CONSTRUCTION OF THE YACHT "CONSTITUTION."

In the SCIENTIFIC AMERICAN of March 30 we gave a very complete description of the structural features of the cup-yacht "Independence," which was illustrated by drawings made from the working plans of that yacht. We are now in a position to present to our readers an equally complete and authentic set of drawings of the cup-yacht "Constitution," which latter, by the time this issue is in the hands of our readers, will have taken her first taste of salt water.

Two years ago the SCIENTIFIC AMERICAN printed the first working plans of the "Columbia"; and, by referring to the illustrations then given, it will be seen that if the sheer-plan of the new boat were laid upon that of its predecessor, they would approximate very closely. The "Constitution" is a high-powered "Columbia," with the same sheer plan, the same draft, a lighter hull, more lead, with exactly a foot more beam (not two feet as currently reported), with less dead-rise, a flatter floor, and a harder bilge. As the result of these combined improvements, all looking to the one object of increased power, she carries about 10 per cent, or about 1,300 square feet, more sail than "Columbia." Her dimensions are as follows: Length over all, 132 feet 6 inches; length on waterline at normal draft, 89 feet 9 inches; beam, 25 feet 2½ inches; normal draft, 19 feet 10 inches.

PRINCIPLES OF DESIGN.—Other things being equal, the fundamental object aimed at in the design of a 90-foot racing yacht is power, or the ability to carry a maximum amount of sail. This may be secured by changes of form, or by reduction or transposition of weights, or both. Increased power due to form is gained by increase of beam, by flattening the floor and "hardening" or filling out the bilges, thereby raising the center of buoyancy and placing the body of the boat more upon the surface of the water. Power due to form, however, is gained at the expense of sweetness of lines and ease of propulsion; hence the genius of the designer is shown in finding that happy mean which gives a maximum power with a minimum hardness of form. Thus, comparing the last three Herreshoff boats, "Defender" presents in her midship section the sweetest and most beautiful form ever seen in an American 90-footer, the bilges rounding in to the reverse curve of the garboards with the unbroken sweep of a letter S. In "Columbia" the floor is flatter, the beam is increased, the bilge hardens and the garboard curve is reduced. In "Constitution" the development has been pushed still further; there is even less dead-rise, there is a distinctly straight line in the floor, and the bilge is still harder than that of "Columbia." The results of this development, in terms of sail area are seen in the respective figures of 12,640 square feet for "Defender," 13,125 for "Columbia," and 14,400 for "Constitution."

Not all of this increased power is to be attributed, however, to form. Much of it is due to improved methods of construction, by which the same strength of spars and hull is secured with the use. of less material. In a yacht of a given displacement every pound of weight that can be taken out of the rigging, spars or hull may be placed in the lead keel with a consequent increase in sail-carrying power. Thus we find that the ballast (that is, the lead keel and the loose pig lead for trimming of the vessel) has gone up from 85 tons in "Defender" to 90 tons in "Columbia," and as high as 93 tons in "Constitution." "Columbia" is a larger boat than "Defender" and probably is slightly heavier in construction; but as compared with "Columbia" the new boat, in spite of her greater beam and increased lead, will be of about the same displacement, a feat of construction for which the greatest credit is due to the designer.

RADICAL CHANGE IN CONSTRUCTION.—The considerable lightening of the hull of "Constitution" (which be it remembered, has been accompanied by a decided gain in strength) has been secured by a radical change in the method of framing. The usual system in yacht construction is to use shallow transverse frames, a few inches in depth, at intervals of 20 to 22 inches, throughout the whole length of the yacht. This is the system adopted in "Independence." It is this framing that holds the hull to form, by resisting the transverse bending and crushing stresses; while the longitudinal stresses are taken up by the plating, assisted by two or four lines of stringers, as the case may be, by far the greater part of the longitudinal strains, however, falling upon the plating itself. Hence the latter must be made of greater weight than is actually necessary to enable it to act as the mere skin clothing of the frames. Herreshoff's innovation consists in running the framing of the yacht in both directions, using deep belt frames of an I-beam section for the transverse system of framing, and associating them with a system of longitudinal T-bar and angle-iron framing, which serves at once to take up a large proportion of the longitudinal strains which ordinarily fall upon the plating, and so enables the weight of this plating to be very materially reduced. The transverse belt frames and the longitudinal framing are so arranged with regard to the width and lengths of the plating that the butt joints meet upon the frames, and the seams follow the longitudinal T-irons, thus doing away altogether with the weight of the washers and liners necessitated in riveting up a boat built in the conventional way.

