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ANEP-70 Volume III

NAVAL SURFACE SHIP MANOEUVRING:
HISTORICAL INFORMATION FOR MISSION ORIENTED REQUIREMENTS

Edition A, Version 1

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NATO LETTER OF PROMULGATION

25 July 2023

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PREFACE

Strong ship manoeuvring performance is vital for the safe operation of all vessels. Safe ship manoeuvring enables vessels to avoid collisions with other vessels and running aground. Standards from agencies such as the International Maritime Organization and technical knowledge from the International Towing Tank Conference and other groups contribute to the design and operation of safe ships.

Naval ships, which must conduct various military missions, have additional demands for manoeuvring performance. Mine warfare requires avoidance of mines and strong performance for station keeping and track keeping. Naval warfare with opposing air, surface, and underwater entities requires strong high speed manoeuvring performance, including torpedo evasion. Replenishment at sea, air vehicle operations, and launch and recovery of water vehicles require strong course keeping performance.

STANREC 4721 and ANEP 70 Volumes I, II, and III provide a framework for design and operation of ships such that their manoeuvring performance will allow them to operate safely and to fulfill naval missions. ANEP 70 Volume I provides design manoeuvring criteria for naval ships and discusses methods for assessing whether ships meet design criteria. ANEP 70 Volume II provides guidance on the provision of ship manoeuvring performance information to ship operators, and includes much information regarding data to be measured during sea trials. ANEP 70 Volume III provides manoeuvring performance data for existing ships and results from surveys of naval operators, forming the basis for the design manoeuvring criteria of Volume I.

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

1. This volume contains background information that was used to develop new manoeuvring criteria for naval vessels given in ANEP-70 Vol. I (2021). Related guidance on preparation of onboard information is given in ANEP-70 Vol. II (2021).

1.2 APPROACH

1. Information presented in this volume is based on observed performance of naval vessels and interviews with naval operators having experience with relevant missions. This volume also draws upon standards from the International Maritime Organization document IMO MSC.137(76) (2002).

1.3 HISTORICAL CONTEXT

1. Much the content of this ANEP was originally published in 2003, and is presented here to provide historical background information.

2. This document does not contain information on manoeuvring trials published in the original 2003 document. More current information on manoeuvring trials is available in the following references:

- ISO 19019:2005;
- ISO 13643-1:2017;
- ISO 13643-2:2017;
- ISO 13643-3:2017;
- ISO 13643-4:2017;
- ITTC (2017).

3. Criteria values, definitions of naval missions and definition of manoeuvring abilities have been preserved as those originally defined in the 2003 publication. These have been further developed in ANEP-70 Vol. I (2021).

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CHAPTER 2 DEFINITIONS

2.1 ACRONYMS

1. A list of acronyms is given below for reference.

Table 1: Acronyms

Acronym/symbol	Definition- explanation
Ship related	
kn	knots
L	Ships length (generally between perpendiculars)
MCR	Maximum continuous rating
MDS	Maximum design speed
s_F	Stopping distance
SLOW	Slow speed, i.e. 2 – 6 knots
y_{0180}	Tactical diameter
ZERO	0 knots
∇	Volume displacement
Missions	
AAW	Anti Air Warfare
ASW	Anti Submarine Warfare
ASuW	Anti Surface Warfare
HM	Harbour Manoeuvring
MIW	Mine Warfare
RAS	Replenishment At Sea
T&P	Transit and Patrol
Other	
IMO	International Maritime Organization
ITTC	International Towing Tank Conference
H_S	Significant wave height
MCM	Mine Counter Measure

2.2 NAVAL MISSIONS

1. Naval missions and tasks are used to organise manoeuvring requirements. ANEP-70 Volume I (2021) gives updated descriptions of missions and speeds. The definitions used to support the operator surveys and requirements in this ANEP are included below.

2.2.1 Transit and Patrol – T&P

1. Transit and patrol can include the following:

   a. Point to point;

   b. Search and rescue;

   c. Offshore patrol;

   d. Military surveillance.

Speed: 15 knots – MCR

2.2.2 Harbour Manoeuvring – HM

1. Harbour manoeuvring consists of manoeuvring in sheltered waters in a harbour. Typical situations/tasks are:

   a. Mooring/berthing;

   b. Anchoring;

   c. Towing (towing other ship or being towed).

Speed: ZERO – SLOW

2.2.3 Anti Submarine Warfare – ASW

1. Anti submarine warfare comprises of Proactive and Reactive ASW sub-tasks where:

   a. Proactive ASW is the offensive ASW sub-task. This sub-task includes manoeuvring abilities associated with launching of airborne assets, deploying towed sensors, target detection and assessment, target classification, launching torpedoes and launching ASW grenades. Speed: ZERO – 80% MCR

   b. Reactive ASW is the defensive ASW sub-task. This sub-task includes manoeuvring abilities associated with underwater threat detection, threat classification, evasive manoeuvring, deployment of decoys and confirmation that the threat has been neutralised. Speed: MCR

2.2.4 Anti Air Warfare – AAW

1. Anti air warfare comprises of Proactive and Reactive AAW sub-tasks where:

a. Proactive AAW is the offensive AAW sub-task. This sub-task includes manoeuvring abilities associated with target detection, target classification (Enemy aircraft, ASCM payload, onboard ESM & Active Radar), weapon deployment and target assessment. Speed: MCR

b. Reactive AAW is the defensive AAW sub-task. This sub-task includes manoeuvring abilities associated with target detection, target classification, aspect control, countermeasures, measures to maintain survivability, hard kill engagement and target assessment. Speed: MCR

2.2.5 Anti Surface Warfare – ASuW

1. Anti surface warfare can include the following:

a. ASuW Ship to Ship;

b. ASuW Ship to Shore.

2.2.6 Mine Warfare – MIW

1. Mine warfare can include the following:

a. Mine hunting is a MIW sub task which includes manoeuvring abilities associated with deployment/recovery of towed equipment, transit over mine fields, target detection, identification and classification, deploying charges, moving outside mine range, mine detonation, target disposal and assessment. Speed: ZERO - SLOW

b. Mine sweeping is a MIW sub task which includes manoeuvring abilities associated with deployment/recovery of sweep equipment, towing sweep equipment, engaging sweep pattern, sweeping/detonating mines and assessment. Speed: 3 – 10 knots

c. Mine avoidance is a MIW sub task which includes manoeuvring abilities associated with transit through an area with underwater threats, deployment/recovery of underwater equipment, detection of underwater threats and manoeuvring outside threat range. Speed: ZERO - SLOW

2.2.7 Vehicle Interaction

1. Vehicle interaction can include the following:

a. Replenishment at sea (RAS);

b. Air vehicle interaction;

c. Sea vehicle interaction (other than RAS), including launch and recovery.

Speed: 8 -18 knots

2.3 MANOEUVRING ABILITIES

1. Relevant abilities for judging the manoeuvrability of naval surface ships were chosen. The list of abilities in Table 2 is the result of evaluations of currently used abilities for all ship types and surveys among operators of naval ships. Table 2 is limited to abilities which were considered relevant and important for assessing the manoeuvrability of naval ships.

2. For each ability in Table 2, a description and a definition of the criteria value is given. In general, there are no restrictions and/or specifications on how to achieve the criteria values; thus, it should also be acknowledged that the definitions differ somewhat from the descriptions in IMO MSC.137(76) (2002), which in general include conditions for the performance of the manoeuvring abilities.

3. ANEP-70 Vol. I (2021) provides updated definitions and manoeuvring abilities.

2.4 RANKING OF IMPORTANCE OF MANOEUVRING ABILITIES

1. During surveys of naval operators, rankings were obtained for the importance of various manoeuvring abilities. A scale 0 – 10 was used, where 10 indicates an ability which is considered as very important for a mission. A ranking below 5 can be interpreted as manoeuvring ability having secondary importance for the mission in question.

2. As expected, some spreading occurred for rankings provided by naval operators. However, it was found that in most cases the spread in ranking among operators for a given mission and manoeuvring ability was less than ± 2.

Table 2: Ability Descriptions and Definition of Criteria

ABILITY	UNIT	DESCRIPTION	DEFINITION OF CRITERIA
Course keeping	Degrees	Course keeping ability describes the accuracy with which the heading (i.e. straight course) is kept. Performance is typically assessed for deep water and calm environmental conditions, but also the effect of wind velocity and wind direction may be included.	Maximum allowed course deviation (95% probability).
Track keeping	Metres	The ability of keeping a given track describes the accuracy and the effort with which a straight track is followed under calm environmental conditions. However, the effects of wind velocity and wind direction on the performance may be included.	Maximum allowed track deviation (95% probability).
Yaw checking	Seconds	Describes the response of a ship to check (stop) a certain rate of turning. Of particular interest are the overshoot angles and the times necessary to check the yaw motion. Performance is typically assessed for deep water and calm environment conditions. However, the effects of wind velocity and wind direction on the performance may be included.	Time from order execute to stop yaw motion, for course changes up to 30 degrees.
Turning from rest	Seconds	Accelerating turning ability describes the response of the ship when accelerating from rest using combinations of propeller ahead and astern and auxiliary devices. Performance is typically assessed for deep water and calm environment conditions. However, the effects of wind velocity and wind direction on the performance may be included.	Time from order execute to turn to 90 degrees from rest.
Stopping	Ship lengths	Stop from ahead describes the response of the ship after active reversal of the propulsion. Performance is typically assessed for deep water and calm environment conditions. However, the effects of wind velocity and wind direction on the performance may be included.	Stopping distance (sF) (Initial speed to be stated).

