days of Kevlar; compare a good full-battened Dacron mainsail to a poorly designed or manufactured or tired Kevlar racing main, and the Dacron sail will likely be faster. Full-battened mainsails will be discussed in more detail later in this chapter.

The other major element of mainsail shape is twist (see photograph on page 118). The reasons why sails are designed with twist was discussed in the previous chapter, but to summarize them here: The wind has a natural vertical twist, and this twist in the wind must be matched to the twist in the sail. Also, twist helps to keep flow attached to the top of the sail, thus minimizing induced drag and maximizing the all-important lift-to-drag ratio.

THE RACING MAINSAIL

The most dramatic change in the design of the racing mainsail is the structure and panel layout of the sail. As recently as 1983, cross-cut Kevlar/Mylar mains were most common. The Kevlar substrate used then was strongest in the fill direction (across the roll of cloth), and in order to match the strengths of the cloth to the loads on the sail, mains were cross-cut. Or to put it another way, the seams roughly paralleled the boom. This was consonant with early stress maps. These stress maps, which show the direction and magnitude of the forces in a sail, revealed that the stresses in a main run in a straight line from head to clew.

During the 1983 America's Cup, however, *Australia II* carried the first vertically cut and radially clewed mainsails. These sails utilized warp-oriented Kevlar cloth. Since the primary strength of the cloth ran the length of the roll of cloth, vertical panels were required. As for the radial clew, advances in computerization led to better stress maps, which showed that the loads did not, as was thought, only run up and down the leech of the mainsail in parallel lines. There is a second important force component that radiates from the clew. Thus was born the radial clew. By matching the cloth's greatest strength to maximum loads, the sail stretches less and holds its designed shape for a much longer time.

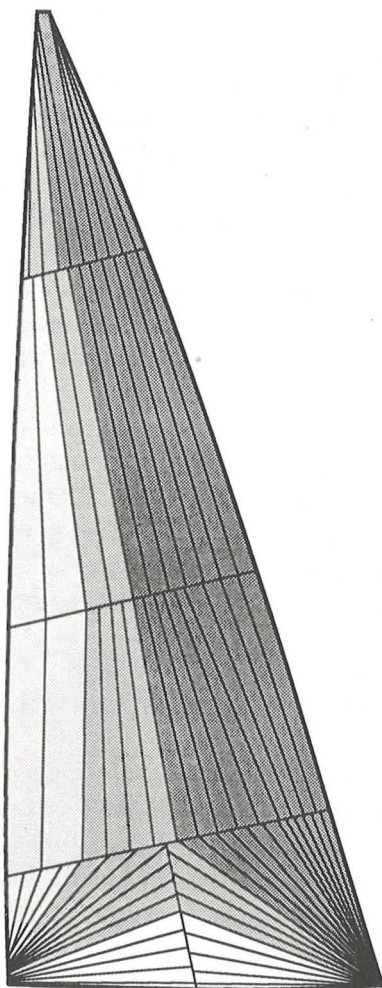


Figure 7.3 Panel layout for a Maxi mainsail. The white areas are polyester/Mylar and the shaded areas are Kevlar/Mylar. Each shade of Kevlar/Mylar denotes a different material, with the darker shades representing the heavier materials.

As should be apparent, none of this precise matching of cloth strength and sail load would be possible without accurate computer-generated stress maps. Accurate stress maps mean that sails can be reinforced precisely where extra strength is needed. This is analogous to building a high-tech fiberglass boat, in which carbon fiber or Kevlar is blended in the glass laminate where extra strength is needed, such as where winches and turning blocks are mounted.

Since 1983, the structure of the racing mainsail has developed further, with the sail being broken into more sections and smaller panels. This is an

even more precise way of matching strength to load. It is now common for a North Sails One Ton main to have nearly fifty panels, and a Maxi main might have ninety panels. Figure 7.3 shows a typical Maxi mainsail (mainsails are the focus of Chapter 10). One ancillary benefit of the multipaneled mainsail is that more panels obviously require more seams, and seams, when aligned to the load, add strength to a sail.

THE CRUISING MAINSAIL

When it comes to the cruising mainsail, the first question the sailor must ask is, Do I want it to be easy or fast? The answer to that question sorely affects the design of the cruising main. Ted Hood, featured in Chapter 2 and no stranger to either world, decided on easy for the cruising main. In the mid-1970s, he brought to the market his inspired Stoway Mast. Here the mainsail winds up neatly on a roller-furling rod inside a specially designed mast. It is not an all-or-nothing solution as the mainsail can be partially furled, or reefed. Further, there was no need for a sail cover, as the sail was protected from sunlight and the elements inside the mast. Fifteen years later, it remains both an easy and an elegant solution to mainsail handling and is found on many cruising boats, particularly in the larger sizes and/or for those who often sail shorthanded. Dodge Morgan, for example, used a Hood Stoway Mast on his Hood-designed sloop, *American Promise*, in his record-setting solo circumnavigation.

Like practically everything in sailing, the Stoway Mast has trade-offs. It is expensive; since it can't be retrofitted, it requires a dedicated mast and a specially designed sail. Also, the mast must be oversized to accommodate the furled sail. The mainsail, which is in an unenviable position to begin with due to the form drag around the mast, suffers even more behind an oversized mast. Further, the mast weighs more than an ordinary mast, which can affect the sailing motion of a boat. Most important, however, is the fact that the mast requires significant compromises when it comes to sail shape. With the Stoway Mast, sail shape, or form, definitely follows function.

A major reason is that since the sail furls in a horizontal direction, regular (horizontal) battens can't be used. Without horizontal battens, however, little or no roach (the area beyond the straight line running from clew to head) is possible; in fact, most sails for this rig are built with hollow leeches. Battens that run up or down the leech are sometimes substituted, but this is nowhere as effective as horizontal battens. Also, to facilitate reefing and furling, the mainsail must be built with a short luff and foot. Depending on one's priorities, these criticisms may sound gratuitous; it is analogous to saying a great car



A full-battened main is seen on the catamaran Stars & Stripes '88—the one with the soft rig rather than the wing (see photograph on page 124). While go-fast catamaran sailors and then boardsailors were the first recreational sailors to use full-battened mainsails, Chinese junks have had them for at least a century. They are now popular on cruising boats and some racers. (Courtesy of North Sails, Inc.)

that race under rules other than the IOR, such as the International Measurement System (IMS), Performance Handicap Racing Fleet (PHRF), and Midget Ocean Racing Club (MORC). It seems likely that the IOR will someday allow their use.

Mainsails are now built with two basic families of battens: full-length (see Figure 7.2, page 130) and short. The latter are most commonly designated as “IOR-type” battens (see Figure 10.1). Each has advantages and disadvantages, which are noted briefly.

Advantages of Full-Length Battens

1. Improved sail durability because of reduced flogging.
2. Quieter because of reduced flogging.
3. Easier to flake on boom.