SCANTLINGS FOR SMALL WOODEN FISHING VESSELS

R. RAJENDRAN*
Central Institute of Fisheries Technology, Ernakulam, Cochin-11
AND
R. L. ROY CHOUDHURY
Craft Unit, Off Shore Fishing Station, Ernakulam, Cochin-11

Studies are carried out to find a suitable basis of specifying scantlings for wooden fishing vessels for India, specially for the range 30′ to 50′ length overall. Equations of the type $y = a + bN^{\frac{1}{3}}$ (where 'y' is scantling in inches, N is cubic numeral in ft^3 and 'a', 'b' are constants) are fitted to the scantling tables (applicable to vessels 50′ and above) available from U. S. A., Newfoundland, Denmark, France and Scotland and they are found to represent the regulations accurately. These lines are corrected for standard frame and beam spacings and moulded/sided dimensions to bring them on a common basis for comparison and minimum scantling lines for the main structural members are derived. These lines are extended to cover the range 30′ to 50′ which is generally outside the range of the above regulations.

INTRODUCTION

Scantling regulations for wooden fishing vessels are available in several countries e. g. U. S. A., Canada, Ireland, U. K., Denmark, France, Japan etc. These scantings are generally applicable for range of vessels from 50′ overall length and above and are based on the local construction methods, timbers and operational requirements. In India the range of sizes of fishing vessels from 30 ft to 50 ft is important for wooden construction, which is outside the range of most of the above regulations. Moreover, the timbers used in construction are also very much different. These necessitated an investigation into a proper basis of specifying scantlings for these vessels. As a first step the regulations from U. S. A., U. K., Denmark and France have been analysed and studied critically to find a basis of specifying minimum scantlings.

* Present address: Central Institute of Fisheries Operatives, Ernakulam, Cochin-16.

MATERIALS AND METHODS

The regulations from the following countries were examined in the study. 1. Scotland, 2. Newfoundland, 3. France, 4. Denmark and 5. U. S. A. (Simpson)

Only Bureau Veritas mentions the ranges of the ratios between dimensions e. g. L/D, B/D for which the scantling tables are directly applicable and also the correction factors when these ratios differ from the given ranges. The other regulations do not mention them. So the dimensions of some typical wooden fishing vessels from each of these countries were collected and the ranges of the ratios of the dimensions estimated from them are assumed to be applicable for the corresponding regulations. The regulations considered here all give the scantling in the form of tables based on a cubic numeral L x B x D. However, L, B, D are defined differently in the regulations and for the purpose of this study the numeral N = L x B x D (where 'L' is length overall, B is breadth moulded, D is depth moulded all dimensions in feet) was used. When L, B, D definitions varied, estimated correction factors were applied to bring them on the above uniform basis.

The minimum values of the numerals given in the above regulations generally correspond to vessels approximately 50′ length overall and it is necessary to extrapolate them to range of 30' long vessels. A comparative study of the scantlings of the basic structural members e. g. keel, frame, beam and hull plank was carried out. Scantlings for other members, it is assumed can be derived directly from these basic members.

As a first step for comparison of regulations, the scantlings of particular structural members according to different regulations were plotted against the cubic numeral (N). No objective comparisons were possible since the lines showed widely different trends and in some cases considerable fluctuations (for the same regulation) occurred in the rates of increase with the numeral. As such extrapolation of these lines were uncertain. Equations fitted to these lines were also of no use since the form of the equations varied considerably.