Judged from an engineering standpoint, this is a far more scientific distribution of the material to meet the special strains to which the hull of a yacht is subjected, particularly in a seaway. Just how great is the saving in weight is shown by the fact that although the superficial area of the Tobin bronze plating on "Constitution" is greater than the superficial area of the bronze on "Independence," the sheer strake in the latter being of steel, the total weight of the bronze plating actually laid on the Boston boat is a fraction under 30 tons, while the total weight of the plating in "Constitution" is slightly under 22 tons. Moreover, it must be remembered that this difference of 8 tons may be put into the keel without calling for a pound more of displacement, or the increase of a single square foot of wetted surface. This is a clear gain due to good engineering; and surely the yacht designer who would dare to use 6-32-inch plating on the topsides of a 90-footer is entitled to all the gain in power and speed that are coming to him. Just here it may be well to state that no little of the credit of these successful results is due to that remarkable material Tobin bronze (the invention of a United States naval officer whose name it bears) which has come to be looked upon as an indispensable material for the plating of our American cup defenders. Not only does it take on a wonderfully smooth polish, but it preserves it indefinitely; while it has the further invaluable quality of showing a tensile strength in the test specimens that is only a few pounds under 40 tons to the square inch.

STRUCTURAL DETAILS.—The transverse belt frames, which are spaced 6 feet 8 inches apart, extend entirely around the hull and do duty at once as frames, floor plates, and deck beams. They are of I-beam section, the web from 5-40 to 6-40 of an inch thick and 15 inches deep amidships, the depth decreasing toward the ends, with flanges formed each of a pair of 1½ x 1½ inch angles. The belts are built up, as shown, in sections with a 2¼-inch lap at the joints riveted with a double row of ⅝ rivets. These beams, by virtue of their great depth, provide far greater stiffness than an equal weight of the shallow 4-inch bulb angles which are used in the conventional type of construction. "Constitution" is not the first yacht to carry these frames, as they were used experimentally in last season's 70-footers. Mr. Herreshoff has profited by that experiment; for in a jump of a sea off Newport the frames buckled, the inner flanges springing out of line; hence the presence of diagonal braces of 1¼ inch pipe which extend, in pairs, from the longitudinal T-irons to the inner flanges of the belts. These struts, moreover, afford stiffness to the longitudinal framing of hull and deck.

The longitudinal framing consists of alternate 4½ x 4½ T-bars and 3 x 2 bulb angles. The T-bars follow the seams of the plating, which, in general, is 48 inches wide, and the angles are spaced midway between the T-bars. The belt frames are cut to allow these longitudinal frames to pass through, and the latter extend in unbroken lines from stem to stern, the ends of the T-bars being jointed with a U-iron splice, riveted to head and web of the bar as shown in the detail drawing, while the bulb angles are placed back to back, at the joints, and riveted. These longitudinal members being continuous and well riveted to the plating, it will be seen that they not merely keep the plating to shape, but also take a large share of the longitudinal stresses. Calculation of the weights of a given area of framing in "Constitution" and "Independence" shows that there is not much weight saved in the framing alone, but it must be remembered that, weight for weight, it is a much stronger construction. The saving is in the weight of the plating, which Mr. Herreshoff has lightened out to the extent, as we have seen, of eight tons, as compared with "Independence." Amidships there are seven strakes of plating. Commencing at the sheer strake, the thicknesses are 6-32, 6-32, 6-32, 7-32, 7-32, 7-32, and 8-32 inch. The first four strakes, to the top of the garboard strake, have flush seams; below this they are lap-jointed. The sheer strake extends above the deck line and is riveted to a 2 x 2 bulbed angle, whose head forms the rail of the boat.

