Making Large Sails in Small Spaces: Rediscovering Sailmakers' Mathematics

Introduction

Up until the early 20th century, sailmakers made large sails in small spaces, small lofting floors, even onboard ship. How did they do it if they couldn't lay out the entire sail? How did sailmakers work in such a way that the first time they saw a completed sail might be when it was hoisted up the mast? The Charles Mallory Sail Loft at Mystic Seaport Museum is, by the author's own rough measurements, about 50' long by 30' wide (approximately 15m x 9m). Such a space would be too small to lay out the sail we will examine below. Similarly, an early photograph of the loft where our subject sail was probably made looks only a little larger.[1]

This paper is an introduction to the field of sailmakers' arithmetic. Sailmakers used mathematics, in ways ranging from quantity arithmetic to circle geometry, not only to make the best of limited workspace, but also to store construction data and convey instructions and details; in other words, to have a design discussion in numbers with colleagues. It is perhaps ironic that since 1977 they have been doing the same thing with computer-aided design (CAD).[2] Much of

---

[1] Kate Katin, "Part 3: Oyster Harvesting Vessels and Tools: A Historical and Technological Evolution" (Mystic Seaport Museum, 2025) [cited 25th October 2025]. Available from https://research.mysticseaport.org/news/.

[2] Anonymous, "North Sails Introduces Digital Sail Design" (1977) [cited 25th October 2025]. Available from https://www.northsails.com/en-uk/blogs/north-sails-blog/1977-north-sails-introduces-digital-sail-design.

this arithmetical method was lost in the mid-twentieth century. and huge lofting floors took over.[3] This short paper is a but glimpse of the role of sailmakers' mathematics; there is plenty more to uncover.

Background

Mystic Seaport Museum (MSM) holds the archive materials of the Wm J. Mills & Co, sailmakers who still trade in Greenport, New York. The archive includes many hand-drawn sailplans showing the mathematical deliberations of the sailmaker. The company is said to have been founded in 1880, although the family agree that this is probably a figure rounded up or down, perhaps for advertising purposes. The sailplan for sailing vessel *Atlantic* that will be discussed below is dated 1871, which suggests either an earlier founding date for Mills & Co or that Mills & Co purchased another sailmaker's books and customer records.

In March 2025, I visited the Collections Research Centre at MSM to view the Mills archive and other documents. Of particular interest were the calculations and notes made on these plans. *Atlantic*'s sailplan (MSM acquisition number 90:25) is just one of many such plans: working documents that are rich in detail, dates, vessel owners' names, annotations, and calculations.

The plans are hand-drawn in pencil on heavy paper, usually landscape-oriented, with a pair of punch holes at one end, sometimes still holding brass eyelets. Clearly, these were once laced in a folder of some kind. The size of the plans varies from 17" x 14" iup to 29" x 19 ¾". They

[3] Debbie Rogers, "Ratsey & Lapthorn—sail makers for the NY32 class in 1936" (2020) [cited 25th October 2025]. Available from https://newyork32.org/wp-content/uploads/2020/04/ratsey-history.pdf. 2.

are large enough to include working detail but small enough to hold in one hand and study and therefore were perhaps carried into the loft itself.

The sheets feature at least one or more vessels, drawn as sail outlines, showing various sail measurements. Spars are usually included. It is not unusual for both sides of a sheet to be used. Occasionally hull shapes are present but generally just a line representing the deck, presumably to save paper. Entries and amendments to these drawings are dated and often cover several years' development of the vessel's sails and variations in cloth weights and specifications. The plans are a conversation between the owner and the sailmaker, and it is easy to picture them discussing the pros and cons of a heavier cloth or other refinements. Such decisions might be revisited each season or if the sails required repair or replacement. A comparison of this practice can be drawn with the way a cobbler keeps a template of a customer's foot or a tailor records and stores customers' measurements.