General equations of the form $y = a + bN^{\frac{1}{3}} + cN^{\frac{2}{3}}$ of a structural member (where 'y' is scantling and N cubic numeral a, b, c constants) were attempted as a next step. It was found that in most cases contribution of $cN^{\frac{2}{3}}$ was small and equations of the form $y = a + bN^{\frac{1}{3}}$ were quite satisfactory. Seperate equations of this latter type were fitted to the tables for frame spacing, and beam spacing, hull plank thickness, keel, frame and beam siding and 'y' denoted each of these items in inches. For the sections e. g. keel, frame and beam, attempts were made to fit equations for the sectional area, moment of inertia and section modulus. But none of them showed regular trends plotted against N and even the general equation of the form $y = a + bN^{\frac{1}{3}} + cN^{\frac{2}{3}}$, was not of use. However the sided dimensions (y) of these sections fitted well in the equation of the form $y = a + bN^{\frac{1}{3}}$, and these were used in the study. The strength properties of the sections depended both on siding and the moulding and the latter was to be accounted for in the comparison. A standard moulding / siding ratito was assumed and the above sided dimensions from the equations were corrected for departures from this standard. The scantling equations mentioned above for plank thickness, beam and frame dimensions were still not directly comparable, since they also depended on the frame and beam spacings. So it was necessary to use a common frame (and beam) spacing and correct the planking thickness, frame and beam siding lines accordingly and also apply several other corrections to make them directly comparable. From a study of the different frame spacing lines, the one according to the Scottish regulations was chosen as basic, the considerations for the choice being (i) this line lay more or less in a mean position between the various regulations and (ii) the total variation over the range of numerals was less. For bent frame constructions, (for which this rule has to be adopted) this latter feature is important.

CORRECTION FACTORS

Hull Planks:—

The nature of correction for plank thickness (t) was derived from simple beam theory. It was assumed that the hull plank of width 'b' inches was simply supported by two frames spaced 's' inches and carried a distributed load of w lbs./ in^2. (The maximum stress and deflection in the case of a single span 's' as considered, were more than those where a length of plank was considered simply supported by several frames of spacing 's') From simple beam theory,

Max. stress in the plank $= 0.75\ w\ (s/t)^2$ .. (1).

For hull planks 'w' was estimated from the water pressure at maximum draft and was equal to 0.037 d lbs./ in^2 ('d' is is max. draft in inches). 'd' varied approximately from 60″ to 100″ for the range of numerals covered by most regulations and the corresponding estimated 'w' varied from 2 2 to 3.7 lbs./ in^2. Allowiug for dynamic effects, a value of 5 lbs. / in^2 could be assumed.

From among the timbers used for planking covered by the regulations 'cedar' had the least strength as beam ie., 9000 lbs./ in^2 and maximum for 'oak' ie, 13,400 lbs/ in^2. Both values corresponded to "along the grain" strength at 15% moisture content. With a factor of safety 10, the allowable stresses were 900 lbs./ in^2 and 1340 lbs./in^2 respectively. However, for hull planks a moisture content above 25% is likely and the resultant reduction in strength values were estimated as 30%. The variations in grain directions affect the planks (smaller thickness) more and reduction of 20% in strength on this account should be allowed. The allowable stresses in hull planks were thus reduced by 50% as a combined effect of these factors.

Substituting w = 6 lbs/ in^2 and Max. stress = 450 lbs. / in^2 and 670 lbs./ in^2 in equation (1),

$s/t = 15.5 = 11$ for cedar

$s/t = 13.9 = 13.4$ for oak

For frame spacing, which might seldom exceed about 24″, the deflections of the hull plank resulting from similar loadings as above were only of the order of 10^{-3} inches and so the maximum stress as considered above was the deciding factor in the determination of scantlings. Equation (1) shows that if s/t is kept constant the stress in the planking is constant and so s/t can be used for correction of plank thickness for changes in 's'. The derived s/t values show that for reasonable stress s/t should not normally be more than 11.

s/t factors, determined from the tabular values of the regulations showed considerable variations but they were less than 11. The corrected hull plank thickness for standard (Scottish) frame spacing was obtained by keeping 's/t' constant as follows.

Corrected plank thickness $t_1 = s/t \times s_1$, where 's' and 't' are the spacing and thickness obtained from the equations of the particular regulation for a chosen $N^{\frac{1}{3}}$ and s_1 is the spacing for the same $N^{\frac{1}{3}}$

according to standard (Scottish) spacing line. 't_1' values for several $N^{\frac{1}{3}}$ were calculated and corrected plank thickness line for each regulation was obtained.

For deck, the loading/in² is much less compared to hull planking and so much larger s/t (i. e. more beam spacing) can be used for same thickness of planking. The problem of deck structure is more of the strength of the beams and of local concentrations of loading and allowances for heavier wear and tear of planks. It appears that deck plank thickness equal to that of hull plank is adequate from strength and deflections point of view.