THE FIN AND LEAD BULB.—From station 28 to station 50 the belt-frames are carried down into the fin and riveted to the keel-plate, which is a Tobin bronze casting, ½ inch thick by 18 inches wide, with 4-inch side flanges, and transverse flanges at every frame station. At the three frame stations in the fin, intermediate between each belt-frame floor-plate, is an angle-iron frame. Of these, the center frame is a 1¾ x 1¾ plain angle, and the other two are 4 x 3 bulb angles. Here again Herreshoff has made a considerable saving of weight; for instead of running the floor plates down to the keel, the frames are tied together merely by a 12-inch keel plate, and a 12-inch floor-plate, with a 1¾-inch square tie-rod midway between them. These floor-plates commence at station 11 and extend aft to station 63. The framed structure of the fin terminates, as we have seen, in a half inch bronze keel plate, and below this plate the 95-ton belt of lead is hung in the following manner: First, the lowest strake of the bronze plating is extended down to overlap the lead by 20 inches, the latter being rabbeted out to receive it. Through these plates 824 bronze tap-screws, ⅝ x 6 inches, are screwed into the lead, 412 on each side. The keel is further supported by thirty-seven 1 x 10 inch vertical lag-screws, which are screwed through the keel plate into the lead. If anyone cares to figure out the total section of the bronze bolts thus employed, he will find that there is an ample amount of holding strength, even should the "Constitution" experience a knock-down in a short, jumpy sea, when the dynamic bending moment at the junction of the keel and lead might easily rise to a total of 400 or 500 foot-tons.

THE MAST-STEP.—To provide the requisite strength at the mast-step (which, by the way, is placed 20 inches further aft than "Columbia's" mast) an extra belt-frame is introduced, there being a belt-frame at stations, 28, 30 and 32. The web of the frames is also increased to 7-40 of an inch. The step is formed by a combination of these frames with a deep keelson of 7-16 inch steel worked intercostally between the frames, from station 24 to station 36, the keel plate being increased to ⅝ of an inch in thickness beneath the mast and for the full length of the mast-step. The keelson increases in depth from frame 24 to frame 28, where it reaches a maximum of 4 feet 6 inches, which depth it holds from frame 28 to frame 32. From frame 32 it decreases in depth until it terminates at frame 36. The floor-plate portions of the frames 28, 30 and 32 carry the same depth as the keel plate. A ⅝ inch, double, cover-plate closes in the mast-step, and below the cover-plate extends a deep, hollow, cone of ⅝-inch plating which is riveted to the cover plate and the keelson. The upper flange of the cone consists of two 1½-inch angles, the outside diameter of the ring, formed by these flanges, being just 24 inches. The bottom of the steel mast will have riveted around it a 1½ inch angle-iron, with an outside diameter of 24 inches, and when the mast is in place it will be bolted down upon the cone by bolts which will pass through the ring on the mast and be made fast by nuts below the cone-ring. It is 6 feet 10 inches from the top of the step to the deck, and on each side of the mast-ring at the deck, intercostal plates are worked in between the belt-frames. The mast framing at the deck is stiffened against fore-and-aft racking strains by a trussing of hollow steel tubing, which extends in a fore-and-aft plane from the deck beams to the cover plate of the keelson. Three-inch tubular bilge struts extend from all the belt frames at the bilge to the same frames at the deck; but in the wake of the mast these struts are moved in to further assist in bracing the mast-ring and mast-step construction. The whole design is entirely novel, and shows the characteristic resourcefulness of the Bristol designer. It is extremely stiff and strong and gives evidence that Herreshoff has learned the lesson of the buckled mast-steps with which he was troubled in previous defenders. In one of these, a step which had a calculated resistance to crushing of 250 tons showed signs of buckling when the yacht was being sailed hard in the scend of a heavy sea. The deck is carried by the belt frames and by longitudinal lines of 1¾ bulb angles, which latter extend in unbroken lines from stem to stern, passing through apertures cut for them in the belt-frames. Galvanized steel deck plating is used, and to protect it from the weather it is covered with a preparation of cork tiling which is impervious to water and at the same time adds but very slightly to the weight of the deck.

SAIL PLAN.—From what has been said of the lowering of weights in "Constitution" and the increased power of her form, it is evident that she can swing aloft a spread of sail which will rival that of "Independence" in area. Compared with "Columbia," the boom will be lengthened to 110 feet, about 4 feet will be added to the hoist, the fore triangle will be lengthened, as will the topmast and gaff, with the result that a total of 14,400 square feet of sail will be carried—an area which may be subsequently decreased or added to according to the ability of the boat as shown in her tuning up. All things considered, we look for "Constitution" to beat "Columbia" over a thirty-knot course by not less than ten minutes in light airs and five minutes in a breeze. This would mean an advantage of respectively eighteen minutes and eleven minutes over "Shamrock I." under the form which the latter yacht showed over here. Will "Shamrock II." display an equal superiority over "Shamrock I."?