Atlantic Sailplan, 1871

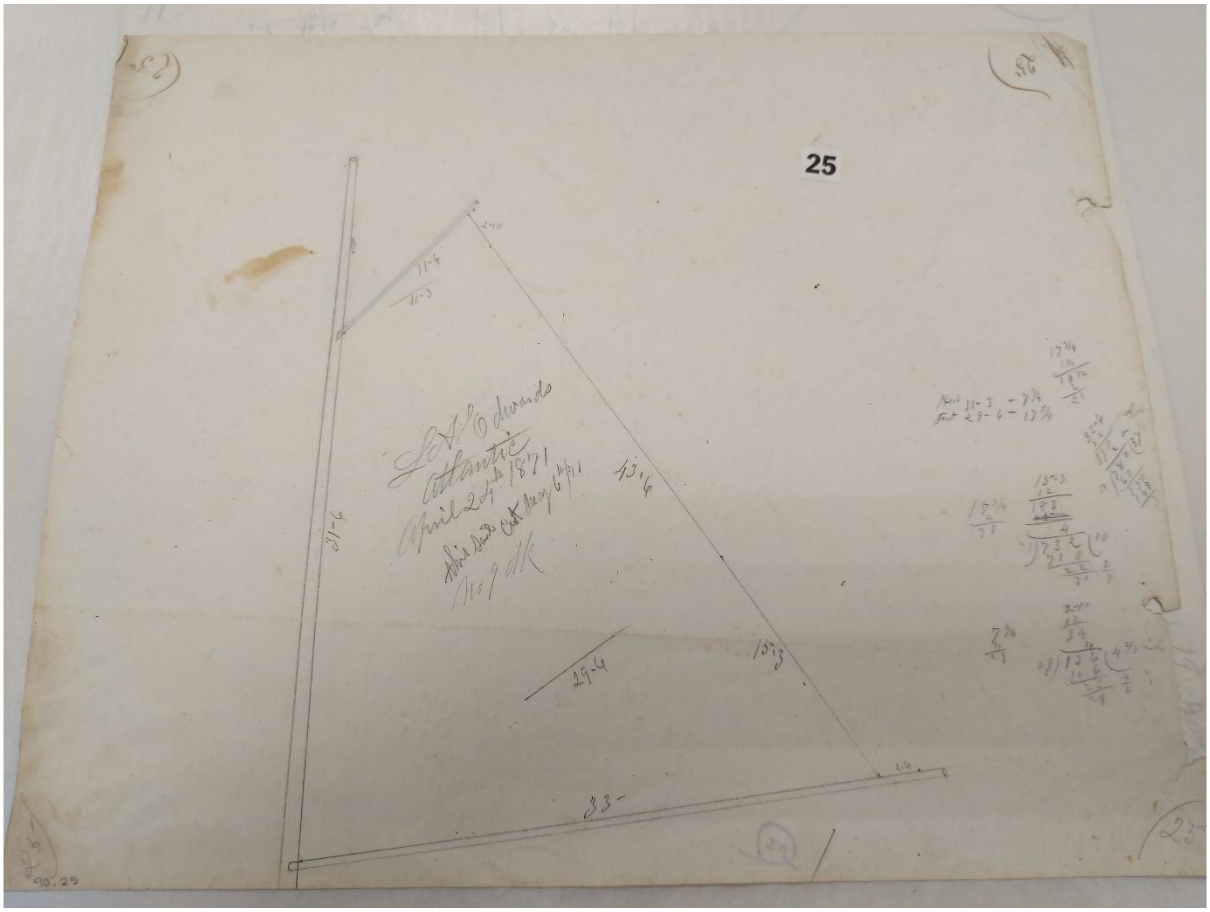

Fig. 1 *Atlantic* Sailplan ©Mystic Seaport Museum. Acquisition No.90/25.

Atlantic, as a local working vessel, might have been a mackerel well-smack, oyster or lobster boat, or small coastal trader. Most likely, it worked as all three in its lifetime.[4] The image above (Fig. 1) shows the sail on the plan with a panel of calculations on the right-hand edge of the paper.[5] These are enlarged in Fig. 2. These calculations will be examined in depth and their meaning decoded.

[4] Ansel, Willets D. Ansel, *Restoration of the Smack Emma C. Berry at Mystic Seaport 1969-1971* (Mystic CT: The Marine Historical Association, 1973), pp. 6-10.

[5] Mills & Co., "Mills & Company Sailmakers" (1871). Archive. Mystic Seaport. Acquisition Number 90:25.

Using the terminology of the time, the gaff mains'l in Fig. 1 is labelled with the following measurements:

Mast-leech [luff] 31' 6"

After-leech [leech] 43' 6"

Head 11'4"

Foot 33'

There appears to be no foot-round, suggesting a straight cut foot, laced to a boom that is also illustrated in the plan.

We also see "squaring lines." The upper squaring line was drawn at right angles from the after-leech to the throat and the lower squaring line from the after-leech to the gooseneck. Since the cloths making up the sail would be laid parallel with the after-leech, these squaring lines cross the cloths at 90°. The lower squaring line crosses all of the cloths used in the sail while the upper line crosses those spanning the head. These lines can be seen in the middle of the sail; they are not drawn the full width of the outline.

Upper Squaring Line 11' 3"

Lower Squaring Line 29' 6"

Finally, we see two further measurements down the after-leech, one from the peak to the end of the upper squaring line and one from the clew up to the lower squaring line. These are called the "peak gore" and the "clew gore" respectively.

Peak Gore 2' 10"

Clew Gore 15' 3"

The term "gore" as used here is a little confusing and seems out of place. In sailmaking, a "gore" is *usually* any cut to a piece of sailcloth that is made at an angle to the weave. In other words, a cut "on the bias," which is a phrase familiar to tailors and dressmakers. Cloth pulled along the bias will stretch far more than cloth pulled along the warp or weft threads—along the woven length or width of the cloth. Cloth pulled diagonally along the bias will also form a "bunt" or baggy fold along the pull. This bunt can be inflated by the wind to give shape to a sail. Gores are found along the luff, foot, and head where cloths meet these sides at an angle. Meanwhile, the leech pulls along the warp threads, giving a flat exit to the airflow over the sail.

