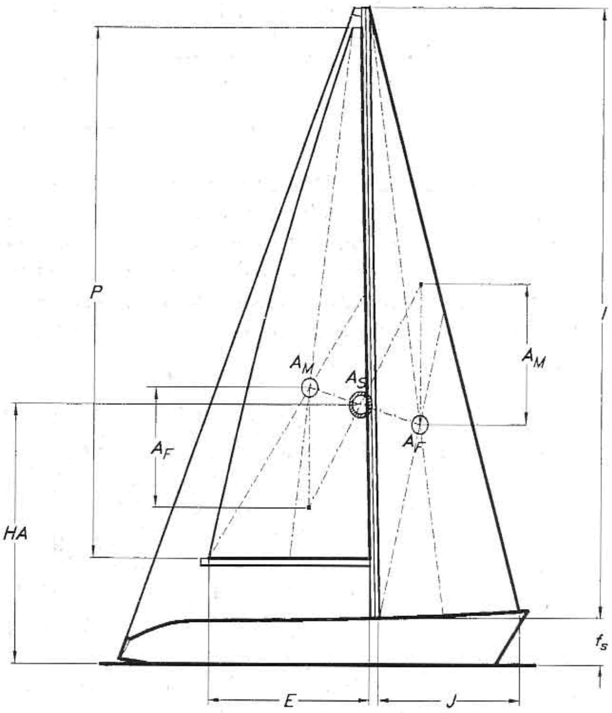
RIG CONSTRUCTION

Definitions and righting moments



G -empty weight of boat (kg)	5749	kg
Δ - full load weight of boat (kg)	6700	kg
g - ballast weight (kg)	2500	kg
Loa - length overal (m)	11,97	m
Boa (B) - beam overall	4	m
As - sail area (m2)	90	m2
RM30 - righting moment at 30deg. heel empty boat (Nm)	40180	Nm
RM1 - righting moment at 1deg. heel empty boat (Nm)		
n - number of person onboard	6	
Fs - freeboard at mast (m)	1,3	m
σRM - additional moment from crew to windward (Nm)		Nm
HA - heelling arm (m)	7,82	m
Am = E*P/2	38	m2
Af = I*J/2	42	m2
As = Am + Af	90	m2
σRM=75*n*(3,4B-4,9Fs)	3254	Nm

Dimentionig righting moment RM = RM30 * Δ/G + σRM 50080 Nm

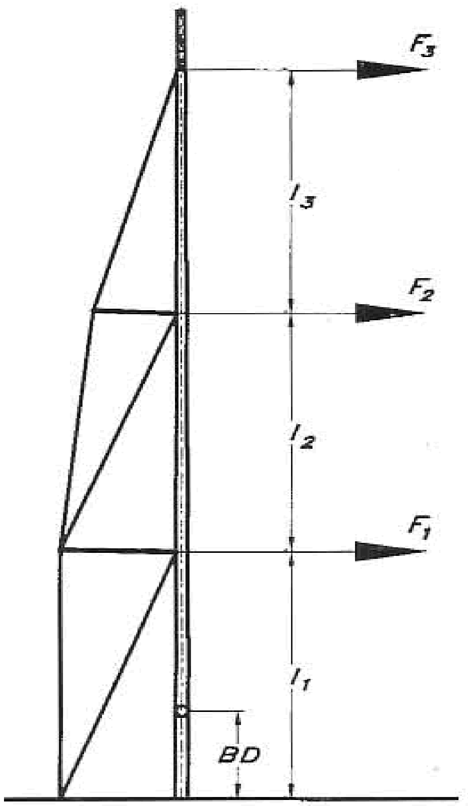
Forces from shrouds

Case 1. Dimentioning transverce force T1 (only foresail) T1=RM/a1 =	2823	N
a1- distance from Wl to appermost shroud = 17,74m	17,74	m
Case 2. Dimentioning transverce force T2 (only deeply reefed main) T2=RM/a2	8634	N
a2- distance from Wl to geometr. centre of reefed mainsail =	5,8	m
Thu - force acting on upper shrouds Thu=Thead*d1/d1+d2	3455	N
Thl - force acting on lower shrouds Thl=Thead*d2/d1+d2	997,4	N
Tbu - force acting on lower shrouds from the boom Tbu=Tboom*BD/L1	750,3	N
Thead - force acting on the mainsail head Thead=0,4*T2	3454	N
Tboom - force acting on the boom Tboom = 0,33*T2	2849	N
d1-distance from mainsail head to lower shrouds	4,23	m
d2-distance from mainsail head to upper shrouds	1,22	m
BD - distance from deck to boom	1,295	m
L1 - Distance from deck to first spreaders	4,918	m
L2 - Distance from first spreaders to second spreaders	5,44	m
L3 - Distance from second spreaders to upper shrouds	5,51	m

