THE DEVELOPMENT OF THE KEEL

In Star Boats

When the Star was designed in November 1910 in the office of William Gardner, there was no thought given to the idea that the Star boat would outgrow its being used as a local New York / New England one-design racer. While the hull was built at various boatyards, Gardner's office was the designer and provider of the various fittings needed to complete the boat. Concerning this, the original Gardner specifications read as follows:

F I T T I N G S.

> All fittings, including fin keel, rigging, blocks, cleats, deck and spar fittings, rudder-post, tiller-jaw, and sails, to be furnished by William Gardner & Company, and put in place by Builder.

At the time the Star was designed it was natural for the Gardner office to turn to a cast iron keel for the fin keel. At the time iron castings were being used for everything from cast iron toys to sewing machine parts to steam engines to building fronts and details, so going with a cast iron keel was a natural thing to do.

It should be remembered that castings made from cast iron is not an exact process. There is a certain amount of shrinkage which takes place as the cast iron cools, so the end result will be a keel which is smaller than the pattern which was used to make the mold. William Gardner undoubtedly knew the vagaries in the casting process, and perhaps that was why originally the specifications required that the keel had to come from a pattern supplied by the Gardner office.

However, during the next few years two things happened. The Class began to expand to areas beyond the New York / New England area and World War I made resources scarce. Thus, in a letter dated March 19, 1917, to a prospective home-built boat builder in Ohio, Gardner wrote the following:

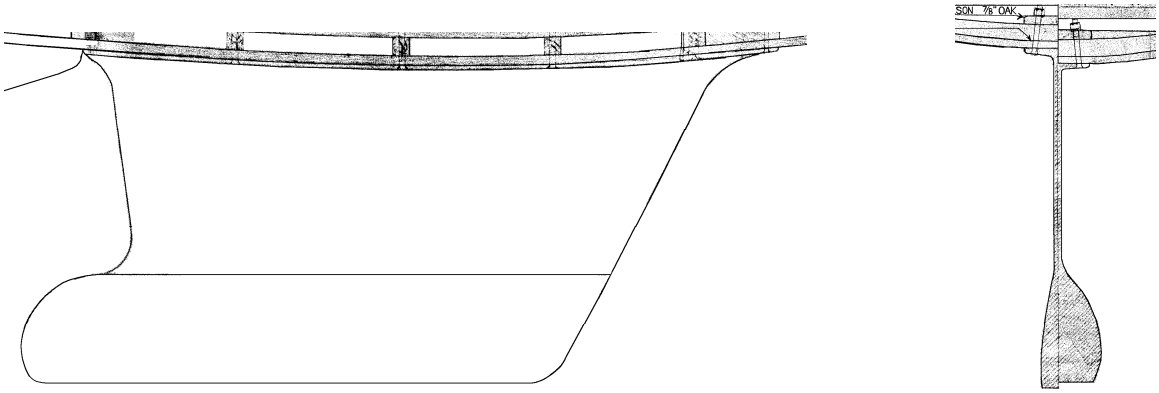
> "As regards the fittings - It would be foolish for you to make patterns of same, as the patterns alone would cost you three times as much as the fittings. If you wish, we can furnish you the fittings, which are the ones used on all the boats here. The prices two months ago were as follows - -
>
> | | |
> |---|---|
> | Bronze blocks and sheaves, | $16.50 |
> | Iron keel, | 50.00 |
> | Deck and spar fittings, | 29.64 |
> | Sails, | 70.00 |
> | Rigging, | 25.00 |
> | Track, slides, etc., | 13.50 |
> | | -------- |
> | | $204.64 |
>
> If you desire them, will get these prices verified, and they will probably not differ very much from the above figures.
>
> As regards the fin - - You could probably do a great deal better by getting this from the Rocky River D. D. Co., as they, I understand have made a pattern for it, which is a very expensive thing and very difficult to make. When the freight is taken into consideration, they could probably furnish you

the fin at a much lower price than the above. If, however, you wanted an absolutely correct fin and didn't mind the slight increased cost, it would be better to get it here, as the fin pattern was checked up very carefully by myself, so there in no question about its accuracy."

Since this was the war time era, perhaps the Gardner office had to back off the original stipulation as shown in the Gardner specifications.