Thus, the measurements on the *Atlantic* sailplan at the peak and clew are not "gores" in the usual sense, especially as they run along the warp threads of the sailcloth. Therefore, the question presents itself: what were clew and peak gore measurements used for? Calculations written in the corner of the *Atlantic* sailplan make use of these peak-gore and clew-gore values. We find similar calculations in the sailmaking manuals written by Samual B. Sadler near the end of the nineteenth century. In this paper, I will refer to three manuals of sailmaking from the eighteenth and nineteenth centuries to look for similarities and attempt to decode the handwritten calculations found on the *Atlantic* sailplan: David Steel's *The Art of Sailmaking* (1794), Robert Kipping's *The Elements of Sailmaking* (1847), and Samuel B. Sadler's *The Art and Science of Sailmaking* (1892). All three manuals went through multiple editions.[6]

In Sadler's 1892 manual, we find that the length of the clew and peak gores is used as a factor by which to calculate the likely stretch of the sailcloth along the head and the foot, both of which sides are gored—angled to the weave—and therefore on the bias (1892, p. 28). Sadler's method differs somewhat from that used on the *Atlantic* sailplan and will be discussed in more detail later. However, some explanation is useful here because Sadler's method is the closest we

[6] Because all three manuals went through multiple editions, I will include the date of the edition as well as the pagination within parenthetical citations.

can find to the Mills calculations. Sadler was a sailmaker from Burnham-on-Crouch in the southeast of England. Significantly, he was “[l]ate in the employment of Ratsey and Lapthorn, of Cowes and Gosport” in the UK (1892, frontispiece). Sadler’s era of sailmaking was reacting to the rise of the steamship, so the cutting edge of sail technology was to be found in the world of competitive yachting. Building on the sailmakers’ manuals of Steel (1794) and Kipping (1847), Sadler aimed to quantify the areas of sailmaking previously left to the judgement of time-served experience (1892, p. 29), and so he introduced various formulae, equations, and arithmetical solutions, as well as tables and diagrams. This progressively more scientific quantification of sailmaking can be seen building throughout the works of all three authors: Steel and Kipping also included some tables and arithmetic techniques. Sadler adds a chapter on “Horizontal-Cut Sails” to his 1906 second edition (1906, p. 135), while later editions of Kipping include instructions on auxiliary sails for steamships (1887, p. 105).

The question which drives this enquiry is a simple one: having become familiar with Kipping’s and Sadler’s introduction of mathematics to sailmaking, I wanted to know if sailmakers actually used calculation methods similar to theirs. While Sadler’s first book was published twenty years after *Atlantic*’s sail was cut, the Mills sailmakers might have been familiar with Kipping’s work, which ran to twelve editions.

Decoding the Calculations for *Atlantic*’s Mains’l

To the right of the main drawing on the Atlantic sailplan can be seen a small cloud of arithmetic, rendered in pencil (see Fig 2.). Initially, this looks like an indecipherable set of numbers, and it has taken many hours of trial, error, and research to determine what those numbers mean.

To aid the examination, the script is annotated: two grey lines indicate two separate branches of calculations (B & C), each emerging from a circled set of figures (A). The written script on the right is reasonably clear on the original and says, “mast gore,” which will be explained later.

