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DETERMINING THE VALUE OF A SAFE SPEED

A.Y. Ganiyev

This article has developed one of the main safety criteria in restricted areas for safe passing of vessels, taking into account the main influencing factors (wind, current, dimensions of the vessel, sufficient sea room, manoeuvring characteristics of vessels), as well as early development of recommendations for safe passing and manoeuvring of vessels in these water areas.
Scientific research and analysis of static data on incidents suggest that in the world fleet annually approximately 20-30 of the 1,500 colliding vessels lost. Based on the foregoing, we can say that the ensuring the safety of vessels is the main task of navigation.
The main problem is science-based research in restricted areas is poorly developed. There are still very low maneuverable vessels at sea. One of the causes of maritime accidents is also the lack of knowledge of navigators of the maneuverability of the vessel.
Keywords: maneuvering characteristics, underkeel clearance, safety criteria, tactical diameter, advance.

In practice, it is believed that under equal sailing conditions, the safe speed of the vessel following with the radar is slightly higher than the speed of the vessel, following without the radar. However, this consideration is incorrect. The safe speed of the vessel should be the same for the vessel without a radar or with radar.

Programming routine navigation processes using the developed algorithm will allow the navigators to facilitate the ships handling process, take early action for passing.

Consider the three main causes of navigation accidents:

1. The navigator does not have enough time to receive and handle information that is necessary to assess the situation, solve problems and make decisions on maneuvering.
2. Close quarter situation.
3. Failure of technical aids.

In most cases, the collision of ships does not occur due to a failure of technical aids, but because the actions of the navigator were delayed.

Therefore, in order to ensure safety, especially in restricted areas, in restricted visibility and in other special sailing conditions, the navigator must know in advance the influence of external and internal factors on his vessel and the behavior of the vessel under the influence of these factors.

That is why the advance accounting of all sorts of factors on the movement and control of the vessel, considered in this article, is one of the effective methods for ensuring the safety of navigation in restricted waters.

One of these key factors is safe speed. COLREG-72 lists factors that should be considered when determining value of the safe speed. However, it should be borne in mind that COLREG-72 has a number of uncertainties, such as "safe speed", "close-quarter situation", etc., which do not have determined yet.

Statement of the problem

Collision analysis show that more than 75% of collisions in restricted visibility, occur due to the high speed of ships (see fig.1).

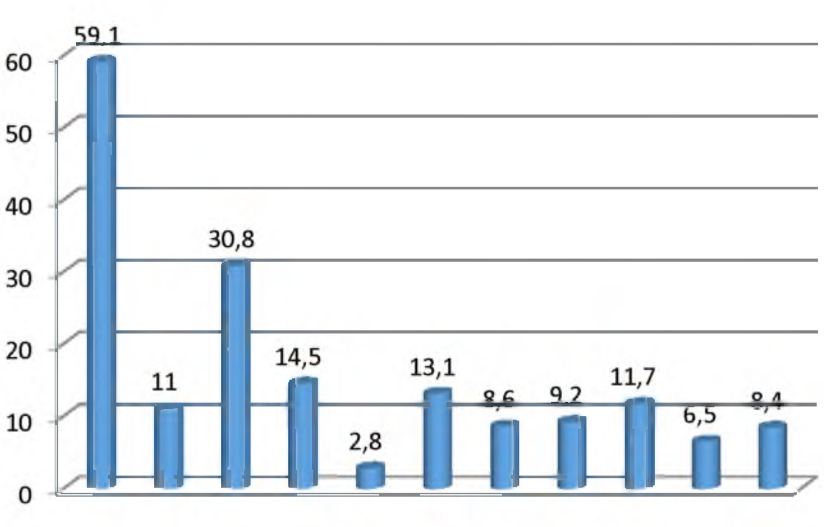

Fig.1 – Accidents due to various sailing conditions

To determine a value of the safe speed, it is necessary to develop a criterion that will reduce the number of factors affecting decision making. The developed criteria should not contradict COLREG-72. The value of safe speed has not yet been determined. In this article, the calculation of safe speed is considered from the point of view at which speed the vessel can increase or at what speed the vessel should reduce speed to prevent the influence of negative influencing factors.

