**Safety Study**

S1/2004M b

# Practices in Pilotage – Past, Present and Future

Translation of the original Finnish report

**Onnettomuustutkintakeskus**
**Centralen för undersökning av olyckor**
**Accident Investigation Board**

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## FOREWORD

In 2006 the Accident Investigation Board published a study called **Piloting Practices and Culture in the Light of Accidents**[1]. The study concluded that both the traditional way of piloting and one based on modern technology are used at the same time in maritime pilotage. The reciprocal importance of these ways to provide pilotage varies, but according to the conclusion drawn by the investigation, the simultaneous impact of two different lines of action causes significant development tensions related to pilotage and its organisation.

The investigation reached the conclusion that it would be advisable, with reference to improving the safety of pilotage and seafaring, to develop good pilotage practices in such a way that pilotage would be improved by making use of the possibilities offered by the new navigation equipment and that cooperation on the bridge would be an essential part of the new method for providing pilotage.

### Safety observations related to pilotage

During the last twelve years the investigations carried out by the Accident Investigation Board contain altogether 99 observations about safety in pilotage. The matters related to these observations have had an effect on the occurrence of accidents either directly or indirectly. The majority of these observations, 56, are related to the work itself, e.g. to route planning and to the manoeuvring and manoeuvrability of the vessel. A matter related to the organizing of the work, bridge cooperation and work rhythm has been the subject of investigation twenty-two times. Twenty-one findings have been related to environmental factors, e.g. ice, wind, fog or the surrounding fairway area.

When classified in more detail, twenty of these safety observations have been connected with turning measures in the fairways or with the monitoring of the turn manoeuvres. The second most common cause of findings is related to the shared responsibilities with reference to bridge cooperation and pilotage, altogether fourteen cases. The lack of route planning and the manoeuvrability of the vessel constitute other significant factors, both with more than ten findings. Other pilotage-related factors have been related to difficulties in port manoeuvring, unclarities with reference to the pilot boarding and disembarkation places, environmental conditions, fairways, fatigue and to the manoeuvrability of vessels in overtaking and meeting situations.

[1] Safety Study S1/2004 M. (Leena Norros, Maaria Nuutinen, Kari Larjo) [available only in Finnish]

## Safety study

The previous safety study on pilotage primarily concentrated on the pilotage organisation and organising the work on the bridge, but did not look at the actual pilotage work in detail.

The Accident Investigation Board decided to launch this safety study **’Practices in Pilotage – Past, Present and Future’** to complete the earlier publication. Master Mariners Kari **Larjo** and Karl **Loveson** and M.Sc. (Tech.) Jaakko **Lehtosalo** were appointed as members of the work group. This report discusses the practical pilotage work and the opportunities to develop it. Pilotage applies to all seafarers who have a pilot licence, fairway certificate, or pilot exemption certificate, as well as all those who work as Masters or as watch-keeping officers. Pilotage is often considered to only concern the pilot from outside the vessel, but pilotage includes navigation and monitoring as well, irrespective of the position or certificate of competency.

## Contents of the safety study

Chapter 1 of this report presents a definition of pilotage, whereas chapter 2 of this Safety Study deals with the history and development of pilotage until the middle of the 20th century. Chapter 3 covers the international and national rules and regulations with reference to pilotage.

Chapter 4 describes the most important phenomena related to the manoeuvrability of the vessel and to the interaction of the vessel and its environment. Matters related to the fairway area and channel alignment are also dealt with. Chapter 5 describes the preparations made prior to pilotage and piloting both as a technical activity and as a part of the bridge organization.

Chapter 6 goes through the technology needed in piloting, the technical minimum requirements and the ergonomic use of the appliances. Chapter 7 deals with integrated piloting devices and the possibilities the technical systems offer to support pilotage.

The List of Sources of this Safety Study includes a list of the investigation reports published by the Accident Investigation Board, in which an accident has taken place when the vessel has been navigated along a fairway in the archipelago. The list presents safety observations from the investigation reports related to pilotage and the section of this safety study that discusses the topic.

The report has been delivered to the Finnish Transport Safety Agency, State Pilotage Enterprise, Finnlines, TallinkSilja, Viking Line, Neste Oil Shipping, Aboa Mare, and the Satakunta and Kymenlaakso Universities of Applied Sciences for comments. Some parts of the report have been modified based on the feedback received.

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## THE ABBREVIATIONS USED

| | |
|---|---|
| AIS | Automatic Identification System |
| ARPA | Automatic Radar Plotting Aid |
| AUTO DRIFT | Automatic correction of the drift angle |
| BACK UP | Emergency steering |
| BEIDOU | The satellite positioning system used in China |
| BRM | Bridge Resource Management |
| CCPR | Consistent Common Reference Point. A point in the hull of the vessel used to determine the coordinates and bearings of all position determination devices |
| COG | Course Over Ground |
| COURSE CONTROL | |
| COURSE MODE | Automatic steering which follows Course Over Ground. |
| COURSE UP | Head Up display orientation of the radar with a compass connection |
| CPA | Closest Point of Approach. The shortest passing distance of vessels |
| CROSS TRACK ERROR | A deviation from the route plan |
| DP | Dynamic Positioning. An integrated control system of position determination, motion sensors and control devices designed for low speeds |
| EBL | Electronic Bearing Line, the electronic bearing line on the radar |
| ECDIS | Electronic Chart Display and Information System |
| EGNOS | The EU designed differential correction of the GPS by using communication satellites. |
| FU | Follow up |
| GALILEO | The EU satellite navigation system |
| GLONAS | The Russian satellite navigation system |
| GPS | The US satellite navigation system |
| HDG | Heading, compass course |
| HEAD UP | Head Up display orientation of the radar without a compass connection |

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|---|---|
| HEADING MODE | Autopilot steering mode using compass course without drift angle compensation |
| IEC | International Electrotechnical Commission |
| IMCO | Inter-Governmental Maritime Consultative Organization 1948-1982, subordinate to the UN |
| IMO | International Maritime Organization since 1982, former IMCO |
| INS | Integrated Navigation System |
| ISM-Code | International Safety Management Code |
| JOYSTICK | Polar pressure control handle used to show the direction and effect of the desired steering power |
| LOT | Line of Turn. The starting mark of a turn on the bearing line of the radar |
| MMSI | Maritime Mobile Service Identity, a vessel-specific identification number allocated by the IMO |
| MSC | The IMO’s Marine Safety Committee |
| NAV | The IMO’s Navigation Sub-Committee |
| NFU | Non Follow Up |
| NORTH UP | The display orientation of the radar north up |
| OOW | Officer of the Watch |
| PI | Parallel Index, a parallel bearing line used when working on radar |
| PIANC | Permanent International Association of Navigation Congresses |
| RAIM | Receiver Autonomous Integrity Monitoring. An independent interference suppression programme in a satellite responder |
| ROT Tiller | Rate of Turn, angular velocity steering lever |
| S/A | Selective availability. Disturbing of a GPS satellite; reduces the accuracy of position determination |
| SMS | Safety Management System. Safety management system of a shipping company |
| SOLAS | The IMO’s Safety of Life at Sea Convention |
| STABILIZED RELATIVE | The display orientation of the radar is north up. The symbol of the vessel does not move on the screen, and the radar targets move according to the relative movement. |
| STCW | Standards of Training, Certification and Watchkeeping |
| TCPA | Time to Closest Point of Approach |

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|---|---|
| TMC | Transmitting Magnetic Compass |
| TRACK CONTROL SYSTEM | An automatic steering functioning mode, which steers the vessel automatically on the route plan |
| TRACK LIMIT | An allowed lateral deviation from the route, programmed into the route plan |
| TRUE MOTION | A radar display mode using true motion in a globe-based system of coordinates. The speed of the vessel is connected to the display device. |
| TVH | The National Board of Public Roads and Waterways (till the year 1990) |
| VHF | Very High Frequency |
| WAAS | Wide Area Augmentation System. Differential correction system of the GPS which uses a communication satellite |
| WGS-84 | World Geodetic System 1984. A three-dimensional system of coordinates, in which measurements are made to a global ellipsoid |
| WOP | Wheel Over Point. The starting point of a turn |
| VRM | Variable Range Marker, the electronic moving range marker of radar |

# 1 INTRODUCTION – DEFINING THE TERMS NAVIGATION AND PILOTAGE

*Navigation is the business of conducting a craft as it moves about its ways.*

*The Principles of Navigation*

*E.W. Anderson*[2]

According to this definition, navigation equals simultaneous position determination, manoeuvring and the control of the vessel's dynamic state of motion. Navigation starts when the vessel begins to move and ends at the port of destination. The objective during the entire voyage is to stay on the pre-planned route. Meeting this objective includes the simultaneous control of position determination and steering.

When the vessel makes way at open sea, the measures described above are adequate in order to guarantee the safe voyage and arrival at the destination. When the vessel approaches a coast, the narrowing of the fairway space forces the navigator in closer detail to estimate the developments in the motion state of the vessel. At the same time, the importance of position determination changes and predicting the vessel’s motion state in the fairway becomes the most important task. This means that the position and the movement of the vessel are estimated with reference to the surrounding terrain. This task consisting of precision navigation in limited fairway space is **pilotage**.

Navigation has traditionally been divided into separate tasks. It is the officers’ duty to familiarize them selves with navigation technology. The pilot, who does not belong to the vessel’s officers and who works for the state, a municipality or a private company, is the expert when it comes to the fairway, motion state and manoeuvring. Basically the officers have the possibility to influence the equipement acquisitions and this way indirectly also the product development. However, the pilots hardly have any influence on the purchasing of the vessels’ navigation instruments or their development.

Pilotage has remained a separate part of bridge work, and there is no accurate official definition of pilotage. Pilotage has become twofold: the person performing the piloting is the expert on the fairway and manoeuvring, whereas the rest of the officers control the usage of navigation technology. There is no textbook on pilotage, and its definition is not a part of maritime education. There are no regulations at all how the pilot should do the actual work. This Safety Study deals with the discrepancy between pilotage in practice and the rules and regulations governing pilotage.

[2] Wing Commander E.W Anderson, President of the Institute of Navigation 1959-1961.

The IMO's (the International Maritime Organization; subordinate to the UN) STCW 95 Convention[3] requires that masters and chief officers must know how to manoeuvre and handle vessels in ports and narrow fairways in all conditions: *'Competence: Manoeuvre and handle a ship in all conditions.'*[4] This requirement is unrealistic because the vessel and its systems have technical operational limits.

In pilotage, position fixing and manoeuvring should not be separated. It would be useful to carry out pilotage in such a way that masters and officers are familiar with the principles of navigation in narrow fairways. In aviation this objective has mostly been achieved, and the aim is for the whole cockpit crew to reach a uniform performance level.

Pilotage affects all seafarers who have a pilot licence, a fairway certificate or a pilot exemption certificate, and all those who work as masters or as watch-keeping officers. Piloting is often considered to be the task belonging only to the pilot, from outside the vessel, but pilotage includes navigation and monitoring irrespective of the position or certificate of competency.

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[3] Standards of Training, Certification and Watchkeeping (STCW)

[4] STCW -95, Table A-II/2

# 2 THE HISTORY OF PILOTAGE

## 2.1 The pilot and the society

Pilotage has traditionally been carried out by a pilot who is not a member of the crew, i.e. an outsider. There are hardly any documents left about traditional pilotage. Therefore the performing of the pilotage task must be construed with the help of the history of the Pilot and Lighthouse Institution, through regulations and with the help of general history.

Finland was part of Sweden until 1809, and in Sweden pilotage was apparently mentioned for the first time in the Town Law of Söderköping in 1280. In King Magnus Eriksson's general Town Law dating to the 1350's, there was a separate section on shipping. Piloting was regarded as a respected and demanding duty. The pilot was a local government official. On the basis of the town laws it can be concluded that pilots came from the archipelago and that they had voluntarily taken up the pilot's position. In 1447 the Hanseatic League ordered that using a pilot was compulsory[5]. It is presumed that this requirement did not have hardly any effect, but it describes well how the society understood the importance of a pilot.

The Swedish state bound the pilot to his position by granting him an exemption from taxes as early as in the 16th century. The aim of the state was to establish pilot families, i.e. the post as a pilot would pass from father to son[6]. This pilot homestead system was useful to the state, because the rulers primarily aimed at securing the piloting of warships. Piloting warships was free of cost to the state, but the pilot charged other vessels. Pilot homesteads took care of the training to the job on their own.

In 1579 King John III of Sweden published a rule stating that pilots were classified as navy members and thus exempted from other military service. As recruiting soldiers from among the people was random in the 17th century, during the period of the great power wars of Sweden, a homestead paying tax devolved statistically once in ten years the duty to send a boy of over 15 years to military service. This intimidated the citizens, because the majority of the youngsters who were called up for military service died during the first half a year of the strains of the military life[7]. Only few returned from the wars fought in Germany, Poland, the Baltic Countries and Russia. A pilot on the other hand did not have to send his son to war because he trained his son to continue his work. This arrangement was beneficial also for the state, because those in power had understood that the pilot was careful when training his son in order to keep him safe. In other words, the pilot tried to perform his duties as well and

5 Aina Lähteenoja 1947, p. 30
6 Erik Hägg, p. 30. In 1606 Duke Charles ordered two officers (mates) to train their children as pilots. This apparently was a normal practice in that era.
7 Heikki Ylikangas 1990, p. 174-190

conscientiously as he could, because losing the post would have meant insecurity for the family and the future generations. The threat of military service made the pilots' work morale high.

Following the 1634 Constitution, regulations were drawn for the Admiralty College. According to these regulations, seafarers had to learn the coast, the shoals and port entrances. The state was responsible neither for the training of the pilot nor for his equipment, but it still kept the pilot's traditional responsibility extensive. Queen Christina did not confirm these regulations, but in practice this procedure was followed.

The authority of the pilot increased considerably after the middle of the 17th century. The Maritime Code[8] of 1667 laid down provisions that it was compulsory to use a pilot where the service was available. The requirement was based on the safety of seafaring, because the pilot's knowledge of the fairway was necessary as there were not any charts or navigation marks. The Maritime Code did not contain any regulations on the professional training of the pilots.

In 1696 King Charles increased the pilots' power in Sweden's first Pilotage Decree by also assigning pilots the task of a coast guard, thus adding the securing of national safety to the pilots' duties. Because of this a pilot had to swear an oath of loyalty to the state in a court of law[9], and he became a government official. The pilot Alderman's oath[10] also included a promise that he would not let any outsider practice pilotage. He also promised to urge pilots to perform their duties including laying of spare buoys, studying fairways, and observing temperance, and to control that pilots would not reveal information about fairway passages. Breaking the oath caused a severe punishment. The pilot alderman's duties also included arranging the pilot examination. The decree did not lay down provisions for the training, and the practical arrangements were left to the pilot alderman.

In cases of accident, the Pilotage Decree set severe punishments for the pilot[11]. If the accident was caused by the pilot's lack of skills or by his negligence, he had to compensate for the damage (Section 5). The punishment was more severe if the accident happened to a naval vessel. If a naval vessel sunk, the pilot expiated this with his life. On the other hand, if the vessel was damaged, the pilot was sentenced to running the gauntlet three times. Running the gauntlet meant that the condemned man, stripped to the waist, was compelled to run between two rows of men equipped with lashes or other weapons. When an accident happened to a merchant vessel, the punishment was running the gauntlet twice (Section 4). Running the gauntlet could cripple a man for the rest of his life.

[8] Erik Severin 1969, p. 4
[9] Erik Severin 1971, p. 1
[10] Aina Lähteenoja 1947, p. 87
[11] Kunglig förordning angående lotsväsendet. CAROLUS, Stockholm 19.9.1696

In 1724 Queen Ulrika Eleonora approved a Navigation Act, which obliged the pilot to make sure that illegal goods were neither loaded on nor discharged from the vessel during the voyage[12]. This stipulation meant that the pilot also became a Customs officer.

Due to military reasons, charts on the archipelago were drawn in an unclear manner. Thus only pilots knew the coastal fairways well. It lay in the interests of the state that a pilot did not reveal the positions of the coastal shoals to a foreign master and that he did not teach the fairways to outsiders. The pilot and the state shared a mutual interest as the pilot's authority was solely based on the knowledge of the fairways. Ceding information would have meant breaking the pilot's oath and losing one's position.

According to the Act, the master was not allowed to give orders to the pilot during the pilotage, and he had to carefully obey the pilot. If the master failed to do this, he was held responsible for a possible accident. If the pilot caused the accident, he had to be punished as was laid down in the Act stipulating on causing maritime damages.