β1 =	13	deg.	0,23	rad.
β2 =	13	deg.	0,23	rad.
β3 =	11	deg.	0,19	rad.
γ1 =	0,3	deg.	0,01	rad.
γ2 =	2,6	deg.	0,05	rad.
I=	16,33	m		
P=	15	m		
E=	5,19	m		

chng	sheet	N docum.	sign.	date	***ROOTS Rig Construction***	***sheet***

Dimentioning Forces for Shroud and Shroud load



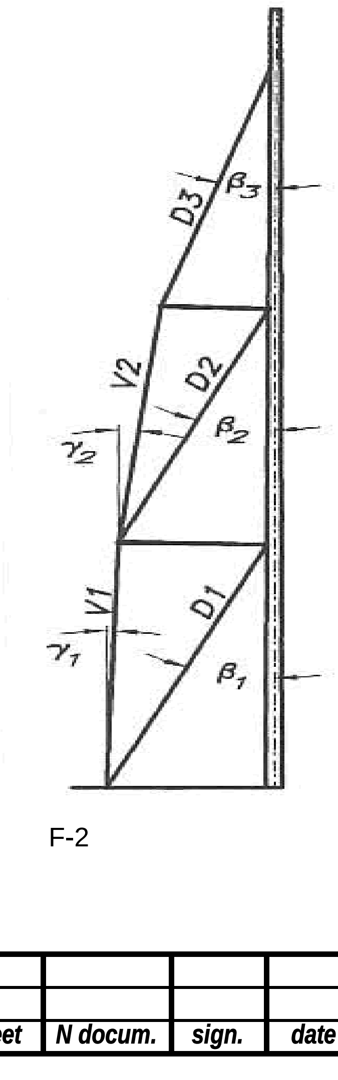
Dimentioning Forces F1, F2, F3						
Type of rig	Case 2(only r/ main)			Case1(only staysail)		
	F1	F2	F3	F1	F2	F3
F0	Thu+Tb	0	0	T1	0	0
M-1/F-1	Thl+Tbu	Thu	0	0	T1	0
M-2/F-2 (1*)	Tbu	Thl	0	0	0	T1
M-2/F-2 (2*)	Thl+Tbu	Thu	0	0	0	T1
Meanings	1747,6	3455	0	0	0	2823

1* - if BD+0,6P>L1+L2
2* - if BD+0,6P<L1+L2

BD+0,6P = 10,271
L1+L2= 10,358

L1 = 4,918 m
L2 = 5,44 m
L3 = 5,51 m
BD = 1,295 m

F-2



F-2

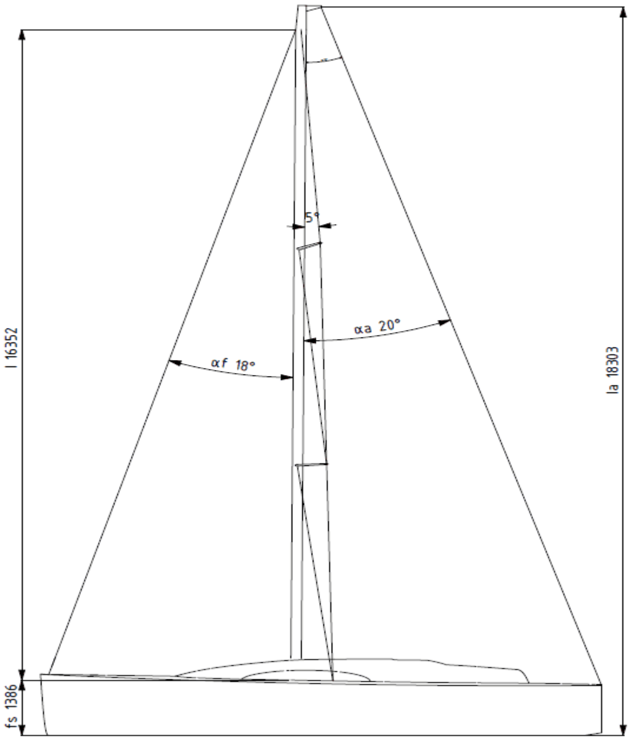
Shroud Tension (D#, V#)