Frames and beams:

The frame can be considered as a beam of length '1' inches simply supported at ends by deck clamps and stringers (or stringers and keel or hog) and a distributed load of w. s. lbs/in of length.

$$\text{Then max. stress} = 0.75 \text{ s. w. } x \frac{l^2}{p^2 b^3} \quad \text{.. (2)}$$

$$\text{Max. deflection} = 0.156 \text{ s. w. } x \frac{l^4}{p^3 b^4} \quad (3)$$

'l' = length between supports in inches, 'b' = frame siding in inches, 's' = frame spacing (in), 'w' = distributed pressure (lbs,/in²), 'p' = the moulding / siding ratio and E = modulus of elasticity (lbs. / in²).

If the allowable stress is assumed to be 1000 lbs. and w=5 lbs/in² then from equation (2)

$$\frac{p^2 b^3}{s\, l^2} = 3.75 \times 10^{-3} \quad (4)$$

If allowable deflection is 0.15 inches and E = 1.1 x 10⁶ lbs/in² then from equation (3), $\frac{p^3 b^4}{s\, l^4} = 4.7 \times 10^{-6}$. (5)

The right hand side figures in equation (4) and (5) show the limit of minimum values. However, the expression on the left hand side of these equations form a basis of the corrections to frame dimensions for changes in 's' and 'l'

If 'l' is constant, then $\frac{p^2 b^3}{s}$ and $\frac{p^3 b^4}{s}$ are to be kept constant for same stress and deflection respectively. If a spacing is increased from a particular value, the dimension changes according to relation $\frac{p^2 b^3}{s}$ = constant ensure that the original stress and deflections are not exceeded. But if 's' is decreased, then the dimensions are to be changed according to relation $\frac{p^3 b^4}{s}$ = constant to ensure that original deflection and stress are not exceeded. Similarly if 's' is constant, then $\frac{p^3 b^4}{l^4}$ = constant and $\frac{p^2 b^2}{l^2}$ = constant respectively to be used for correction for 'l' longer or shorter than a given value.

The frame siding is first corrected for standard spacing, keeping the siding / moulding ratio (p) unchanged, as follows.

If s_1, b_1 and p are obtained from the equations of a particular regulatlon, all of them corresponding to $N_1^{\frac{1}{3}}$ and if 'b_2' is corrected sided dimension (p remaining same) for standard spacing 's_2' corresponding to $N_1^{\frac{1}{3}}$, then for $s_2 > s_1$.

$$b_2 = b_1 \sqrt[3]{\frac{s_2}{s_1}} \quad \dots \quad 6\text{ (a)}$$

for $s_2 < s_1$

$$b_2 = b_1 \sqrt[4]{\frac{s_2}{s_1}} \quad \dots \quad 6\text{ (b)}$$

Similarly for same 's' but relative variation of 'l' for $l_2 > l_1$

$$b_2 = b_1 \frac{l_2}{l_1} \quad \dots \quad 7\text{ (a)}$$

for $l_2 < l_1$

$$b_2 = b_1 \left(\frac{l_2}{l_1}\right)^{\frac{1}{3}} \dots \quad 7\text{ (b)}$$

The corrected sided dimensions of the frame as obtained by applying the above corrections still have the particular tabular value of 'p' and thus a further correction is also necessary for variations in 'p'. 'p' varies with $N^{\frac{1}{3}}$ for same regulation and also from one regulation to another and so a reasonable standard value is chosen to bring all the sided dimensions on same basis for comparison. To keep the stress values same, the frame modulus is to be kept constant i. e. $p^2 b^3$ = constant. So if 'b_2' is the sided dimensions corresponding to chosen standard ratio p_2 and p_1 and b_1 are tabular values.