Safe speed relative to the Underkeel clearance

One of these methods is the determination of the maximum permissible speed, which will correspond to the value of safe speed. This method, in this article, for calculating safe (maximum permissible) speed in a restricted area is based on the well-known formula.

$$\Delta d_v = \mathrm{H}_d - (\Delta d_{max} + \Delta d_{n.r} + \Delta d_w + \Delta d_l + \Delta d_d) \tag{1}$$

where Δd_v – maximum permissible speed in shallow water;

H_d – depth at the given point where the vessel is located (from the map or according to the echo sounder)

Δd_{max} – maximum draft (known to the navigator);

$\Delta d_{n.r}$ - it is recommended to take a navigation reserve of at least 0.3-0.4m

Δd_w – wave reserve;

Δd_l – increase in draft in list.

Having found the value of the underkeel clearance, you can find the speed at which this squat value will correspond. This will be our safe speed, taking into account the shallow water and channel width.

This problem can be solved using the transformation of formulas of A.P. Kovalev:

$$V_{safe} = \sqrt{\frac{UKC*10^2}{\mathrm{K}}} \quad \text{when } \frac{\mathrm{H}_d}{d} \le 1.4 \tag{2}$$

or

$$V_{safe=}\sqrt{\frac{UKC*10^2}{\mathrm{K}}}\sqrt{\frac{\mathrm{H}_d}{d}} \quad \text{when} \quad 1.5 \le \frac{\mathrm{H}_d}{d} \le 1.4 \tag{3}$$

where the coefficient K is taken from the table 1.

Table 1 – **Determination of the coefficient K relative to ships dimensions**

L/B	4	5	6	7	8	9
K	1.35	1.03	0.80	0.62	0.55	0.48

When determining the safe speed in the channel, additional squat should be considered.

$$V_{safe} = \sqrt{\frac{UKC*10^2}{\mathrm{K}+K'}} \quad \text{when} \quad \frac{\mathrm{H}_d}{d} \le 1.4 \tag{4}$$

$$V_{safe} = \sqrt{\frac{UKC*10^2}{\mathrm{K}\sqrt{\frac{\mathrm{H}_d}{d}}+K'}}\sqrt{\frac{\mathrm{H}_d}{d}} \quad \text{when} \quad 1.5 \le \frac{\mathrm{H}_d}{d} \le 1.4 \tag{5}$$

where ***K'*** is selected from the table 2

Table 2 – **Determination of the coefficient K relative to the squat of the vessel**

Ψ_c / Ψ_Ω	3	4	5	6	8	10	12
K'	0.98	0.61	0.44	0.35	0.24	0.18	0.15

This method can be used when a ship proceeding in shallow water or when there is a channel effect. Although this method allows us to control the value of safe speed, but given the time limit, the practical application of this method is impossible and therefore, for the practical application of this method, an algorithm is proposed in fig.2 for calculating the safe speed relative to the underkeel clearance and the channel effect.

Determination of safe speed relative to advance

The second method for determining the value of the safe speed that we propose in this article is relative to the advance. According to the COLREG-72 - 8 (c), alternating the course is the most effective action to prevent a collision, since it takes much less time, which is very important in restricted areas. If the ship intends to make such a maneuver, it must assess the situation in advance and make a decision for maneuver. To make a decision, the navigator must know at least two factors as it is shown in fig.3