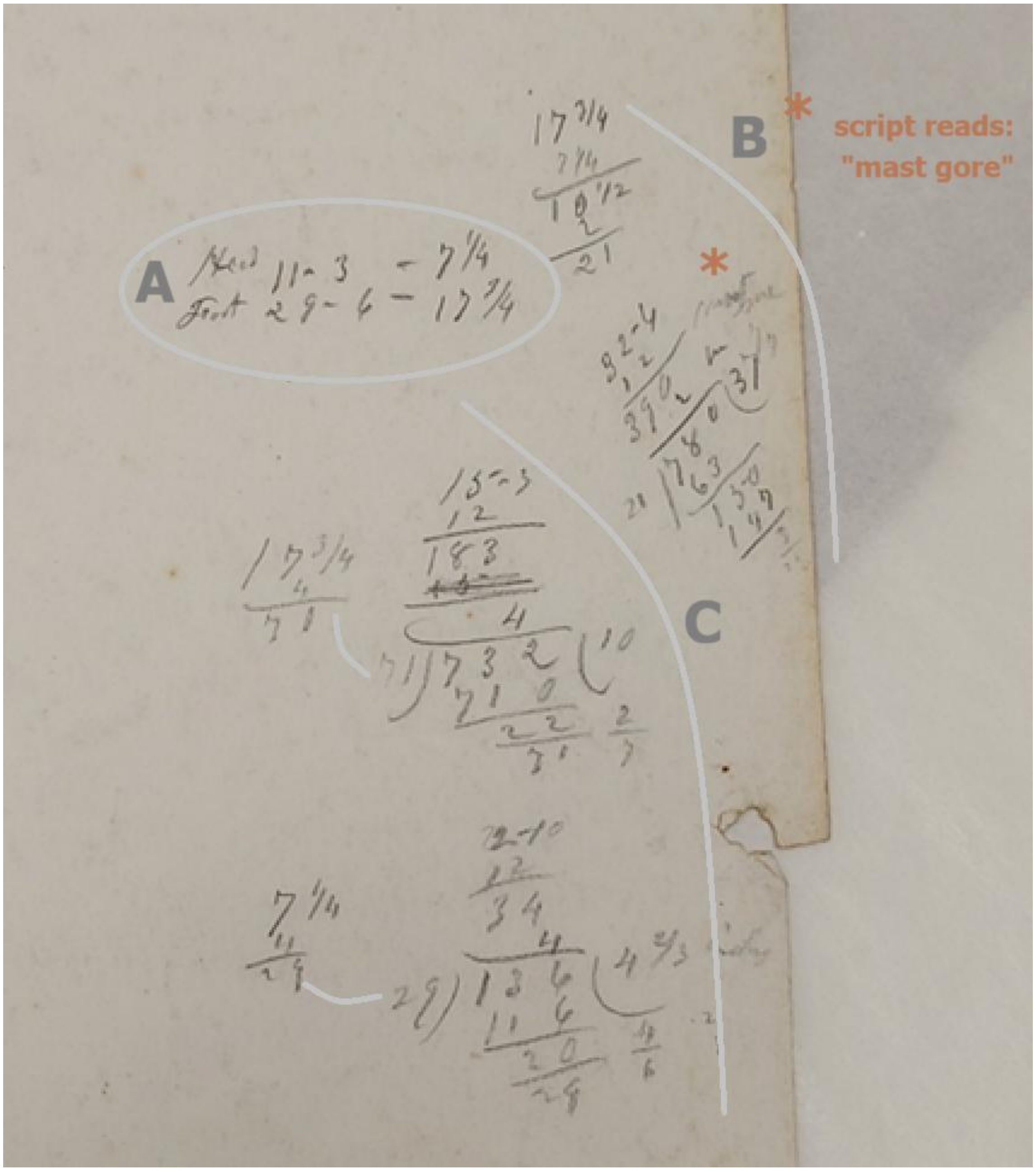

Fig. 2 *Atlantic* Sailplan calculations with annotations by author.

Refer to Fig 2 and the figures circled and labelled A. These numbers run through the whole calculation. Here we see the labelled dimensions of the head and foot squaring lines, each followed by a value. The figures are written at the start of the calculations. The first mystery is what 7 ¼ and 17 ¾ actually represent. After much trial and error, it was concluded that these figures are the number of cloths—vertical strips of sail cloth, seamed together—crossing the upper and lower squaring lines, which is strongly indicated by the calculation at the top of arc B.

Here we see the number of cloths in the "head" being subtracted from the number of cloths in the "foot." The remainder is the number of cloths ending in the luff section between the throat and the tack: 10 ½. Sadler performs this subtraction in his book and explains the values (1906, p. 27). Notice that in this same calculation the total is doubled to make up the fraction for use at the bottom of arc B resulting in 21. Where a value has a fraction attached, the sailmaker multiplies the value by the fraction's denominator to round it up to a whole number and make the value arithmetically easier to use. Any other value in the calculation is similarly multiplied. Thereafter, the two figures may be used in division calculations, producing the same result. We will examine what is done with these figures shortly.

Before moving down arc B, let us further examine those key values in circle A: the numbers of cloths in the head and foot of the sail. The values may have been calculated elsewhere or perhaps in the sailmaker's head. Steel, Kipping, and Sadler all give similar methods for arriving at the number of cloths. Squaring lines are very important here, spanning the cloths at right angles as they do. The calculated number of cloths is a product of cloth width, seam width, number of seams, length of the squaring lines, and the amount of tabling: cloth turned over at the edges of the sail.

Calculating the number of cloths is the first part of an arithmetical system by which sailmakers were able to make large sails in small spaces. The *Atlantic* calculations are an example of that, and they split into two branches. Let us stay with the current branch B, where so far, our sailmaker has arrived at the number of cloths arriving at the luff, or leading edge of the sail. This edge is a gore, as each cloth has an angular cut as it meets the luff. The number of cloths intersecting the luff—10 ½—is doubled to 21 to cancel out the fraction and make the sums easier. The figure of 21 is used further down branch B.

The lower calculation on B starts off with the sail's luff length of 32' 6" being multiplied by 12 to convert it to inches. This gives 390 which is multiplied by 2 to keep up with the fact that the 10 ½ cloths were doubled to 21 to remove the fraction. Doubling 390 gives 780, which is then divided by 21. In other words, the luff length in inches is divided by the number of cloths at the luff. Although both have been doubled to get rid of the fraction, the resulting answer is correctly 37.

So, what is 37? Before answering that, a brief incidental point. The luff length used in this calculation is given as 32' 6", but a glance at the *Atantic* sailplan shows a discrepancy: the plan gives 31' 6". Perhaps the figure 31'6" was an error by the sailmaker; nonetheless, just to the right of the calculation, the sailmaker has written "Mast Gore," the gore next to the mast—in other words the luff—which at least confirms what the measurement is supposed to be.