Thus, while it appears that the original intent of the Gardner office was that Gardner & Co. was to be the only source of fittings for the Star, including the keel, because of various circumstances, including the distance from a central distribution point and war time restrictions, the Gardner office changed its policy with regard as to where Star fittings such as the keel could be manufactured. It would seem that most certainly, if the Gardner office, and later the Star Class Association after it had acquired the rights to the Gardner plans, had continued the stipulation that the keel be provided by only one source, the Class would not have grown into being a worldwide Class at a time when shipping such items as keels was very prohibitive.

The Star keel, as shown on the Gardner plan of November, 1910, from all appearances looks like the keel of today.



The Star Keel as shown on the Gardner Plan of November, 1910

However, if one looks closely at the keels on boats from various periods there is a noticeable refinement in shape, especially that of the bulb. A couple of items of note in this plan are:

1) In the drawing of the cross section there was a gradual widening of the bulb with the widest part of the bulb being within a couple of inches of the bottom of the keel. This is in contrast to some bulbs of today which flair out very quickly near the top of the bulb.

2) There were no wood fairing strips around the flange of the keel to make a smooth transition between the hull's bottom and the keel. Fairing strips came some time later, and by the 1950's were in universal use.

After World War I the Star started to evolve. The first change was for the rig to change from a gaff rig to the short Marconi rig in the early 1920's. The Star's keel, along with the rest of the boat and rigging, also went through a process of evolution over the more than 100 hundred years of the Star's existence.

One item that has long been played with is the fore and aft positioning of the keel. For two years running, 1922 and 1923, Bill Inslee of the Western Long Island Sound fleet was the

Champion of the Star Class. Bill wrote an article about boat preparation for the April-May, 1924, issue of Starlights. This article is very illuminating in letting us see what a top skipper considered to be necessary to tune up his Star. Bill begins with a description of how to get the smoothest bottom. Then he deals with getting the proper balance in the helm when going to windward. He mentions the importance of the proper position of the keel, the placement of the mast, the rake of the mast, the position of the jib fairleads, and backstay tension as various components which went into getting a balanced boat. In the original design of the Star the keel was a little too far forward and it became quite common to move the keel as part of the process of getting the boat tuned up. Since the hull was sitting on top of the keel flange, as shown in the plan above, and there were no fairing strips, moving the keel aft was not an especially difficult project.

In the 1925 Log there is the first attempt at giving specifications for Star boats. As shown in this Log, it was allowed to move the keel "forward or aft 4 inches from position shown in blue print". In 1939 this was changed to allow 6" fore and 4" aft of the position as shown on the plan. At the present this allowance is much more restrictive, being 51 mm or about 2" fore or aft of the point known as dimension E.

In the 1925 Log there is also the earliest comment about keel shape: "Must be cast from a pattern approved and registered with the association." This wording was soon changed to read "Must be cast from a pattern recorded with and approved by the Measurement Committee." This second wording was used for a number of years until the 1945 Log when the wording was changed to read only "Must be cast as per plan…"