King Gustav IV Adolf consolidated the pilots' position in 1798 the renewed decree on pilotage. The decree included the pilots' official duties and compulsory pilotage. The state regarded the pilots' duties with apparent seriousness, because fouls and violations committed by a pilot were, in accordance with the decree, court-martialed. According to the new decree, the pilot's life was no longer in danger, and accidents to warships and merchant vessels were no longer specified. The corporal punishment changed from running the gauntlet to fifteen pairs of lashes (Section 73). A pilot could be punished even though there had not been any damages. In other words also "close calls" could result in being sentenced to the lash. If the pilot's assets were not adequate to compensate the damage in full, he had to work for the shipowner until the compensation was paid (Section 73). The pilot could also be imprisoned for his debts (Section 63). This decree on pilotage was the last one for Finland during the Swedish rule.

[12] Helge Jääsalo 1962, p. 2 and Aina Lähteenoja 1947, p. 107

For pilots the Swedish rule meant a clear increase in public esteem. The rulers made the pilots pursue the interests of the state and bound them to their positions by the oath of allegiance. The state rewarded the pilot's loyalty by granting him exemption from taxes and military service and made him an esteemed government official, who took care of the duties of the pilot, coast guard and preventive officer. A pilot was the king's trusted man who held a privileged position.

Originally the pilot was not an advisor, but he had a clear authority over the vessel's master with respect to all the operations connected to pilotage. He was the keeper of national security, and keeping information about fairways was part of his duties. The pilot's job description and the interests of the state did not include giving advice and teaching fairways to outsiders. The state withdrew from the liabilities with respect to the traffic by allocating the training to the pilot himself, and inflicted a severe punishment for a failure.

Due to the indisputable advantages going with a pilot's position, the pilots were loyal subjects to those in power. The traditions created by the Swedish rulers with reference to compulsory pilotage and pilot training were further passed to the regulations of Russia and the independent Finland. The principles of these old regulations have had an effect on pilotage till our days. The principle of training has remained almost the same in the respect that pilotage skills are learnt through experience, and the skills are still evaluated on the basis of the duration of the employment. History created a way of pilotage which was based on individual performance, and this can still be seen in modern pilotage.

At the beginning of **the period of Finland as the Grand Duchy of Russia** (1809-1917), Swedish rules and regulations were followed. Czar Alexander I of Russia copied Gustav IV Adolf's Decree on pilotage[13] in Vilnius 17.5.1812. The Czar signed the first pilotage Decree of the Grand Duchy of Finland while expecting Napoleon to attack[14]. The principles of compulsory pilotage included in the Swedish legislation passed as they were to the Russian pilotage decree. This new Decree was as to its contents in principle the same as the Swedish decree from 1798, and the pilotage services remained unchanged.

The authority of the Finnish pilotage services was established to manage the Pilot and Lighthouse Institution in 1850. It was meant to be a similar central administrative authority as the National Board of Post and Telegraph, the National Board of Customs and the National Survey Board.

A new decree on pilotage was issued[15] in 1870. According to the decree:

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13 Kejserlig förordning rörande Båk- och Lotsinrättningen uti Finland. ALEXANDER. 17.5.1812

14 Iisakki Laati 1946, p. 16

15 Keisarillisen majesteetin armollinen julistus luotsi- ja majakkalaitoksesta Suomessa. 9.5.1870. Alexander II

*The master is responsible for the manoeuvres of the vessel according to the orders and advice given by the pilot.*[16]

The pilot's orders are mentioned in the context when the master hands over his duties to the officer, in which case the officer must fulfil the pilot's orders[17].

*The pilot must ... give the ship's foreman the orders considered necessary with respect to the safety of the ship.*[18]

The orders given by the pilot were mentioned three times in the decree, advice only once. The pilot was not clearly yet an advisor, but it can be read between the lines that the times were changing.

In Sweden the pilotage decree from 1862 had made the pilot an advisor. According to the decree, the master was responsible for the manoeuvring of the vessel according to the pilot's advice[19]. Thus the Swedish pilot became in a legal sense an advisor, but the method of working and the power based on the pilot's personal authority did not change in practice.

In Finland the Russian pilotage Decree had kept the corporal punishment unchangeable and the claim for damages with imprisonment for debts remained the same (Section 65). The 1870 Pilotage Decree had changed whipping to imprisonment on bread and water only. The punishment for the first grounding was 12-20 days on bread and water and for the second one 24 days. If a pilot had deliberately caused a near miss situation, he was imprisoned on bread and water for 22 days. If the deliberateness caused damages or grounding, the sentence was confinement for 6-10 years of hard labour. The most severe punishment was a life sentence to confinement of hard labour. In all cases, the pilot was liable to compensate for the damage (Section 14), and he was court-martialed (Section 15).

The liberal thinking which was characteristic for the time did not reach Russia, since the corresponding Swedish Pilotage Decree[20] from 1862 no longer mentioned the pilot's liability for damages nor did it list the punishments. The decree only stated that a pilot is sentenced in the naval court-martial (Section 35, subsection 4). In Sweden the 1881 Decree on Pilotage Services allocated handling a pilotage-related accident to city courts[21].

[16] Pilotage Decree 1870, Chapter 1, Section 12(2)(a)
[17] Pilotage Decree 1870, Chapter 1, Section 12(2)(c)
[18] Pilotage Decree 1870, Chapter 1 (Section 14 (1))
[19] Kongl. Maj:ts förnyade förordning angående lots- och fyrinrättningen. 9.6.1862. (Section 13), Carolus XV
[20] Kungliga Majestets förordning angående lots- och fyrinrättningen i riket, 9.7.1862
[21] Kungl. Maj:ts förordning angående lotsverket, 15.02.1881. Section 53. I. Azelius, Sjölagen jämte viktigare författningar. Stockholm 1907, Norstedt & Söners förlag

An imperial proclamation 27.4.1899 made a Maritime Inspector the leading public authority within seafaring in Finland. He worked for the Trade and Industry Commission. The duty of the maritime inspector was to supervise that the regulations on the vessels' seaworthiness, equipment and usage were followed. In addition to this, the inspector supervised the inspections of passenger steamships and helped the Board of Industry in dealing with matters laid down in the Decree on Passenger Steamships. Furthermore, his duties included giving ships' masters advice on following the rules preventing collisions, inspecting maritime schools and standardizing the training given in these educational establishments. The maritime inspector also compiled the shipping register on Finnish ships, kept himself up to date with respect to matters related to seafaring and took measures to promote seafaring. A Senate regulation 1.2.1904 put the average inspectors under the obligation to send a copy of damage survey protocols to the maritime inspector in such a case that the vessel had been declared unseaworthy or seaworthy only after repairs.

The Russianization of the pilotage services started when Czar Nicholas II's yacht grounded in the Riilahti fairway in 1907. The Finnish pilot protested to the master against choosing the narrow fairway, but the Russian naval officer insisted that the fairway had to be used. The blame for grounding which was caused by this decision was however put on the pilot. The Russianization was begun in 1910, and in 1912 the managers of the pilotage services were given notice. As the result of this, most of the pilots gave up their posts, and as replacement pilots were brought in e.g. from the Caspian Sea[22].

As to the rules and regulations, the pilotage services **in the independent Finland** (from 1917) had to start from where the development had come to a halt after the Swedish-Russian War 1808–1809. The pilotage services first functioned according to the pilotage decree from 1870 Russian rule, which as to its principles was the old Swedish Pilotage Decree from 1798.

The National Board of Navigation was established on 15 December 1917, and at the same time the earlier decrees on the maritime inspectors' posts were repealed. Finland was divided into maritime districts, in which maritime inspectors acted as the highest-ranking government officials. The Pilot and Lighthouse Institution became part of the National Board of Navigation.

President Ståhlberg signed the first Finnish Pilotage Decree[23] on 1st June 1922. He also signed the Prohibition Act on the same day. Compulsory pilotage, a principle created by the Swedish rulers, passed unchanged to the new Pilotage Decree, exactly as had happened during the Russian rule in 1812. According to the tradition a pilot, whose professional title in the independent Finland was the historical "pilot of the Crown", still had to take care of his own training.

[22] Iisakki Laati 1946, p. 209
[23] Luotsausasetus 152/1922. President Stålberg

The pilot now lost his authority, because the decree laid down provisions that *‘the master of the vessel was responsible for the manoeuvring of the vessel according to the pilot’s instructions on the course, waters, etc.’*[24]. The same principle was repeated in the 1957 Pilotage Decree[25].

Judicially the responsibility was transferred to the master and the shipowner, but in the practical work the pilot still retained his authority because it was based on professional skills. This may suggest that the changes in the legislation were made bearing the liability issues in mind. This led to a problematic division of authority between the master and the pilot. The division, which still exists today, is underlying in normal pilotage work, but it becomes apparent when an irregularity occurs in a manoeuvre. According to the regulations, the master of the vessel is in charge, but in such a situation the pilot's professional skills are more useful. Divided authority can in this kind of a situation completely paralyse the decision-making process.

During the period between the two world wars, the pilotage services functioned almost according to the same principles as during the Russian rule. The pilots learnt their profession through practical training in the same way as craftsmen during the time of trade guilds[26].

The 1922 Pilotage Decree no longer included liability to or punishments of the pilot. They were passed on to the Criminal Justice Act, in which pilots are not mentioned separately. Pilots were considered on a par with other government officials. Between the years 1945-1947, 28 pilots were punished, but the form of punishment was not revealed[27]. The liability for damages was not mentioned in the committee report.

When the pilot’s liability for damages ended in 1922, the pressure correspondingly increased with reference to the state. At first, the shipowners’ role in pilotage did not interest legislators. The fact that the pilot was no longer liable for damages meant that the liability was passed on to the shipowner. The state was still free from liabilities with reference to the damages which occurred in pilotage.

Between the years 1900 and 1926, there were nine consecutive Navigation Committees in Finland. A new maritime act had been under consideration already in 1908. The old principle, according to which the shipowner was only responsible for the damages caused by the master and the crew, was again repeated in the proposal. The statement of reason referred to the Scandinavian custom[28].

[24] Chapter 2, Section 18
[25] Luotsausasetus 393/1957, 5.12.1957. President Kekkonen
[26] Yrjö Kaukiainen and Pirkko Leino-Kaukiainen, 1992, p. 82
[27] Committee report 1952:8
[28] Committee report 1908:8 (Section 10)

The Scandinavian custom suddenly changed in 1931 when the act on the Shipowner's liability entered into force[29]. Not even a committee was appointed for the change. Section 2 in Chapter 1 of the act ordered that

*‘A shipowner is liable for damages that have been caused by a mistake or negligence by the vessel’s master, its crew, the pilot or a person not belonging to the crew who has been working on the vessel by the order of the shipowner or the master. If the shipowner has been obliged to pay indemnity for the damages mentioned in subsection 1, he should then have a right to receive compensation from the person who has caused the damage.’*

Because the opinions expressed during the preparations of the act have not been filed, the dissenting opinions are not known today. Only the Governmental proposal to the Parliament has been filed, but it does not mention the fundamental change concerning the liability with respect to a pilotage error[30]. The act in question was also not issued on the basis of any other act. The above-mentioned section 2 can hardly have become part of the act upon the industry's suggestion. The new act served the interests of solely the state, i.e. the pilotage services, because it made a government official a private employer’s responsibility.

The preparations for a new maritime act were commenced in 1936, and the act[31] was finally renewed in 1939. The contents of its section 11 were the same as subsection 2 in the above-mentioned act on the shipowner’s liability. The act on the shipowner’s liability was passed into subsections 10-23 in the Maritime Act. In connection with the preparations of the Maritime Act it was stated that the subsection 11 dealing with the shipowner’s liability had been phrased to correspond with the changes made in the common Scandinavian revision of maritime law[32]. The Scandinavian preparations had thus been made before 1931. The liability to pay damages had now in practice been passed to the shipowner.

## 2.2 The development of pilotage

During the Swedish rule a pilot was an important government official within the armed forces. He swore to the king an oath not to reveal his information about the fairways to outsiders. Fairways were inaccurately marked on the charts, and only pilots knew the fairways well. They were the king’s trusted men, and had to remember the fairway by heart.

Even today pilotage is an act of safety, securing the transport, but no longer to guarantee national security. Instead the objective is to make transportation safe, i.e. to secure human lives and property and to protect the environment. The old

29 Laki laivanisännän vastuusta ja meripanttioikeudesta 73/1931, 20.2.1931
30 The National Archives’ Code, Ministry of Justice Ea 76
31 Merilaki 167/1939, 9.6.1939
32 The National Archives’ Code; Ea 146 OM/KD, statements KD 19/242 1938 Ea

way to use the recollection of the chart has, however, continued until our days. Even today pilots are required to know the chart by memory in the pilotage examination, even though the fundamental reason with reference to securing national safety ceased to exist as early as during the period of Finnish autonomy. The old line of action is regarded as the prevailing good seamanship, *'ordinary practice of seaman'*, without really realizing the real origin of this way of working. In today's society the documentation of procedures and methods of work is considered absolutely necessary. One exception to this is, however, the concept of *good seamanship*, which does not have a jointly drawn, objective definition.

At first pilotage was solely based on visual and relative navigation. This meant that the pilot carried out position fixing by comparing the landscape with his recollection of the waterway chart. He did not concentrate on position fixing, because the position at the moment of his observation was already history with respect to the control of the vessel's motion state. Instead the pilot determined the vessel's motion state and its development from the landscape in front of him, mainly on the basis of navigation marks and the relative movement of fixed objects. He determined the vessel's future position to where it would be after about half of minute. The pilot had to interpret the vessel's motion state without any kind of calculations. Pilotage was based on the close monitoring of the environment even without auxiliary devices, and e.g. bearings to immovable objects were not calculated. This way of pilotage based on visual and relative navigation has continued until our days.

There were not any sector lights in the archipelago at the end of the 19th century[33], so navigation was possible only in the daytime. Shoals were marked by using floating navigation marks, but this way of marking was not systematic. The planning of channel alignments was still done by using the marks in nature. The way to draw fairways on the chart was quite free in form, and the fairway line was drawn straight only on the open areas of the water area.

The pilots learnt to remember tracks by utilizing landmarks which lay conveniently one after each other. Landmarks which remained directly on the side of the track were chosen as turning marks. When night pilotage was later taken up, it became customary to call these landmarks as daymarks.

The building of sector lights was started in the eastern Gulf of Finland as early as in 1880, and by 1904 the major fairways were marked by sector lights. This facilitated traffic also at night. Tracks ran along the narrow white lighthouse sectors[34] (Figure 1). A practical problem in piloting was to maintain the correct distance to the lighthouse while navigating around it.

33 Iisakki Laati 1946, p. 154
34 Öfverstyrelsen för Lots och Fyrinrättningen I Finland, Kartblad till lista öfver finska fyrar och mistsignalstationer, Utgiven år 1904, Helsingfors 1905, AB Weiling & Göös

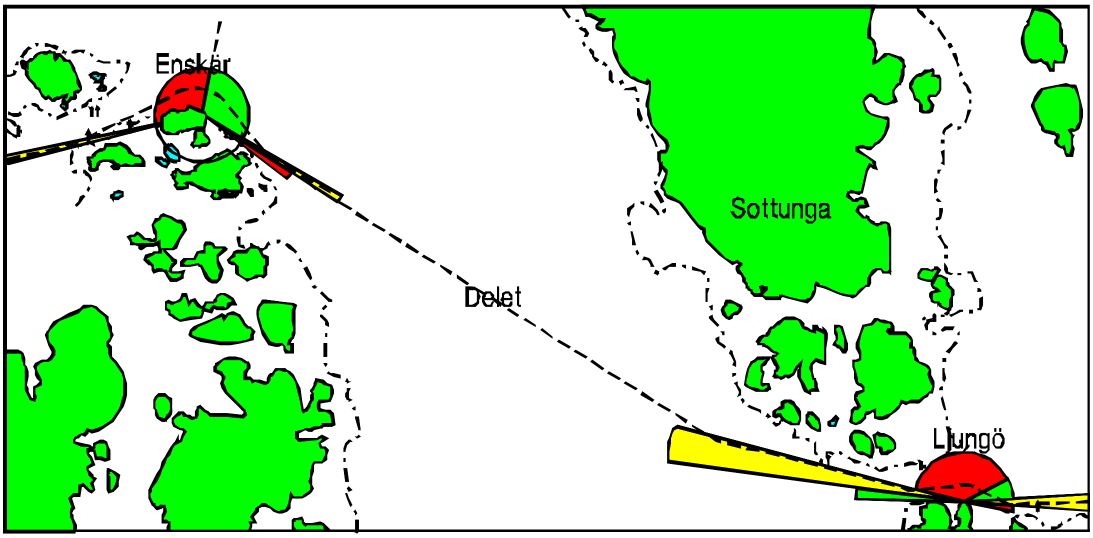


*Figure 1. Sector lights made piloting possible in the dark. The figure illustrates the stretch Ljungö-Enskär in the Åland Islands. This channel alignment was still the same at the beginning of the 21st century. This type of channel alignment has been removed from other main fairways.*

In the night-time or when the visibility was restricted, both the speed of the vessel and time to reach the start of the next turn had to be defined. The speed was checked by using the revolution indicator of the main engine, and the time to the target was calculated using distance. If the searched object was not visible after the calculated time, the vessel had to be stopped. Still in the 1950's on the bridges there were clocks with movable hands to indicate the arrival time of the next target. The gleams of lighthouses were used to determine the starting moments of a turn. A turn could be started e.g. when the vessel had first entered the sector of the white light and the light had then flashed three times. Since the beginning of the 20th century, pilots had to memorize both '*daymarks*' and '*nightmarks*'. The basis for defining them had been completely different from each other.