Then $p_1^2 b_1^3 = p_2^2 b_2^3$

$$b_2 = b_1 \left(\frac{p_1}{p_2}\right)^{\frac{2}{3}} \quad \ldots\ldots (8)$$

The relative change in length 'l' and correction 7 (a) or 7 (b) are considered only for beams. Beam lengths are directly proportional to breadth of the vessels. However, (B) of vessels according to different regulations vary. This can be found out from the relation-ship between breadth (B) and numeral (N) derived as follows

$$N = \frac{L}{B} \times \frac{D}{B} \times B^3 = CB^3$$

$$B = \frac{1}{C}^{\frac{1}{3}} N^{\frac{1}{3}} \ldots\ldots (9) \text{ where } C = \frac{L/B}{B/D}$$

The value of $(c)^{\frac{1}{3}}$ is calculated for the range of dimensions for the vessels in the different countries and it varies between 1.20 and 1.30 and so the correction is negligible and is not applied.

All the correction factors for frames are also applicable to beams but with corresponding spacing, siding dimensions and siding to moulding ratio.

Keel:-

The correction according to equation (8) is applied to keel siding dimensions for purposes of comparison.

Results and discussion

In Table I, the numerals used, the definitions of the dimensions used in the numerals of the different regulations and the ratios of range of dimensions of typical vessels to which these regulations are applicable are presented. The correction factors for changing the numerals to common (L. o. a x Bmld x Dmld) basis, and the estimated values of factor 'c' in equation (9) are also shown. It is seen that the $c^{\frac{1}{3}}$ factors for different regulations cover practically the same range and so no corrections in this respect are necessary.

In Table II, the co-efficients 'a' and 'b' in the equation for the scantlings $y = a + bN^{\frac{1}{3}}$ fitted to the scantling tables (y in inches) of the different regulations and the correlation co-efficient (r) between each scantling (y) and $N^{\frac{1}{3}}$ are shown. The correlation in all cases are significant at 0.1% level and so the lines represent the relationship accurately.

The scantling tables studies here cover the range of values of $N^{\frac{1}{3}}$ from 16 to 28. However, the lines fitted are extrapolated down to $N^{\frac{1}{3}} = 10$, which correspond to 30′ long vessel. The scantling tables (and the equations fitted to them) are applicable for both hard and soft woods available in the respective countries.

The scantling lines for the Denmark regulation are always much higher than the others. However, for the other regulations, the lines for some members indicate heavier scantlings while the others indicate lighter scantlings. This shows that comparison between them are possible only when they are brought to a common basis. The co-efficient 'b' indicating the rate of increase of a particular scantling with size ($N^{\frac{1}{3}}$) varies widely from one regulation to another and so the relative heaviness or lightness of scantlings accord-

TABLE I NUMERALS AND CORRECTION FACTORS TO CONVERT THEM TO COMMON BASIS

Regulation	Numeral 'N'	Correction factor of Numeral 'N'	Range of relative dimensions Loa/Bmld	Range of relative dimensions Bmld/Dmld	Correction factor $C^{\frac{1}{3}}$
Scotland	L x B x D ft^3 L = Loa, B = Bmld D = from bottom of keel	1.1	3.1 to 3.7	2.0 to 2.3	1.23 to 1.10
Simpson	$3\sqrt{}$ L x B x D/100 ft. L = Loa, B = Bmld D = Dmld	100 x $(\text{'N'})^{\frac{2}{3}}$	3.12 to 5.26	1.76 to 2.18	1.35 to 1.16
Bureau Veritas	L x B x D m^3 L = Lbp, B + Bmld D = Dmld	40	4.0	2	1.26
New-foundland	L x B D x 0.0075 ft^3 L = Loa, B = Bmld D = from top of ceiling	133.4	3.45 to 3 62	1.73 to 1.94	1.28 to 1.23
Denmark	L x B x D m^3 L = Loa, B = Bmld D = Dmld	35.314	—	—	—

ing to a regulation is also very much dependent on the size of vessel indicated by $N^{\frac{1}{3}}$. The negative values of 'a' are generally associated with large 'b' values and results in relatively smaller scantlings for the smaller vessels.

The Scottish frame sapcing line $y = 11.25 + 0.162\ N^{\frac{1}{3}}$ where 'y' is spacing in inches, is taken as the standard and the hull plank thickness and frame dimensions of all the other regulations are corrected for this stardard spacing. Similarly, the beam dimensions are corrected to corres-pond to Scottish beam spacing line $y = 16.5 + 0.25\ N^{\frac{1}{3}}$ which is taken as standard.