Table 2: Ability Descriptions and Definition of Criteria (continued)

ABILITY	UNIT	DESCRIPTION	DEFINITION OF CRITERIA
Acceleration	Seconds	Acceleration describes the ability to increase the speed either from zero or from a given initial speed to a given target speed. Performance is typically assessed for deep water and calm environment conditions. However, the effects of wind velocity and wind direction on the performance may be included.	Time from order execute to accelerate from slow speed to a target speed. Initial speed and target to be specified.
Astern course keeping	Degrees	Astern steering control describes the ability to maintain a predetermined heading within reasonable limits when going astern, under calm environment conditions. However, the effects of wind velocity and wind direction on the performance may be included.	Maximum allowed course deviation (95% probability), when going astern.
Station keeping	Metres	Station keeping ability describes the ability to maintain a predetermined position despite environment disturbances in form of current, wind and waves. Station keeping may include the ability to maintain a predetermined heading	Maximum allowed position deviation (95% probability).
Slow speed	Knots	Minimum manoeuvring speed describes the minimum speed at which the ship can be fully controlled without interaction with other ships or maritime structures. Performance is typically assessed for deep water and calm environment conditions. However, the effects of wind velocity and wind direction on the performance may be included.	Minimum required speed for safe manoeuvring.

CHAPTER 3 MISSION ORIENTED MANOEUVRING REQUIREMENTS

3.1 BASIC CONSIDERATIONS

1. The proposed criteria are based on the results from the mission surveys. The following principles have been used in the development of the criteria values:

a. Overall ranking ≥ 5 (mean of all participating nations);

b. Participating nations (and ship types) ≥ 3;

c. Calm environmental conditions are defined as significant wave height $H_S \leq 0.01\ L$.

2. Table 3 gives rankings of importance for combinations of missions and manoeuvring criteria.

3.2 Initial Baseline Criteria Values for Naval Surface Ships

1. The results in Table 3 show that some abilities are considered important for all missions. These results have been used to develop initial baseline criteria given in Table 4, with IMO MSC.137(76) (2002) providing criteria for non-military ships. Criteria in Table 4 can be divided into requirements at low speed and at transit speed.

3.3 Proposed Criteria for Naval Surface Ships

1. Table 5 shows proposed manoeuvring criteria for naval surface ships.

2. The following comments apply to the proposed values:

a. The criteria reflect in general the desired performance as formulated by the operators;

b. In general, it is not specified how to meet the criteria; thus, navies are free to select technologies that will achieve specified criteria;

c. The criteria should be used in context with the rankings, which can be used when considering adjustment of individual criteria;

d. The criteria in Table 5 should be considered as recommendations rather than as stringent values.

Table 3: Mean Ranking Values for Combinations of Missions and Turning Abilities

	T & P Point to point	HM	ASW proact	ASW react	AAW	MIW hunt	MIW swp	MIW avoid	RAS
Course keeping	**8**	**9**	**9**	**7**	**7**	**8**	**9**	**8**	**9**
Track keeping		**8**	**(6)**	**(5)**		**10**	**10**	**9**	
Turning	**6**	**9**	**9**	**9**	**7**	**8**	**7**	**7**	**5**
Initial turning	**6**	**8**	**8**	**9**	**7**	**7**	**9**	**9**	**9**
Yaw checking	**6**	**8**	**8**	**9**	**7**	**7**	**8**	**8**	**8**
Turning from rest		**9**				**9**	**(5)**	**6**	
Stopping		**9**			**5**	**8**	**5**	**7**	
Acceleration		**(7)**	**8**	**9**	**8**				**5**
Astern course keep.		**8**				**5**		**5**	
Station keeping		**(6)**				**9**		**7**	**(7)**
Slow speed		**8**				**8**	**6**	**7**	

Note: Ranking values in brackets denote abilities with ranking ≥ 5 but where no criteria could be attributed.

Table 4: Initial Baseline Manoeuvring Criteria

Ability	**Units**	**Proposed criteria value**		**IMO requirement**
		Transit speed	Slow speed	
Course keeping	deg	± 4	± 4	-
Turning y_{0180}/L	-	3	2	5 ship lengths
Initial turning	s	10	10	2.5 (length/speed)
Yaw checking	s	7	10	*

* IMO defines yaw checking but refers to overshoot angles

Table 5: Proposed Manoeuvring Criteria Values for Naval Ships

Ability	**Units**	T & P	HM	ASW pro	ASW react	AAW	MIW hunt	MIW swp	MIW avoid	RAS
Mission speed	knots	15-MDS	0-6	0-80% MDS	MDS	MDS	0-6	3-10	0-6	8-18
Course keeping	deg	±4	±4	±3	±3	±5	±3	±3	±3	±2
Track keeping	m		±10				±5	±7	±7	
Tactical diameter y_{0180}/L	-	3	2	3	3	3	2	5	3	3
Initial turning	s	10	10	5	5	15	10	10	10	7
Yaw checking	s	7	10	7	7	7	7	7	7	7
Turning from rest	s		30				30		30	
Stopping s_F/L	-		1			2	1.5	2	2	
Acceleration	s			30	45	30				30
Astern course keep.	s		±5				±4		±7	
Station keeping	m						±10		±10	
Slow speed	knots		3	4			2	4	3	

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CHAPTER 4 DISCUSSION AND ANALYSIS

4.1 DISCUSSION OF FEASIBILITY OF MANEOUVRING CRITERIA VALUES ARISING FROM OPERATOR SURVEY

1. Criteria values presented in the previous chapter reflect the requirements for specific missions. The realism and feasibility of these values is discussed in this chapter.

2. The values emerging from the operator surveys are more stringent than those requested by the International Maritime Organization in IMO MSC.137(76) (2002). This is to be expected, since IMO criteria represent a minimum safety standard for all seagoing ships, while the mission-oriented approach encourages superior performance.

3. The majority of the most stringent values are related to ships which have to perform the MIW mission, and which are usually equipped with more effective manoeuvring devices.

4. To evaluate the feasibility of the proposed criteria, a scale of difficulty has been assigned as follows:

1 = Easily achievable. The majority of existing ships can already fulfil the criteria;

2 = Moderately demanding. Approximately 50% of existing ships can already fulfil the criteria;

3 = Demanding. A small portion of existing ships can already fulfil the criteria;

4 = Very demanding/Impossible. Requires significant ship improvements to be fulfilled.

5. Table 6 summarizes the assessed feasibility of the manoeuvring criteria developed from the operator survey. Related tables used for developing the summary are given in Annex D.

6. It is evident that some of the requirements are difficult to meet, especially for initial turning and yaw checking.

7. The feasibility of many criteria is dependent upon the associated mission speed. For example, AAW has higher mission speeds, leading to challenges meeting criteria for turning, stopping, and acceleration.

8. Speed influence is also related to acceleration and stopping ability, for which the initial and final velocity are very important. In particular, extreme velocity variations, such as those connected to a slam start or a crash stop, seem to be unachievable in the desired times obtained from the survey.

9. Finally, as regards turning from rest, the request to turn a ship 90° in 30 seconds seems to be very demanding (with an average yaw rate of 3°/s), even if using all the devices and considering the possible presence of thrusters.

10. As a general comment, it seems to be important to evaluate the influence of speed on the required criteria values, since in some cases it appears that the answers to the survey were given neglecting speed or implicitly referring to different scenarios. The most evident

example is probably the value of 2 ship lengths obtained for stopping ability and AAW (which is related to MCR); this value is likely unfeasible but at the same time not essential for this mission.

Table 6: Feasibility of Manoeuvring Criteria Obtained from the Operator Survey

Ability	Criteria achievable with present technology	Criteria requiring significant improvements
Course keeping	All	-
Track keeping	HM, MIW	-
Turning	HM, MIW, (RAS)	ASW, AAW, T&P
Initial turning	-	All
Yaw checking	-	All
Turning from rest	MIWh, MIWa	HM
Stopping	HM, MIW	AAW
Acceleration: moderate speed increase (5 – 10 knots)	ASW, AAW, RAS	
Acceleration: large speed increase (0 – maximum design speed)		ASW, AAW, RAS
Astern course keeping	HM, MIWa, MIWh	
Station keeping	MIWh, MIWa	
Slow speed	HM, ASW pro, MIW	

4.2 LEGACY DATA FOR SHIP MANOEUVRING PERFORMANCE

1. Manoeuvring performance data for existing naval ships, referred to as legacy data, were collected to assist with the development of realistic manoeuvring criteria. Table 7 gives the number of ships categorised by type for the legacy data. Note that 2 of the Type 3 (mine counter measures) ships are sister ships.

2. In the following presentation of legacy data, only results for Type 1 (cruiser, destroyer, frigate, corvette) are given due to number of ships available.

3. Additional results from legacy data are presented in Annex B.

Table 7: Number of Ships by Type for Legacy Manoeuvring Data

Ship type	**Number of ships**
Type 1: Cruiser, destroyer, frigate, corvette (ships with $L/\nabla^{1/3} > 6.7$)	23
Type 2: Auxiliary, logistic, amphibious (ships with $L/\nabla^{1/3} < 6.7$)	4
Type 3: Mine counter measures	9 (2 sister)
Type 4: Patrol vessels and light vessels	8

4.2.1 Turning

1. Legacy data for tactical diameter at maximum rudder angle of 35 deg are presented in Figure 1, which includes the influence of Froude number. Most of the Type 1 naval ships meet the IMO requirement of tactical diameter being less than 5 ship lengths.