The depth of water used to be the most important information on a nautical chart. The masters had to deduce the navigability of the fairway on the basis of the depth information. The classification of fairway depths did not exist on the old Swedish charts. At the beginning of the Finnish autonomy, depth classifications were missing until at least 1832. The situation changed sometimes in the middle of the 19th century, because in the Russian nautical charts from the year 1850 fairways have been classified on the basis of depth[35]. The fairway lines were marked with one to four dots (— • —, — •• —, — ••• —, — •••• —). The dots indicated the vessel's permitted draughts of 6, 12, 18 or 24 feet for the fairway. The deepest draught, 24 feet (four dots on the chart) was enough even for the larger vessels trading to the ports of the Gulf of Finland. The draught of the biggest

[35] The chart collection of the Helsinki University Library

ocean-going four-masted barks was 27 feet and they did not proceed to the Gulf of Finland[36]. The numerical values of the dots were apparently given in a separate list describing chart symbols and depth contours. From 1918 onwards, the depth of a fairway was indicated by using a numerical value, and the reading was marked inside the brackets. This Finnish method was more accurate and clearer than the Russian one.

The practice of using depth-markings for the fairways meant that the master only had to pay attention to the fact that the draught of the vessel did not exceed the value indicated on the chart. The so-called *squat* effect (see 4.1.3) was not yet known. As the vessels were small and their speeds moderate, the phenomenon did not affect the operating of the vessels. Inaccurate sounding results constituted a worse problem. It can be assumed that sometimes the groundings which were caused by squat were also classified to have been caused by unreliable soundings.

Pilot Johan Erik Bernhard Nylund made a pilot plan[37] from Helsinki to Bomarsund in 1929. The plan was intended for pilotage in daylight. In the plan the passing of the spar buoys was secured by the pilot's own back-up lines. The following example describes pilotage from Helsinki westwards along the coastal fairway.

*'When Gråhara lighthouse tower is sighted between the navigation marks of Räntan and Abrahamsholmen, one is clear of the south spar buoy of Viberg. After that the course is altered to port in the direction of Hundhällen, and if one proceeds with this as the lead until the Rönnskär bridge, a leading line is formed by Likgrundet leading light, the beacon lead at Melköhällen and a large rock at the southern point of Mälkö. These marks lead clear of the 18-foot North spar buoy of Glasmästargrundet.*

*Thereafter the course is somewhat altered to starboard WSW (247.5°)*[38] *or to straight ahead towards the Knaperskär islet. Keeping this course leaves the spar buoys Rönnskär north (13 feet), Melkö Nöthällen north (19 feet) and Melkö north (15 feet) on the starboard side. The buoys Hunden (south 18 feet) and Gripenberg south (12 feet) are left on the port side.*

[36] Strang, Harju and Laurell, Suomenlahden saaristokartasto 1880, pages 13 and 106
[37] The personal archives of Captain Sven-Erik Nylund
[38] The true course to Knaperskär is 244°. The course 247.5° mentioned by the pilot pointed to Gåsgrund and Eteläinen Lehtisaari. Declination was -7° 30' in the year 1918, and decreased 7' each year. This means that declination was - 6° 12' in the year 1929. Thus the course mentioned by the pilot could not have been the magnetic course, because the magnetic course would have been approximately 239.5°.

*The line defined by the lighthouse at Tirgrund and the flagpole at Sveaborg lead clear of these spar buoys. Thereafter the course is altered to port and when the lights at Melköhällen and Rönnskär lay on top of each other, the course is SW.½.S.'* (219.5°)[39].'

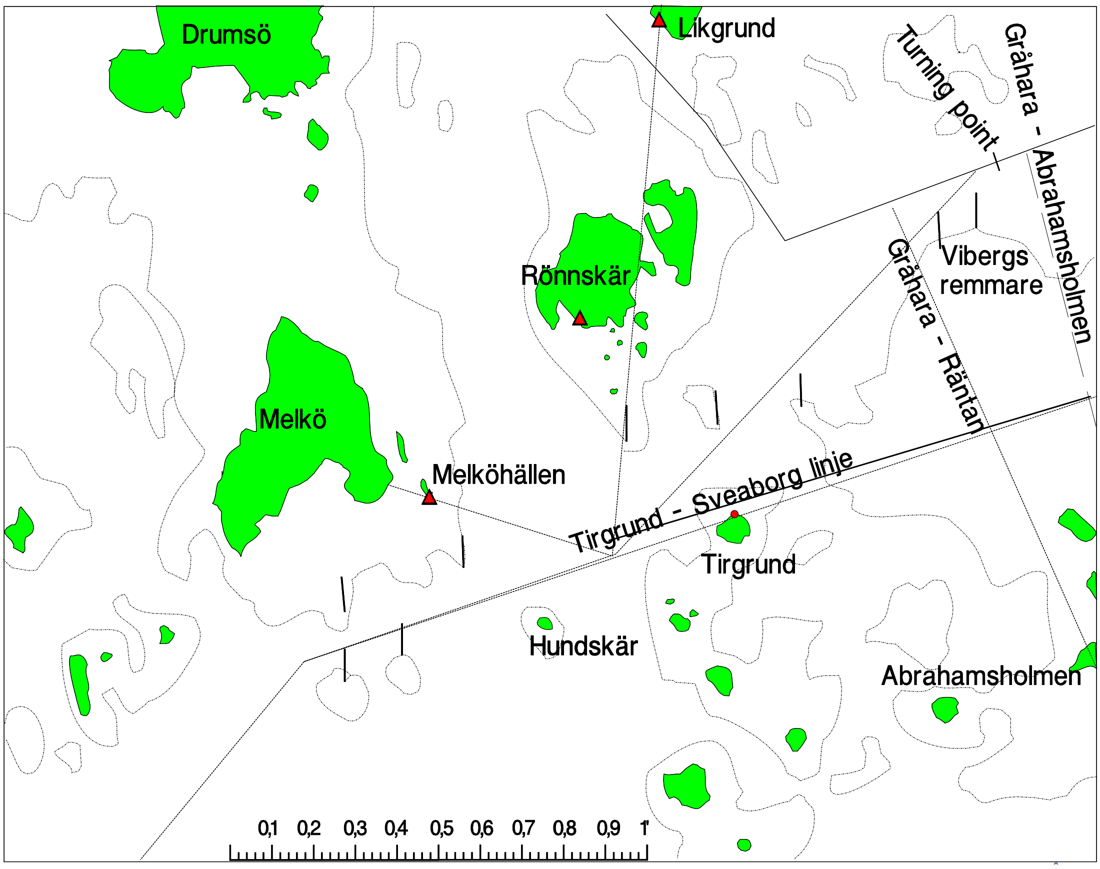


*Figure 2. A copy of the National Board of Navigation's nautical chart number 19, Porkkala-Söderskär 1:60.000, from 1928. The dashed line indicates the fairway line of the chart and the solid line the tracks corresponding with Johan Nylund's route plan.*

What is noteworthy in the plan is the fact that pilots defined tracks which guaranteed that the spar buoys were passed safely. At some points the fairway alignment of the nautical chart lay too close to the spar buoys. It was difficult to place the pair of leading lights in such a way that a long navigation line would be in the center of the navigable water area for the whole passage. Only the crossings of the lines were printed on the maps to indicate turns. The turning radii were missing.

[39] The true course of the Melkö-Rönnskär line was 222°. The course 219.5° mentioned by the pilot was the true course. The line was somewhat passed approximately to the border of the white sector of the Melkö light.

When departing from Helsinki, the vessel was first steered towards the south shore of Rönnskär. The turn was commenced when the Harmaja [Gråhara in Swedish] lighthouse could be sighted between Abrahaminluoto and Räntan, and then a turn was made towards Hundhällen (221°). By doing this the shoals of Rönnskär could be avoided. The next turning mark was the line of Likgrund-Rönnskär quay or the line formed by Melköhäll and the rock behind it. The lines crossed on the border of the white sector of Tirgrund light. The course 247°, which went between spar buoys, was taken from here. In dark it was possible to ascertain this by using the white sector of Tirgrund light. The course was steered to 219.5° on the border of the white sector of Melköhällen. Pilot Nylund's plan continued to Bomarsund. Pilots did route planning in writing at least 50 years before the IMCO's[40] first route plan recommendation[41] was issued in 1973.

The above described way to plan pilotage required a lot of work. It is not known how much the government pilots cooperated. The National Board of Navigation gave the pilots only a nautical chart to use.

It was possible to maintain a steady course along the line by using a compass, but there were no reliable methods to monitor how a turning manoeuvre proceeded. Seafarers found major alterations of the course unpleasant, because during the turn it was difficult to control the motion state of the vessel. The difficulties with controllability led to the dispersion of tracks at the end of the turn. The turns were executed with large rudder angles, so that a straight course could be reached quickly. On a straight line it was easy to control the motion. The turn was divided into two parts in an attempt to correct the situation. The seafarers requested that the checklines were drawn to indicate major alterations of course. These checklines were, however, of such kind that it was usually not possible to steer the courses they indicated. The checklines helped mainly in determining the starting points of the turns, and they made it easier to monitor how the turn proceeded. In the first place the objective of the checklines was to prevent the turns from starting too late. They were important in the days when radar was not yet usual in seafaring. Figure 3 illustrates a typical checkline.

[40] Inter-Governmental Maritime Consultative Organization, the former name of the IMO
[41] IMCO Res. A. 285(VIII), 20. Nov. 1973, Annex A, (iii) Navigation, (1): *'The intended voyage shall be planned in advance taking into consideration all pertinent information and any course laid down shall be checked.'*

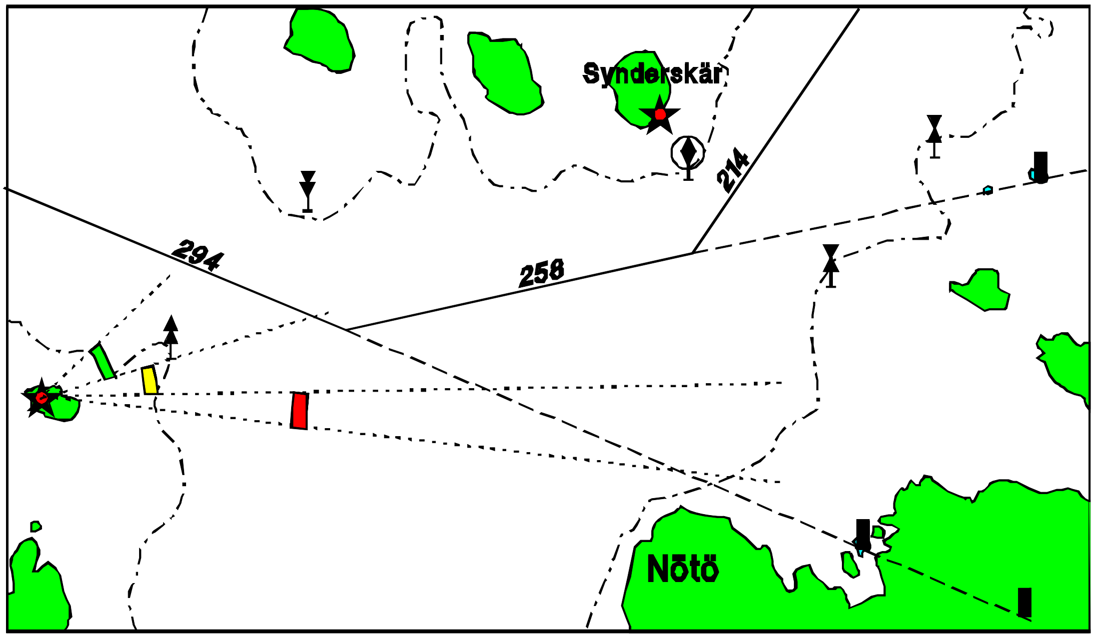


*Figure 3. A turn from the Labbskär line 214° to Nötö line 294°. The white sector describing the checkline helps to determine the starting point for the turn.*

Since 1925, the qualification requirement for pilots was a second mate's certificate, but this requirement was not complied with until 1946[42]. The pilotage services tried to improve the pilots' proficiency level by arranging courses, and urged them to study English. Earlier it was a custom that the pilot acquired his training himself. Still, there was no actual theoretical training for pilotage.

It was common to use company[43] pilots for the voyage on the passenger vessels trading back and forth between Finland and Sweden. The pilot worked for the shipping company and was employed on the vessel. Route planning became easier for these vessels, because the vessel could maintain consistent speed profile on the route. The distances on the straight fairway legs were measured with a clock, and the constant speed was determined from the revolution indicator of the propeller or the main engine. The turning points had been determined directly to the side perpendicular to the track. On a straight leg, the heading mark was always taken from the front of the bow.

Monitoring pilotage was at first an unknown concept. Monitoring the route plan was impossible especially because recognizing the motion state was based on the relative movement of fixed targets. The officers could only monitor how the vessel proceeded in the fairway. There was no way they could be familiar with the turning marks and pilot signals which the pilot had learnt by heart.

[42] Yrjö Kaukiainen and Pirkko Leino-Kaukiainen, 1992, p. 198
[43] Comanys own pilot who is called a line pilot in Finnish

The pilots did not always trust their own recollections of the chart. They compiled on their own initiative small notebooks, but they were not keen to show these notebooks to anyone, because spreading information about pilotage had been traditionally forbidden. Also the notes were in a way a proof that the memorized recollection could be unreliable. The pilots' notebooks were personal and only a few remain today.

*Table 1. An example of company pilot Kuno Eriksson's route notes for the voyage from Turku to Mariehamn from the year 1947. He used a magnetic compass and clock as navigational instruments. The distances between the beacons represented the time how long it took to proceed from one beacon to the following one. This plan did not include turning points.*

| | | |
|---|---|---|
| Skiftet | 70° | 20 min |
| Rödskär - Smörgrund | 50° | 30 min |
| Smörgrund | 60° | 4 min |
| Kåkombrink | 52° | 5 min |
| Björnholm | 68° | 8 min |
| Lövskär | 66° | 7 min |

Figure 4 illustrates the notes on company pilot Kuno Eriksson's nautical chart from the year 1952. The chart was to be read south up when proceeding southwards so that it would correspond with the view through the bridge windows. The example is from the eastern border of the Porkkala lease area. The courses in the notes are magnetic compass bearings. Compass declination was not printed on the chart, and the vessel's deviation curve is not known. The distances between the turning points were measured using a clock, because a taffrail log could not be used in the archipelago. The speeds were approximately 11–12 knots. There were no notes referring to radar navigation in the plan.