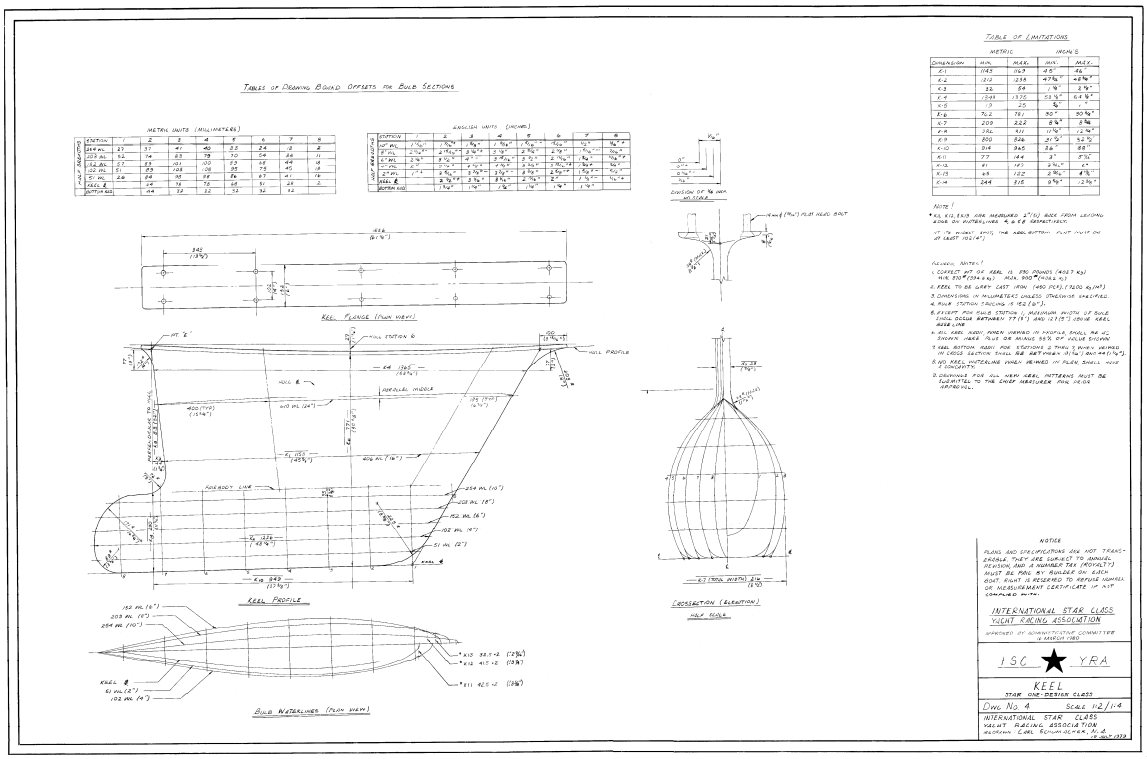
The first time keel dimensions are listed in the "Table of Limitations" was in the 1954 Log. Only three keel dimensions are given: the vertical distance from the bottom of the hull at Station 6 to the bottom of the keel, the thickness of the keel fin at the thickest point, and the thickness of the keel bulb at the thickest point.

The earliest known existing keel drawing which gives details on the various keel contours was made by Skip Etchells in July, 1946. This was the original Drawing No. 4. There is no "Table of Limitations" given on this drawing. It does however include a "Table of Drawing Board Offsets for Bulb Sections" plus numerous other dimensions.

In July, 1979, during the period when the Star Class was tightening up on hull tolerances, Drawing No. 4 was redrawn by Carl Schumacher, showing the same shape and dimensions giving in the Etchells drawing but now including data in both English units and Metric units. Furthermore, a "Table of Limitations" for the keel was added to the plan. The number of measuring points on the "Table of Limitations" increased from 3 to 14. This is in addition to the various points (53 in number) given in the "Table of Drawing Board Offsets for Bulb Sections". Also added were various "General Notes". Some of the more pertinent ones to this article are as follows:

5. Except for bulb station 1, maximum width of bulb shall occur between 77 (3") and 127 (5") above keel base line.
6. All keel radii, when viewed in profile, shall be as shown here plus or minus 33% of value shown.
8. No keel waterline when viewed in plan, shall have a concavity.
9. Drawing for all new keel patterns must be submitted to the chief measurer for prior approval.

One significant change made in the Schumacher drawing from the earlier plans of Gardner and Etchells is that rather than showing the hull profile sitting on top of the keel flange, the underside of the keel flange is now shown as being in line with the hull profile. This change in depiction was brought about by the fact that in wooden boat construction it was neither desirable nor by Class rules permissible to recess the keel flange into the keel plank. However, with fiberglass construction this was structurally feasible, and the Class allowed this construction technique in lieu of using fairing strips to fair in the keel flange.