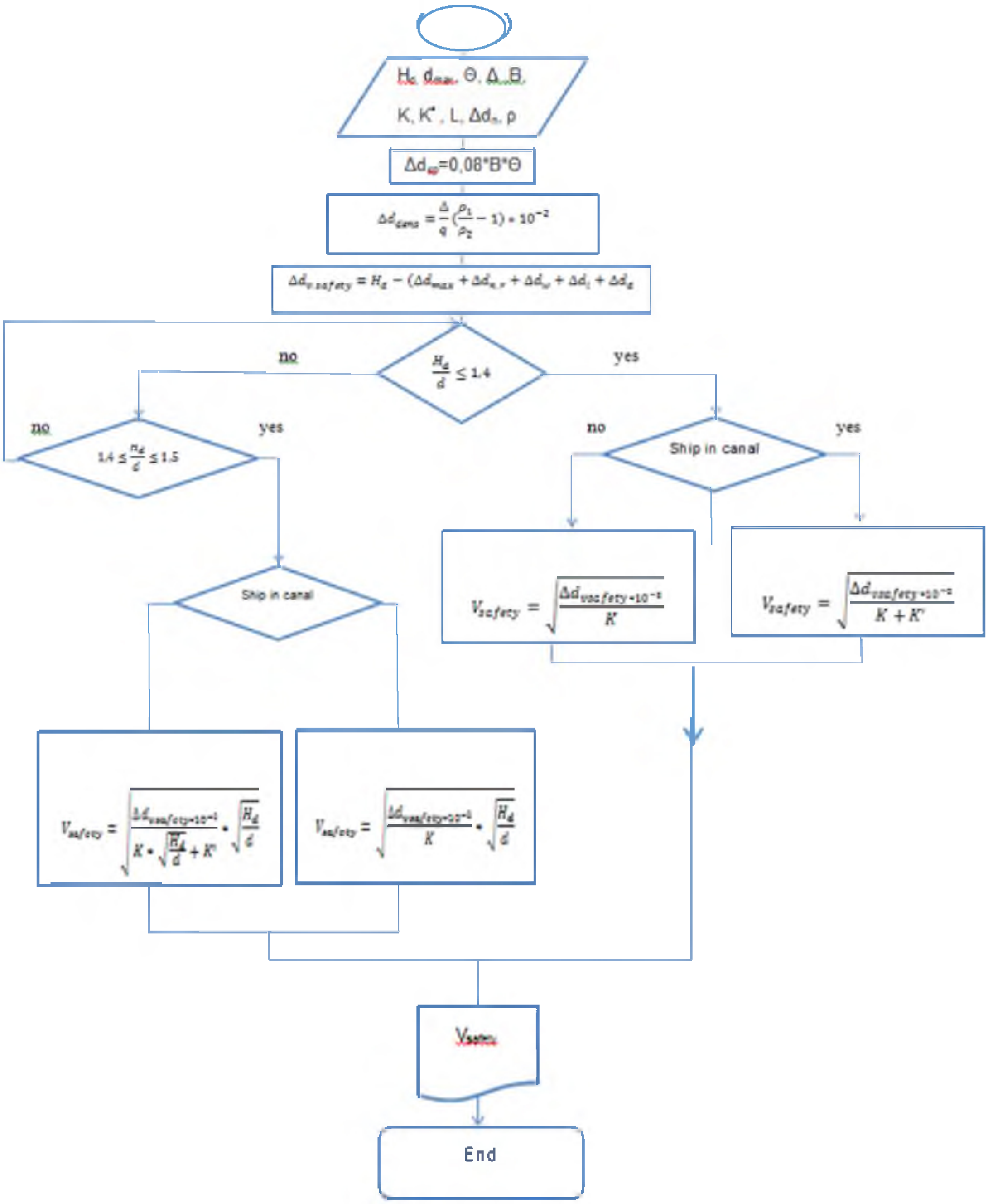

Fig.2 – Algorithm for determination value of the safe speed relative to the underkeel clearance

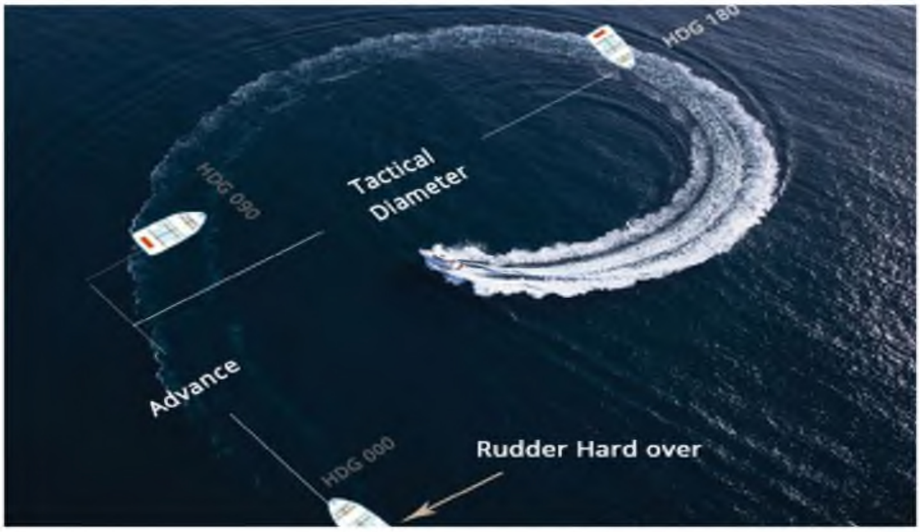

Fig.3 – Advance and tactical diameter during turning of vessel

The first is if the navigator puts the wheel hard over, how far the ship will go forward. The second is how far the ship will be transferred in side reach.