Fig. 1. shows the hull plank thickness lines corrected for the standard (Scottish) frame spacing. The corrected line for Danish regulation is not shown. The frame spacing according to this regulation actually decreases with increasing $N^{\frac{1}{3}}$ and so the correction makes the already large plank thicknesses abnormally high. The corrected Newfoundland regulation line (Fig. 1) represents generally the minimum line. This line extrapolated to $N^{\frac{1}{3}} = 10$ (i. e. 30′ boat size) gives hull plank thick-ness which is slightly higher than the adequate value in practice. The equation of the line obtained from Fig. 1 is $y = .75 + 0.045\ N^{\frac{1}{3}}$.

The frame sidings obtained from equation (table II) are first corrected for standard frame spacing mentioned above with the help of equations 6 (a) and 6 (b). These values are further corrected for standard moulding/siding ratio (which is taken as 1.5) with the help of equation (8). These corrected values are shown in Fig. 2. The ranges of variation of moulding/siding ratios are as follows for the different re-gulations, Danish regulation practically constant at 2.8, Bureau Veritas 1.35 to 1.7 (increasing with $N^{\frac{1}{3}}$), Newfoundland 1.25 to 1.02 (decreasing as $N^{\frac{1}{3}}$ increases) and

TABLE II

Egulation	Bureau Veritas			Scottish			Newfoundland			Simpson			Denmark		
Numeral	LBD			LBD			$\frac{LBD.75}{100}$			$3\sqrt{\frac{LBD}{100}}$			LBD		
Scantlings	Coeff· a	Coeff: b	Correla-tion Coeff: r	Coeff: a	Coeff: b	Correla-tion Coeff: r	Coeff: a	Coeff: b	Correla-tion Coeff: r	Coeff: a	Coeff: b	Crrela-tion Coeff: r	Coeff. a	Coeff: b	Correla-tion Coeff: r
Plank thickness	0.2836	0.0725	0.9997	0.186	0.090	0.9886	–0.36	0.126	0.9800	0.500	0.108	0.9991	0.100	0.120	0.9811
Keel siding	1.35	0.336	0.9747	0.300	0.383	0.9913	1.402	.3007	0.9800	–2.00	0.432	0.9991	1.700	0.342	0.9860
Frame siding	–1.766	.251	0.9747	0.69	.193	0.9298	–1.55	0.37	0.9920	–	–	0.9991	0.05	0.185	0.9845
Frame spacing	12.03	.248	0.9963	11.25	.162	0.7800	–1.05	1.12	0.9908	–	–	0.9991	14.00	-0.29	0.9995
Deck beam siding	–.461	.2900	1.000	–	0.2675	0.9763	.33	0.126	0.9854	–	–	–	–8	.8	0.9936
Deck beam spacing	12.5	.630	0.9997	16.5	0.25	0.9779	.20	1.00	0.8228	–	–	–	–	–	–

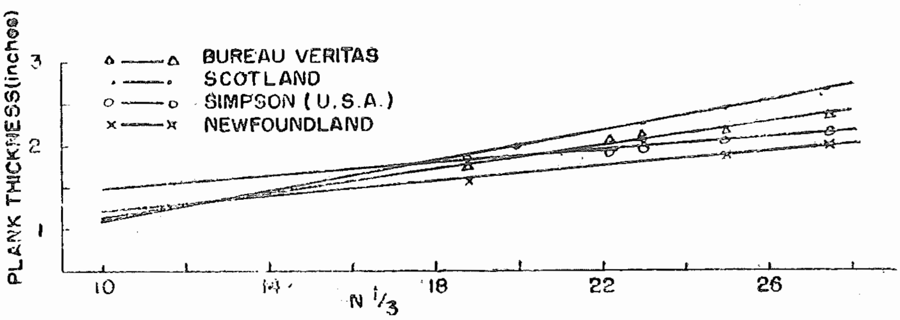

Fig. 1. Plank thickness corrected for standard spacing.