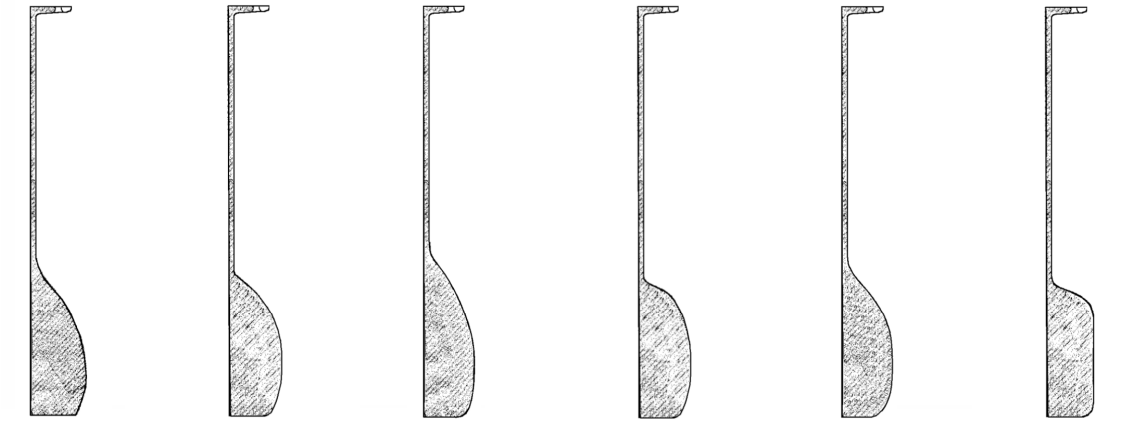
As stated previously, castings made from iron is not an exact process. There is a certain amount of shrinkage which takes place as the iron cools, so the end result will be a keel which is smaller than the pattern which was used to make the mold. By the 1970's it was recognized that there was a need to have a "Table of Limitations" giving an envelope into which the Star keel could fit.

Thus, during the 1970's efforts were made to tighten the hull's "Table of Limitations" and create the keel's "Table of Limitations" to bring construction of these two key components to the Star under tighter control. The hull's "Table of Limitations" underwent further tightening during the 1980's. This tightening was in part in response to the fact that during the last years of wooden boat construction, as builders became more adept at carrying the hull lines to the extreme limits of the limitation envelope, hull shapes which were obviously not the original intent of the Gardner lines became prevalent. A good example is the late Eichenlaub boat form which had a very pronounced V bottom. There were many complaints about a continual "arms race" in which each builder tried to out-do the other in introducing innovative features in their boats. Boats were very distinctive from builder to builder and one could often say at a glance who the builder was. With the present fairly restrictive "Table of Limitations" for the hull one now has to look elsewhere on the boat to have some

idea which builder built the boat. Such things as deck construction and layout, and keel features, are tip-offs as to what company built the boat.

In Note 1 to the original Gardner plan above, mention was made of the fact that the cross section of the bulb in these later plans is shown to widen out more abruptly at the top. Also the thickest part of the bulb was moved up to the middle of the bulb, in general giving the bulb more of a torpedo-like shape. In fact, the "General Notes" to Drawing No. 4 specify that the "maximum width of the bulb shall be between 77 (3") and 127 (5") above the keel base line."

To give some idea of the changes in bulb shape here are some keel cross sections:



1910 Keel | 1946-1979 Keel Plan | 3800 O.G. Keel | 7700 Folli Keel | 8100 Mader Keel | 8300 Mader Keel

Relative to the original Gardner keel plan, some of the bulbs today flair out very quickly near the top of the bulb. On some bulbs, as for example on the 7700 series Follis, this feature is so abrupt that there is almost a flat shelf created on the top side of the bulb. These keels have been dubbed "beer can" keels because supposedly one could place a beer can on the shelf created by this abrupt flair.

Milled Keels

As stated in the comments about the 1979 Drawing No. 4, a Table of Limitations for keels was introduced in 1979. Recently, the milling of keels using a computer to determine the finished shape has become possible. The result of this is that it has become possible to pour over-sized keels and then mill off the excess to a desired shape. This allows the boat builder to take any point on the table of limitations to the maximum or minimum, depending on the desired keel shape, and produce a keel, which while falling within the bounds given in the Table of Limitations, still has a bulb shape which was not the original intent of the keel drawing.

Of course, the process of milling a keel adds significantly to the cost of building the boat. Builders charge anywhere between 3,000 € and 9,000 € for this extra service.

A Couple of Recent Developments

One of the most recent developments is the flat-sided bulb seen on some of the newer Maders. This is shown above in the last depiction of keel cross sections. One of the results of carrying this feature all the way to the trailing edge of the bulb is that the trailing edge is mostly vertical with almost equal radii at the top and the bottom of the trailing edge. While visually this is not the intent of Drawing No. 4, given General Note # 6 which states that "All keel radii … shall be as shown here plus or minus 33% of value shown" and taking the upper and lower trailing edge radii to the 33% limits, then in fact the radii can be close to being the same at about 4 ½".