D3 = F3/sinβ3 =	14795 N
V2 = F3/(cosγ2*tgβ3)=	14538 N
C2 = F3 - V2*sinγ2 =	2164 N
D2 = (F2+C2)/sinβ2 =	24977 N
V1 = (F2+C2)/(cosγ1*tgβ2) + V2*cosγ1/cosγ2=	38890 N
C1 = F2+C2+ V2*sinγ2-V1*sinγ1 =	6074 N
D1 = (F1+C1)/sinβ1 =	28751 N

Dimentioning Loads (P#)

PD1 = 2,8*D1(single lower shrouds) =	80502 N
PD1 = 2,5*D1(double lower shrouds) =	71877 N
PD2 = 2,3*D2 =	57446 N
PD3 = 3,0*D3 =	44400 N
PV1 = 3,2*V1 =	124447 N
PV2 = 3,0*V2 =	43614 N

Forces on the stays



The foremost sail carrying forestay shall have a breaking strength (Pfo) of at least:

$Pfo = 15*RM/(I+Fs) =$ 42609 N

The inner forestay shall have a breaking strength (Pfi) of at least:

$Pfi = 12*RM/(I+Fs) =$ 36802 N

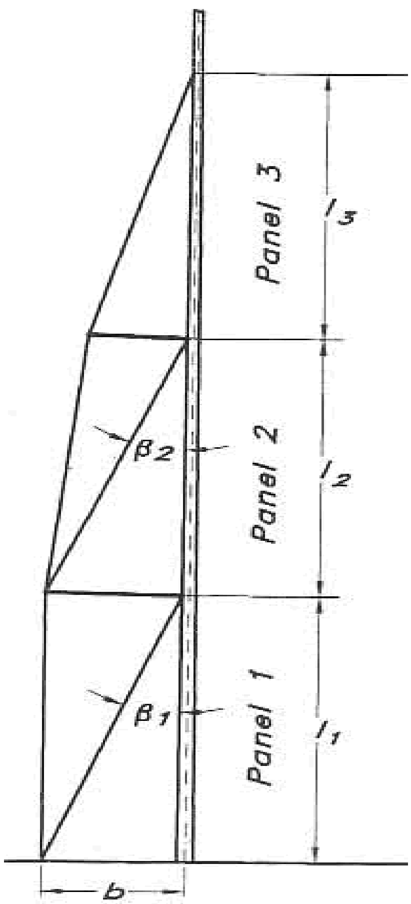
The aft stay shall have a breaking strength (Pfi) of at least:

$Pa = Pfo*\sin\alpha f/\sin\alpha a =$ 38498 N
(masthead rig)

$Pa = 2{,}8*RM/(Ia*\sin\alpha a) =$ 22355 N
(fractional rig)

αf = 18 deg. 0,314 rad.
αa = 20 deg. 0,349 rad.
Ia = 18,34 m

Transverse mast dimentioning



M-2/F-2

Reguired transverce moment of inertia (Ix) for the mast:

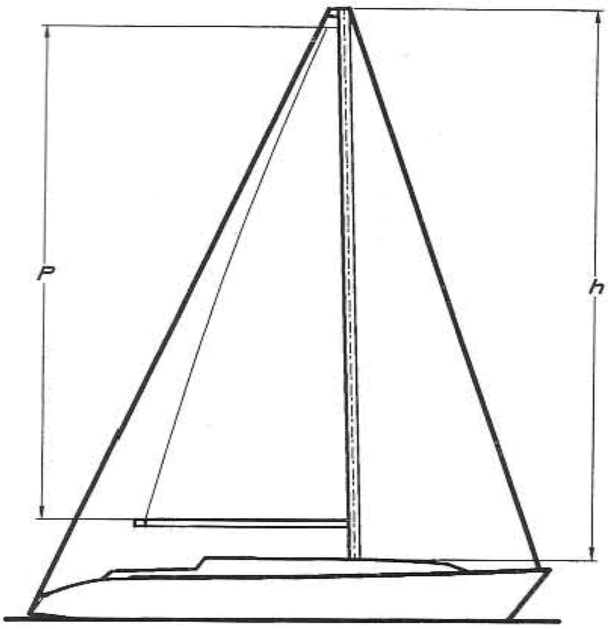
$Ix = k1*m*PT*L(n)^2$ 4689230 mm4

$PT=1{,}5*RM/b =$ 55235 N
k1 - panel factor (from table below) = 3,51
m - for aluminium = 1
L(n) - actual panel length
k3 = 1,35 for deck stepped mast 1,35
k3 = 1,0 for deck stepped mast 1
b = 1,36 m
Wnen calculating Ix for panel 2 PT can be decreased by:
$D1*\cos\beta 1$
Wnen calculating Ix for panel 3 PT can be decreased by:
$D1*\cos\beta 1+ D2*\cos\beta 2$