These areas must be clear for safe turning of the ship. So, we need to know the maximum values of these transfers – head reach and side reach.

In other words, these values correspond to the values of the advance and tactical diameter of the vessel during circulation, which we can find from the table of maneuvering characteristics.

To account for external factors - current, wind, the values of these quantities are doubled. When maneuvering, the advance value may vary depending on the rudder angle. Consider the following inequality by which we can determine the value of safe speed. As shown, the components of this inequality will be as follows:

$$D_{det} \geq S_L + m_D + S_{m.s} + L_1 + D_{stop} + S_{n.r} \quad (6)$$

where S_L – distance from the antenna to the extreme fore point;

m_D – error in determining the distance to danger;

$S_{m.s}$ – the distance which your own ship will proceed during the making decision;

L_1 - advance, table value;

$S_{n.r}$ – navigational margin entered by the navigator to account for errors;

D_{stop} – distance from danger at which the ship will stop.

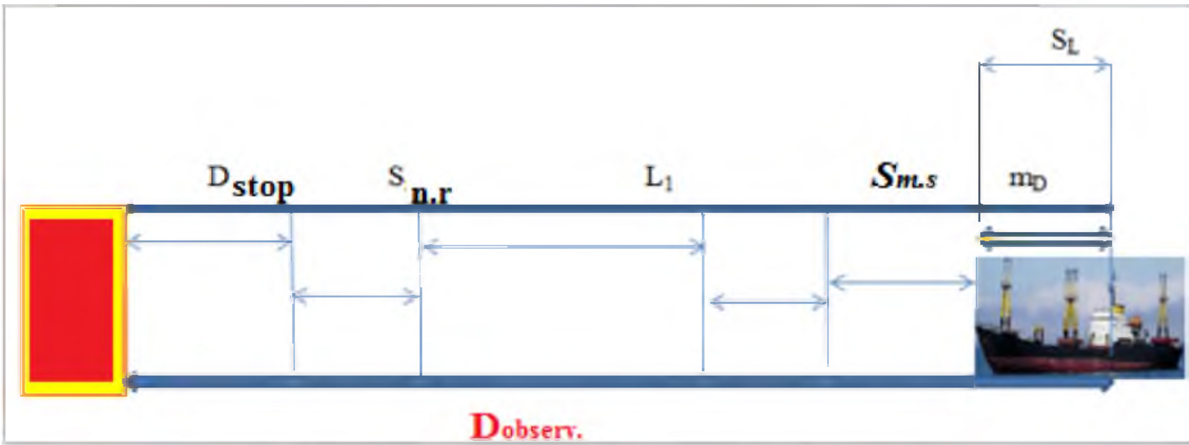

Fig.4 – Determination of safe speed relative to advance

If $D_{stop} = 0$ in formula (6) then,

$$L_1 = D_{observ} - S_L - m_D - S_{m.s} - S_{n.r} \quad (7)$$

From this inequality, we can say that if L1 (calculated) according to the formula proposed by us is greater than L1 (15) i.e. the advance of the vessel, when the rudder is put 15°, then the vessel follows at a safe speed

Safe speed relative to the stopping distance of the vessel

The last method for determining the safe speed value in this article is regarding the manoeuvering characteristics of the vessel. To develop a safe speed value relative to the stopping characteristics, we consider the case when the danger is not moving, is located directly ahead, or the vessel should anchor at a certain point or at a certain distance from the danger or from the platform, and our vessel proceed at a speed of V_0.