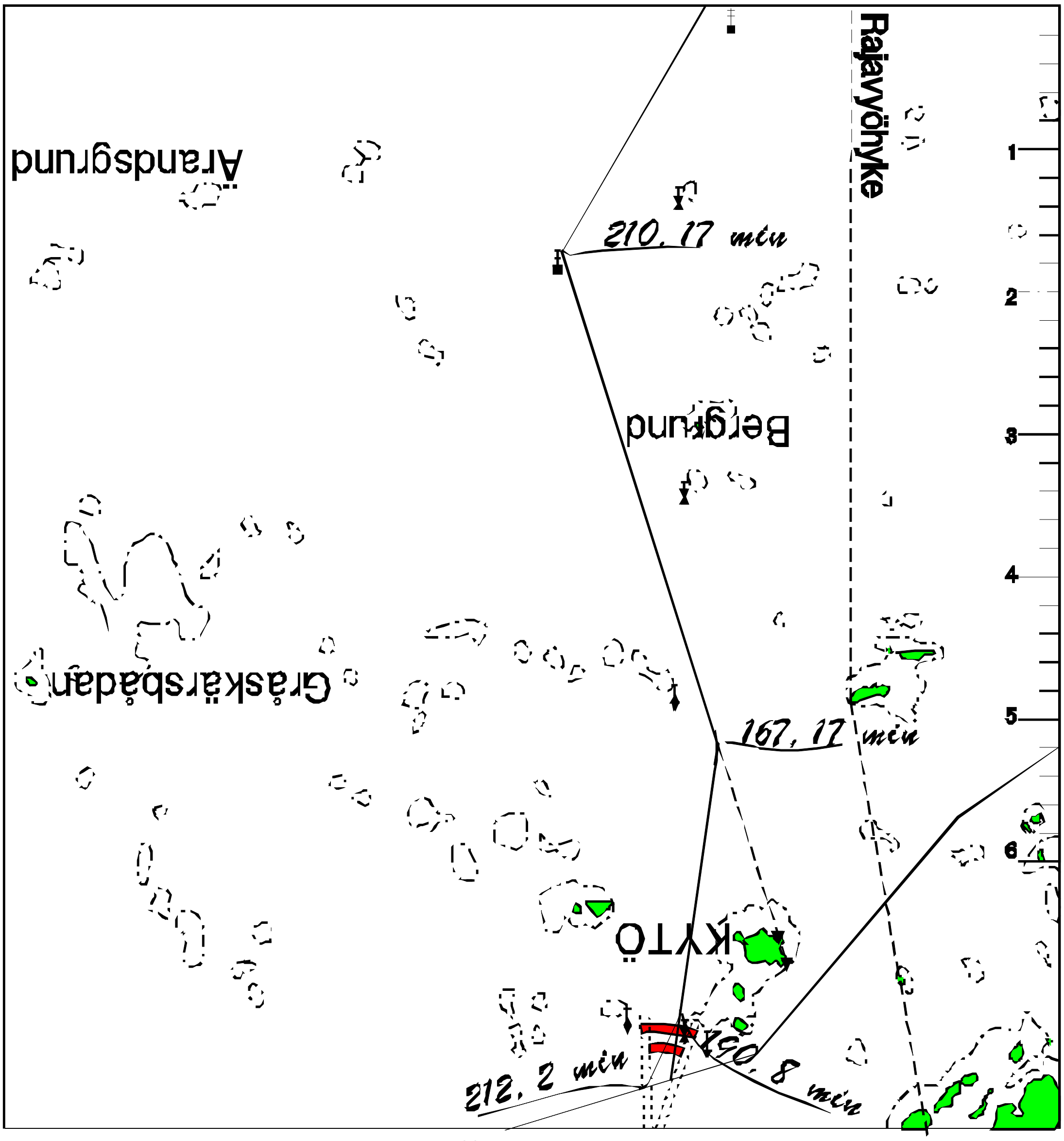


*Figure 4. The notes on the chart[44] used by route pilot Kuno Eriksson from the years 1952-1956 have been marked on the chart with the ships heading upwards. The depth contours illustrate shoals which are less than 10 metres in depth.*

When pilotage was solely based on visual observations, all officers participated in the lookout. The use of radar was becoming more common on merchant vessels in the 1950's, and thereby pilotage more and more became something performed by one individual only. Almost without exception there was only one radar on the vessel, and because it was expensive, it was used sparingly. The radar screen was small and it was covered with a sun visor, so that only one person at a time could monitor the radar image. This duty devolved upon the pilot, who at first used the radar only when the visibility was poor, but gradually

[44] The personal archives of M.D. Olli Turunen

the durability of the radar appliances grew better, and as a consequence of this, their utilization rate eventually increased.

At first the only display mode of the radar was an unstabilized HEAD UP image. This corresponded with the traditional pilotage method, because the display orientation of the radar corresponded with what could be seen from the window, and the radar image was monitored in a similar way as the landscape. The turning marks and pilot signals of the straight fairway legs had been different in daytime and night-time navigation respectively. In the daytime the navigators had looked for the lines formed by the landscape. At night they had relied on the borders of lighthouse sectors and on the number of the flashes from the lighthouse. Lighthouse flashes were later replaced by radar marks in defining the starting point of a turn. Navigation was still performed without radar assistance in the daytime, and radar navigation and visual navigation were regarded as two distinct pilotage methods. When the use of radar became more common, pilotage gradually became something one individual, the pilot, performed in all visibility conditions.

In the pilotage examination the student had to remember the turning marks of the fairway in as many as three different versions; as daymarks based on natural objects, as nightmarks based on beacons and also as radar marks. Thus the use of radar did not to make navigation easier in all respects.

*Table 2. An example of route pilot Kuno Eriksson's route notes from the 1950's when turning points were defined as distances straight ahead[45]. The scale of the radar, distance to the target, the desired course after the turn and time to the next turning point are indicated in the columns after the name of the turning point.*

| | | |
|---|---|---|
| Skötskär aheadr | 27 | 6 min |
| Staholm ahead | 0-1 | 2 min |
| Enskärens ahead | 326 | 2 min |
| Finngrund astern | 14 | 7 min |

It became customary to note distances straight ahead from the vessel's bow to indicate turning marks in old chart books, where the times between the targets had been noted. The scale setting of the radar display was also noted in the books. Later this kind of marking in a chart book was to be called an operational

45 The personal archives of M.D. Olli Turunen

procedure. The route plan consisted of the leg times between the beacons, as was the case before radar navigation, and of the turning marks.

The HEAD UP display of the radar is well suited for piloting if there are a lot of fixed targets and no movable targets within sight. The major disadvantage of this display mode is that it is not possible to give the helmsman the compass course which should be steered. Instead the manoeuvring orders must be given in the form 'steady as she goes'.

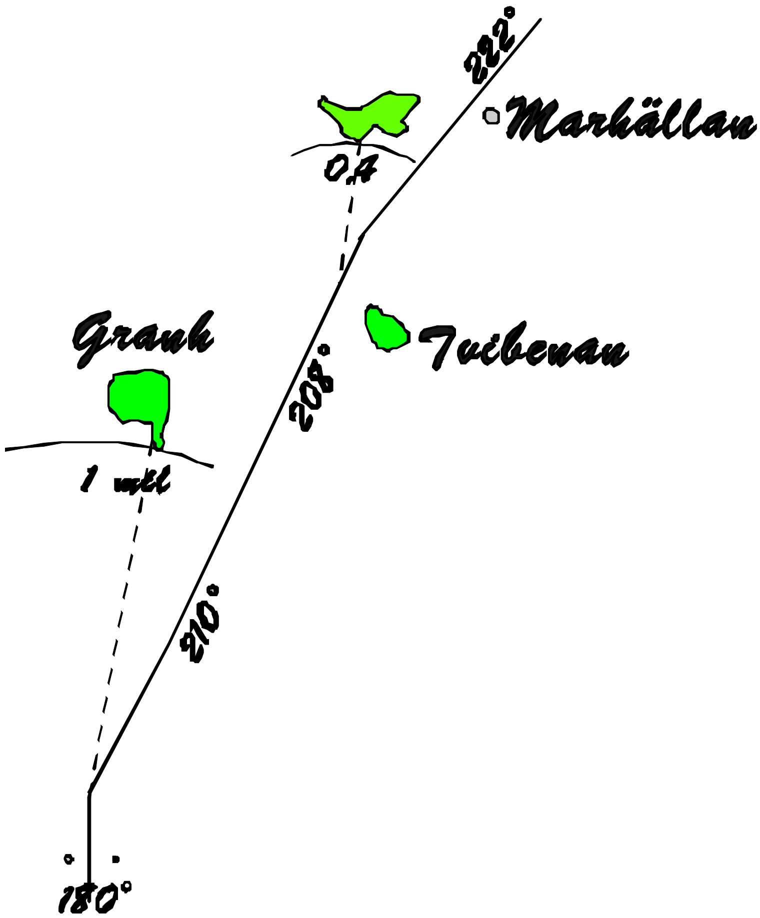


*Figure 5. The figure illustrates a loose leaf in route pilot Kuno Eriksson's notebook. The drawing is orientated as south up. The route plan describes leaving Mariehamn by using a HEAD UP radar display[46].*

The plan above has been drawn south up so that it could be used with the help of a radar display. The drawing is only indicative because the islands are not located in the correct positions in relation to each other. The plan has probably been drawn at the beginning of the 1950's. The turn geometry has not been taken in to account yet.

[46] The personal archives of M.D. Olli Turunen

In radar navigation the distances were estimated visually with the help of the fixed range marker rings of the radar display, and the turning points were distances to the fixed targets located straight ahead. Seafarers usually chose as radar targets such objects, which at the beginning of the turn were located as close as possible to one of the fixed range marker rings of the radar scope.

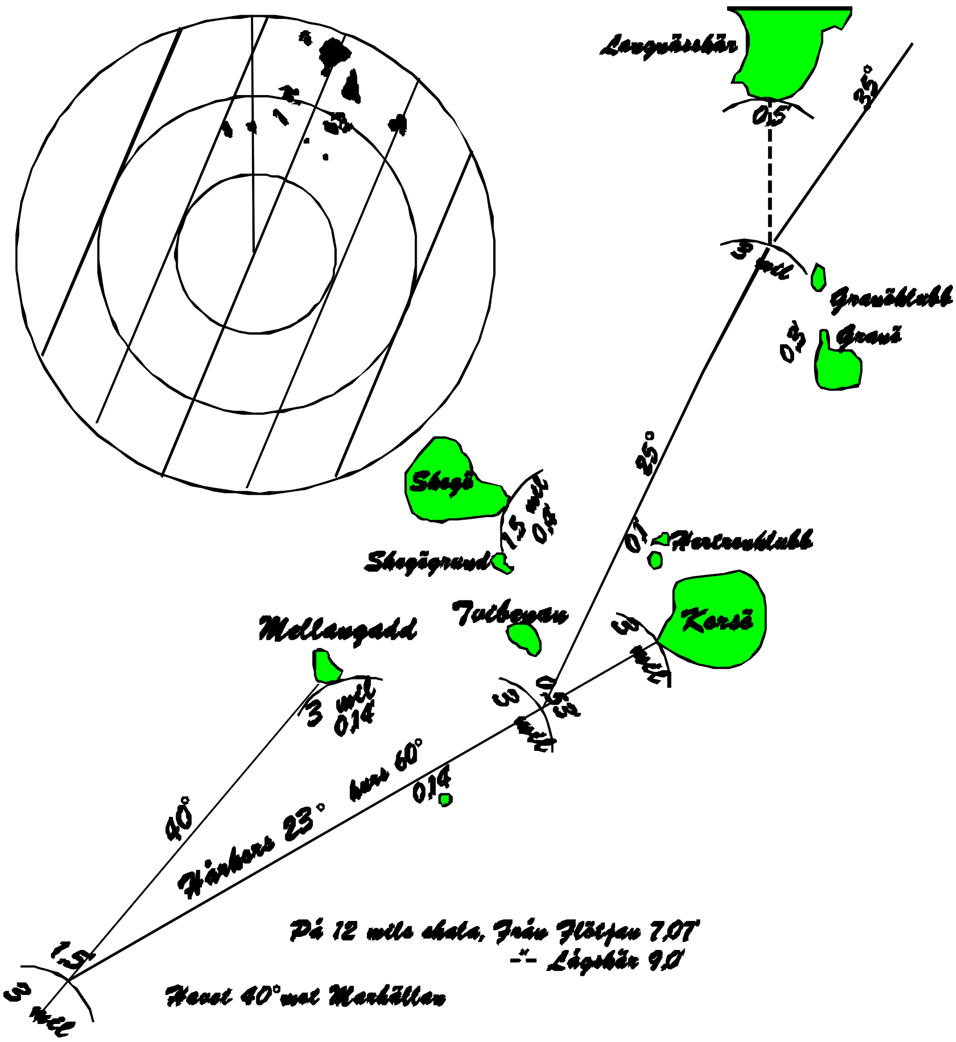


*Figure 6.* *Figure illustrates a drawing of a route plan from the Sea of Åland to Mariehamn made by route pilot Kuno Eriksson. The orientation of the chart drawing is north up, whereas the radar orientation is here shown head up, which was typical of that time. The chart had been drawn without a scale. The radar image illustrates the vessel at the turning point from the magnetic compass course 040° to course 060°. The cross hairs of the radar have been turned 23 degrees to the head bearing.* [47]

[47] The personal archives of M.D. Olli Turunen

The route plan in Figure 6 was drawn at the end of the 1950's for a HEAD UP radar. This can be seen from the marking *'Hårkors 23°'*, which describes the turn from the sea towards Korsö Island. *Hårkors* stands for the mechanical plate placed on the radar scope. When the head bearing 23° points to Korsö Island, a turn is made to heading 60°. All alterations of heading were based on the distances measured by the radar from the targets which were straight ahead. Passing distances and the scale of the radar are marked at the most important places. This pilot has probably used a display with an adjustable range marker VRM (Variable Range Marker), because the distances were indicated as hundredth parts of a mile. The turn geometry was not noted.

It was difficult to control the vessel's motion state during the turn. It was difficult to estimate the turning radius if there was not any radar target close to the geometric centre of the curve, to which the distance could be measured during the turn. The estimate on the motion state was based on the chart the pilot had memorized, and which he compared with the visual outlook in the window. Controlling motion state with the help of radar has been explained in Figure 7.

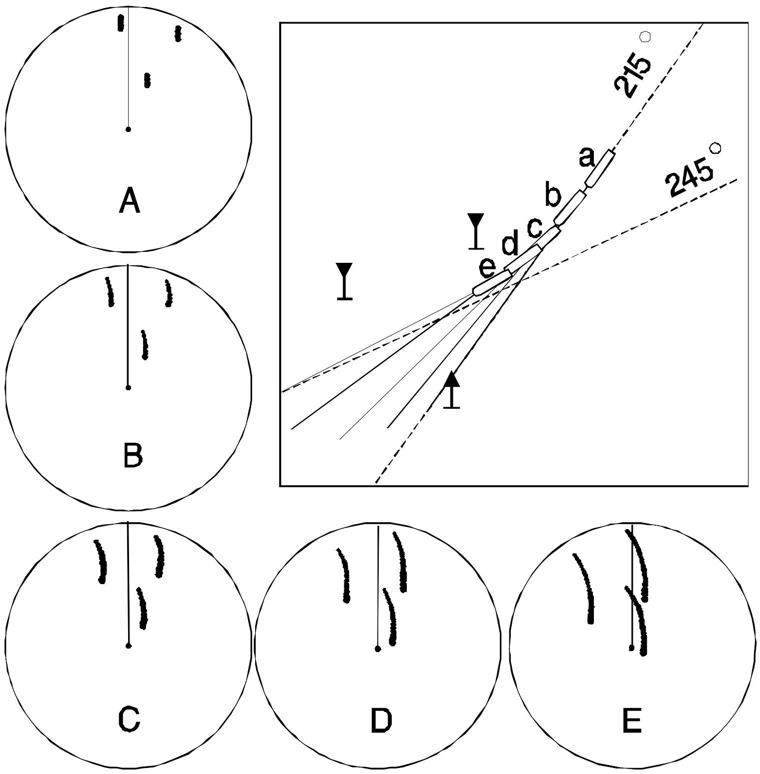


*Figure 7.* *The chart is shown as north up, whereas the display orientation of the radar is head up. The vessel turns from course 215° to course 245°. The points a-e on the chart correspond with the radar displays A-E. The curves of the afterglow left by fixed targets correspond with the mirror image of the vessel's own turn.*

The turning motion of the vessel was estimated from the movement of a fixed target on the radar screen. The pilots had an experience-based recollection of the movement of the fixed targets in the scenery discernible from the bridge. The

HEAD UP image on the radar corresponds with the scenery as to its display mode, and the pilot can deduce the turning speed of the vessel from the movement direction of the radar targets on the radar screen. The arched tracks drawn by the afterglow of the radar illustrate the turning radius of the turn as its mirror image.