Type of rig	Panel Factor k1	
	Panel1	Panel 2 & 3	
F-0	2,4*k3		
F-0 shrort spr.	1,6*k3		
M-1	2,3*k3	3,5	3,5
F-1	2,4*k3	3,35	3,35
M-2	2,7*k3	3,8	3,8
F-2	2,6*k3	3,6	3,6

Panel 1
$Ix = k1*m*PT*L1^2 =$ 4689230 mm4
Panel 2
$Ix = k1*m*(PT-D1*\cos\beta 1)*L2^2 =$ 2827586 mm4
Panel 3
$Ix=k1*m*(PT-(D1*\cos\beta 1+D2*\cos\beta 2))*L3^2 =$ 307425 mm4

Longitudinal mast dimentioning



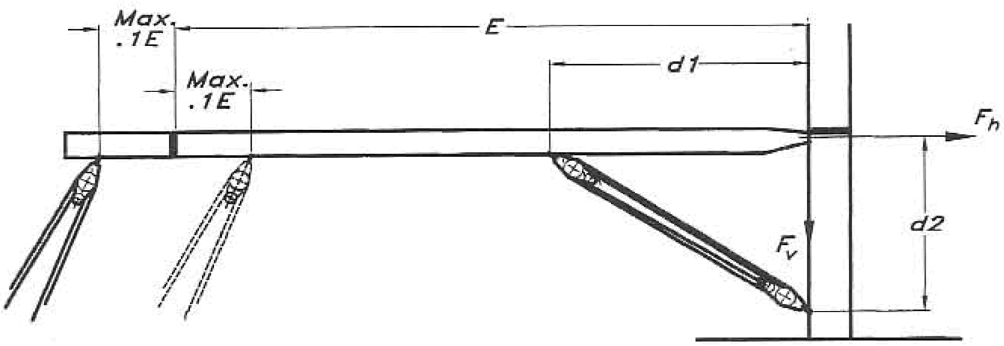
Reguired longitudinal moment of inertia for mast (Iy):

Iy = k2*k3*m*PT*h^2 = 15024325 mm4

PT=1,5*RM/b = 55235 N
k2 - staying factor (from table below)= 0,8
m=1 for aluminium 1
k3 = 1,35 for deck stepped mast 1,35
h - heigth above deck or superstructure
to the highest sail carrying forestay = 15,87 m

Type of staying	Staying Factor k2				
	F-0	M-1	F-1	M-2	F-2
Double lowers		0,85	0,8	0,9	0,85
Single lowers		0,8	0,75	0,85	0,8
Runners & i.1			0,85		0,8
Runners & c.s		1	0,95	0,95	0,9
Swept spreadr.			1		0,95
Short spreadrs	1,05				
No spreaders	2				

Boom reguirement



The gooseneck shall be able to withstand a vertical and horisontal force of:

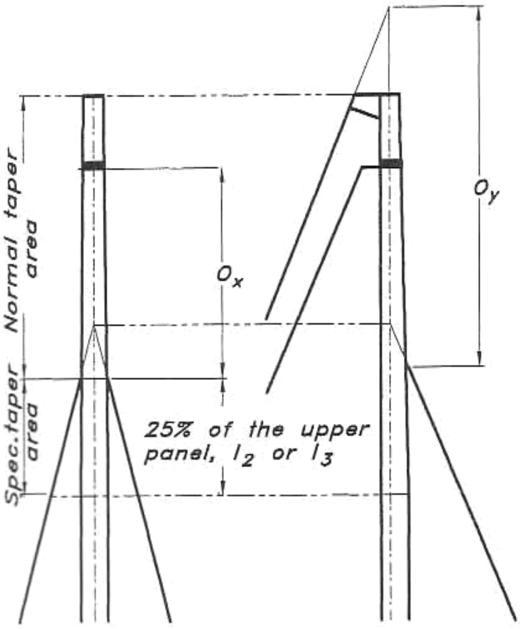
Fv = 0,5*RM*E/(HA*d1) = 10387 N
Fh = 0,5*RM*E/(HA*d2) = 13622 N