Another recent development is what some have called a "drooping keel", in which the aft end of the keel bulb is significantly lower, and conversely the forward end of the keel bulb is significantly higher, than what is shown on Drawing No. 4. This can be achieved by taking the forward keel measurement K6 which is shown as 30 ⅜" to its minimum which is 30" and taking the aft keel measurement K9 which is shown as 32" to its maximum which is 32 ½".[1]

Leading Edge

One of the subjects not previously touch on in this article is that of leading edge in keels. While this may seem minor compared to what has been talked about above, in fact there is reason to believe that this factor has more to do with the keel's performance than other factors such as bulb shape and orientation.

In the Spring 2001 issue of Starlights there appeared an article by Paul Bogataj which addresses this topic. In it he shows three different leading edge shapes and gives a graph showing the up-wind and down-wind performance for each of these leading edges. Briefly stated: A rounded leading edge has good lift for up-wind performance but high drag for down-wind performance. The opposite is true for a fairly narrow leading edge. He gives a third leading edge which he suggests is the best compromise between the two extremes. Although seldom talked about, for years top skippers have paid attention to this detail, and today practically all of the variations mentioned here can be found on Stars. The preference is related to what type of racing the skipper plans to do most, whether short course racing where high lift is needed, or traditional long Star course racing were speed is more important.

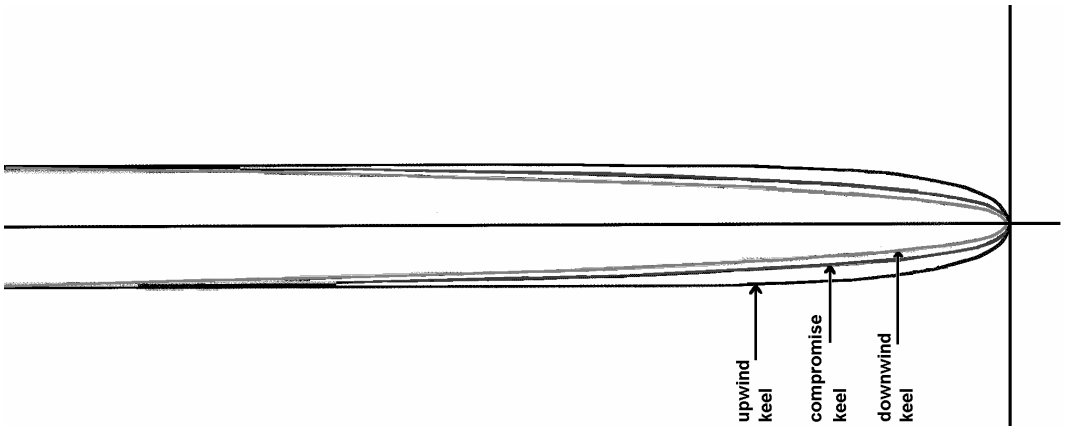


Figure 1. Three keel section leading edge shapes designed for different conditions.

[1] For various examples of keel shapes see Appendix A.

Keel Coatings
and the problem of rusty keels

One of the more bizarre things to happen in the last twenty years is the reduction of the amount of coating on the keel so that the overall density of the keel is as high as possible in order to obtain the maximum righting moment. Carrying this concept to the logical extreme, milled keels in which the keel is milled to the final shape so that no filler is necessary have become fashionable. As mentioned above, the process of producing milled keels is quite costly. While this concept is correct and all very well, it would seem that applying a coat of protective material which is so thin that water penetrates it and begins to cause rust after only a short time is carrying the concept too far. Surely, having the proper amount of a protective barrier coat applied on the keel cannot increase the overall volume of the keel significantly enough to affect the righting moment.

On keels receiving this treatment it is quite common for the original coating to bubble up and flake off the keel due to rust. This is an unfortunately common problem with boats built by one company in particular, and boats as new as only 4 years old have had to have their keels recoated, usually at a cost of between $3,000 and $5,000.