2. Figure 1 shows that tactical diameter for legacy ships tends to increase with increasing Froude number. At the target value of 3 ship lengths, in particular, it can be observed that less than 20% of the data meet the criteria, whereas for Fn higher than 0.4, none of the ships meets the criteria.

3. Additional data for tactical diameter are presented in Annex B.

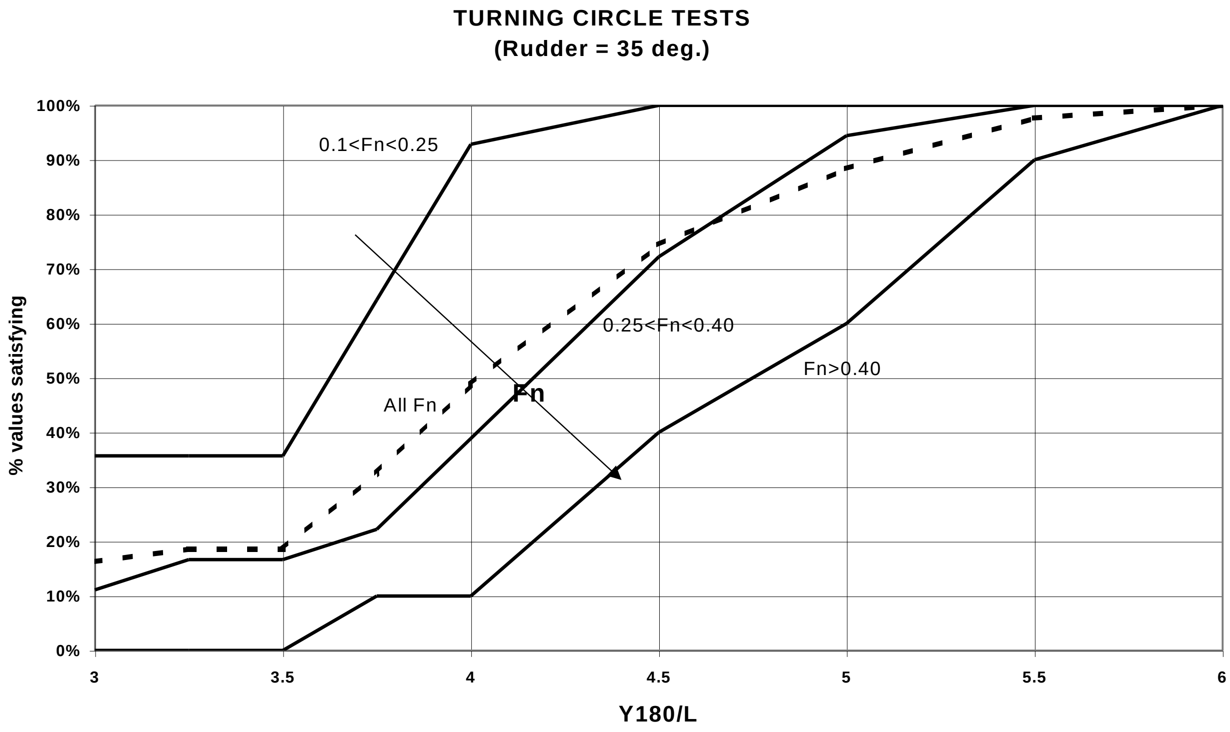

Figure 1: Influence of Ship Speed on Tactical Diameter for Existing Type 1 Ships (Cruiser, Destroyer, Frigate, Corvette)

4.2.2 Initial Turning

1. Figure 2 gives initial turning times t_{10} from 10/10 zig-zag manoeuvres for Type 1 ships (cruiser, destroyer, frigate, corvette).

2. The line giving the IMO limit in Figure 2 is based on the assumption that ship velocity *V* is constant during the manoeuvre.

3. Most of the legacy data satisfy the IMO limits for initial turning; however, the proposed criteria for naval ships are more demanding. Figure 2 indicates that the proposed initial turning requirements can only be met at the highest ship speeds.

4. Improved initial turning ability can be achieved by increasing rudder rotational velocity and rudder effectiveness.

5. The following considerations can be made:

   a. Due to the small amount of data on the 10°/10° zig-zag manoeuvre, criteria validation is difficult. Moreover, the definition of the criteria is not fully in accordance with the zig-zag manoeuvre, since the criteria do not specify rudder angle (the ability refers to a “moderate helm”).

b. The IMO limit in the figure is an approximation of the effective limit; it assumes that the ship velocity is constant during the manoeuvre (IMO criteria require less than 2.5 ship lengths to reach a heading variation of 10° with a rudder angle of 10°).

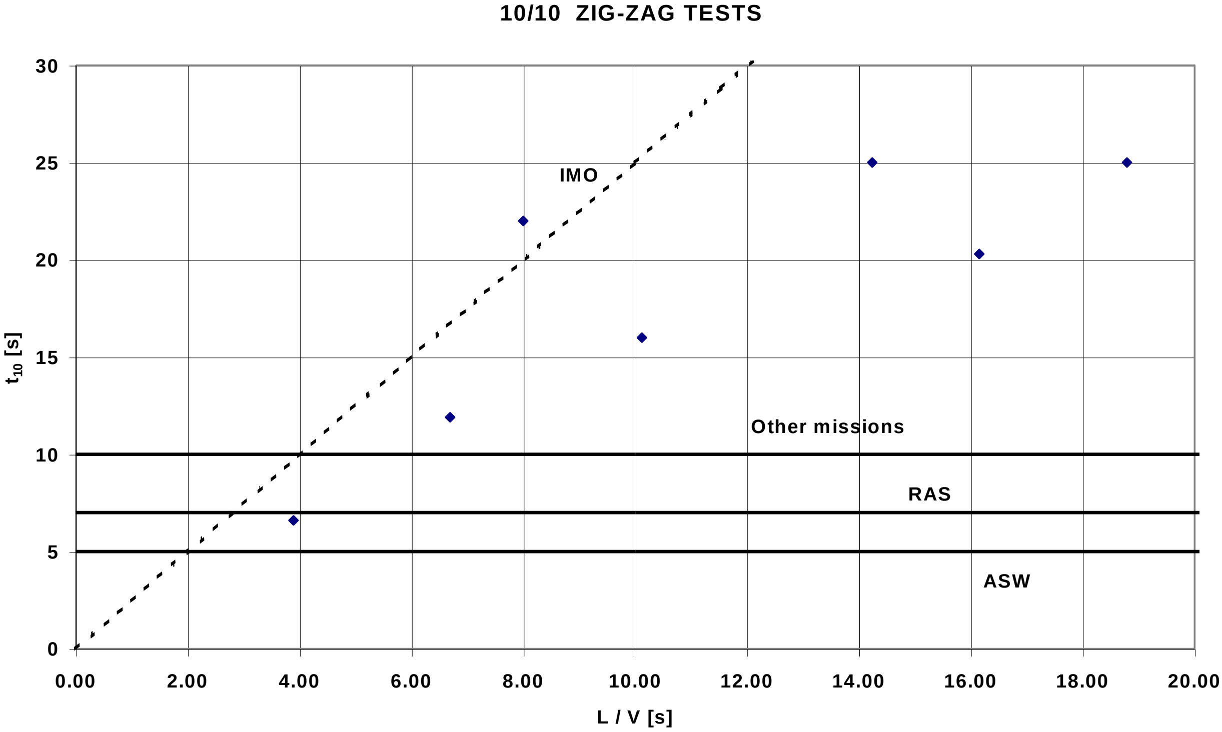

Figure 2: Initial Turning Ability from 10/10 Zig-zag Tests for Existing Type 1 Ships (Cruiser, Destroyer, Frigate, Corvette)

4.2.3 Yaw Checking

1. Figure 3 gives yaw checking times from 20/20 zig-zag manoeuvres for Type 1 ships (cruiser, destroyer, frigate, corvette). The harbour manoeuvring criterion of 10 s is not shown on the diagram since manoeuvres in harbour can be made with auxiliary propulsion devices; the performance assessment of these devices is not suitable for a traditional zig-zag manoeuvre assessment.

2. Figure 3 indicates that the legacy Type 1 ships are only able to meet the target value at high ship speeds.

3. The definition of the ability in the survey is not in accordance with the usual zig-zag manoeuvre, since counter rudder in the criteria can be up to the maximum rudder angle; moreover, the initial turning rate could influence the time to check yaw.

4. Most of the legacy data satisfy the IMO criteria. The new criteria values obtained from the operator survey set more stringent limits, with most of the observed values not satisfying them. The legacy data show strong speed dependence. For example, a vessel length of 100

metres and a velocity of 28 knots (L/V about 7 seconds) sets the criterion value at 7 seconds, which would be unachievable for most of the legacy ships, and the same requirement at a lower speed would be more demanding.