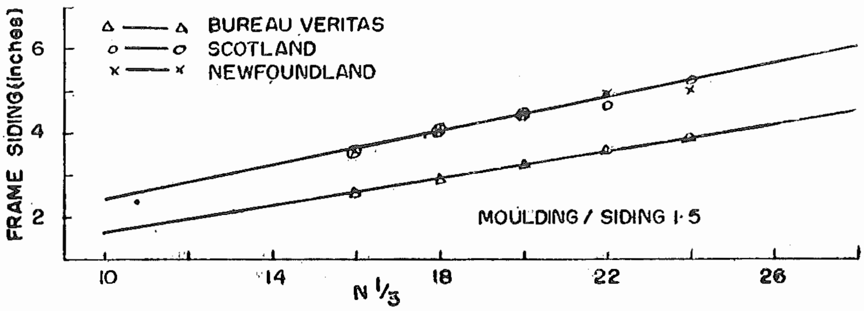

Fig. 2: Frame siding corrected for standard spacing and moulding/siding ratio.

Scottish 1.5 to 1.22 (decreasing with increasing $N^{\frac{1}{3}}$). The corrected line for Denmark is omitted since it gives too high values. The sidings for Scottish and Bureau Veritas are for single futtock of swan frames (moulding/siding ratio being taken at the bilge). Newfoundland regulation shows siding for single swan frame and it practically coincides with line for Scottish regulations. The basis of specifying frame scantlings according to Simpson is somewhat different and is not included. From Fig. 2 the minimum line is the corrected Bureau Veritas line, but it is only for single futtock of double swan frames. So the Newfonndland line (single swan frame) corrected for standard frame spacing and standard moulding / siding ratio of 1.5 is taken as the minimum line. The equation for the line obtained from Fig. 2 is $y = 0.45 + 0.29 N^{\frac{1}{3}}$ where 'y' is the frame siding in inches.

The sided dimensions of the beam obtained from the equations (table II) are first corrected for standard beam spacing mentioned above. These are further corrected for standard moulding/siding ratio which is taken as 1.3 and are shown in Fig. 3. The sidings and moulding from Bureau Veritas tables are increased by 25% as specified by the regulation for the absence of pillars which are normally required by this regulation. The corrections are annlied in the same manner as in the case of frames. The basis of specifying beam scantling according to Simpson is somewhat different and is not included. The line for Danish regulation is not shown, because it gives too large values. The Newfoundland line (Fig. 3) gives too small value at $N^{\frac{1}{3}} = 10$ and so the line for Bureau Veritas is taken as the minimum. The equation for the line is $y = 0.025 \ N^{\frac{1}{3}}$ where 'y' is the siding in inches.

Fig. 4 shows the keel siding corrected according to equation (8) for standard

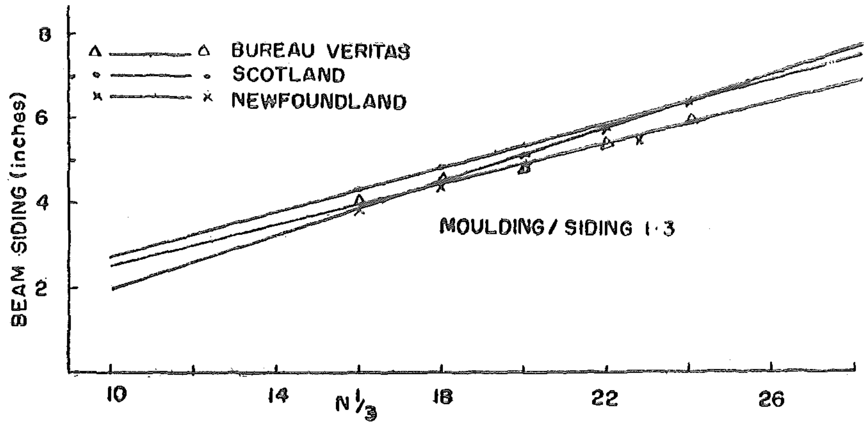

Fig. 3: Bean siding corrected for standard spacing and moulding/siding ratio.