HA - distance from WL to centre of effort of sails = 7,82 m
E = 5,19 m
d1 = 1,6 m
d2= 1,22 m
σ0,2 - yield strength for spreaders (N/mm2) = 210 N/mm2

Reguired vertical Section Modulus for the boom is:

SM = 600*RM*(E-d1)/(σ0,2*HA) = 65688 mm3

The horizontal Section Modulus is to be at least 50% of the vertical = 32844 mm3



Fractional mast top

The Section modulus for the mast top in fractional rigs, shall at the intersection of the forestay of upper shrouds and mast be:

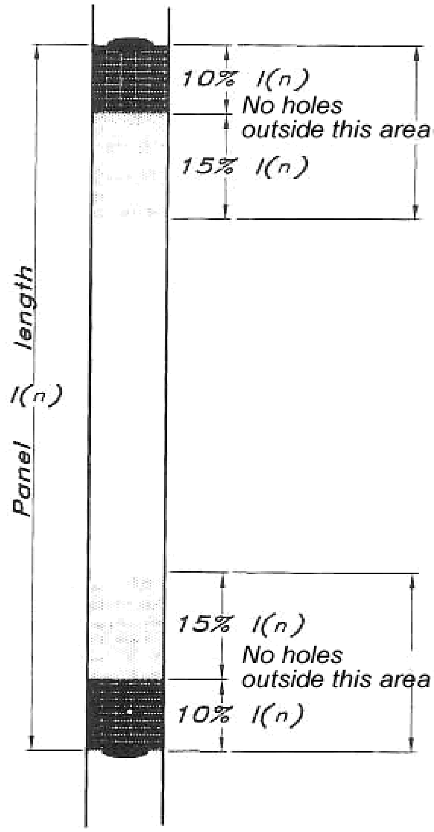
SMx = 8*RM*Ox/P = mm3
Smy = 2100*RM*Oy/(σ0,2*(Oy+h)) =

σ0,2 - yield strength of mast = 210 N/mm2

At the top of the mast the rewuired Section Modulus is half of the above calculated

Tapering of SMx and Smy might be done down to a level of 25% of the panel length below the upper shrouds/mast intersection and upper spreadeers
If Ox is less the 6% of the mast length (h) then the rig is considered to be a masthead rig.

Oy = m
Ox = m
h = 15,87 m



Holes in the mast

Reduction of Section modulus of mast

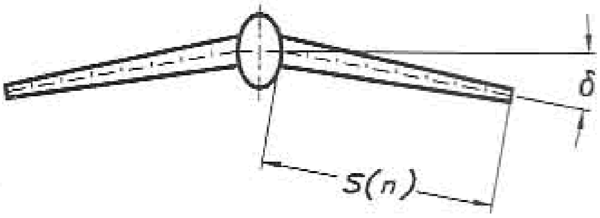
In the 10% L(n) area the Section Modulus is allowed to be decreased by 50%
In the 15% L(n) area the Section Modulus is allowed to be decreased by 30%

The Modulus reduction is (Im):

Im = b*t*r

b -width of hole = mm
t - whall thickness = mm
r - distance to neutral axis = mm

Spreader requirement



The moment of inertia of the spreader at half span is to be:

I = 0,8*C(n)*S(n)^2/(E*cosσ) = 127213 mm4

E -modulus of elasticity of spreader= 69340
S(n) - length of spreader 1260 mm
σ - horizontal angle of spreader = 29 deg. 0,51
C(n)-transverce component of shroud force = 6074 N

Close to the mast spreader shall have a Section Modulus of
SM = k*S(n)*V(n)*cosσ = 32653 mm3
k = 0,16/σ0,2 = 8E-04
Vn = V1 for lower spreaders, D3 - for upper spreaders 38890 N/mm2
σ0,2 - yield strength for spreaders (N/mm2) = 210 N/mm2
The spreaders attachment shall be able to withstand a moment of:
Ms = 0,16*S(n)*cosσ = 176,3 Nmm

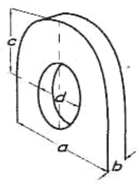
Enter in the table below with all values to pick the relevant shrouds, stays and rig components.