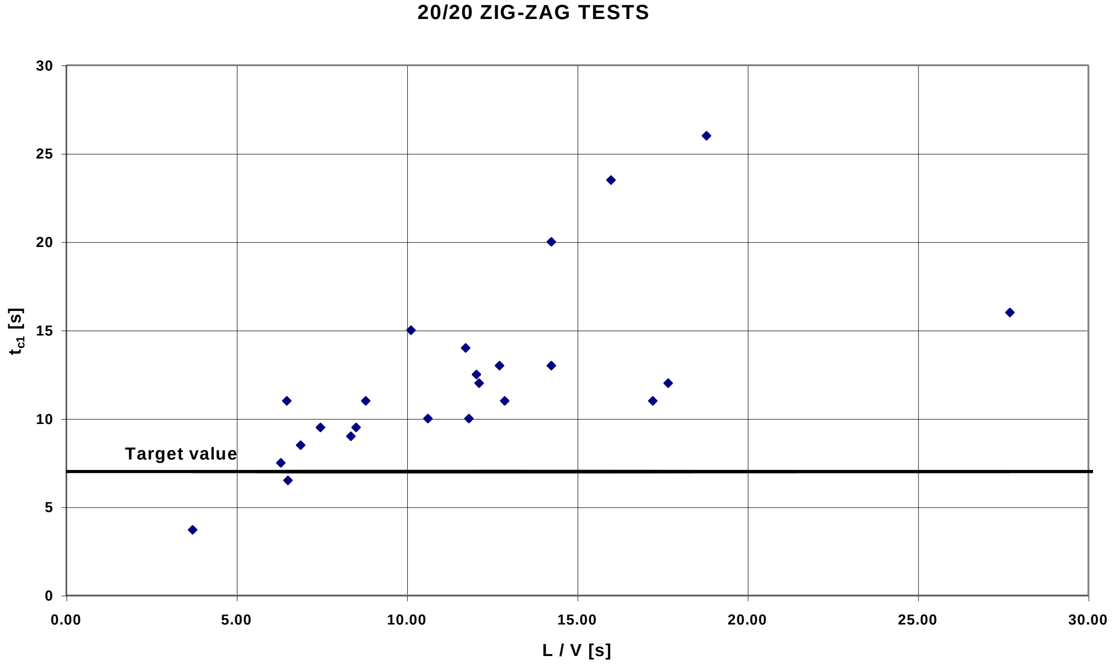

Figure 3: Yaw Checking from 20/20 Zig-zag Tests for Existing Type 1 Ships (Cruiser, Destroyer, Frigate, Corvette)

4.2.4 Stopping

1. The values of the criteria obtained refer mainly to low speed missions (HM and MIW). The criteria values are not comparable to the usual crash stop manoeuvre from MCR or to the other data about stopping manoeuvres collected in the legacy database, which are related to initial velocities higher than the slow speeds of HM and MIW (the legacy data are given in Annex B, Figure 7).

2. The only value which can be compared to the legacy database is the one obtained for AAW mission, which, in accordance with the definition, considers the MCR speed. The legacy database is obtained from stopping manoeuvres with different initial velocities; thus, the lower values often do not correspond to the maximum velocity reduction. Almost all the stopping distances of existing ships are higher than the criteria; however, the IMO requirement is easily met by naval vessels.

4.3 CONCLUDING REMARKS ON ANALYSIS

1. The objective of this document is to obtain naval ship manoeuvring criteria that can incorporate operator input regarding mission requirements.

2. The proposed manoeuvring criteria for naval ships are usually more stringent than those required for commercial ships (IMO criteria). In some cases, the proposed manoeuvring criteria would dictate significant improvements in the manoeuvring characteristics of naval vessels. Consequently, the proposed manoeuvring criteria should be considered as guidance rather than absolute limits.

3. Research and development will be required to obtain significant manoeuvring improvements for naval vessels. The impact of such improvements on other ship characteristics (e.g., operability, signature, shock performance) must be considered carefully.

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CHAPTER 5 SAFETY

5.1 GENERAL

1. Manoeuvrability is one of many factors influencing the safety of a ship at sea. Safety in the context of manoeuvrability can be divided into:

   a. Onboard aspects;

   b. Environmental aspects.

2. Onboard aspects of safety consider the well-being of the ship and its crew.

3. Environmental aspects of safety consider potential damage to the environment external to the ship. For example, a collision arising due to poor manoeuvring performance of a ship could cause significant damage to the natural environment and to other vessels. IMO MSC.137(76) (2002) addresses general manoeuvring requirements associated with collision avoidance.

5.2 SAFETY AND NAVAL MISSIONS

1. Naval ships are designed to achieve manoeuvring performance needed for military applications, derived from high performance requirement for sensors and weapon systems and in accordance with the naval mission-oriented requirements presented herein. These requirements result in criteria which are far more stringent than those recommended for commercial vessels.

2. The operation of naval ships includes manoeuvring situations that are challenging relative to those experienced by merchant ships. Examples of challenging manoeuvring situations include sharp turns at high speed, sailing close to other ships, and travelling at high speed in following/quartering seas. These situations place significant demands on ships and their operators.

3. In addition to meeting requirements for manoeuvring in calm water, a naval ship must possess an adequate range of stability in all operating conditions and must also be manoeuvrable during heavy weather.

5.3 SHIP DESIGN

1. Ship design for strong manoeuvring performance can utilize various tools, including analytic methods, simulations, and physical model tests. All aspects influencing ship safety must be considered during design.

5.4 OPERATORS

1. Well trained operators are essential for safe operation of naval ships.

2. Onboard information regarding ship manoeuvring performance can greatly assist operators in maintaining the safety and performance of a naval ship. Guidance on the presentation of onboard manoeuvring information is given in ANEP-70 Vol. II (2021).

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ANNEX A MANOEUVRABILITY SURVEY OF NAVAL OPERATORS

1. Surveys of naval operators were conducted to provide guidance for the development of naval ship manoeuvring criteria.

2. A mission-orientated approach was used for development of manoeuvring criteria. Alternatively, a bottom-up approach could have been used based on different ship types (e.g., frigates, corvettes, destroyers, etc.). Organization of the work by naval missions was believed to be a superior approach because a reference to any specific ship type, such as a frigate, does not necessarily clearly consider the intended purpose of the ship.

3. Surveys with experienced operators of naval ships were conducted to inform the mission-orientated approach. The main aim of each survey interview was to obtain, for a particular mission, perceived importance rankings and criteria values for all manoeuvring abilities.

A.1 COMPLETED SURVEYS

1. Table 8 gives a summary of surveys that were completed. Although additional missions were considered, results were not obtained due to challenges including lack of time and concerns regarding confidentiality.

Table 8: Completed Surveys of Naval Operators

Mission	Lead nation	Sub mission	Number of nations
Transit and Patrol	France	Point to point	4
		Search and rescue	2
		OPMS	2
Harbour Manoeuvring *Note: 2 nations gave results for 2 ship types*	Poland	Aggregated results (mooring, anchoring and towing)	7
Anti Submarine Warfare	Norway	ASW reactive	6
		ASW proactive	6
Anti Air Warfare *Note: 1 nation provided importance rankings but no criteria.*	Germany	Aggregated results (reactive and proactive)	7
Mine Warfare	Sweden	Hunting	7
		Sweeping	5
		Avoidance	6
Vehicle interaction	UK	RAS Abeam	4

A.2 SURVEY RESULTS FOR NON-WARFARE MISSIONS

1. Results from naval operator surveys for non-warfare missions are given as importance rankings in Table 9 and as recommended manoeuvring criteria in Table 10.

Table 9: Importance Rankings from Naval Operators for Manoeuvring Performance during Non-warfare Missions

	Transit and Patrol Point to point	Harbour manoeuvring	Replenishment at sea
Course keeping	8	9	9
Track keeping	4	8	4
Turning	6	9	5
Initial turning	6	8	9
Yaw checking	6	8	8
Turning from rest	3	9	2
Stopping	3	9	4
Acceleration	4	7	5
Astern course keeping	1	8	0
Station keeping	2	6	7
Slow speed	4	8	1

Table 10: Recommended Manoeuvring Criteria from Naval Operators for Non-warfare Missions

	Unit	Transit and Patrol Point to point		Harbour manoeuvring		Replenishment at sea	
		Mean	Min Max	Mean	Min Max	Mean	Min Max
Course keeping	deg	±4	±3 ±5	±4	±1 ±10	±2	±0.5 ±5
Track keeping	m			±10	±1 ±100		
Tactical diameter y_{0180}/L	-	3	1.5 7	2	1 4	3	2 4
Initial turning	s	10	6 20	10	2 20	7	2 15
Yaw checking	s	7	5 10	10	2 20	7	3 12
Turning from rest	s			30	15 90		
Stopping s_F/L	-			1	0.5 2		
Acceleration	s				3 90	30	10 45
Astern course keeping	deg			5	3 10		
Station keeping	m				±4 ±60		±5 ±10
Slow speed	knots			3	0 5		

A.3 SURVEY RESULTS FOR WARFARE MISSIONS

1. Results from naval operator surveys for warfare missions are given as importance rankings in Table 11 and as recommended manoeuvring criteria in Table 12.