WHY IT MATTERS

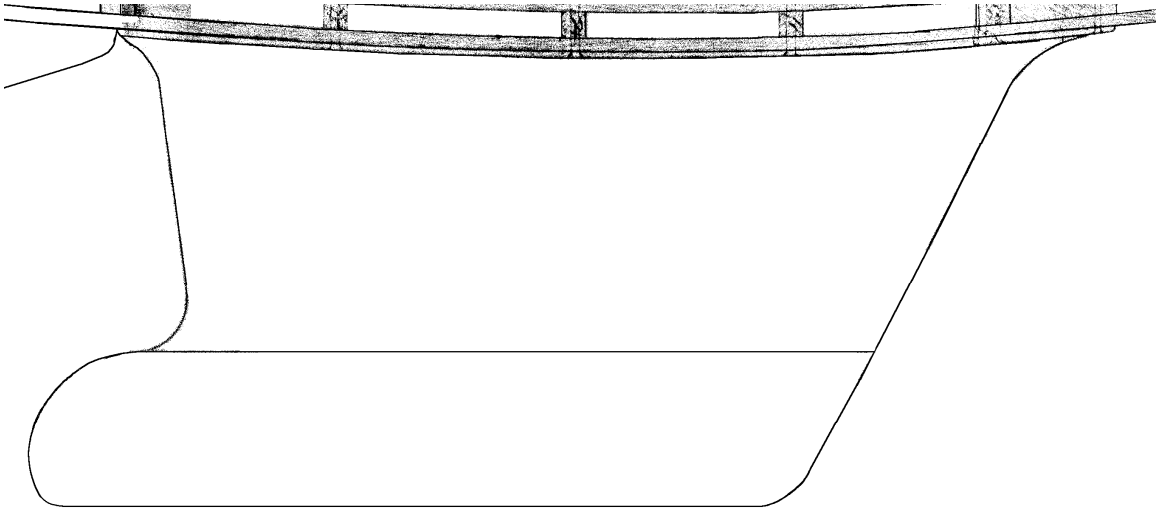
The reader may wonder why it matters that the keels are so obviously different, both from builder to builder and from year to year, and indeed in terms of performance it may well be in part all in the head. However, what we have found out is that in terms of fleet building these obvious differences are a real hindrance in terms of getting people to buy into a Star. There have been enough occasions where a perspective buyer has thrown up his hands and has walked away because he is afraid that he is making the wrong choice when buying a Star. He can see the difference in the various keels and gets the feeling that he may be buying a boat which is not competitive. All of our assurances that in fact the differences in keel shape is only a small factor in a boat's performance and that the major factor is the ability of the skipper to read the wind and water go for nothing. I believe that standardizing the keel will go a long way to helping fleets grow.

SOME FINAL THOUGHTS

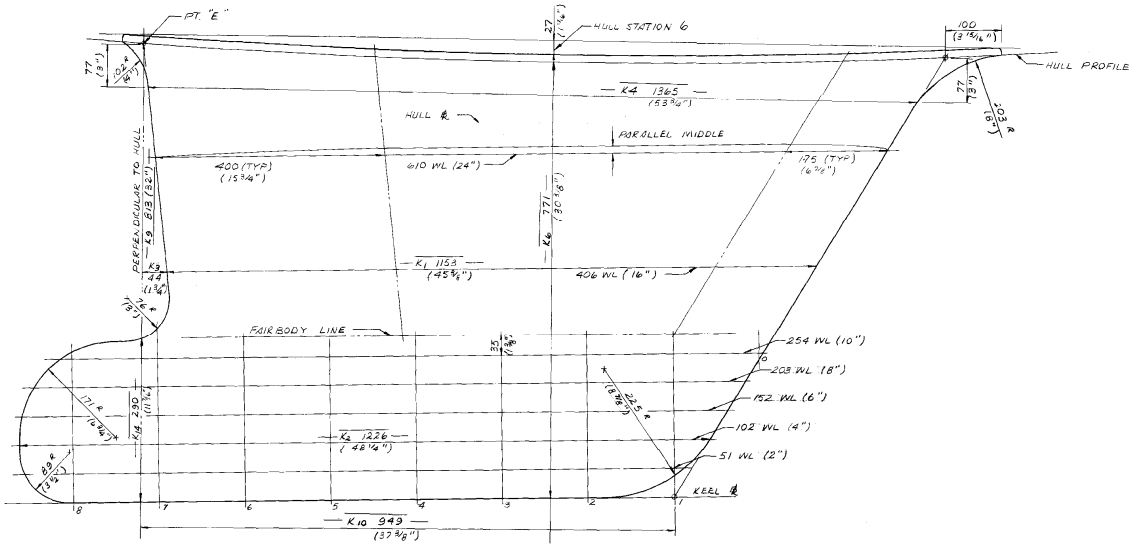
During the time when wooden boats were being built all over the world it was common sense to allow foundries local to where boats were built to produce keels. Now however there are in effect only three builders of Stars, all located in relatively close proximity to each other. This fact makes it possible for there to be a single foundry which could provide keels to all three builders. With the advancements in foundry practices it is now possible to pour keels with much greater precision. Keels could then be finished off by milling them to the desired shape as specified by the Class. I believe that it is time for the Star Class to return to the original principle concerning keel construction; that is that all keels come from the Class-approved source.