Typical properties for aluminium extrusions

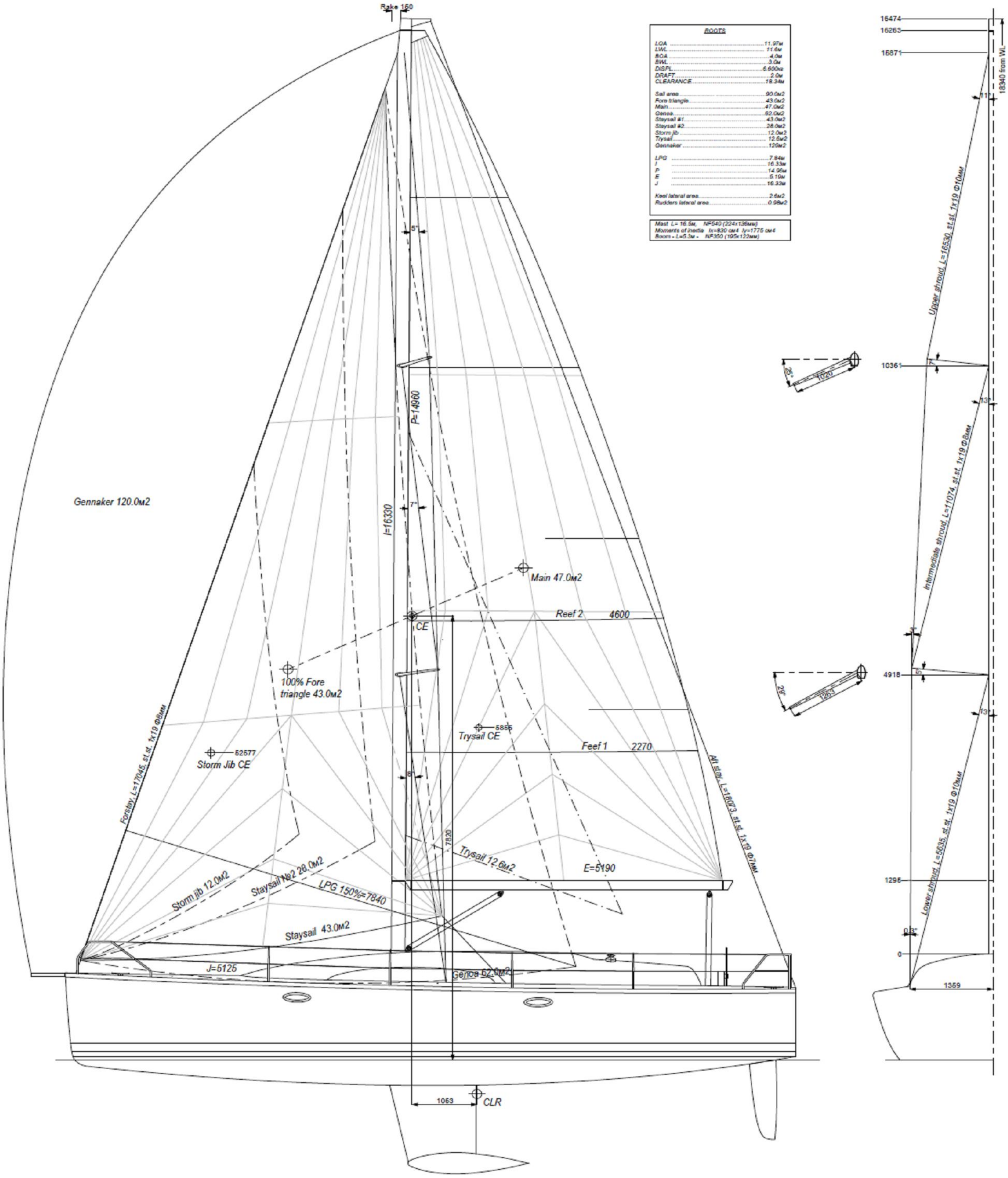
Mast	Main Dim. (mm)	Iy (cm4)	Ix (cm4)	Wall Thkn. (mm)	Weight Kg/m	SMy (cm3)	SMx (cm3)
Oval Sect.	122/85	165	75	2.45	2.43	23.6	17.6
	130/93	215	100	2.50	2.71	29.0	21.5
	138/95	287	139	2.85	3.35	35.0	29.3
	155/104	413	191	3.05	3.69	45.9	36.7
	170/115	569	260	3.10	4.11	58.1	45.2
	177/124	725	345	3.40	4.75	74.7	55.6
	189/132	956	458	3.70	5.73	89.3	69.4
	206/139	1310	613	4.10	6.44	115	88.2
	224/150	1775	830	4.50	7.32	143	111
	237/162	2360	1120	4.85	8.76	176	138
	274/185	3650	1650	4.90	10.32	232	178
Delta Sect.	121/92	205	122	3.00	3.15	28.9	26.5
	129/100	292	175	3.50	3.74	38.9	35.0
	137/113	375	250	3.90	4.21	50.0	44.2
	146/112	508	310	4.40	5.05	61.9	55.3
	160/132	750	500	5.30	6.67	80.6	75.7
Furl. Sect.	190/94	580	200	3.00	4.69	55.4	42.5
	213/104	850	290	3.15	5.45	73.2	55.7
	235/116	1240	435	3.40	6.55	97.6	75.0
	232/126	1590	605	5.00	8.71	128	96
	260/136	2400	900	5.75	10.36	176	132
	290/150	3520	1300	6.00	12.63	224	173
Boom Sect.	86/59	60	23	1.80	1.67	14.0	7.8
	120/62	155	42	1.80	2.16	24.8	13.7
	143/76	290	80	2.20	2.83	39.4	20.9
	162/125	615	330	2.80	4.75	76.0	53.0
	171/94	610	170	2.80	4.03	67.7	35.7
	200/117	1190	325	2.80	5.36	112	55.5
	250/140	2410	640	3.20	6.96	185	91.4
Spinn Pole Sect.	48/48	7.65	7.65	2.00	0.75		
	60/60	15.4	15.4	2.00	1.00		
	72/72	29.9	29.9	2.20	1.38		
	84/84	48.8	48.8	2.20	1.53		
	96/96	72.3	72.3	2.20	1.76		
	99/99	123	123	3.60	2.65		
	111/111	197	197	4.10	3.38		