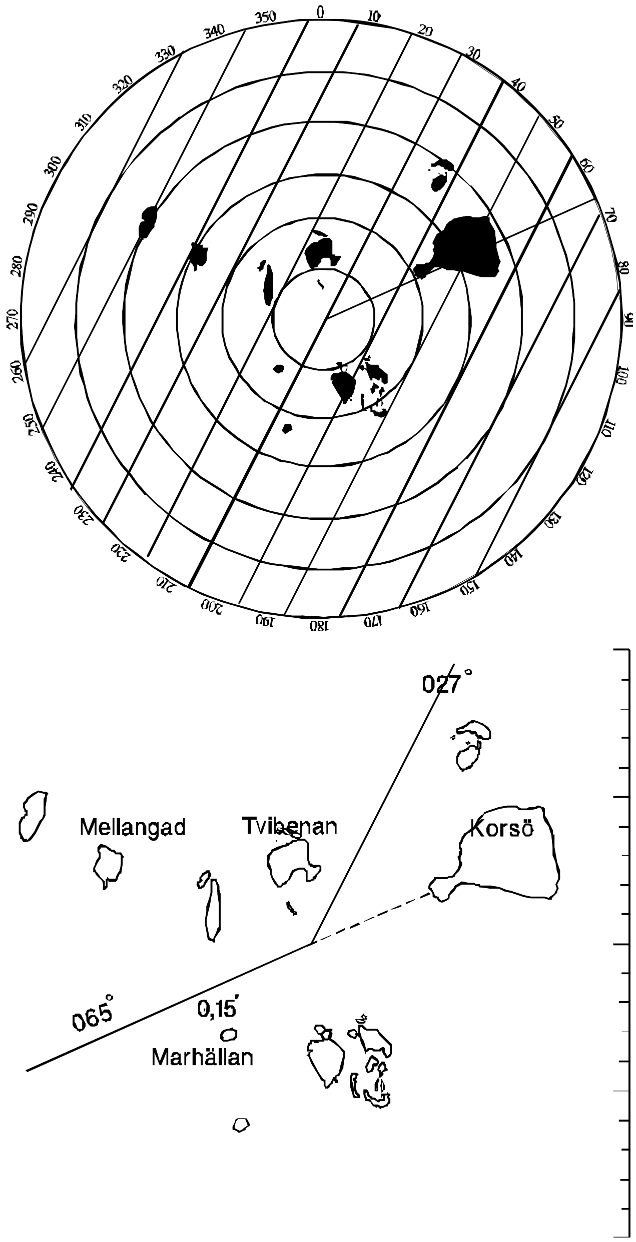


*Figure 8. The compass-stabilized NORTH UP image became common during the years 1955-1965. In the situation illustrated in the figure, the turn starts when the 0.5' (nautical miles) range marker ring touches the island located ahead.[48] The mechanical bearing plate indicates the new course 028°.*

[48] The personal archives of M.D. Olli Turunen

Compass-stabilized radars became more common at the end of the 1950’s. They often had a steplessly adjustable range marker ring VRM. The compass-stabilized NORTH UP display orientation provides a good possibility to estimate the risk of collision with other vessels. This display mode was very slowly established on the vessels. Two schools were formed with respect to radar work. At first the majority of seafarers were for the HEAD UP display mode (Figure 7), because it corresponded with what could be seen from the window. Gradually the NORTH UP display mode became more common, because the display remained clear for the whole turn since the afterglow did not blur the radar image.

The electronic bearing line, EBL, became more common at the beginning of the 1960's. At first the EBL showed bearings only outwards from the vessel. When it came to small alterations of course, this EBL was already suitable for determining the starting point of the turn. Movable EBL measuring courses between two points became more common in the 1970's. This made it possible to accurately determine the starting point of the turn.

# 3 REGULATIONS CONCERNING PILOTAGE FORMERLY AND TODAY

25 of the investigation reports related to pilotage published by the Accident Investigation Board concern the national pilotage requirements. Of these, 14 incidents are related to bridge cooperation, 11 to route planning, and 5 to the pilot boarding and disembarkation places.

Previously, national regulations applied to bridge cooperation, pilotage, and route planning. Since the end of the 1990s, these instructions have been removed and, today, bridge cooperation and pilotage are not regulated on a national level.

## 3.1 The IMO requirements on pilotage

In 1973 the UN subordinate maritime organization IMCO[49] (since 1982 the IMO) noted that the cooperation between pilots and masters did not work out in a professional manner. Voyages were not planned beforehand, and sea watch was often kept carelessly. The IMCO published a resolution which aimed at correcting the defects[50]. It emphasized the master's responsibility when the pilot was onboard. In addition, the resolution introduced a new concept, route planning. According to the resolution a voyage had to be planned also with respect to the fairway legs which were piloted. The requirement on route planning is of vital importance with respect to the safety of navigation. The requirement also incorporated the thought according to which navigation had to become teamwork instead of being something carried out by an individual - the objective of the requirement on route planning was to force the vessel's officers to familiarize themselves with fairways. The route planning described in the resolution did not, however, pass on to the Finnish national regulations.

The contents of the 1973 Resolution were repeated in the STCW Convention in 1978. It was expected that the coming into force of the STCW Convention would improve route planning. The recommendation was not, however, complied with in practice.

Since 1978 the IMO has required[51] that the master must give the pilot necessary information about the vessel's manoeuvring characteristics. With respect to manoeuvring characteristics, the IMO specified the matter in 1987 by issuing a

[49] IMCO, Inter-governmental Maritime Consultative Organization, nowadays the IMO, International Maritime Organization, subordinate to the UN
[50] IMO Resolution A.285(VIII)
[51] STCW convention 1978, Chapter II, paragraph 10 and STCW Code 1995, Chapter VIII, paragraph 49, Navigation with pilot on board

Resolution[52] in which it defined two documents: the *Pilot Card* to be given to the pilot and the *Wheelhouse Poster* to be displayed on the Bridge wall.

When the pilot boards the vessel, it is important to go through the checklist on the Pilot Card, which puts the master under the obligation to clarify the following matters affecting the pilotage:

- the wavelengths of the radar
- the working principle of the log (speed through water or speed over ground)
- the drift angle calculation of the log
- the working method of the engine order telegraph, the number of steering gear
- the location of the rudder angle indicator, revolution indicator and the possible angular velocity gauge and
- the compass error to be notified to the pilot.

The information available in the documents is, however, only partly useful in piloting performed in the Finnish fairways.

In 1981 the IMCO issued a Resolution[53], which dealt with pilotage. Its Annex listed that a pilot must:

- memorise the chart
- know how to use radar, ARPA (Automatic Radar Plotting Aid) and bridge equipment

The requirement on knowing the chart from memory is a historical and international tradition. The pilot is not required to keep a written route plan with him/her while providing pilotage. It would, however, be useful for the employers to draw a route plan for their own seafarers providing pilotage, because an own separate pilot plan for each vessel /person does not promote safety.

Annex 2 in the IMCO resolution lists some customary routines. The master and the pilot must prepare for the pilotage and

- agree on a passage plan
- take into consideration the prevailing conditions, traffic and the speed of the vessel
- agree on matters affecting the handling of the vessel and
- decide on whether tugs are used.

[52] Resolution A.601 (15) 19 Nov. 1987, Annex: Appendix 1, PILOT CARD. Appendix 2, WHEELHOUSE POSTER

[53] A.483(XII), Training, Qualifications and Operational Procedures for Maritime Pilots other than deep-sea pilots

Operational procedures are useful, because they promote cooperation on the bridge. According to the Annex, the pilot must use expressions corresponding with the IMO Standard Marine Vocabulary, i.e. English must be the language of communication.

The common language requirement also partly improves bridge cooperation. Language problems may not arise even though there are representatives of several nationalities on the bridge. The typical situation is e.g. such that the master speaks English with the pilot, but the officers converse in their own mother tongue and the pilot uses a third language when communicating with the tugs. The IMO has intervened with the tangled situation already with respect to radio communications[54]. With reference to bridge cooperation and safety it is important that one common language, English, is adopted if the persons present on the bridge do not understand each other's native languages.

The IMO amended the STCW Convention in 1995 (Amendment, STCW 95). The Amendment required the voyage to be planned from the port of departure to the port of destination. This was not a fundamental change when compared with the 1978 Convention, but what was new were the different factors contributing to route planning which were now introduced for the first time. These included e.g. the turning points and areas of shallow water. In Finland the STCW Convention entered into force by a decree[55] in the year 1997.

The STCW-95 does not issue a direct practical instruction on how to define the route plan, but the criteria were expressed so clearly that, based on them, a seafarer is able to draw upa reliable pilotage method based on radar navigation and angular velocity navigation. As to route planning, Chapter II in the A Part of the Code is definitely a step forward compared with the earlier regulations.

In 2003 the IMO issued a resolution on the training of pilots and on the operational procedures for pilots[56]. The resolution recommends that pilots receive both theoretical and practical training. Practical training can be complemented by simulator training and manned ship models. The resolution emphasizes the cooperation between the master of the vessel and the pilot (BRM, Bridge Resource Management). An important part of the cooperation is the exchange of information when preparing for the pilotage. According to the IMO, the responsible authority must check at intervals of at least five years that the pilots have adequate navigational skills and knowledge of regulations. Pilots must receive training in the English language and bridge cooperation and practise in a ship-handling simulator, and they must participate in seminars on the latest navigation techniques. The resolution does not mention learning buoyage by heart. The recommendation of this Resolution has been taken into account in the internal guidelines of the State Pilotage Enterprise.

[54] IMO A.578(14) Nov. 1985, ANNEX 1, 2.4 Communications. 3.4.3
[55] Decree 1256/1997
[56] Resolution A.960(23), 5 December 2003. Recommendations on Training and Certification and on **Operational Procedures** for Maritime Pilots other than Deep-Sea Pilots

The section on *Training* in Annex 1 of the Resolution states that the authority should develop standards with reference to the training given to the pilots and the reporting of incidents as well as define the required work experience and cooperation training. According to the resolution the pilot must be familiar with the national and international regulations and know the chart from memory. Consequently, the number of matters to be known by heart has increased further. There is no requirement that the pilotage authority should define the commonly used route plans.

The Resolution[57] states the following about the cooperation between the master and the pilot:

*'Every pilot should be trained in* ***bridge resource management*** *with an emphasis on the exchange on information that is essential to a safe transit. This training should include requirement for the pilot to assess particular situation and to conduct an exchange of information with the master and/or officer in charge of navigational watch. Maintaining an effective working relationship between the pilot and the bridge team in both routine and emergency conditions should be covered in training. Emergency conditions should include loss of steering, loss of propulsion, and failures of radar, vital systems and automation, in narrow channel or fairway.'* [58]

The Resolutions have not brought any solution to the pilotage method itself. Neither of the Resolutions (1981 nor 2002) takes a stand on the actual work of the pilot, i.e. how a vessel must be conducted and manoeuvred. The IMO is of the opinion that it cannot determine how pilotage is performed on the territorial waters of the different member states.

The SOLAS Convention and other technical resolutions indicate that according to the IMO, the two fundamental tasks to be performed on the bridge are position determination and collision prevention. According to these technical regulations, pilotage is not one of the seafarer's fundamental tasks, so the definition of pilotage must be looked for in the requirements set by the STCW Convention.

The STCW 95 does not mention pilotage as a separate task belonging to the seafarer's duties, but the STCW Code lists the essential factors[59] which constitute pilotage. All the chief officers and masters working on vessels with a gross tonnage of over 500 are required to know these factors. This large group of seafarers exceeds many times the number of all the pilots in the world. The STCW Code mentions the following factors connected with the work:

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[57] IMO, Res 960(23), 5 Dec, 2003. Recommendation on Training and Certification and Operation and on Operational Procedures for Maritime Pilots other than Deep-Sea Pilots

[58] IMO , Res 960(23), Annex 1, paragraph 5.3

[59] STCW, Chapter VIII, Section A-VII/2, part 2 and Table A-II/2

- *'Voyage planning'*, which means drawing a route plan from port to port. The following criteria must be taken into consideration: the fairway planning instruction, the meeting prohibitions in force in vessel traffic and the vessel's speed in shallow waters.

- *'Blind pilotage techniques'*, which means that the route plan is carried out by radar navigation.

- *'Application of constant rate of turn techniques'*, which means that turn geometry is controlled with the help of angular velocity. In order for this requirement to be feasible in practice, there should be an angular velocity gyroscope or a similar device on the vessel.

- *'Handling of ships in rivers, estuaries and restricted waters, having regard to the effect of current, wind and restricted water on helm response and berthing and unberthing under various conditions of wind, tide and current with and without tugs.'* This means recognizing the vessel's motion state, which can be supported e.g. with the help of a *predictor* (see Section 7.3.1). The presentation of a predictor requires that at least the vessel's geographic position, true course, angular velocity and speed and course over ground are known.

The IMO tried to include the requirement on bridge cooperation in the STCW 95. The majority of the IMO member states opposed this, and the attempt did not succeed. The IMO attached bridge cooperation to Part B of the STCW 95 Code as a mere recommendation[60].

The IMO's technical regulations from the year 1998 on integrated navigation equipment do not mention the importance of cooperation in using the system[61]. The recommendation only states that the purpose of the equipment is to increase the value of information and to reduce workload. The importance of cooperation in the utilization of the equipment is not emphasized.

The IMO guides shipping companies to instruct the vessels' officers with reference to all dangerous situations[62]. Section 2.2.1.3 in the ISM Code puts forth the objective to create and continuously develop a safe working environment and safe working methods. The practical measures to meet the objectives are, however, not defined in the Code.

[60] IMO STCW CODE 1995, Annex 2, Part B, Recommended guidance regarding provisions of the STCW Convention and its annex. Chapter VIII, Section B-VIII/2, Part 3-1. Bridge Resource Management

[61] IMO MSC.86 (70) 1998, Annex 3, Recommendation on Performance Standards for an Integrated Navigation System

[62] IMO Res. A.913 (22) 2001. Revised Guidelines on Implementation of the International Safety Management (ISM) Code by Administrations

Through the ISM Code[63] the IMO has passed the drawing of detailed bridge instructions to the shipping companies. The definition of the ISM is, however, so superficial that this has led to such a situation in which the bridge instructions issued by the shipping companies are heterogeneous, and the modern defining of pilotage is as a rule not done.

Defining the method of pilotage thus remains in the discretion of each state. Even if each member state issued an instruction on pilotage, common requirements with reference to bridge equipment could not be achieved without the IMO's contribution. It would be important to describe how turning manoeuvres are planned, performed and monitored. After this it could be charted which appliances a pilot needs in his/her work and the equipment requirement could be set hereafter.

European regulations on equipment used in river traffic[64] pilotage require the vessels to have an angular velocity gyroscope and an angular velocity indicator. If a helmsman is not employed on the bridge, there has to be an automatic control of angular velocity. Vessels must be equipped with a centred manoeuvring place, and the information on angular velocity must be available also on the top of the radar image. The orientation of the radar display must always be head up, and the radar cannot be gyrostabilized. One major drawback in the regulations concerning seagoing vessels is the fact that they do not require the vessels to carry an angular velocity gyroscope, gauge or an automatic control of the angular velocity autopilot.

## 3.2 The IMO requirements on equipment

In the IMO the development of navigation technology and navigation work has been divided as tasks of two different sub-committees. The NAV Sub-Committee (Navigation) draws resolutions on the technology of the navigational equipment and the STW Sub-Committee (Standards of Training and Watchkeeping) defines the skills required in bridge work.

The NAV Sub-Committee defines the technical standards for the navigational instruments. With respect to displays, the NAV takes a stand on only technical requirements, such as the physical size of the screens, but when it comes to the user interfaces, the Sub-Committee only comes forth with a general requirement according to which human interfaces have to be ergonomic or easy to use. As to fairway navigation, there are, however, no regulations on the equipment. According to the view expressed by the NAV Sub-Committee, defining navigation and pilotage work remains the task of the STW Sub-Committee.

The job description of the STW Sub-Committee includes defining navigation work, but it does not define the functions of the display appliances used in the work. Because of this, the design of user interfaces has remained with the

[63] International Safety Management Code
[64] Rheinschiffsuntersuchungsordnung (RheinSchUO) 1995. Zentralkommission für die Rheinschiffahrt

equipment manufacturers. The STW does not pay attention to the equipment used in fairway navigation nor to the training connected with their usage, so the IMO has completely failed to deal with fairway navigation. The features of the display equipment needed in pilotage have not been defined at all.

The requirement to know all the existing navigation equipment would be unreasonable, so the IMO should first define the technical characteristics of the piloting equipment before pilots can be asked to know how to use them.

The IMCO's first resolution on radar A 222(VII) was issued in 1971. 180 mm (9") was enough as the diameter of the radar screen. As to pilotage, the most important requirements expressed in the resolution had to do with range marker rings, the mechanical bearing plate placed on the scope and compass-stabilization. In practice these features became more common in seafaring approximately ten years earlier. Because of the IMCO's method of working, it took about eight years after appointing the working group dealing with the technical features of radar before a new resolution was passed in the Assembly.

The IMCO Resolution 278(VII) from 1973 aimed at standardizing radar equipment interfaces by recommending symbols to be used on the radar display control buttons instead of text. Only one manufacturer used these symbols, and because of that received unjustified critique from the users. The failure of this recommendation could have been the reason for the fact that after this the IMCO did not intervene with the ergonomics of the equipment. In 1981 the IMCO only required that *'Operational controls should be accessible and easy to identify and use.'* Because of this development, there can be major differences in the usage ergonomics of different radar equipment.