The length in inches of the angled cut made at the top end of *each* sailcloth that intersects the luff, then, is 37. The *Atlantic* plan lists the cloth as No 9 Duck (Mills 90:25 1871) but does not give the cloth width; however, we see on contemporary plans, including one for the same owner, that the Mills's No 9 Duck sailcloth was 22" wide (Mills 90:25 1870). The gore length of 37" was used for cutting each piece of sailcloth at an angle where it met the luff. The sailmaker did not need to lay out a full-scale outline of the sail: the loft might not be big enough and a ship's deck certainly wasn't. The sailmaker simply unrolled the end of the cloth, took a measured line of 37", and placed it on the top corner of the cloth, one inch in from the edge to take account of a one-inch seam overlap. The sailmaker then took the other end of the line down until it struck the opposite edge of the sail cloth and then marked and cut the gore. Please see the diagram in Fig. 3 below.

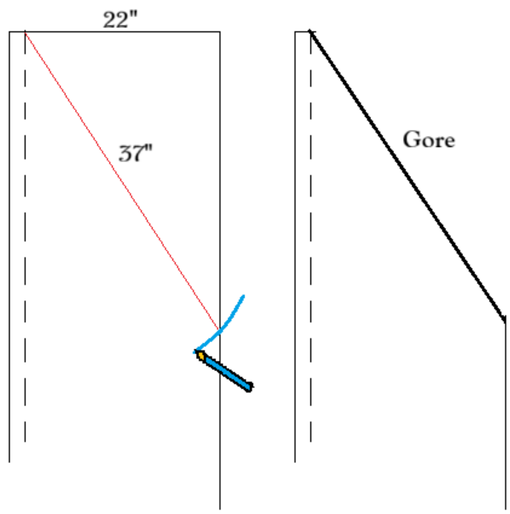

Fig. 3. Diagrams for cutting sailcloth. ©Mark Shiner.

With the method explained above, the sailmaker can cut individual cloths for a sail in a small space. They are marked and piled up as a kit of parts, to be assembled by the seamers in the loft. Of course, a similar calculation must be done at the other end of the cloth to create the gore, or angle, at the foot, but what about the overall the length of each cloth? Kipping (1847, p. 49, "Article 65") describes the process whereby the first cloth at the "mast leech" (luff) is calculated, then the longest edge of that cloth forms the shortest edge of the next and so on, building up the sail. In this way cloth lengths almost measure themselves.

Kipping gives a set of tables that converts the angled gore length to a simpler measurement down the selvedge—called a gore *depth*—including an adjustment to compensate for a variety of seam widths, known as "eating in" (see Kipping, pp. 50-51). Once the gore's length had been calculated, it was far easier to convert it to a gore depth and measure down the side of the cloth using a conversion table that takes account of the seam width. Most convenient!

TABLE.—Showing the length of any gore by its depth, from 1 inch to 12 feet, advancing by 1 inch in depth on the selvage of the canvass 24 inches wide; and also showing the length on the selvage of the eating of any gore from the creasing of the seams, in widths from 1 inch to 4 inches wide the seams, advancing by 1/4-inch;

Depth down the Selvage.		Length of the Gore.		Length of the Eating-in Seaming on the Selvage of the Width of the Seams.												
				In. 1	Ins. 1 1/4	Ins. 1 1/2	Ins. 1 3/4	Ins. 2	Ins. 2 1/4	Ins. 2 1/2	Ins. 2 3/4	Ins. 3	Ins. 3 1/4	Ins. 3 1/2	Ins. 3 3/4	Ins. 4
Ft.	In.	Ft.	In.	Ins.	Ins,	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1/8
0	2	2	0	0	0	1/8	1/8	1/8	1/8	1/8	1/8	1/4	1/4	1/4	1/4	1/4
0	3	2	0 1/8	1/8	1/8	1/8	1/8	1/4	1/4	1/4	1/4	3/8	3/8	3/8	1/2	1/2
0	4	2	0 1/4	1/8	1/8	1/4	1/4	1/4	3/8	3/8	3/8	1/2	1/2	1/2	5/8	5/8
0	5	2	0 3/8	1/8	1/4	1/4	3/8	3/8	3/8	1/2	1/2	5/8	5/8	5/8	3/4	3/4
0	6	2	0 1/2	1/4	1/4	3/8	3/8	1/2	1/2	5/8	5/8	3/4	3/4	7/8	7/8	1
0	7	2	0 3/4	1/4	1/4	3/8	1/2	1/2	5/8	5/8	3/4	7/8	7/8	1	1	1 1/8
0	8	2	1 1/8	1/4	3/8	1/2	1/2	5/8	3/4	3/4	7/8	1	1	1 1/8	1 1/4	1 1/4
0	9	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fig. 4. Table showing "the length of any gore by its depth" from Kipping, 1847, p. 50.

Refer once more to Fig. 2. We will now turn to arc C. We begin again with the two figures representing the number of cloths for the head and foot (circled A). The sailmaker deals with the foot figure first: 17 ¾. Remember this is not a measurement but the number of cloths. The foot figure is multiplied by 4, on the left-hand side, to dispense with the fraction and create a whole number, with 71 as the result.