Table 11: Importance Rankings from Naval Operators for Manoeuvring Performance during Warfare Missions

	ASW proactive	ASW reactive	AAW	MIW hunting	MIW sweeping	MIW avoidance
Course keeping	9	7	7	8	9	8
Track keeping	6	5	4	10	10	9
Turning	9	9	7	8	7	7
Initial turning	8	9	7	7	9	9
Yaw checking	8	9	7	7	8	8
Turning from rest	4	3	3	9	5	6
Stopping	4	4	5	8	5	7
Acceleration	8	9	8	4	3	3
Astern course keeping	0	1	0	5	3	5
Station keeping	4	3	4	9	4	7
Slow speed	6	3	4	8	6	7

Table 12: Recommended Manoeuvring Criteria from Naval Operators for Warfare Missions

	Unit	ASW proactive		ASW reactive		AAW		MIW hunting		MIW sweeping		MIW avoidance	
		Mean	Min Max	Mean	Min Max	Mean	Min Max	Mean	Min Max	Mean	Min Max	Mean	Min Max
Course keeping	deg	±3	±1 ±5	±3	±1 ±5	±5	±3 ±10	±3	±2 ±5	±3	±2 ±10	±3	±2 ±5
Track keeping	m		±10 ±20		±10 ±15			±5	±1 ±10	±7	±5 ±10	±7	±5 ±15
Tactical diameter y_{0180}/L	-	3	1,5 5	3	2 5	3	1 5	2	1 3	5	3 10	3	2 4
Initial turning	s	5	3 10	5	3 10	15	10 20	10	5 20	10	6 20	10	5 20
Yaw checking	s	7	5 10	7	5 10	7	5 10	7	5 10	7	5 10	7	5 10
Turning from rest	s							30	12 60			30	30 90
Stopping s_F/L	-					2	1 4	1.5	1 3	2	1 3	2	1 3
Acceleration	s	30	15 60	45	30 60	30	30 30						
Astern course keeping	deg							±4	±4 ±5			±7	±4 ±10
Station keeping	m							±10	±5 ±L			±10	±5 ±L
Slow speed	knots	4	3 6					2	0 4	4	<4 4	3	2 4

A.4 COMMENTARY ON OPERATOR SURVEY RESULTS

1. Values for both importance rankings and manoeuvring criteria have significant spread due to differences among navies and individual operators.

2. As mentioned in Section 4-1, the following scale has been developed to communicate the perceived difficulty achieving proposed criteria:

1 = Easily achievable. The majority of existing ships can already fulfil the criteria;

2 = Moderately demanding. Approximately 50% of existing ships can already fulfil the criteria;

3 = Demanding. A small portion of existing ships can already fulfil the criteria;

4 = Very demanding/Impossible. Requires significant ship improvements to be fulfilled.

3. The difficulty of achieving various manoeuvring criteria is discussed below.

A.4.1 Course Keeping

1. Table 13 gives course keeping criteria based on operator survey results. In general, the criteria are not overly demanding, and can be achieved with a suitable autopilot system. Naval ships are typically specified to have directional stability, which contributes to course keeping ability.

2. Course keeping criteria are often more difficult to meet with smaller ships, which are more influenced by environmental effects. The values given in Table 13 are representative of ships that have sizes similar to corvettes and frigates.

3. For ships requiring replenishment at sea, particular attention must be given to the stringent course keeping requirement for RAS.

Table 13: Course Keeping Criteria and Difficulty Achieving

Mission	Related speed	Value	Difficulty achieving
RAS	8-18 knots	±2 deg	2
ASW proactive, ASW reactive, MIWh, MIWa, MIWs	0-MDS	±3 deg	2
T&P, HM	0-MDS	±4 deg	1
AAW	MDS	±5 deg	1

A.4.2 Track Keeping

1. Table 14 gives track keeping criteria based on operator survey results. Track keeping is often specified for harbour manoeuvring at slow speed. Introduction of devices such as transversal thrusters to meet harbour manoeuvring requirements can cause problems in other areas, such as ship signatures.

2. The most stringent track keeping criteria are associated with MIW. Fortunately, these criteria are relatively easy to meet.

Table 14: Track Keeping Criteria and Difficulty Achieving

Mission	Related speed	Value	Difficulty achieving
MIWh	0-slow	±5 m	2
MIWa, MIWs	0-10 knots	±7 m	2
HM	0- slow	±10 m	2

A.4.3 Turning

1. Table 15 gives tactical diameter criteria based on operator survey results. The basic ship requirement for almost all the missions analysed is to have a tactical diameter not exceeding 3 ship lengths. This value is demanding for most ships, especially for the highest velocities and for ships with high directional stability.

2. The low tactical diameter requested for HM is generally achievable due to freedom to select various devices (e.g., bow thrusters) and operational modes.

3. Note that legacy data were available for tactical diameter. These legacy data significantly influenced final recommended manoeuvring criteria.

Table 15: Tactical Diameter Criteria and Difficulty Achieving

Mission	Related speed	Value y_{0180}/L	Difficulty achieving
HM, MIWh	0-slow	2	1
MIWa	0-slow	3	1
RAS	8-18 knots	3	3
ASW proactive, ASW reactive, AAW, T&P	15 knots-MDS	3	4
MIWs	3-10 knots	5	1

A.4.4 Initial Turning

1. Table 16 gives initial turning criteria based on operator survey results. As expected, longer initial turning times are generally associated with slower ship speeds.

2. Available legacy data from zig-zag 10/10 tests influenced final recommended values.

Table 16: Initial Turning Criteria and Difficulty Achieving

Mission	Related speed	Value	Difficulty achieving
ASW proactive, ASW reactive	0-MDS	5 s	4
RAS	8-18 knots	7 s	4
T&P, HM, MIWh, MIWs, MIWa	0-MDS	10 s	3
AAW	MDS	15 s	2

A.4.5 Yaw Checking

1. Table 17 gives yaw checking criteria based on operator survey results. The yaw checking criteria are difficult to achieve.

Table 17: Yaw Checking Criteria and Difficulty Achieving

Mission	Related speed	Value	Difficulty achieving
T&P, ASW pro, ASW react, AAW, MIWh, MIWs, MIWa	0-MCR	7 s	3-4
HM	0-slow	10 s	3

A.4.6 Turning from Rest

1. Table 18 gives turning from rest criteria based on operator survey results. The turning from rest criterion for harbour manoeuvring is difficult to achieve. This ability is considered important only for missions related to slow speeds, thus implicitly considering all auxiliary manoeuvring devices.

Table 18: Turning from Rest Criteria and Difficulty Achieving

Mission	Related speed	Value	Difficulty achieving
HM	0-slow	30 s	4
MIWh, MIWa	0-slow	30 s	2

A.4.7 Stopping

1. Table 19 gives turning stopping criteria based on operator survey results. The values are low in all cases. As expected, difficulty achieving is very dependent on both specified value and initial ship speed.

Table 19: Stopping Criteria and Difficulty Achieving

Mission	Related speed	Value s_F/L	Difficulty achieving
HM	0-slow	1	2
MIWh	0-slow	1.5	2
MIWs, MIWa	0-10 knots	2	2
AAW	MDS	2	4

A.4.8 Acceleration

1. Table 20 gives acceleration criteria based on operator survey results. Difficulty achieving is highly dependent on allowable time and the required speed change.

Table 20: Acceleration Criteria and Difficulty Achieving

Mission	Speed change	Value	Difficulty achieving
ASW proactive, AAW, RAS	0 to MDS	30 s	2-4
ASW reactive	0 to MDS	45 s	2-4

A.4.9. Astern Course Keeping

1. Table 21 gives astern course keeping criteria based on operator survey results. Astern course keeping ability is related primarily to slow speed manoeuvres typical of minehunters and harbour operations.

Table 21: Astern Course Keeping Criteria and Difficulty Achieving

Mission	Related speed	Value	Difficulty achieving
MIWh	0-slow	±4 deg	2
HM	0-slow	±5 deg	2
MIWa	0-slow	±7 deg	1

A.4.10 Station Keeping

1. Table 22 gives a station keeping criterion based on operator survey results. The criterion appears to be relatively easy to meet provided that the ship is suitably equipped.

Table 22: Station Keeping Criteria and Difficulty Achieving

Mission	Speed change	Value	Difficulty achieving
MIWh, MIWa	0-slow	±10 m	2

A.4.11 Slow Speed Operation

1. Table 23 gives slow speed operation criteria based on operator survey results. Note that mine hunting vessels are typically designed to facilitate slow speed operation.

Table 23: Slow Speed Operation Criteria and Difficulty Achieving

Mission	Speed change	Value	Difficulty achieving
MIWh	0-slow	2 knots	2
HM, MIWa	0-slow	3 knots	1
ASW proactive, MIWs	0-80% MDS	4 knots	1

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ANNEX B OBSERVED MANOEUVRING PERFORMANCE FOR ALL SHIP TYPES FROM LEGACY DATABASE

1. This annex gives observed performance for all ship types from the legacy database (see Table 7).

B.1 TURNING CIRCLE

1. Figure 4 gives tactical diameters for all ship types in the legacy database. Figure 4 includes the limit from IMO MSC.137(76) (2002) and the target value from the operator surveys for higher speed missions.

TURNING CIRCLE TESTS
(Rudder = 35 deg.)