Radar was commonly used in seafaring from the beginning of the 1950's, but the IMCO-ratified Rules of the Road at Sea did not mention radar usage in collision prevention until 1972. The international regulations on radar equipment entered into force in 1977. In other words, radar was used at sea for over 26 years before the official regulations accepted its use in navigation. During that time different schools and standard procedures were formed, and it was later difficult to change these with the help of regulations.

*Table 3. The resolutions issued by the IMCO Assembly dealing with the technical provisions of maritime radar from the point of view of pilotage. Almost all the requirements have been written for technical equipment already broadly used*

| The resolutions issued by the IMCO Assembly on the technical provisions of maritime radar | | **In practice** the changes had been carried out already before the regulations have entered into force |
|---|---|---|
| **A.222 (VII) 1971** | **A.477 (XII) 1981** | |
| The fixed range marker rings of the display | The fixed range marker rings of the display | Since 1948 |
| Compass-stabilization | Compass-stabilization | At the end of the 1950's |
| Radar screen 9" | Radar screen 9" 500 brt<br>Radar screen 12" 1,600 brt<br>Radar screen 16" 10,000 brt | 9" in the 1950's<br>12" in the 1960's<br>16" in the 1970's |
| | Variable Range Marker, VRM | At the end of the 1950's |

The Resolutions[65,66] issued by the IMO's Maritime Safety Committee MSC 64(67) in 1996 and by the MSC 192(79) in 2004 also registered equipment corresponding with the table below.

*Table 4. A list of equipment mentioned in the resolutions by the IMO's Maritime Safety Committee (MSC) 1996-2004 applicable in performing pilotage.*

| | **MSC 64 (67) 1996** | **MSC 192(79) 2004** |
|---|---|---|
| EBL (Electronic Bearing Line) movable bearing | One EBL bearing | Two EBL bearings |
| VRM (Variable Range Marker) | One VRM was required as early as in 1981 | Two VRM rings |
| PI (Parallel Index), a parallel line with the track | Two PI lines | Four PI lines |
| Setting the own vessel to the desired position | Off Center | Off Center |
| | | The common reference point of the antennas is defined, e.g. the manoeuvring place |
| | | Course Up display |

65 Resolution MSC 64(67) 1996, Annex 4, Recommendation on performance standards for radar equipment.
66 Resolution MSC 192(79) 2004, Annex, Revised recommendation on performance standards for radar equipment.

The MSC Resolution 192(79) from the year 2004 takes a stand on position determination and prevention of collisions, but pilotage is not mentioned in the resolution.

The electronic navigation equipment used after the Second World War has been called aids of navigation in the IMCO and IMO terminology. According to the IMO regulations, any information retrieved from each aid of navigation must be compared with the data obtained from another aid of navigation so that the possible errors can be detected. For example in a situation in which the officer in charge of the navigational watch has three different hyperbola position determination devices[67] and the compulsory radio direction finder device at his/her disposal, he/she should, according to the IMO regulations, compare the position indicated by all the devices with each other. The first IMO Resolution on autopilots[68] was issued in 1975. It did not, however, lend support to pilotage or integrated navigation.

## 3.3 National requirements on pilotage

The 1957 Pilotage Decree defined the general principles of pilotage in Finland. The pilot was required to stay in the fairway, to keep a Nautical chart of the area with him/her and to inform the master when the vessel approached the turning point in the fairway.

Traditions are strong in seafaring, and the first Finnish Pilotage Decree from the year 1922 is an example of this as the pilot was still called “the pilot of the crown”. In pilotage the transfer of information has traditionally been one-way communication, as the master was obliged to give the information that the pilot requested. The pilot was under no obligation to share information. The 1957 Pilotage Decree did not change the situation in this respect. The pilot acted independently and worked on his/her own responsibility.

### 3.3.1 State liability

The state’s discharge from liability with respect to pilotage was stated in the Tort Liability Act in 1974. The most important objective of the Act can be found in Chapter 3, Section 1. According to it, the employer is usually always liable in damages for injury or damage caused by the employee. The Act also defines that a public corporation is liable in damages for injury or damage caused through an error or negligence in the exercise of public authority.

[67] Decca Navigator, Loran C, and Omega
[68] Resolution A.342 (IX). Recommendation on Performance Standards for Automation pilots

An exception to the general custom of the Act was made with respect to pilots. The state wanted to be discharged from liability for injury or damage caused in maritime piloting. The reasons in the Government Bill to the Parliament were stated as follows:

- The Government was not aware that public authorities would in any country be liable for the damages caused by a pilot.
- Sea damage is often of major nature because of the value of the vessels and the cargo, so the state and municipalities cannot be liable for damages.
- Insurance is always taken to cover maritime transportations.
- The committee also referred to the fact that according to the Pilotage Decree (Section 19(1)), the master is responsible for the manoeuvring of the vessel despite the pilot being present.

Based on this, the Parliament decided that:

*'The state and the municipalities shall not be liable in damages for injury or damage caused in maritime piloting.'*[69]

The union of pilots and lighthousekeepers had asked in a letter to the Ministry of Justice dated 24.9.1969 pilots to be discharged from financial liability caused by a maritime accident taking place during the exercise of their official duties. This proposal was not taken into account in the drafting of the Act.

According to the Maritime Act, first the shipowner had to pay for the damages caused by the pilot, and only afterwards apply for damages from the pilot. The pilot's liability to pay damages was personal, but according to the protective provisions in Chapter 4 in the Tort Liability Act, liability in damages could be limited[70].

[69] Tort Liability Act 412/1974, Section 7
[70] Sirkka-Heleena Nyman 1997, p. 81

### 3.3.2 Pilot boarding and disembarkation places

In five of the cases studied, confusion related to the pilot boarding and disembarkation places played a significant role in the accident. This section discusses the instructions related to the topic.

The 1957 Pilotage Decree[71] does not specifically mention pilot boarding and disembarkation places. An unspecified incident made the National Board of Navigation issue instructions on pilot boarding places in a circular in 1972. The instructions were published in the National Board of Navigation Bulletin[72]:

> *Pilot boarding the vessel and disembarking it.*
>
> *For certain reasons the National Board of Navigation reminds pilots of the fact that the point marked in charts as 'Pilot' located off pilot stations at the open sea indicates the place where the pilot takes upon himself/herself the duty of pilotage when the vessel is inbound from the sea. When the vessel is outbound, the pilot disembarks the vessel at the same place.*

The wording of the circular was strict and precise.

The tanker ANTONIO GRAMSCI grounded at the entrance of Emäsalo fairway on 6.2.1987. It was not possible to follow the instruction on the pilot boarding place, because the ice situation hampered the movement of the pilot vessel. This caused confusion as to the pilot boarding place, and the situation resulted in a grounding. The accident led to a widespread public debate. The Director General of the National Board of Navigation insisted that the pilot boarding and disembarkation places had to be checked. The National Board of Navigation gave new instructions on the moving of pilot boarding places to the outer ends of fairways, away from the shallows[73]. An exception was made as to complying with the pilot boarding place compared with the previous instruction:

> *'Due to circumstances related to weather, ice or other reasons, the pilots can also board the vessel or disembark it at other points of the fairway.'*

The new instruction revoked the principle of the previous instruction, and changed the contents of the document in such a way that it corresponded with the prevailing practice. What was new in the instruction was the fact that the pilot had to come to an agreement with the master if another place than the one marked in the chart was used.

The Chancellor of Justice criticized the new instruction by expressing a concern that a vessel carrying dangerous cargo could proceed far into the archipelago without any pilot assistance. He also criticized the new instructions because the

[71] Luotsausasetus 393, 3.12.1957
[72] National Board of Navigation Bulletin No. 9/72, 2.4.1972.
[73] National Board of Navigation Bulletin No. 7/87, 10.4.1987

wording *'special circumstances'* was not specifically defined[74]. The Chancellor of Justice's message was clear. Such a situation in which a foreign vessel did not receive pilotage assistance could not be allowed to develop.

Because of the Chancellor of Justice's criticism, the regulations on pilotage were revised and the first Finnish pilotage instruction[75] was issued on 8 February 1988. However, the principle which the Chancellor of Justice had criticized remained in force. The section in the instruction dealing with pilot disembarkation stated as follows:

> *'The areas for pilot boarding and disembarkation has been marked in the charts, and the pilotage distances have been presented in lists confirmed by the National Board of Navigation. Due to special circumstances the pilot can, on the basis of the pilot station duty officer's or his/her own consideration, board or disembark the vessel even at other points of the fairway or also at open sea if there is a mutual understanding of this with the vessel's master and if a well-grounded and approved reason for this exists.'*

Twelve years later, in the year 2000, the Finnish Maritime Administration issued a new instruction on pilotage. Section 5 in the instruction reads as follows:

> *'Agreeing upon the pilot boarding and/or disembarkation place*
>
> *If the pilot, due to special circumstances, boards or disembarks the vessel at another point of the fairway than at the pilot boarding/disembarkation place, he/she must agree upon this with the master of the vessel and with the pilot Duty Officer or the VTS centre.'* [76]

The Finnish Maritime Administration removed the pilotage instruction from the list of decisions in force between December 2003 and February 2004. As to the pilot boarding/disembarkation place, the situation had thus declined to the level preceding the year 1972. The situation has deteriorated further when pilot duty service in connection with an organizational change was transferred from the VTS centres to the State Pilotage Enterprise. VTS operators criticize that they in certain situations do not know in which position of the fairway the pilot boards the vessel.

The 1988 pilotage instruction had listed all the technical requirements caused by performing pilotage operations:

- When pilotage is commenced, the pilot must present the master with the regulations concerning pilotage, and he/she must find out the information affecting the progress and manoeuvring of the vessel and especially the condition of the maritime equipment.

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[74] Helsingin Sanomat 10.12.1987

[75] National Board of Navigation Bulletin No. 6/88, 8.2.1988

[76] FMA Bulletin No. 10/20.6.2000

- The pilot must have '*in the chart extracts the necessary markings for radar navigation, e.g. the required courses, voyages and distances*'.
- The instruction states that the accidents mainly take place in turns. A whole chapter deals with the control of the speed, defining turning points and monitoring the progress of the turn with the help of pilot signals.
- The instruction emphasizes that radar navigation should be practised also in clear weather.
- The instruction gave the pilot the right to interrupt pilotage if he/she deemed it necessary because of the safety of the vessel.

Ten years later, the obligations this instruction placed on the pilot were removed from the new Decree[77]. They were issued by a separate pilotage instruction in the year 2000. The instruction remained in force only for a couple of years.

### 3.3.3 Compulsory pilotage

The new Pilotage Act (90/1998) defined compulsory pilotage on the basis of the vessel's size and cargo. A pilot must be used on a vessel which is over 10 metres in breadth or over 60 metres in length and has a draught of over 4.5 metres and is using a common navigable waterway. A vessel that carries e.g. liquefied gases or other dangerous or polluting goods or substances as bulk cargo must use a pilot regardless of its size.

The revolutionary principle in the new Pilotage Act was that there had to be a state-employed pilot or a master who holds a fairway certificate. Compulsory pilotage thus became an obligation to have a certificate.

The old Pilotage Act (393/1957) had allowed a discretionary exemption to use a pilot without a fairway certificate. In practice it had become difficult to monitor the realization of the regulations. For example if a passenger vessel proceeded from Helsinki via Porkkala to a location outside the Nordic Countries, i.e. to Tallinn, the vessel had to use a state-employed pilot in Porkkala. If the same vessel passed via Porkkala to another Nordic country, e.g. to Sweden, the master was allowed to use a route pilot employed on the vessel. If the vessel proceeded in domestic traffic from Helsinki via Porkkala to e.g. the Naantali shipyard, the master or an officer was allowed to pilot the vessel without any fairway certificate whatsoever. The confusion was increased by the fact that cargo vessels were granted pilotage exemptions based on gross register tonnage. In addition to this, the authority changed the tonnage limitation based on needs testing. In practice this made it impossible to monitor the situation.

[77] A.92/1998

Section 12 in the Pilotage Act lays down provisions on the Pilot Licence. It grants the right to provide pilotage on fairways marked on the licence on all vessels. The Pilot Licence can be granted if the applicant:

- has a master's certificate
- meets the medical and physical fitness requirements on seamen
- has made at least 25 training voyages in both directions of the fairway before the first licence is granted and at least five training voyages if the applicant already holds a licence for another fairway
- has passed a written examination
- has undergone a practical pilotage test
- knows **both** Finnish **and** Swedish

The government Decree on Pilotage and Section 3 in it defines more closely the prerequisites for granting the licence.

Section 14 in the Pilotage Act lays down provisions on the Pilotage Exemption Certificate. It gives the master a right to pilot a specific vessel in a specific fairway; both are entered in the licence. A Pilotage Exemption Certificate[78] may be granted if the applicant:

- has made training voyages on the vessel subject to the application or on a similar vessel, as a master or a navigating officer
- has passed a written examination
- has undergone a practical pilotage test
- knows Finnish **or** Swedish

Section 6 in the Government Decree on Pilotage defines more closely the prerequisites for granting a Pilotage Exemption Certificate. Section 16 of the Pilotage Act lays down provisions on exemptions.

The situation has become clearer as there is no automatic exemption on using an external pilot. The pilot must hold a Pilotage Exemption Certificate in order for the vessel to be allowed to traffic without an external pilot. A navigating officer can be granted a Pilotage Exemption Certificate, but he/she is not allowed to provide pilotage if the master does not have a fairway certificate for the same route. The new principle is a major clarification when compared with the previous, varied pilot exemption practices.

[78] ”Route pilot” is not an official title, but it is a term indicating that the person in question has a certificate as to knowing a certain fairway

### 3.3.4 Pilot's duties and responsibilities

The pilot's duties and responsibilities were entered in the 1998 Pilotage Act[79] in the spirit of the Tort Liability Act. In the bill to the government, the pilot's duties and responsibilities were not motivated otherwise than by referring to the Tort Liability Act. The Parliament decided that the pilot holds personal liability for the pilotage, but the vessel's master is responsible for manoeuvring his/her vessel.

The Ministry of Justice was not, however, fully satisfied with the bill and stated as follows:

> *'It can, however, be presumed that in pilotage there are more specified liability provisions with reference to pilotage, which have developed in the course of long-standing practice and which could now be entered in the legislation.'*

The Ministry of Justice felt that the draft decree contained sections better suited as parts of the Act instead of the Decree.

The Ministry of Justice stated as follows on the liability distribution of the master and the pilot[80]:

> *'The compactness of the Pilotage Act Bill is apparent e.g. in the provision dealing with the division of duties and responsibilities between the master and the pilot. This is problematic, because the limitation of liabilities can be regarded as one of the principal main problems of the Pilotage Act, and it is important especially when it comes to the application of the liability and penalty provisions.*
>
> *For example Section 6 in the Act states that the master of the vessel is responsible for manoeuvring his/her vessel also when he/she complies with the pilot's instructions with regarding to manoeuvring of the vessel. What is the master's responsibility when he/she in good faith complies with incorrect instructions given by the pilot? How strictly does Section 6 require that the master should be able to estimate whether the pilot's instructions are correct or incorrect - in other words to be a better expert than the pilot?'*

The Ministry of Justice noticed that the operational leadership was two-fold.

The Transport Committee of the Ministry of Transport and Communications and the Finnish Maritime Administration, in which representatives from employer organizations and unions as well as government officials were present, did not

[79] FMA Bulletin 7/1998, Pilotage Act 90/1998, Section 7
[80] The Ministry of Justice's pronouncement to the Ministry of Transport 19.9.1995, registration number 2307/43/95.

take a stand on the pilot's liability. The pilot's liability for damages was an established practice, and none of the parties took a stand.

The development of the provisions reveals an interesting line of action, in which the interests of the pilot and the pilotage organization are not converging. The organization has left all the decisions related to pilotage to the pilot. Thus the pilot has to continuously make decisions which belong to his/her employer, and he/she also bears for them a responsibility which belongs to the organization. This is something that has been observed repeatedly when pilotage accidents have been investigated.

### 3.3.5 Bridge cooperation

The Accident Investigation Board has published 14 reports where faults in bridge cooperation contributed to the accident.

The pilotage instructions which followed the 1998 Pilotage Act and Decree dealt for the first time with bridge cooperation[81], but today there are not any national requirements in force on bridge cooperation during pilotage.

According to the Resolution issued by the IMO in 2003, there should be an instruction on bridge cooperation in the Safety Management System. There is no example of such an instruction provided by the authority; the availability of such an instruction would help shipping companies in developing their own systems.

The IMO provisions are inconsistent, because the requirement on cooperation training for pilots also affects the vessel's officers. The STCW Code has, however, issued the cooperation requirement concerning masters and officers in the form of a mere recommendation[82]. Even this recommendation does not deal with the cooperation between the officers and the pilot.