Appendix A

Given here are photos of various keel shapes



The original keel plan from the 1910 Gardner blueprint



The keel plan from the 1978 keel plan

1987 Mader

1998 Mader

2000 Folli

2000 Folli

2003 Lillia

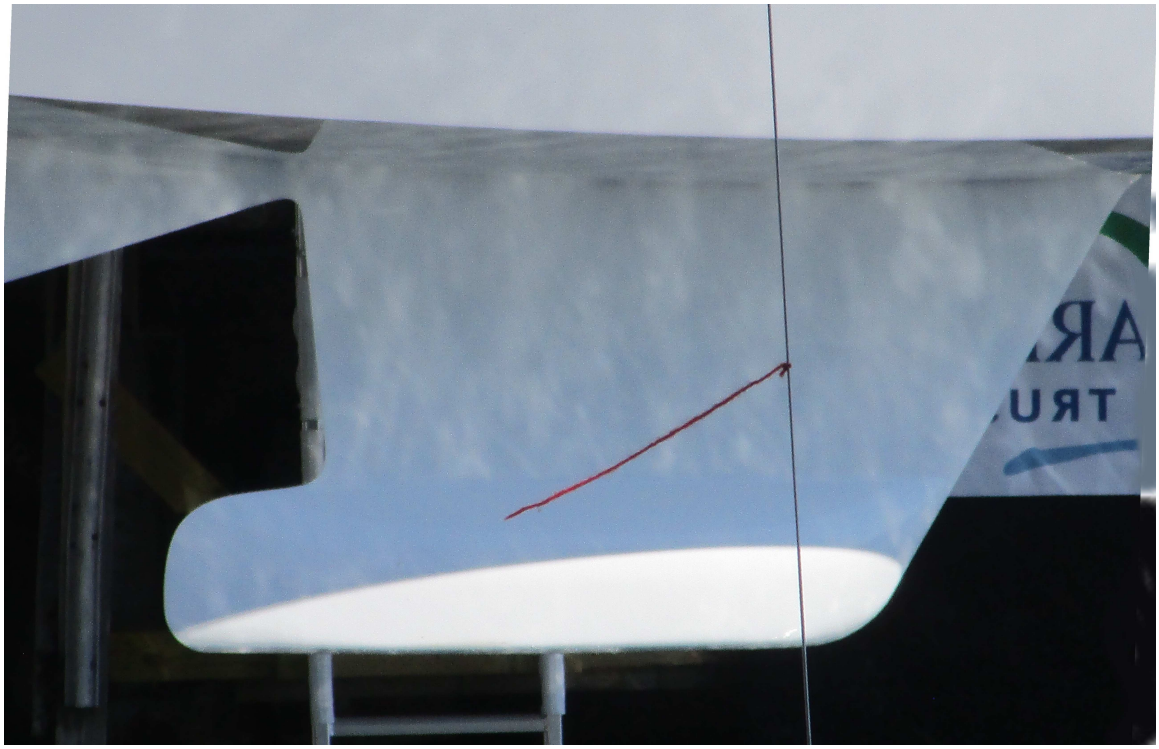
2004 Folli

2005 Folli

2006 Folli

2007 Lillia

2007 Lillia



2007 Lillia

2011 P-Star

2011 P-Star

2013 Mader

2015 Folli