It is gratifying to know that the new cup-defender will be under the management of William Butler Duncan, Jr., whose very able handling of "Defender" in the tuning-up trials of "Columbia" added greatly to the interest of the trial races of the season of 1899.

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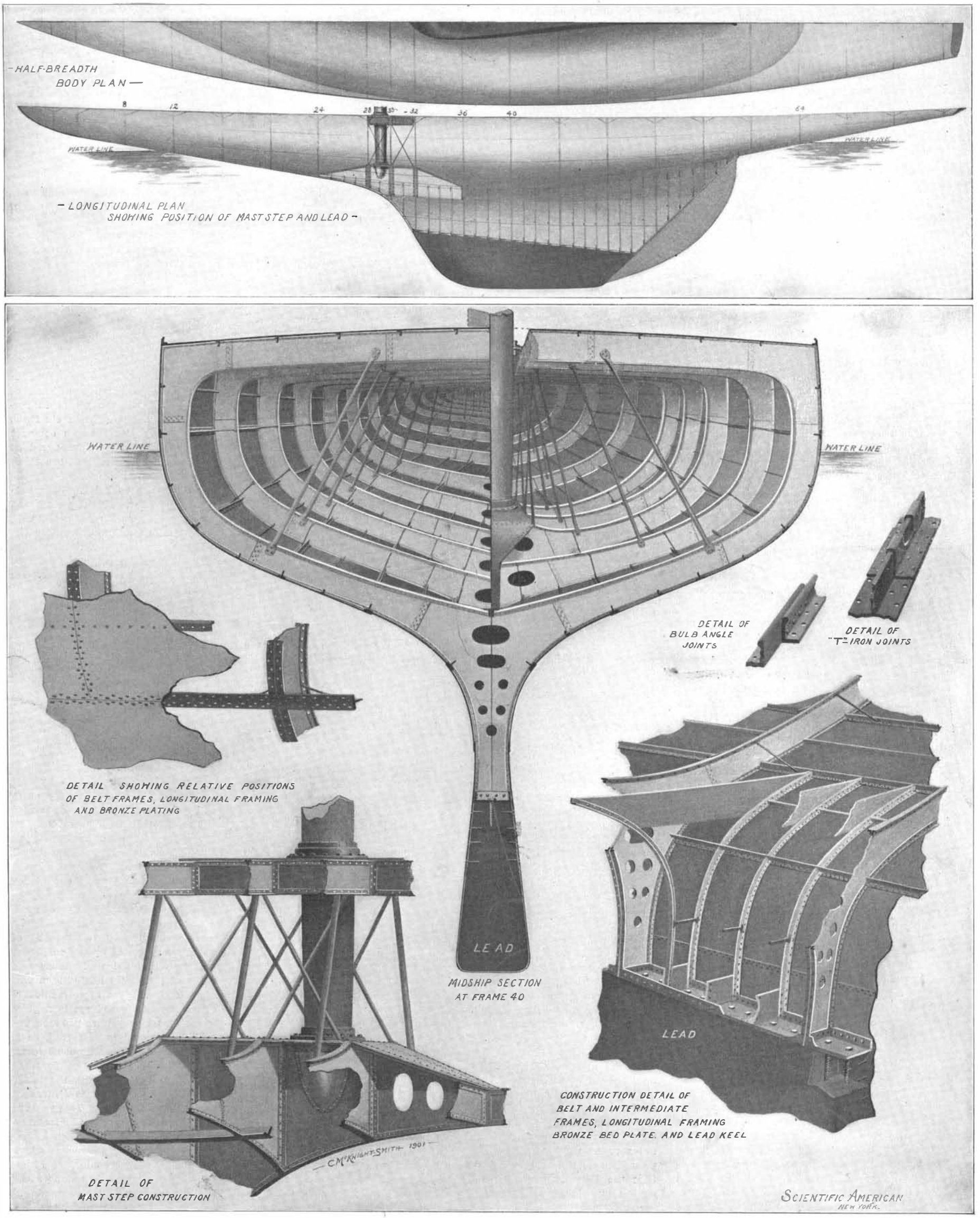

Length over all, 132 feet 6 inches; waterline length on normal draught, 89 feet 9 inches; extreme beam, 25 feet 2½ inches; normal draught, 19 feet 10 inches; sail area, subject to modification during trials, 14,400 square feet.

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