The Finnish Maritime Administration's stand on bridge cooperation is clear. In the statement given with reference to the HERAKLES-BULK Investigation Report[83], the Finnish Maritime Administration is of the opinion that the safety recommendation which is given in the Investigation Report referring to bridge cooperation described in the STCW 95 Convention is '*not pertinent'* as bridge cooperation is represented in the Convention in the form of a recommendation.

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81 Luotsausohjeet. FMA Bulletin 10/2000, 20.6.2000. These instructions were on the list of regulations in force in December 2003, but they had been removed from the list before February 2004.

82 IMO, STCW Code Annex 2, Part B, Section B-VIII/2, Part 3-1. Bridge Resource Management

83 Tutkintaselostus, Työntöproomuyhdistelmä HERAKLES-BULK uppoaminen Selkämerellä 2-3.3.2004. ISBN 951-836-185-1. Statement issued by the Finnish Maritime Administration on 5.7.2006.

### 3.3.6 Right of the pilot to refuse pilotage

The Pilotage Act from 2003 gives the pilot a right to refuse pilotage[84], and when refusing pilotage he/she must state to the master the reason for his/her refusal. The Act and the Decree which followed thereupon did not clarify the grounds for refusal[85]. The Decree has not been followed by any pilotage instruction. The pilotage instructions[86] from the year 2000 were in force in 2003, and they laid down provisions that the pilot can refuse or discontinue pilotage on the grounds provided in Section 8 in the Pilotage Act (90/1998). The Act left these criteria to be decided by the pilot, and thus the grounds for discontinuing pilotage can, according to the Act, be a matter of opinion. Discontinuing pilotage should not be left only for the pilot to decide. For this reason there are circumstantial limitations for pilotage at the pilot stations of the State Pilotage Enterprise. Information about these limitations passes through shipping agents to the vessels.

Discontinuing pilotage means that the master has to perform pilotage himself/herself. This must be noted into the ship’s log book. The pilot can still give the master advice, but he/she is not responsible for the pilotage.

For example weather conditions can lead to unsafe manoeuvring of a vessel in a fairway. Most ports and shipping companies do not define circumstantial limitations with reference to port or vessel operations. It would, however, be clear to all those providing pilotage if their employer organisation defined circumstantial limitations for safe operations. These limitations would not necessarily have to be binding for those providing pilotage, but they would, however, be useful in supporting the decision-making. If the vessel’s master or the pilot does not have pre-defined wind limitations to support decision-making, neither of them necessarily has the courage to discontinue the pilotage. It may be easier for the master to take the risk than to discontinue the voyage.

In the accident investigations it has been found that in some studies dealing with port manoeuvring the master has ignored the pilot's opinion, and this has led to an accident. A clearly defined circumstantial limitation would help the pilot to motivate his/her decision.

In addition to the circumstances, the operational safety is affected by technical factors and factors related to the working culture of the crew. The vessel must pass the annual inspection, and it has to fulfil the IMO requirements. Without maintenance, the condition of the equipment can fall below the IMO minimum level. For example the vessel’s radar equipment can turn out to be in bad condition. In such cases it must be possible to discontinue pilotage. The pilot should be able to check that e.g. the compass connection of the radar appliances, the VRM and the EBL are functioning.

[84] Pilotage Act 21.11.2003, 940/2003, Section 11. FMA Bulletin No.14/2003
[85] Government Decree on Pilotage 17.11.2003, 982/2003.
[86] Luotsausohjeet. FMA Bulletin 10/2000, 20.6.2000. These instructions were on the list of regulations in force in December 2003, but they had been removed from the list before February 2004.

There must be an officer on the bridge to assist the pilot. He/she must know English according to the principles of the IMO's Standard Marine Communication Phrases[87]. The helmsman must know the standard wheel orders in English. The pilot should have the right to stop the vessel until a person who has knowledge of English arrives on the bridge.

### 3.3.7 Route planning

Of the cases studied by the Accident Investigation Board, deficiencies in route planning contributed to the accident in 14 cases. Therefore, the following section will discuss the instructions for route planning and implementing them in practice.

The decision made on route planning in the IMCO Convention 1978 became a requirement by the Decree on Watchkeeping onboard in 1981 in Finland[88]. The provision on route planning was, however, never followed. The lack of route planning was noted in one +accident investigation in 1989. The Accident Investigation Board recommended that maritime inspectors pay attention to route plans when visiting vessels in order to form an overall picture of the route planning practices. The Accident Investigation Board also came forth with the proposition that the National Board of Navigation would draw route planning instructions[89]. Route plans were not reviewed in the vessel inspections.

The Finnish Maritime Administration published a route planning instruction[90] in 1995. The instruction was based on the British route planning instruction[91]. However, the Finnish Maritime Administration removed the guideline from the list of effective Bulletins on 10.7.1998.

Following the IMO amendment to the STCW Convention in 1995, the Convention entered into force in Finland by a Decree in 1997[92]. Watchkeeping and route planning had been treated in Part A, in Chapter VIII, which was translated into Finnish. It entered into force by a decision made by the Ministry of Transport and Communication in 1997[93]. The decision required that a voyage had to be planned from the port of departure to the port of destination. These documents do not directly contain any practical instructions, but on the basis of the specified route planning objectives it would in practice have been possible to draw a reliable pilotage method based on radar navigation and angular velocity navigation.

[87] Resolution A.918(22) 29 November 2001
[88] Decree 666/1981
[89] Investigation report 3/1989 (abridged version), p.35
[90] National Board of Navigation Bulletin 19/1995
[91] Department of Trade 1980. Annex III
[92] Decree 1256/1997
[93] Ministry of Transport and Communications Decision 1257/1997

The IMO resolutions are only to a certain degree translated into Finnish and included in the national regulations. The parts which are not translated thus remain in a weak position. The important Chapter II in Part A has not been translated into Finnish, which means that following the route planning requirements in that particular chapter is fairly difficult as there is no Finnish translation available. These route planning requirements are nevertheless included in the curricula of the maritime colleges. They draw the curriculum for the masters and watchkeeping officers according to Chapter II in Part A. The maritime colleges have developed their own pilotage methods on the basis of the regulations, since the authority has not done this. The maritime colleges are, however, independent units, and they do not share a common curriculum. The inspections carried out by the authority are restricted to an audit conducted prior to the approval of the curriculum.

Inspections of the maritime colleges' quality systems were conducted in the summer 1998, and it could be concluded that the curricula complied with the requirements presented in the STCW Convention. The inspections did not deal with the uniformity of training related to route planning methods. This can cause varied practices within the area when it comes to providing pilotage. It is also worth noticing that if the authority translated the IMO's route planning instructions, their content would better reach all the masters in active duty. The curricula of the maritime colleges only apply to new students.

It will thus take years before route planning on vessels will be carried out according to the principles of the STCW Convention. In practice this will only happen after the masters of all vessels are captains who have studied at a maritime college after the year 1998.

In 1998 a study was carried out on the decision-making on the bridge while the vessel is being piloted. The study dealt with 17 cases. Only in one of the cases was it found that the vessel had a route plan[94]. On the vessel in question the plan was programmed into an integrated navigation system.

In one dismissal the prosecutor has drawn the conclusion that a route plan cannot be legally required if the authorities do not by inspection activities indicate that a route plan is also expected in practice[95].

### 3.3.8 Regulations and pilotage in practice

With respect to pilotage in practice, the pilot's position as an advisor has proved unsuccessful as defined in regulations. Historically the pilot has always made the decisions alone. This has derived from the history of how pilotage has been carried out, and it has not changed at all even though the regulations have changed.

94 Norros, Hukki, Haapio, Hellevaara 1998, p. 49

95 Dismissal issued by Kotka District Court 1.12.1999. Diary number 99/187

The instructions issued by authorities with reference to pilotage have remained on a general level during the whole history of pilotage. How the work is done and how training with reference to providing pilotage is carried out are issues that have received very little attention. According to the Pilotage Act and the Tort Liability Act, the state is not liable for the consequences of pilotage accidents[96]. This gives reason to think that this is why the instructions have not been specified so that they would be clear, and that pilots are responsible for their work alone and therefore they also themselves take care of the training for providing pilotage.

It would be in the interests of the master of the vessel to monitor and secure pilotage. If the master does not have a route plan of his/her own, and he/she cannot monitor pilotage. Thus the pilot today has to take the position of the responsible leader, which is against the regulations. This emphasizes the pilot’s standalone performance, and the master becomes an advisor as to the usage of the vessel’s equipment. This practice is internationally common. According to regulations the limitation of liabilities is clear, but it does not realise in the practical work, and pilotage lacks an internationally standardized line of action. The situation has led to a division of power, which easily leads to an accident in a crisis situation[97].

The master has the right to intervene with the pilotage in an emergency situation, but the liability issue is in practice unclear, and the master may be partly blamed[98] if

- the master has intervened with the manoeuvring without any good reason and this leads to an accident or
- the master does not intervene with the manoeuvring and this leads to an accident.

In an accident situation this shared leadership is disadvantageous for the master of the vessel. In normal cases of pilotage, this problem does not come up. From the master’s point of view the best way to be prepared is to draw a route plan of one’s own, to monitor pilotage and to practise pilotage when the situation allows. Reaching this situation would require that the various parties actively strove for team work on the bridge. The regulations on pilotage do not support this kind of objective.

The continuous negligence with reference to provisions on route planning during the last 25 years is possibly caused by two factors. The seafarers may have got the impression that the authorities have quietly approved the negligence as they have not dealt with it. Another possibility is that the guidelines have been so general in nature that it has been difficult to create practical instructions based on them.

96 Peter Wetterstein, 1999. p. 20
97 Green 1983, p. 86
98 Green 1983, p. 91

*Table 5. The regulations and instructions on Finnish national pilotage between the years 1957 and 2003. The new regulations were more concise than the old ones, and finally the pilotage instruction was totally removed.*

| Regulations and instructions 1957-1988 | Regulations and instructions 1998-2004 |
|---|---|
| Pilotage Decree 393/1957 [only available in Finnish]<br>The pilot must keep the vessel in the fairway<br>The pilot must pay attention to:<br>- manoeuvring<br>- position determination<br>The pilot must inform:<br>- when the vessel approaches a turn in the fairway<br>- when the pilot is not certain about the fairway<br>The pilot has to have a nautical chart with him/her. | Pilotage Act 940/2003<br>The pilot must provide the master with information.<br>The pilot has the right to discontinue pilotage.<br><br>Government Decree on Pilotage 982/2003.<br>The Decree does not contain any regulations as to pilotage work. |
| **Pilotage Instructions**<br>National Board of Navigation Bulletin 6/1988<br>The pilot's chart extracts must contain notes for radar navigation<br>There was a warning about the problems<br>with reference to turns.<br><br>The pilot had to check<br>- navigational equipment<br>- the vessel's manoeuvring information<br>The pilot's right to discontinue pilotage<br>- due to visibility<br>- because of the vessel's condition<br>- because of the overloading of the vessel<br>The pilotage instruction from 1998 gave instructions on draught, radar navigation, planning of a turn and using two pilots. | **Pilotage Instructions**<br>FMA Bulletin 10/2000<br>The pilot's chart extracts must contain notes for radar navigation.<br><br>The pilot must ask the master to provide report on the<br>- navigational equipment and<br>- manoeuvring information<br>The pilot's right to discontinue pilotage<br>- no criteria given<br>This pilotage instruction was revoked at the turn of the year 2003/2004. |

The national regulations do not deal with the pilot's and the master's cooperation on the basis of the STCW Convention. The master should be aware of the challenges connected with pilotage, but the historical barrier between the pilot and the master is still prevailing. Defining of the pilot's role as an advisor has made it difficult to give instructions on pilotage itself. This has created the development tensions, which are described in the Foreword of this Safety Study.

In Finland there are no route planning or pilotage guidelines in force compiled by the authority. The Finnish Maritime Administration issued a route planning instruction[99] to Finnish vessels in 1995. This instruction was removed from the Finnish Maritime Administration's list of decisions in force in 1998. A pilotage instruction was issued in 2000, but it was removed from the list of decisions in force in 2004. It is worth noting that the decisions were not revoked by new decisions, but they were simply removed from the Finnish Maritime Administration's list of decisions in force.

There are not any international or national instructions which would describe how actual pilotage work is planned and carried out. Documented and uniform practices have not come into being. The lack of national instructions does not encourage the forming of modern ways of work.

### 3.4 The national authority

During the last centuries the respect for the pilotage service has been high. The pilotage service has guarded military interests and represented the defence of the nation. The authority has been led by vice-admirals, lieutenant-generals and members of the Senate. In 1925 the Pilotage Board became the Pilot and Lighthouse Department of the National Board of Navigation[100]. In 1946 nine persons worked for it. There were eight pilotage districts under the department[101].

A traffic office, a pilot and maritime rescue office and a technical office were in 1985 under the Pilot and Lighthouse Department[102]. The name of the old pilot and lighthouse service disappeared in a great organizational restructuring in 1990. The Pilot and Lighthouse Department had shrunk and become the pilotage office under the traffic department. Its powers were reduced, because the management of the piloting activities was allocated to the maritime districts. The pilotage office could intervene with matters related to pilotage only through the Director General[103]. Only one person remained to take care of the pilotage office of the traffic department, and this person had not possibilities to define the work itself. In practice four independently functioning pilotage services came into existence in Finland as there were four maritime districts. At the beginning of

99 Alukselta vaadittava reittisunnitelma. National Board of Navigation Bulletin 19/1995
100 Asetus merenkulkuhallinnosta 26.10.1925
101 Iisakki Laati 1946, p. 247–249
102 Yrjö Kaukiainen and Pirkko Leino-Kaukiainen, p. 272.
103 Tutkintaselostus 2/1975, Tallink p. 70

2004, the Pilotage Department of the Finnish Maritime Administration became the independent State Pilotage Enterprise, and the Pilotage Authority subordinate to the Vessel Traffic Services remained as a part of the Finnish Maritime Administration.

The power of the pilotage authority changed at the same time as the pilot became an advisor. In addition to this change, the general nature of the guidelines compiled by the authority has moved pilotage to the background, away from the core activities of the area.

# 4 THE VESSEL AND THE FAIRWAY

Of the reports published by the Accident Investigation Board, 28 contain observations on the manoeuvring of the ship and the effect of the manoeuvres on the accident. Of these, 13 are related to manoeuvres in general, 8 to strong winds and/or rough seas, 5 to operating in ice-covered waters, and 2 to meeting or passing other vessels. The following section discusses the operation of the ship on the fairway and its interaction with the environment and other vessels.

## 4.1 On the manoeuvring of the vessel

When a vessel proceeds through water, water flow is formed around it. This flow causes, according to the so-called Bernoulli's principle, dynamic pressure changes, which normally even out in stagnant water. The pressure field, which forms around the vessel, affects the vessel's movements through water.

The form of the pressure field can be seen in the form of the waves which appear around the vessel; the increase in the dynamic pressure raises the water level e.g. at the bow of the vessel. The pressure field forming around the vessel and therefore the wave pattern depend on the form of the hull and the speed. As long as the vessel's speed is lower than the velocity of a hull-length wave, the vessel proceeds at a so-called subcritical speed. When the speed grows faster than the velocity of the wave, the hull starts to climb on its bow wave and finally, when the speed increases, the vessel rises up so that it surfs on the surface of the water. This is analogical with an aeroplane breaking the sonic barrier; the wave source then moves faster than the wave that it has created.

It is difficult to solve the hydrodynamic forces formed by the vessel's hull numerically. In principle the hull functions like a vertical wing in the water, and the forces generated by it can to some extent be estimated with the help of the wing theory. Because the underwater part of the hull is considerably "thicker" than the optimal lifting surface, i.e. it is broad, the flow of the water at the stern of the vessel is turbulent. When the vessel proceeds straight ahead without a drift angle, the form of the stern can be designed bearing economic fuel consumption in mind. It is also possible to estimate the flow conditions around the hull by numerical methods in this kind of a stable flow situation. But when the drift angle of the vessel increases and the whole vessel is under turning motion, the flow situation at the stern of the vessel becomes more complex. Because the vessel's draught is small with respect to its length, a big part of the pressure difference forming around the hull has a tendency to even out below the bottom of the vessel. This causes whirls to form at the bilges of the hull, which further interfere with the flow condition at the aft part of the hull. It is not yet mathematically possible to fully describe this kind of a complex flow situation, but e.g. adapted polynomial equations are used to describe the phenomenon in manoeuvring predictions and ship-handling simulators. The coefficients of the equations are defined with the help of results from sample tests and sea trials.

The hydro- and aerodynamic factors affecting the manoeuvring of the vessel will be studied next.