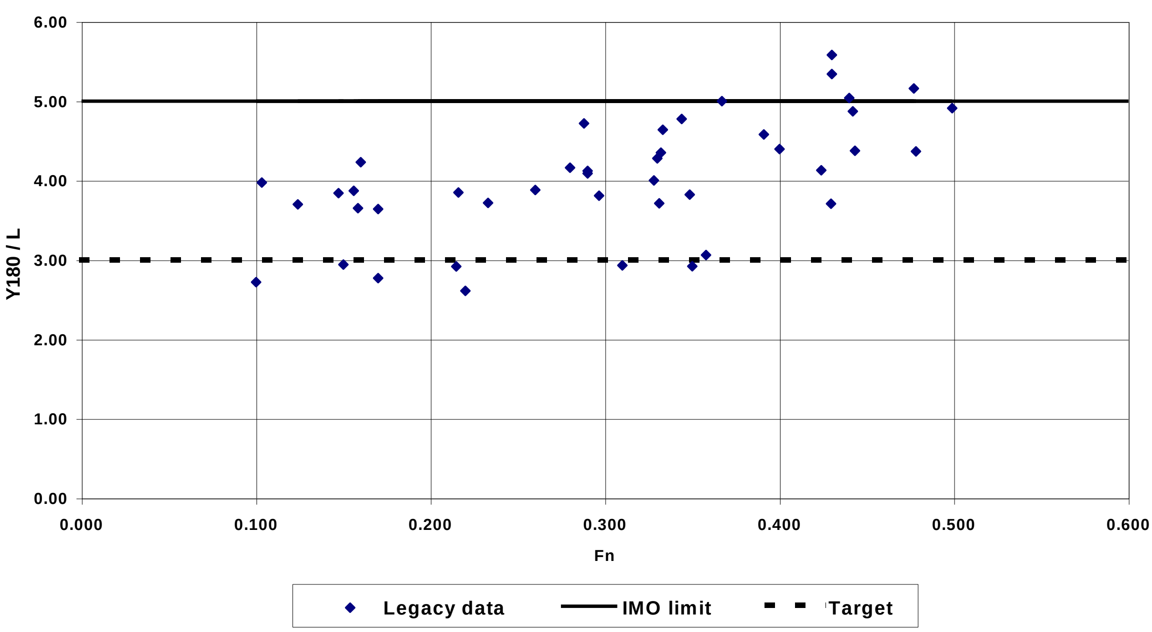

Figure 4: Tactical Diameter for All Ship Types in Legacy Database

B.2 YAW CHECKING

1. Figure 5 and Figure 6 give yaw checking for 10/10 zig-zags and 20/20 zig-zags from legacy data for all ship types.

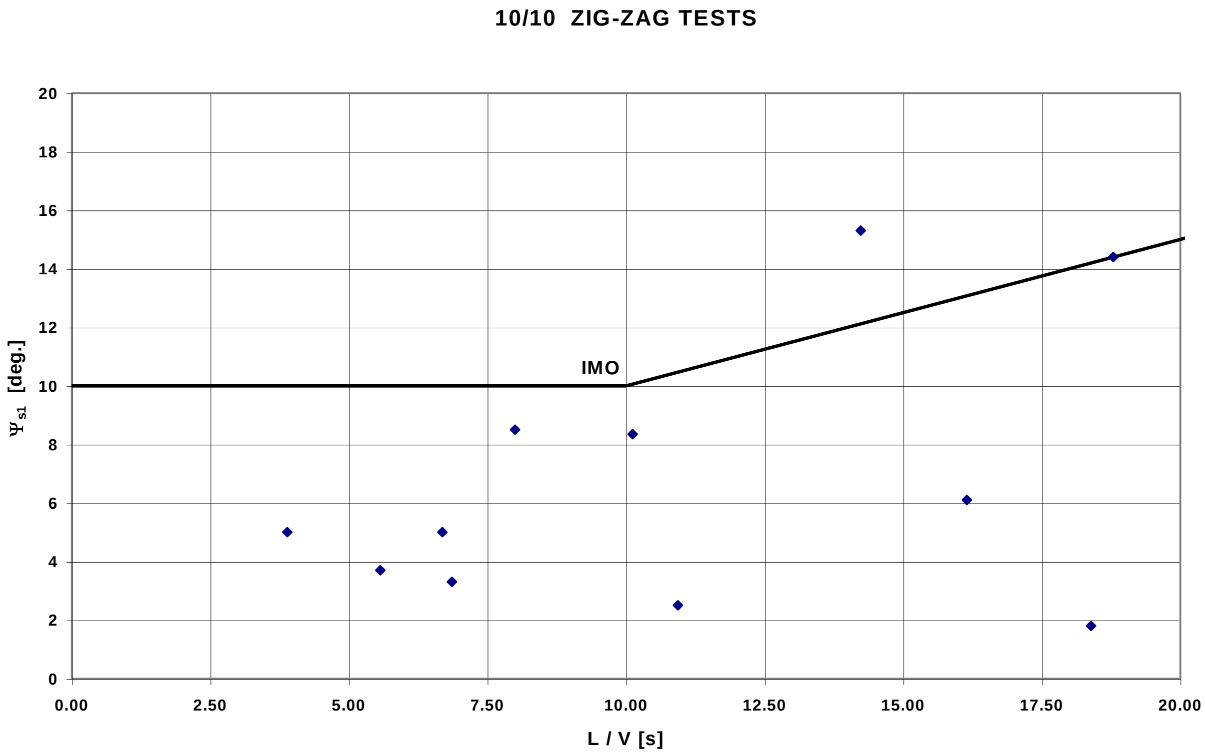

Figure 5: Yaw Checking for 10/10 Zig-zags from Legacy Data for All Ship Types, with IMO Criteria

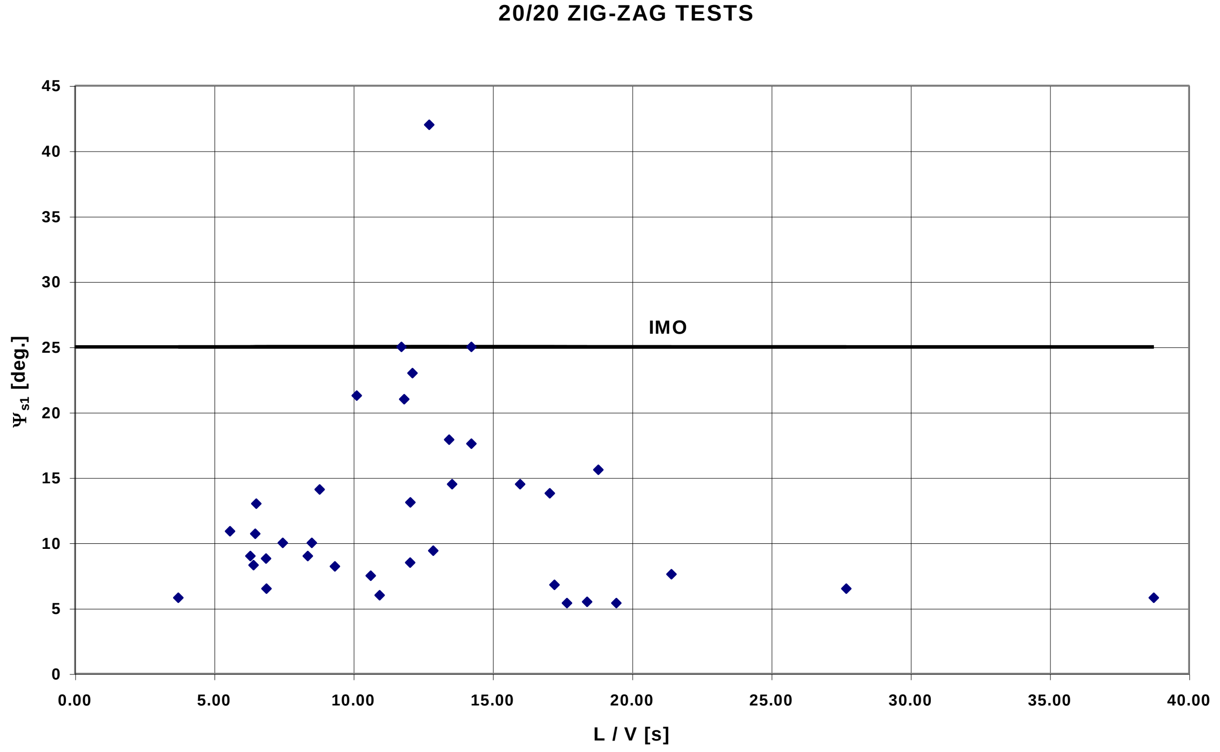

Figure 6: Yaw Checking for 20/20 Zig-zags from Legacy Data for All Ship Types, with IMO Criteria