To the right, we see 15,3 (fifteen foot, three inches; it is not a decimal) multiplied by 12 to convert the whole figure to inches. That is the "clew gore": the section of the after-leech below the lower squaring line. This figure is also multiplied by 4 to bring it onto a par with the multiplied cloths figure. Then we get to the point: the clew-gore in inches is divided by the number of cloths in the foot resulting in a figure of 10 2/7".

The head of the sail gets the same treatment: the measurement of the peak-gore, 2’10”, is divided by the number of cloths in the head. Again, all are multiplied up to get rid of the fractions and the peak gore figure converted to inches. This gives a result of 4 2/3”.

The obvious question is to ask what these measurements were for. The sailmaker has taken a lot of trouble to get them, bringing in calculations from off the page: the number of cloths and lengths for squaring lines and peak/clew gores. The simple, but not the full, answer is that these measurements represent the amount by which the head and foot will “give out” or stretch, along their spars. Such an amount of stretch needs to be taken into account but, as we shall see, not in an obvious way. Before examining how these measurements are used, let us recap a little.

Fig. 5 below shows the *Atlantic* sailplan again, this time with a red triangle created by the head of the sail, its squaring line, and the peak-gore. The peak-gore is the short distance from the leech end of the squaring line to the peak of the sail. The blue triangle on the lower part of the sailplan is made up in the same way. The shortest side is the clew gore, running from the squaring line to the clew corner. Also annotated onto Fig. 5 is the position of the cloths, in brown, and lines to indicate the direction of the weave, warp, and weft fibres, in black. The squaring lines cross the cloths and therefore the weave at right angles, aligned with the weft, or fill threads. Correspondingly, the head and foot of the sail cross the cloths, and the weave, at an angle, or “on the bias.” Cloth pulled on the bias is less stable and more stretchy. As the sail is lashed and hauled out along the gaff and boom, it will stretch far more than if it were pulled along the squaring lines.

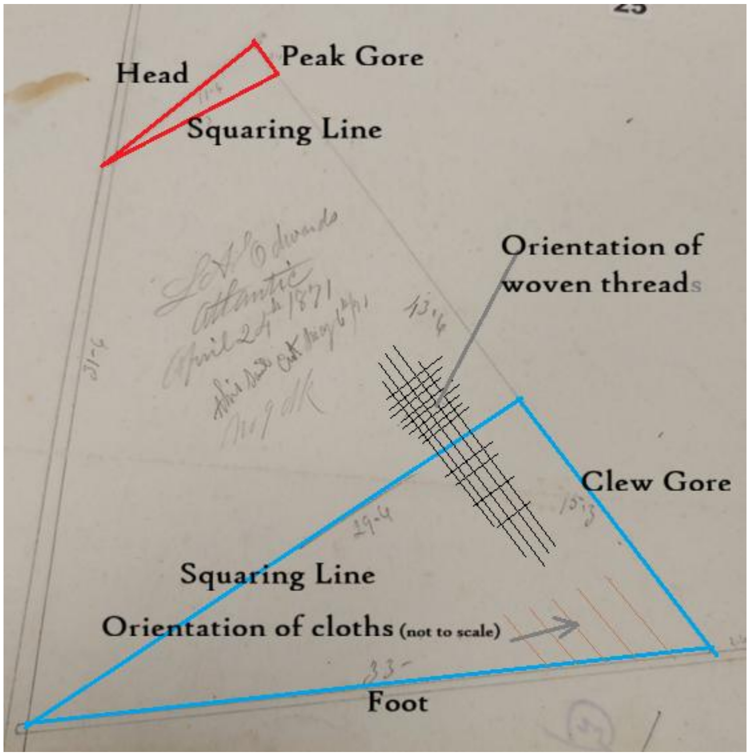

Fig. 5. *Atlantic* Sailplan annotated by the author.

Imagine if the peak or clew gore was longer; the head and foot would cross the weave at an even greater angle, causing even more stretch in the cloth. The longer the clew/peak gore, the more stretchy the foot or head. Cloth width remains constant throughout the sail. The head has fewer cloths than the foot, as we know. The length of the peak and clew gores is being applied to the number of cloths as a kind of "factor" to determine likely stretch.

Is it mathematically correct? Does the head of this sail stretch an extra 4 2/3" and the foot an extra 10 2/7"? Without some experimental trials, we don't know. However, we *do* know that Sadler used peak and clew gores in an *almost* identical way, and we will look at his method now for comparison.

Sadler: Allowances for Stretch

In his 1892 manual, Sadler used peak and clew gores in order to ascertain how the head and foot of a sail would stretch along their spars. For the various calculations in the book, he gives fifteen example sail types with tables, rules, and worked answers. These examples are all fore-and-aft sails, ranging through gaff tops'ls, cutter yacht mains'ls, foresails, jibs, and a "lugsail," which looks much more like a modern gunter main, plus several others.