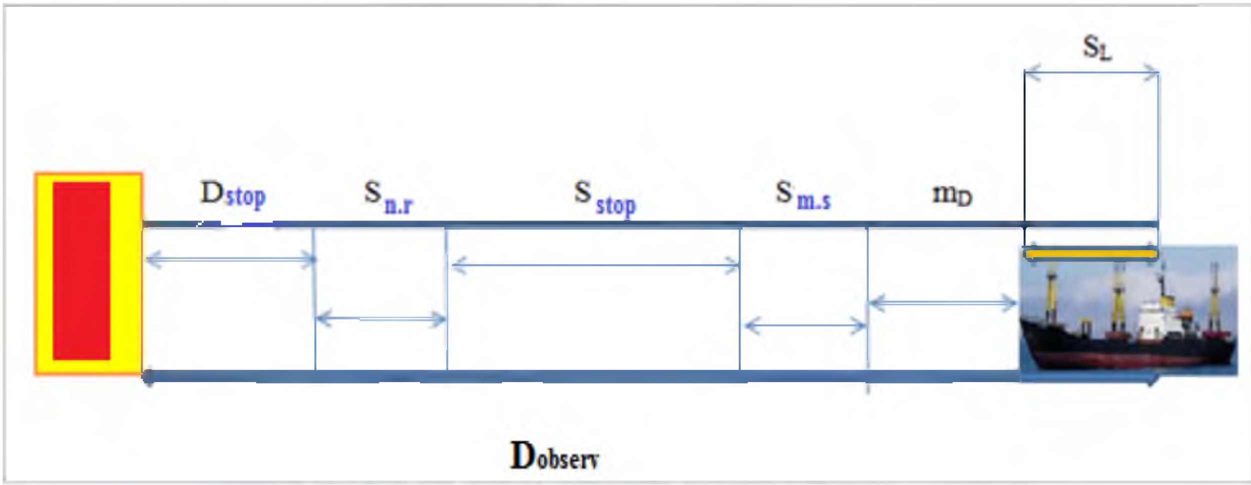

Fig.5. –Choosing a safe speed relative to a unmoved object

In addition, it should be noted that the safe speed cannot be greater or less than the speed at which the vessel can steer on course and confidently reverse.

The collision shown in the figure will not occur if the observation distance of the objects satisfies the following inequality.

$$\text{Dobserv} \geq S_L + m_D + S_{m.s} + S\,\text{stop} + \text{Sn.r} + \text{Dstop} \qquad (8)$$

where S_L – distance from the antenna to the extreme fore point;

m_D – error in determining the distance to danger;

$S_{m.s}$ – the distance that our ship will pass during the decision;

S_{stop} - track reach;

$S_{n.r}$ – navigational margin entered by the navigator to account for errors;

D_{stop} – distance from danger at which the ship will stop.

S_L and m_D are known to navigator.

$$S_{m.d} = V_0 * t_{m.d} \qquad (9)$$

where V_0 – current speed of vessel;

$t_{п\,р}$ – time to making decision;

If $D_{stop} = 0$

then, taking into account the navigational reserve after the vessel has passed the stopping distance, the distance between the vessel and the danger will be zero.

To determine the safe speed, the inequality should be solved with respect to S_{stop}, i.e. the only way to avoid a collision is to reverse the engines, as in restricted areas it is not always possible to alter course.

$$S_{stop} = D_{observe} - S_L - m_D - S_{m.d} - S_{n.r} \qquad (10)$$

Using the formula, an algorithm is developed for determining the value of the safe speed. After the navigator enters data, if the vessel does not follow a safe speed, then the following message appears on the screen: “Follow safe speed V ≤ X knots.”

Conclusion

Using these methods we can not only control the value of safe speed, but also determine its digital value. For the practical use of this method, the VTS or other allied services, in their database, must have elements of the maneuverability of the vessel. The main elements of maneuvering characteristics, for our case, are the value of the advance and tactical diameter of the turning. VTS having these datas can give recommendations to the ships for passing in restricteded areas. The table below shows the different gradations of speed for the tanker “Zengezur” are shown.