B.3 STOPPING

1. Figure 7 gives stopping results from legacy data for all ship types.

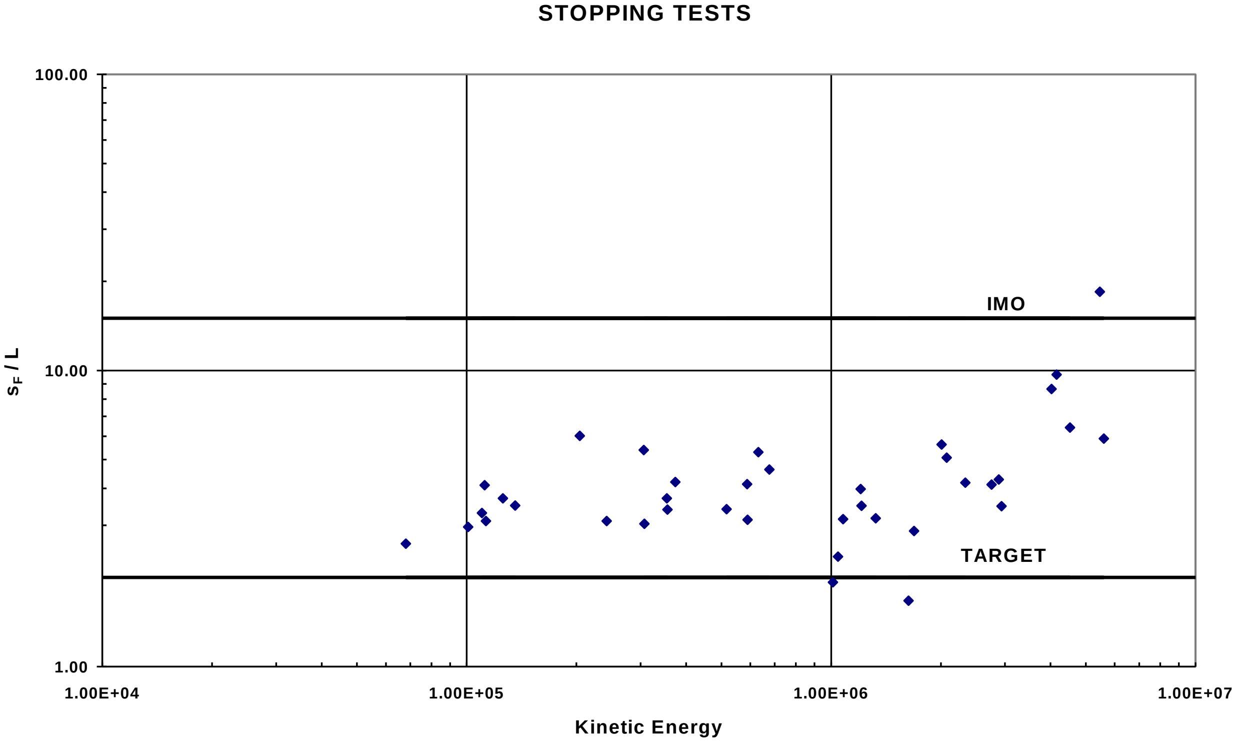

Figure 7: Stopping from Crash-stop Legacy Data for All Ship Types, with IMO Criterion and Target Value from Operators for AAW Mission

ANNEX C DISCUSSION OF INDIVIDUAL MANOEVRING ABILITIES

C.1 INITIAL TURNING

1. Reference to IMO Resolutions: IMO A.601(15) (1987) regarding onboard guidance requires data for the initial turning ability. IMO MSC.137(76) (2002) regarding manoeuvring standards includes the following requirement for the time to reach 10° change of heading, t_{10}, with a trial rudder angle of $\delta_{Ri} = 10°$:

$$t_{10} \leq 2.5 \cdot L_{PP} / V_0.$$

2. The typical initial speed for a trial is defined close to the maximum speed.

3. Assessment in Annex A: Table 9 and Table 11 show that initial turning ability ranked most relevant (at least 5 out of 10 possible points) for all 11 missions/sub-missions. The averaged requirements included in this ANEP range between extreme values of:

$t_{10} \leq 5$ s for ASW–P and ASW–R,

$t_{10} \leq 7$ s for RAS,

$t_{10} \leq 10$ s for P-to-P, for HM and for MW–A, MW–H, MW–S,

$t_{10} \leq 15$ s for AAW.

3. These performance requirements should be seen in the context of the typical ship speeds for the missions/sub-missions. Assessment of the requirements ranged from “moderately demanding” in the case of AAW, to “demanding” in the cases of the TaP point-to-point sub-mission, the HM mission and the three sub-missions of MW, and to “very demanding/impossible” in the cases of the two sub-missions of ASW and of the RAS mission.

4. A major concern regarding the developed requirements is that their dimensional form (units s) discriminates against larger and/or slower ships.

5. Tactical implications: Tactical implications could include the risk of excessive underwater noise generation, which could limit the allowable rudder angle

C.2 TURNING

1. Reference to IMO Resolutions: IMO A.601(15) (1987) requires data on turning ability to be included in the manoeuvring booklet as well as the wheelhouse poster. IMO MSC.137(76) (2002) includes requirements for advance and tactical diameter under full rudder:

$x_{090} \leq 4.5 \cdot L_{PP}$ and
$y_{0180} \leq 5 \cdot L_{PP}$

2. The initial speed for a trial is typically defined close to the maximum speed.

3. Assessment in Annex A: Table 9 and Table 11 show that turning ability ranked most relevant (at least 5 out of 10 possible points) for all 11 missions/sub-missions. The averaged requirements for tactical included in this ANEP are as follows:

$y_{0180} \leq 2 \cdot L_{PP}$ for HM and MW–H,

$y_{0180} \leq 3 \cdot L_{PP}$ for the other missions and sub-missions,

$y_{0180} \leq 5 \cdot L_{PP}$ for MW–S.

4. These performance requirements should be seen in the context of the typical ship speeds for the missions/sub-missions. Assessment of the requirements in Table 15 ranged as follows:

a. "easily achievable" in the cases of HM and the three MW sub-missions;

b. "demanding" in the case of the RAS mission;

c. "very demanding/impossible" in the cases of the TaP and AAW missions as well as the two ASW sub-missions, which are performed up to higher speeds.

5. Tactical implications: Tactical implications could include the risk of excessive underwater noise generation, which could limit the allowable rudder angle and/or propulsor support. Other limitations could include stability requirements in high-speed turns.

C.3 ACCELERATING TURNING

1. Reference to IMO Resolutions: IMO A.601(15) (1987) requires data on the turning ability for the manoeuvring booklet. There is no requirement for accelerating turning ability in the manoeuvring standard IMO MSC.137(76) (2002).

2. Assessment in Annex A: Table 9 and Table 11 show that accelerating turning ability ranked most relevant (at least 5 out of 10 possible points) for the missions/ submissions HM, MW–H and MW–A, which are typically performed at low speed. The requirements included in this ANEP are for an accelerating turning time, and are averaged values for a time ≤ 30 s. Feasibility assessment of these requirements in this ANEP was "moderately demanding" for the two MW sub-missions and "very demanding/impossible" for HM. The stringent proposed criteria are likely based on the expectation that mine counter-measure vessels are highly manoeuvrable.

3. Tactical implications: Tactical implications could include the risk of excessive underwater noise generation, which could limit the allowable rudder angle.

C.4 YAW CHECKING

1. Reference to IMO Resolutions: IMO A.601(15) (1987) requires data on the yaw checking ability in the form of results from zig-zag and pull-out trials. The manoeuvrability standard IMO MSC.137(76) (2002) includes requirements for the first and second overshoot angles, ψ_{S1} and ψ_{S2}, of the 10°/10° zig-zag trial, and for the first overshoot angle of the 20°/20° zig-zag trial as a function of L_{PP}/V_0. The initial speed is defined close to the maximum speed.

3. Assessment in Annex A: Table 9 and Table 11 show that yaw checking ability ranked most relevant (at least 5 out of 10 possible points) for all 11 missions/ sub-missions. The averaged requirements included in this ANEP are for first times to check yaw:

$t_{C1} \leq 7$ s for ten of the missions/sub-missions;

$t_{C1} \leq 10$ s for HM.

2. These performance requirements should be seen in the context of the typical ship speeds for the missions/sub-missions. Assessment of achievability of these requirements in this ANEP ranged from "demanding" to "very demanding/impossible". Neither initial turning rate nor rudder angle is specified.

3. It should be noted that the dimensional form (units s) discriminates against the larger and/or slower ships. Furthermore, there is uncertainty whether the response refers to a 10°/10° zig-zag, a 20°/20° zig-zag, or another trial.

4. Tactical implications: not defined.

C.5 TURNING ON THRUSTERS

1. Reference to IMO Resolutions: IMO A.601(15) (1987) requires data on the turning ability while using bow and stern thrusters acting separately and in combination at zero forward speed, and on the effect of forward speed on the turning performance. There is no requirement for turning ability on thrusters in the manoeuvrability standard IMO MSC.137(76) (2002).

2. Turning ability on thrusters has not been covered in this ANEP. A requirement for turning on thrusters could either be in the form of a wind velocity up to which the thruster(s) shall be able to turn the ship or an achievable steady rate of turn.

C.6 YAW STABILITY

1. Reference to IMO Resolutions: IMO A.601(15) (1987) doesn't require direct data on yaw stability for the manoeuvring booklet. The manoeuvrability standard IMO MSC.137(76) (2002) includes an indirect requirement for yaw stability in the form of limitations on overshoot angles in zig-zag trials.

2. Assessment in Annex A: Yaw stability has not been covered by this ANEP.

3. Tactical implications: Tactical implications due to underwater noise generation are less likely for yaw stability as deviations from a straight track and rudder actions are usually small.

C.7 COURSE KEEPING

1. Reference to IMO Resolutions: IMO A.601(15) (1987) doesn't require data on course keeping ability for the manoeuvring booklet. There is also no requirement for course keeping ability in the manoeuvrability standard IMO MSC.137(76) (2002).

2. Assessment in Annex A: Table 9 and Table 11 show that course keeping ability ranked most relevant (at least 5 out of 10 possible points) for all 11 missions/sub-missions. The averaged requirements range between extreme changes of heading of $|\Delta\psi_{MAX}| \leq 2°$ and $|\Delta\psi_{MAX}| \leq 5°$ (suggested to be interpreted as an (E+2σ) value). These had been assessed as

"moderately demanding" or "easily achievable". These performance requirements should be seen in the context of the typical ship speeds for the missions/sub-missions.

3. Under more severe environmental conditions, course keeping ability appears to be a challenge for the majority of naval ships. A requirement should therefore include threshold values for wind, waves and current, which should normally differ from recommendations for calm conditions, and should consider that smaller ships are more affected by the environment than larger ones.