Sadler's example "Fig 4 Cutter Yacht's Main Sail (laced foot)" (1892, plates between pp. 21 & 22) is almost twice the size of *Atlantic*'s main; however, the shape and proportions are fairly similar. In deciding how much the foot of this sail will stretch along the boom, Sadler writes: "The amount of the stretch upon the boom is 2 in. per foot of the clew gore, the gore is 16 ft., therefore it will give out 32 in" (1892, p. 34). Rather than divide the clew or peak gores by the number of cloths, Sadler uses a rule: the sail will stretch on the boom by two inches for every foot of clew gore. The figure in this example is the same for the head, but the factor used—two—sometimes varies with different types of sail according to his book. It might be interesting to ask what would happen if the sailmaker at Mills & Co. had used Sadler's rule, so let's apply it to *Atlantic*'s mainsail at head and foot in the workings below.

Atlantic Stretch Comparison: Mills vs Sadler

Atlantic's Peak Gore is 2'10".

Sadler's Rule: 2" of stretch per foot of peak gore = 5 3/5" of stretch.

Mills calculation = 4 2/3".

Atlantic's Clew Gore is 15'3".

Sadler's Rule: 2" of stretch per foot of clew gore = 30 ¼" of stretch.

Mills calculation = 10 2/7".

The comparison does not work well, at least not for the foot of the sail The calculated stretch for the head is reasonably close, but the foot differs by almost 300%. It is easy to see why: Sadler's example of a cutter yacht's mains'l has a similar sized clew gore, but its foot that is 60' in length, twice as long as the *Atlantic*'s. Sadler's rule, which he applies to a number of different sail shapes, takes no account of foot length, whereas Mills's calculations account for all the relevant dimensions of the sail, including the foot length.

Before we give up on Sadler's rules for calculating stretch, there is one more thing we can try. In some of Sadler's other sail examples, he suggests first taking the total of the seam widths for the side under consideration, in this case the foot, and deducting that amount from the clew gore, then accounting 2" per foot of however much clew gore is left. It took the author several re-readings of Sadler's original text to fully understand this instruction. So, back to *Atlantic*'s foot then for another try.

Atlantic's Clew Gore is 15'3".

Number of foot seams: 16 seams, probably 1 1/8" wide = 18".

Clew gore 15'3"; take away 18" total foot seam widths = 165" or 13'9".

Sadler's Rule: 2" of stretch per foot of remaining clew gore = 27 ½" of stretch.

Mills calculation = 10 2/7".

No, Sadler's rules do not appear to compare with Mills and Co. However, this is not an in-depth examination of Sadler, but of Mills's methods. I have studied Sadler for years and can vouch for the fact that Sadler is extremely obscure and complex in places and further factors, such as rope stretch, have not been accounted for here.

Let us use one more source to evaluate what Mills were up to. In 1994, experienced, time-served sailmaker Emiliano Marino published *The Sailmaker's Apprentice*. This is, in my opinion, the most consequential sailmaking text of the twentieth century. It spans natural and synthetic fibres and is based very much on floor-cutting, or the practice of laying cloths on a large surface within a marked-out periphery. Marino does not include calculations for making large sails in small spaces; however, he does have plenty to say about accounting for stretch. He gives the following rule for natural fibre canvas with a natural fibre bolt rope (p. 230, paraphrased): reduce the edge measurement by 3" per 10'. However, double this for very large sails and edges cut on the bias.

So, one last time, how does Mills's method compare?

Atlantic's head dimension: 11' 4"

Reduce for stretch by 3" per 10' = approximately 3 1/8"

Double for an edge on the bias = 6 ¼ ". Mills's original figure: 4 2/3".

Atlantic's foot dimension: 33'

Reduce for stretch by 3" per 10' = approximately 10".

Double for an edge on the bias = 20". Mills's original figure: 10 2/7".

Three sailmakers, three different ways to calculate, and account for, how much a sail's edge will stretch. In truth, we are not comparing like for like. When Marino was learning his trade, modern power-looms were making cotton canvas which was much denser and more stable than canvas in Sadler's time, which is turn was a few decades' more stable than Mills's.

Some thoughts on the word "stretch." In a recent conversation between myself and Marino, he pointed out that "stretch" has many meanings, and indeed causes: "Looking at gores/bias . . . we are concerned with elasticity, elongation, permanent elongation, and breaking strength. It is confusing, I think, to use the ambiguous term 'stretch' unless one specifies the nature, cause, and results of it."[7] I agree with Marino, and the use of the word "stretch" throughout this paper should be taken as pertaining to the way in which cloth elongates—temporarily and harmlessly—when tensioned, in this case, along a spar. In other cases, stretch can be damaging

[7] E. Marino and M. Shiner, Personal communication with Emiliano Marino, 2025.

and permanent. It all depends on the circumstances. Sadler, while often using the word "stretch," also refers to the sail "giving out" along a spar, which seems to describe it best.[8] Sadler uses the term "giving out" not in the sense of structural failure, but a more literal giving additional length by its own flexibility, with no permanent ill effects. What has not been discussed in this paper is the fact that sails were often edged with rope, which formed the ultimate limiter of giving out, indeed, protecting the sail from the structural damage of giving in. Roping a sail was a skilled task, one that Sadler, Steel, and Kipping certainly covered, but we must visit that aspect of sailmaking in another study.