Matching components made of stainless steel, type AISI-316

1x19 Wire			Rigging Screw		Chainplate lug (see fig.)			
Diam (mm)	Br.str (N)	Weight (kg/m)	Diam (in)	Br.str (N)	a (mm)	b (mm)	c (mm)	d (mm)
3	7700	0.040	1/4	14700	20.0	5.0	12.0	8.5
4	13800	0.073	5/16	22600	22.0	6.0	13.0	10.0
5	21600	0.113	3/8	33400	25.0	8.0	16.0	12.0
5.5	25700	0.139	7/16	46100	30.0	10.0	18.0	14.0
6	30000	0.165	7/16	46100	36.0	10.0	21.0	14.0
7	40900	0.225	1/2	66700	38.0	12.0	24.0	16.0
8	53500	0.327	5/8	93200	40.0	13.0	25.0	16.0
10	69100	0.475	3/4	123000	45.0	14.0	27.0	18.0
11	83500	0.648	3/4	123000	50.0	14.0	30.0	18.0
12	120200	0.820	7/8	167000	60.0	18.0	36.0	22.0
14	160100	1.000	1	218000	65.0	22.0	38.0	25.0



Chainplate lug
a = width
b = thickness
c = centre of hole to top of lug
d = diameter of hole



ROOTS	
LOA	11.97м
LWL	11.6м
BOA	4.0м
BWL	3.0м
DISPL	6.600кг
DRAFT	2.0м
CLEARANCE	18.34м
Sail area	90.0м2
Fore triangle	43.0м2
Main	47.0м2
Genoa	62.0м2
Staysail #1	43.0м2
Staysail #2	28.0м2
Storm jib	12.0м2
Trysail	12.6м2
Gennaker	120м2
LPG	7.84м
I	16.33м
P	14.96м
E	5.19м
J	16.33м
Keel lateral area	2.6м2
Rudders lateral area	0.98м2

Mast L= 16.5м, NF540 (224x136мм)
Moments of inertia Ix=830 см4 Iy=1775 см4
Boom - L=5.3м - NF350 (195x122мм)

Chn	Sheet	№ docum.	Sign.	Date	ROOTS 10-02			
Develop.					SAILPLAN	Litera	Mass	Scale
Check.								
N.Kontr.						Sheet	Sheets	
Approve								

ROOTS Rig Construction