4. Tactical implications: Tactical implications could refer to limits of the applicable rudder angle.

C.8 TRACK KEEPING

1. Reference to IMO Resolutions: IMO A.601(15) (1987) as well as the manoeuvrability standard IMO MSC.137(76) (2002) do not mention track keeping ability.

2. Assessment in Annex A: Table 9 and Table 11 show that track keeping ability ranked most relevant (at least 5 out of 10 possible points) for 4 of the 11 missions/submissions, i.e. the HM mission and the three MW sub-missions. The averaged requirements for the track deviation range between extreme values of $|\Delta y_{0MAX}| \leq 5$ m and $|\Delta y_{0MAX}| \leq 10$ m (suggested to be interpreted as an (E+2σ) value) had been assessed as "moderately demanding". These performance requirements should be seen in the context of the typical ship speeds for the missions/sub-missions.

3. Under more severe environmental conditions, track keeping ability appears to be a challenge for the majority of naval ships. A requirement should therefore include threshold values for wind, waves and current, which should differ from recommendations for calm conditions.

4. Tactical implications: Tactical implications due to noise generation are less likely for track keeping as deviations from a straight track and rudder actions are usually small, except under strong environmental disturbances.

C.9 ASTERN COURSE KEEPING

1. Reference to IMO Resolutions: Neither IMO A.601(15) (1987) nor the manoeuvrability standard IMO MSC.137(76) (2002) mentions astern course keeping.

2. Assessment in Annex A: Table 9 and Table 11 show that astern course keeping ranked most relevant (at least 5 out of 10 possible points) for 3 of the 11 missions/sub-missions, i.e. the HM mission and the MW–H and MW–A sub-missions. The average requirements are for extreme values of the change of heading (suggested to be interpreted as (E+2σ) values):

$|\Delta \psi_{MAX}| \leq 4°$ for MW–H,
$|\Delta \psi_{MAX}| \leq 5°$ for HM,
$|\Delta \psi_{MAX}| \leq 7°$ for MW–A.

3. Astern course keeping had been assessed as "easily achievable" to "moderately demanding", as the requirements were related to a low sea state.

4. Tactical implications: not defined.

C.10 STOPPING

1. Reference to IMO Resolutions: IMO A.601(15) (1987) requires data on the stopping ability to be included in the manoeuvring booklet as well as the wheelhouse poster. The manoeuvrability standard IMO MSC.137(76) (2002) requires the following stopping track reach:

$$s_F \leq 15 \cdot L_{PP}$$

2. The initial speed is defined close to the maximum speed

3. Assessment in Annex A: Table 9 and Table 11 show that stopping ability ranked most relevant (at least 5 out of 10 possible points) for 5 of the 11 missions/sub-missions (HM, AAW and the three sub-missions of MW). The averaged requirements for the track reach are:

$s_F \leq 1 \cdot L_{pp}$ for HM,

$s_F \leq 1.5 \cdot L_{PP}$ for MW–H,

$s_F \leq 2 \cdot L_{PP}$ for AAW, MW–S and MW–A.

4. These requirements have been assessed as “moderately demanding” for HM and the three sub-missions of MW, as they relate to low speeds. The requirement for AAW was assessed as “very demanding/impossible” in comparison to stopping abilities of existing ships.

5. Tactical implications: Tactical implications could include the risk of excessive underwater noise generation, which could limit the applicable reverse power.

C.11 ACCELERATION

1. Reference to IMO Resolutions: IMO A.601(15) (1987) requires data on the acceleration ability from zero speed to full sea speed to be included in the manoeuvring booklet. There is no acceleration requirement in the manoeuvrability standard IMO MSC.137(76) (2002).

2. Assessment in Annex A: Table 9 and Table 11 show that acceleration ability was ranked most relevant (at least 5 out of 10 possible points) for 4 of the 11 missions/submissions. The averaged requirements included in this ANEP are for an unspecified acceleration time:

$t_a \leq 30$ s ASW–P, AAW and RAS,

$t_a \leq 45$ s for ASW–R.

3. These performance requirements should be seen in the context of the typical ship speeds for the missions/sub-missions. Assessment of the achievability of requirements in this ANEP was in the range from “moderately demanding” to “very demanding/impossible” for all four missions/sub-missions, depending on the speed change intended.

4. Tactical implications: Tactical limitations could include the risk of excessive underwater noise generation, which could limit the applicable power change.

C.12 STATION KEEPING

1. Reference to IMO Resolutions: Neither IMO A.601(15) (1987) nor the manoeuvrability standard IMO MSC.137(76) (2002) mentions station keeping.

2. Assessment in Annex A: Table 9 and Table 11 show that station keeping ability ranked most relevant (at least 5 out of 10 possible points) for only 2 of the 11 missions/submissions, i.e. for MW–H and MW–A. The averaged requirement of extreme values (suggested to be interpreted as an (E+2σ) value) is:

$r_{MAX} \leq 10$ m.

3. The station keeping requirements had been assessed as “moderately demanding”, provided that adequate control devices could be available.

4. Under more severe environmental conditions, station keeping may become challenging. A requirement should therefore include threshold values for wind, waves and current, which should differ from the recommendations for calm conditions.

5. Tactical implications: Tactical implications could include the risk of excessive underwater noise generation, which could limit the applicable rudder angle, propulsion power and/or thruster power.

C.13 LOW SPEED

1. Reference to IMO Resolutions: IMO A.601(15) (1987) requires data on the minimum propeller rate and the corresponding speed in the pilot card and the manoeuvring booklet; information is also required on the minimum speed at which the ship can maintain course while still making headway after stopping the engines. There is no requirement for low speed ability in the manoeuvrability standard IMO MSC.137(76) (2002).

2. Assessment in Annex A: Table 9 and Table 11 show that low speed ability ranked most relevant (at least 5 out of 10 possible points) for five of the 11 missions/sub-missions, i.e. HM, ASW–P and the three sub-missions of MW. The averaged requirements are for limiting speeds of:

$V_{LIM} \leq 2$ knots for MW–H,

$V_{LIM} \leq 3$ knots for HM and MW–A,

$V_{LIM} \leq 4$ knots for ASW – P and MW–S.

3. These requirements were rated as “easily achievable” or “moderately demanding”, possibly based on the assumption of a moderate disturbance due to the environment.

4. A requirement for low speed controllability should include a specification of environmental conditions.

5. Tactical implications: Not defined.

ANNEX D REFERENCES

Chapter 1

ANEP-70 Vol. I (2021): *Naval Surface Ship Manoeuvring: Design Criteria*, NATO, ANEP-70, Edition 1 Volume 1.

ANEP-70 Vol. II (2021): *Naval Surface Ship Manoeuvring: Guidance for the Preparation of Onboard Information*, NATO, ANEP-70, Volume II, Edition A Version 1.

IMO MSC.137(76) (2002): *Standards for Ship Manoeuvrability*, International Maritime Organization, Resolution MSC.137(76).

ISO 19019:2005: *Sea-going vessels and marine technology. Instructions for planning, carrying out and reporting sea trials*, International Organization for Standardization.

ISO 13643-1:2017: *Ships and marine technology – Manoeuvring of ships – Part 1: General concepts, quantities and test conditions*, International Organization for Standardization.

ISO 13643-2:2017: *Ships and marine technology – Manoeuvring of ships – Part 2: Turning and yaw checking*, International Organization for Standardization.

ISO 13643-3:2017: *Ships and marine technology – Manoeuvring of ships – Part 3: Yaw stability and steering*, International Organization for Standardization.

ISO 13643-4:2017: *Ships and marine technology – Manoeuvring of ships – Part 4: Stopping, acceleration, traversing*, International Organization for Standardization.

ITTC (2017): *Full Scale Manoeuvring Trials*, International Towing Tank Conference, Recommended Procedures and Guidelines 7.5-04-02-01, Revision 02.

Chapter 2

ANEP-70 Vol. I (2021): *Naval Surface Ship Manoeuvring: Design Criteria*, NATO, ANEP-70, Edition 1 Volume 1.

IMO MSC.137(76) (2002): *Standards for Ship Manoeuvrability*, International Maritime Organization, Resolution MSC.137(76).

Chapter 3

IMO MSC.137(76) (2002): *Standards for Ship Manoeuvrability*, International Maritime Organization, Resolution MSC.137(76).

Chapter 4

IMO MSC.137(76) (2002): *Standards for Ship Manoeuvrability*, International Maritime Organization, Resolution MSC.137(76).

Chapter 5

ANEP-70 Vol. II (2021): *Naval Surface Ship Manoeuvring: Guidance for the Preparation of Onboard Information*, NATO, ANEP-70, Volume II, Edition A Version 1.

IMO MSC.137(76) (2002): *Standards for Ship Manoeuvrability*, International Maritime Organization, Resolution MSC.137(76).

Annex B

IMO A.601(15) (1987): *Provision and Display of Maneuvring Information On Board Ships*, International Maritime Organisation, Resolution A.601(15).

IMO MSC.137(76) (2002): *Standards for Ship Manoeuvrability*, International Maritime Organization, Resolution MSC.137(76).

Annex C

IMO A.601(15) (1987): *Provision and Display of Manoeuvring Information On Board Ships*, International Maritime Organisation, Resolution A.601(15).

IMO MSC.137(76) (2002): *Standards for Ship Manoeuvrability*, International Maritime Organization, Resolution MSC.137(76).

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ANEP-70 Vol III (A)(1)