Conclusions

Please take a moment to again consider again Fig. 2., a group of rough calculations made in pencil one working day in the late April of 1871. They are no longer so incomprehensible that we might skim past them. The calculations tell us so much about what was in the mind of the sailmaker that day.

First, he worked out how to cut the gores for the cloths at the luff. A similar calculation was probably made elsewhere for the gores at the head and foot. In this way a kit comprised of cloths rolled off the bolt, each carefully measured and angled, so it could be handed to the seamers in the loft, to be joined together.

Our sailmaker goes on to decide by how much to reduce the head and foot of a sail against stretch, so that it would fit the gaff and boom onto which it was to be laced. These totals, 4 2/3" for the head and 10 2/7" for the foot, weren't simply chopped off the length of these sides. Steel,

[8] Samuel B. Sadler, *The Art and Science of Sailmaking* (1892), p. 29.

Kipping, and Sadler all indicate that these values would be divided between the seams of the head and foot and "creased in." That means that the seams would be widened in addition to their specified width, usually around one inch or slightly more. That additional width, applied at the edges of the sail, was then reduced, or blended, as the seam ran into the sail. This method is still called "broadseaming" by modern sailmakers but today is used solely for adding shape to sails made from stable modern fabrics. Historically, broadseaming was acknowledged as performing two functions: absorbing potential stretch and adding shape to the sail (Kipping. 1847, p. 11, article 31).

Decoding this cloud of calculations took time and the study of contemporaneous sailmaking manuals. Do we need this information today? That is a debatable point but, expressed glibly, all craft knowledge is worth saving in case the oil runs out. Modern sailcloth is made from resinated polyester with the trade name "Dacron" that has minimal stretch characteristics and does not require the same consideration as natural-fibre canvas.

Did working sailmakers actually use the often-complex mathematics of Sadler and Kipping? The Mills's sailplans certainly show that sailmakers used calculations for several aspects of the process. There is no doubt that Sadler and Kipping were enthusiastic about expressing the art of sailmaking as a science. Perhaps a better term might be *quantifying*. Maybe Steel's 1794 manual was motivated by an urgent economic purpose, to impart the knowledge of a hard-learned craft in a form which might produce sailmakers at a rate to match the expansion of trade in the British Empire. There is so much more to be examined. If nothing else, we can look at the pencil jottings of a busy sailmaker on a spring day in Greenport, New York, in 1871 and know what that sailmaker was thinking.

Bibliography

References

Anonymous. 1977. “North Sails Introduces Digital Sail Design.” [accessed October 25, 2025]. Available from https://www.northsails.com/en-uk/blogs/north-sails-blog/1977-north-sails-introduces-digital-sail-design.

Ansel, Willets D. 1973. *Restoration of the Smack Emma C. Berry at Mystic Seaport 1969-1971*. 1st ed. Mystic CT: The Marine Historical Association.

Katin, Kate. 2025. “Part 3: Oyster Harvesting Vessels and Tools: A Historical and Technological Evolution.” Mystic Seaport Museum [accessed October 25, 2025]. Available from https://research.mysticseaport.org/news/.

Kipping, R. 1887. *Sails and Sailmaking*. 12th ed. London: Crosby Lockwood and Co.

_____. 1847. *The Elements of Sailmaking*. 1st ed. London: F.W. Norie & Wilson.

Marino, Emiliano, and Shiner, M. 2025. Conversation with Emiliano Marino.

Marino, Emiliano. 1994. *The Sailmaker's Apprentice: A Guide for the Self-Reliant Sailor*. 1st ed. Camden ME. USA.: International Marine.

Mills & Co. 1871. Mills & Company Sailmakers. Archive. Mystic Seaport. Acquisition Number 90:25.

Rogers, Debbie. 2020. “Ratsey & Lapthorn—sail makers for the NY32 class in 1936.” [accessed October 25, 2025]. Available from https://newyork32.org/wp-content/uploads/2020/04/ratsey-history.pdf.

Sadler, Samuel B. 1892. *The Art and Science of Sailmaking*. 1st ed. London: Crosby Lockwood and Co.

Sadler, Samuel, and B. 1906. *The Art and Science of* Sailmaking. 2nd ed. “with additional chapter.” London: Crosby Lockwood and Co.

Steel, David. 1796. *The Art of Sailmaking, as Practiced in the Royal Navy and According to the Most Approved Methods in The Merchant Service*. 1st ed. London: The Navigation Warehouse.

Steel, David. 1843. *The Art of Sail-making, as Practised in The Royal Navy, and According to the Most Approved Methods in the Merchant Service*. 4th ed. London: Charles Wilson.

Steel, David, et al. 1932. *Steel's Elements of Mastmaking, Sailmaking and Rigging*. 2nd ed. New York: Edward W Sweetman.

Stevens, Terry. 2024. Bucked in the Yarn. The Unique Heritage of Coker Canvas. 1st ed. Llanelli: Graffeg Ltd.