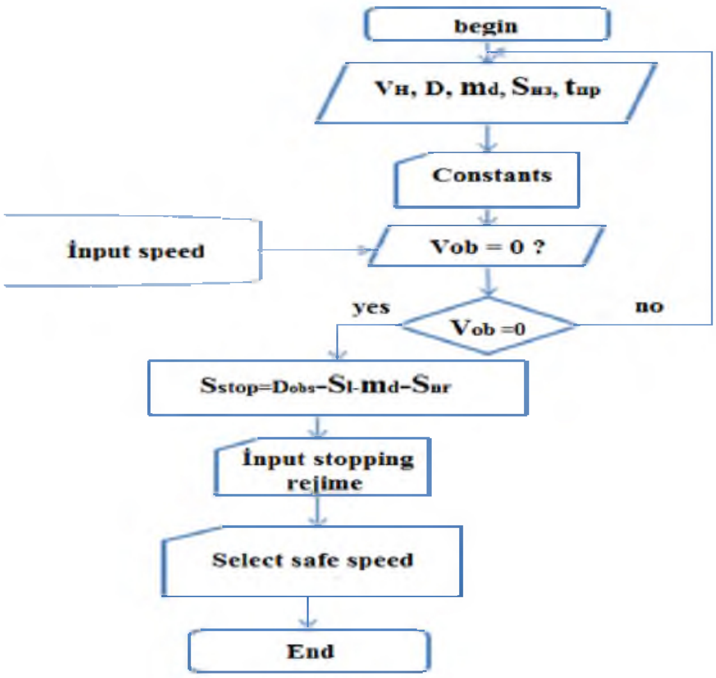

Fig.6. – Algorithm for determining the value of the safe speed relative to a stationary object

Table 3 – **Speed gradations of the tanker «Zengezur»**

ME rejime		Revolution of ME	Speed, kn	
			Loaded	In ballast
Full speed ahead		1000	12.01	12.7
Half speed ahead		800	9.65	10.9
Slow speed ahead		600	7.23	8.16
Dead slow speed ahead		500	6.05	6.6
Full speed astern		900	5.9	6.3

Table 4

Full ahead-Full astern	1450	Full ahead-Half astern	1519
Half ahead-Full astern	865	Half ahead-Half astern	891
Slow ahead-Full astern	497	Slow ahead-Half astern	520
Dead slow ahead-Full astern	380	Dead slow ahead-Half astern	420
Full ahead-Slow astern	1630	Full ahead-Dead slow astern	2050
Half ahead-Slow astern	1460	Half ahead- Dead slow astern	1680
Slow ahead-Slow astern	880	Slow ahead- Dead slow astern	870
Dead slow ahead-Slow astern	560	Dead slow ahead-Dead slow astern	540

Stoping distance values for various maneuver rejime

We make a nomogram depending on the initial speed of the vessel from the stopping distance. According to the compiled graph in the figure, we determine the numerical value of the safe speed. After we determine the value of S_{stop}, we need to determine which reverse in this case is confident. In this case, the Half speed astern was selected, the value of which corresponds to V_{safety} = 7.2 knots.

If the distance to the object is 4 cb, then the nomogram shows, that the vessel will not be able to stop in the rejime of the "Half speed astern" and "slow astern". It can be seen from the nomogram that in order to prevent a collision, only in the "Full speed astern" mode, S_{stop} will be equal to 3.2 cb and in the "Full speed astern" mode the S_{stop} will be equal to 2.1 cb. The nomogram we have proposed can be used for both not underway and underway vessels. When using this method for the vessels which are underway, the approach speed of the oncoming vessel will be required.

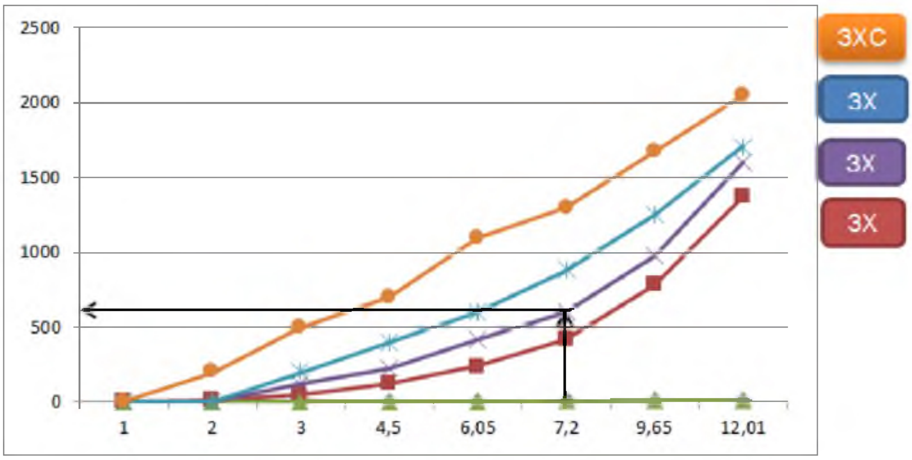

Fig 7 – Dependency nomogram of the initial speed of the vessel from the stopping distance

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