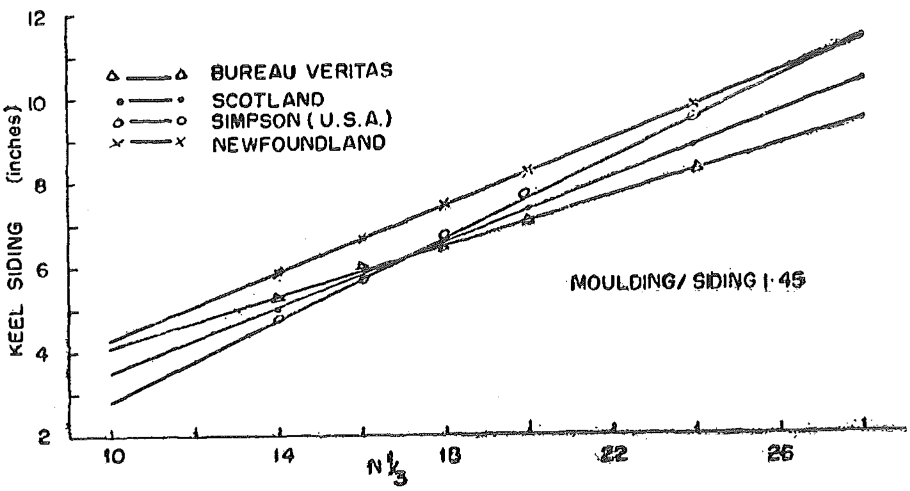

Fig. 4: Keel siding corrected for standard spacing and moulding/siding ratio.

moulding / siding ratio 1.45. The ranges of variation of this ratio are as follows. Scotland 1.45, Newfoundland 1.45, Denmark 1.50, Simpson 2.00 and Bureau Veritas 1.20. The values for Danish regulation are too high and are not shown. The Scottish line is taken as the minimum line and its equation is $y = 1.20 + 0.295 N^{\frac{1}{3}}$ where 'y' is the keel siding in inches. Moulding/siding ratio is 1.45.

The suggested minimum lines are summarised below.

i) Frame spacing $y = 11.25 + 0.162 N^{\frac{1}{3}}$

ii) Frame spacing $y = 16.5 + 0.25 N^{\frac{1}{3}}$

iii) Hull plank thickness $y = 0.75 + 0.045 N^{\frac{1}{3}}$

iv) Frame, sided dimension. Moulding/siding = 1.50, $y = 0.45 + 0.29 N^{\frac{1}{3}}$

v) Beam, sided dimension. Moulding/siding = 1.30, $y = 0.025 N^{\frac{1}{3}}$

vi) Keel, sided dimension. Moulding/siding = 1.45, $y = 1.20 + 0.295 N^{\frac{1}{3}}$ 'y' inches, $N^{\frac{1}{3}}$ in feet.

Conclusions

The scantling tables converted to the form of equations $y = a + bN^{\frac{1}{3}}$ are quite accurate, offer an easy method of representing the scantlings on common basis and are useful as corrections to scantlings for changes in frame spacing and other scantling parameters. The lines for keel frame and beam sidings (for corresponding standard *moulding/siding) and the minimum* hull plank thickness line, are applicable for both hard and soft woods. But if only hardwoods are used in the construction, the suggested minimum lines can be further corrected to give lower scantlings. These corrections can be easily incorporated in the co-efficients 'a' and 'b' which require further investigations.

Acknowledgement

The authors are deeply indebted to Dr. A. N. Bose, Director, Central Institute of Fisheries Technology for his keen interest and the encouragement during the course of this investigation.

References

Brown, Panshin and Forsaith, 1952, McGraw-Hill book company, I. N. C., Newyork.

Perelvgin L. M. 1965, Science of wood, Higher School, publishing House, Moscow.

Rules and regulation for the construction *and classification of wooden fishing* vessels 1963, Bureau Veritas

Rules and regulation for the construction and classification of wood and composite Yacht Lloyds Register of Shipping, London.

Simpson, 1960 Fishing boats of the World-2 pp 152-187

Standard specifications for the construction of wooden fishing vessels, overall length 30 feet to 90 feet inclusive, white fish authority, 5 Forres Street, Edinburgh-3.

The fishing ship (Bounties) Act, 1955 and regulations made under the Act, Division of vessel constrution and inspection. Department of Fisheries and co-operatives.