### 4.1.1 Course stability of the vessel

The course stability of a vessel means its natural ability to proceed straight forward. A vessel which has good course stability resists the turning motion. Long and narrow vessels with a deep draught have good course stability and they do not turn easily, whereas short and wide vessels with minor draught do turn more easily. In addition to course stability, the effectiency of the rudder affects the course stability of a vessel. The form, size and possible optional devices of the rudder have a major effect on manoeuvring, and a vessel with good course stability and effective rudder can be very swift and manoeuvrable because of the rudder.

The loading situation also affects the course stability. When the vessel is in ballast, its course stability is basically weaker than fully laden, but the aft trim which is typical for ballast situations improves course stability. Fins added to the aft of the hull improve course stability, and thus increasing the surface of the rudder helps in addition to the skeg. If one wants to improve the turning ability of the vessel by increasing the rudder area, the course stability improves at the same time. In most cases this is an advantage, because the vessel not only reacts better to rudder steering, but it also straightens quicker after a turn.

In general it can be said that all fins that increase the transverse resistance of the hull increase course stability. The point of application of the transverse force caused by a hull which is deflected from its course affects the vessel’s ability to keep the course.

### 4.1.2 Manoeuvring of the vessel

When the rudder of a vessel proceeding straight ahead is deflected e.g. to port, the side force caused by this starts to move the vessel to the opposite direction, i.e. to starboard. As a result, the flow of water meets the hull diagonally from the starboard side, and according to the wing theory this generates a lateral side force to port. The point of application of the hull force is located close to the bow, and it causes a port-turning moment on the vessel. The rudder is thus used to control the hull's angle of attack, and the hull force turns the vessel. This can be clearly noticed e.g. with reference to course unstable vessels. When the counter rudder has been initiated, it is possible that the yawing motion has to be slowed down by keeping the rudder somewhat deflected to the opposite direction.

It is nowadays possible to numerically estimate the forces generated by rudders and propellers in an accurate manner. In a similar way as the wing of an aeroplane, rudders and propellers are also effective lifting surfaces, and their shape can be optimized and their flow-steering effect can be calculated. This is important with respect to propellers when one wants to minimize the fuel consumption and the vibrations generated by the propeller. When it comes to estimating the manoeuvring force generated by the rudder, the most difficult part is to estimate the flow field around the rudder. The objective is to place the rudder behind the propeller, in its slip stream, because a faster flow increases the steering power of the rudder. The forces generated by the flow are according Bernoulli's principle proportional to the square of the flow rate, which means that even a minor increase in the flow rate increases the performance of the rudder. This applies in particular when the vessel is accelerating. Then also the manoeuvring power of the rudder is high. Correspondingly, when the speed of the vessel is reduced, the slip stream around the rudder slows down, and the manoeuvrability of the vessel may decrease significantly. Normally, when the vessel is stopped and the propeller pushes water forwards, the flow field in front of the rudder becomes turbulent, the flow rate gets slower and the manoeuvrability of the rudder may disappear altogether.

The manoeuvring power of the rudder can be increased by different optional devices. These include e.g. Becker rudders equipped with a trailing edge, which is separately united by joints. It is possible to use the flap to change the profile of the turning rudder so that it becomes asymmetric, giving extra force to the rudder. In the leading edge of Jastram rudders there is a cylinder which is rotated by a separate engine. The surface of the cylinder changes the flow of water and makes it follow the rudder profile at large rudder angles. With the help of the Jastram device it is possible to use steering angles which are as big as 65 degrees instead of the normal 35 degrees without the rudder stalling.

The power of the steering gear affects the turning speed of the rudder. A rudder which turns quickly reduces especially the time which it takes for a vessel to straighten after the turn. Steering gear, which is built according to the IMO requirements and which fulfils the minimum requirements is, however, not adequate when it comes to operating in the fairways of the archipelago.

### 4.1.3 Shallow water

In shallow water, the water flow between the vessel's bottom and the sea bed is blocked increasing the flow velocity. The effect of shallow water on the manoeuvring of the vessel becomes discernible when the depth of the water is less than three times the vessel's draught. When the depth of the water is only 1.2 times the vessel's draught, the term extremely shallow water is used. The increase in flow rate under the hull reduces the pressure, and it sucks the vessel downwards and causes a trim. The term *squat* is used to describe this increase of draught and the trim[104]. The extent of squat depends on the depth of the water, the vessel's speed, the form of the hull and the propeller loading. Propellers with a heavy load suck more water from below the hull especially at the stern increasing fore trim in shallow waters. With respect to full-bodied hulls, the decrease of pressure is more prone at the bow of the vessel. This makes the vessel trim by the bow. Streamlined vessels trim by the stern. The powerful engines of these vessels further increase the aft trim.

[104] To squat = to crouch, to heel down

The extent of the vessel's trim caused by shallow water can change drastically as the depth of the water changes. Extensive studies of this mechanism have been carried out recently, but there is still no comprehensive theory to predict it.

The speed of a wave pattern depends on the depth of the water in such a way that a wave proceeds slower in shallow water than in deep water. This also applies to the waves generated by the vessel. When the vessel reaches shallow water, the speed can become overcritical with respect to the wave pattern. In this kind of a situation squat increases drastically, and the changed wave pattern increases the vessel's aft trim. Due to the large mass of the vessel, it takes a while before the added resistance reduces the vessel's speed. During this time there is a danger that the vessel runs aground. However, studies have shown that this kind of dynamic squat is not necessarily larger than it would be in even and shallow water if the vessel had so powerful main engines that it could continuously sail at an overcritical speed.

Shallow water restricts the pressure field surrounding the hull to its lower part to the level of the sea bottom. In manoeuvring situations the proximity of the sea bottom reduces the cross flow under the vessel's hull. Because of this, the normalization of the pressure differences at the opposite sides of the hull grows weaker. The transverse resistance of the vessel increases, and the course stability almost always improves even if the vessel is full-bodied and trimmed by the bow. Almost always this also results in an increased reduction of manoeuvrability in shallow water.

On the other hand the proximity of the sea bottom affects the rudder in the same way, i.e. the sea bottom works as if it was an end plate reducing the normalization of pressure differences under the rudder blade. When the tip vortex of the rudder grows weaker, its effective side ratio increases. In some special cases it has been noted that the increase in the manoeuvrability of the rudder has been so strong that the vessel's turning ability has increased even though the turn resistance in shallow water has increased.

#### 4.1.4 Narrow channels and fairways

The banks of islands and shoals affect the vessel's progress by the same principle as shallow water. When the vessel passes a shoal or an island, water presses between the hull and the obstruction. The pressure field around the vessel becomes asymmetrical causing forces that move and turn the vessel. When the vessel passes the obstruction, the water pressure at the sides of the bow first increases and pushes the vessel away from the obstruction. The flow of water increases at the middle of the hull and especially at the stern thus causing negative pressure which pulls the vessel's hull towards the obstruction. The bank effect is most effective in canals in which the vessel proceeds at the side of the terraced edge. As an overall effect, the vessel tends to turn away from the obstruction, and if the turn is prevented by using the rudder, the vessel finally attaches to the obstruction by suction. In the state of equilibrium, the vessel makes way having a drift angle parallel with the side of the canal, its bow pointing away from the bank. The vessel’s speed, distance from the bank and also the depth of water affect the suction effect, because the normalization of pressure differences decreases in shallow water and the bank effect grows stronger. In shallow water the bank effect can grow faster than the square of the vessel's speed. In some situations it can, however, occur that the vessel's wave pattern, which reflects from the bank of the canal, pushes the vessel away from the proximity of the bank.

In conditions typical for the archipelago, the bank effect caused by islands and shallows does not normally affect the whole length of the hull simultaneously. Because the banks of islands and shoals are normally shorter than the vessel, the bank effect moves along the vessel’s hull as it passes the obstruction. In this way the bank effect changes drastically especially in narrow channels and fairways, when the areas around the passage restrict from various directions the pressure field which has been formed around the hull. In the archipelago the uneven sea bottom and the changes caused by the effects of shallow water caused by this unevenness make it more difficult to predict the bank effect. Local knowledge is required in the difficult points of the fairway so that the bank effect can be predicted accurately enough.

#### 4.1.5 The wind and the waves

Estimating the effects of the wind on the manoeuvring has become more and more important as the wind areas of the vessels become larger. The superstructures on especially passenger and ro-ro vessels are large in relation to the side projection of these vessels' underwater hull. On the other hand, large ballast-laden tankers can also be wind-sensitive. The modern design of superstructures also makes manoeuvring in the wind more difficult. Superstructures which have been designed to be even and streamlined make the airflow follow the vessel's contours. If airflow also follows the vessel's contours on the leeside, this reduces pressure in the leeward, and wind effects increase. When modern passenger vessels sail close-hauled, stronger wind forces caused by the wing effect can be detected than when they sail in side wind.

Observing the true wind speed can be difficult onboard a vessel. The sensor of the vessel’s anemometer is most often located high, in a place where the wind blows freely, but still in the wind-steering boundary layer of the superstructures. The anemometer of a vessel making way observes the relative wind, which includes the effects of the vessel’s own movement.

When estimating the true wind speed, the effects of the vessel's own movement must first be eliminated. Most anemometers make this correction automatically if they receive information about the ship's motion e.g. from the vessel's log.

A second factor is that the wind steering effect of the superstructures may distort the wind information which has been measured. For example the sensor of the anemometer fitted in the radar mast of a modern cruiser proceeding headwind is located at a point where the airflow raises along the leading edge of the superstructure, and the flow rate increases. Without model testing it is difficult to estimate these kinds of effects caused by the superstructure on the wind direction and speed. According to tests carried out in a wind tunnel, the speed of the wind can change over 20 per cent due to the steering effects of some vessels' superstructures. The effect on the direction of the wind can be over 10 degrees. These effects vary a lot from vessel to vessel.

Thirdly, the high installation place of the anemometer is located in a different layer of air than the 10-metre measuring height used in meteorology. This average effect of the boundary level of the atmosphere can be calculated with adequate accuracy by using the following formula

$$\frac{v_h}{v_{10}} = \left(\frac{h}{10}\right)^{\frac{1}{7}}$$

in which

| | | |
|---|---|---|
| $v_h$ | = | wind speed at height h |
| $v_{10}$ | = | wind speed at ten metres |
| $h$ | = | the observation height of the wind |

The exponent of the calculus formula is called the Hellman's exponent, and its value of one-seventh part corresponds well with the conditions in the archipelago. For the open sea, the value 0.10 can be used as the exponent.

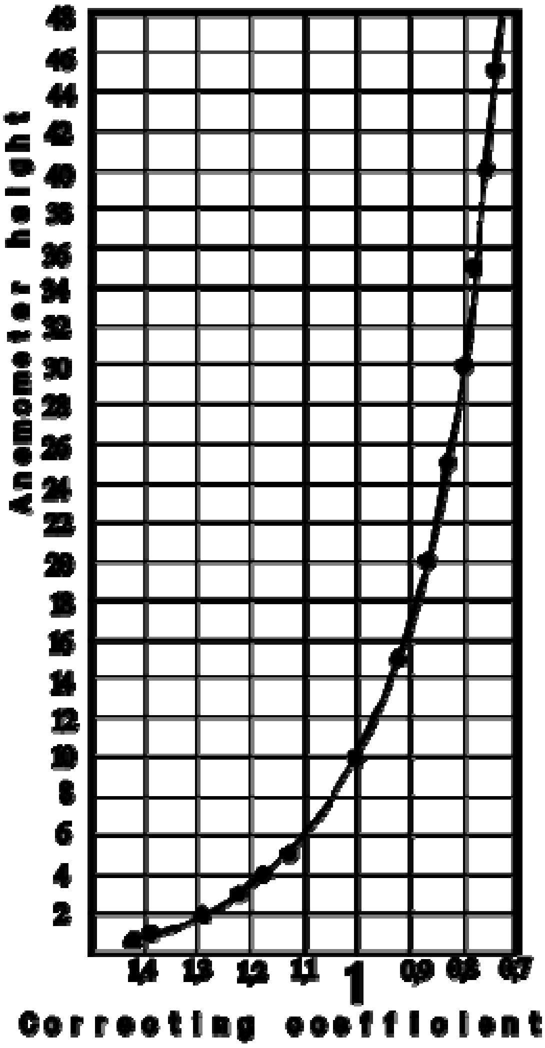



*Figure 9. The coefficients to correct the anemometer reading so that it corresponds to the height of 10 metres, which can be compared with the weather forecast[105].*

Fourthly, the wind speed in weather forecasts is informed as the mean value of 10 minutes, and the instantenous wind speed observed on the vessel can differ significantly from the mean value due to the gusts and obstructions in the terrain.

Because of all the factors described above, when observing the readings in the display of the anemometer, it must be remembered that the difference to the mean value of the wind measured at the height of 10 metres can be significant. Some of the correction factors described above must also be taken into account when studying the readings obtained from the ports, from the shipping company's own anemometer installed ashore.

[105] Nils Norrbin, 1983. Page 6.8. Basic Ship Theory Vol. 1. p. 320

The turbulency of the air currents, i.e. the gustiness of the wind, vary according to the effects of the weather type and the surrounding terrain. Earlier on quite little attention was paid to the gustiness of the wind. The inner masses of the anemometers located on weather stations caused delays in the measuring of instantenous wind speed. A short wind gust had already passed before the revolving speed of the gauge had increased so that it corresponded with the level of the gust. Thus even the starting point for the basis for the measured information can be incorrect. Studying the gustiness has started only with the help of the weather stations situated in connection with airports. On airport areas the form of the surrounding terrain can quite well correspond with the situations in the archipelago: there is some forest some distance away, and near the gauge there is some even lawn similar to water. Different gustiness conditions can be divided into as many as seven main types depending on the weather type.

Modern anemometers can be very sensitive to the turbulency of the wind, especially if there are not any movable parts in them but the wind direction and speed are measured e.g. with the help of a hot wire or a pressure sensor. A single anemometer can, however, not measure the size of the air masses causing the gust. A anemometer can indeed measure the air masses causing the gust, the length of the gust pad (the duration of the gust multiplied with its speed), but the height of the gust pad and its width remain unknown to the anemometer. The gust pad does not always hit the whole vessel, but it can e.g. only affect the stern of the vessel. It the anemometer is situated at the bow, it does not show information about gusts, but a gust can, however, try to turn the vessel against the wind. Due to its great mass, the vessel does not, however, react that quickly to the changes in wind, and if the gust is very brief, it can pass without having that much effect on the vessel's motion state.

The dimensions of gust pads depend on the weather type. The proximity of islands and coast can increase the wind whirls, so that the conditions in the port area can be demanding with respect to the wind condition. On the other hand, if the wind blows more than 10 m/s, the temperature differences in the air mass and thus the whirls in the basic wind start to get even.

The wind force affecting a vessel which sails close-hauled pushes the vessel to the leeward side, and if the design of the superstructures generates wing force, the wind force is usually at its strongest when the apparent wind direction from the bow is 50-60 degrees. The side force generated by the wind makes the vessel drift to the side. The drift angle then makes the underwater hull generate a wing force, which is opposite to the wind force and the point of application of which lies at the bow of the vessel. The vessel's drift angle grows until the transverse force of the hull is equals with the side force caused by the wind. The distance between these two opposite points of application defines the value of the moment which turns the vessel and which must be compensated for by using the rudder.

The point of application of wind when sailing close-hauled is usually, depending on the vessel, at the bow, so that its distance to the point of application of the hull force is short. Thus, even if the vessel's wind force and thereby also the drift angle are at their largest in this wind direction, the turning moment of the wind is small and large rudder angles are usually not required. The point of application of the wind force is usually located behind the point of application of the hull force, and the vessel has the tendency to turn towards the wind. This tendency is also increased by the heeling effect of the wind, which makes the underwater part of the hull asymmetric with respect to the keel line. Then the hull also has the natural tendency to turn to the opposite direction of the heel, i.e. against the wind. If the vessel’s superstructure is mainly located at the bow, the vessel can, when sailing close-hauled, have the tendency to turn away from the wind. However, the position of the point of application of the hull force is not always a constant. The point of application changes not only because of the cargo situation, but also according to the value of the drift angle. Because of the trim by the stern or if the drift angle increases as the wind rises, the point of application can move towards the stern, and the vessel which earlier tried to sail close-hauled against the wind starts to turn away from the wind.

The force of the wind does not point perpendically to the side of the vessel, but it also affects the resistance. Wind tunnel measurements show that this longitudinal component of wind force may, exceptionally, have an effect ahead at a close-hauled wind on some vessels on which the design of the superstructures causes wing effect. In other words, the vessel is then similar to a sailing ship, which, when proceeding diagonally towards the wind, gains extra power from the wind to move ahead. However, at the same time the vessel's drift angle, list and the deflected rudder cause more increase in the resistance, so as a whole the vessel's speed decreases.

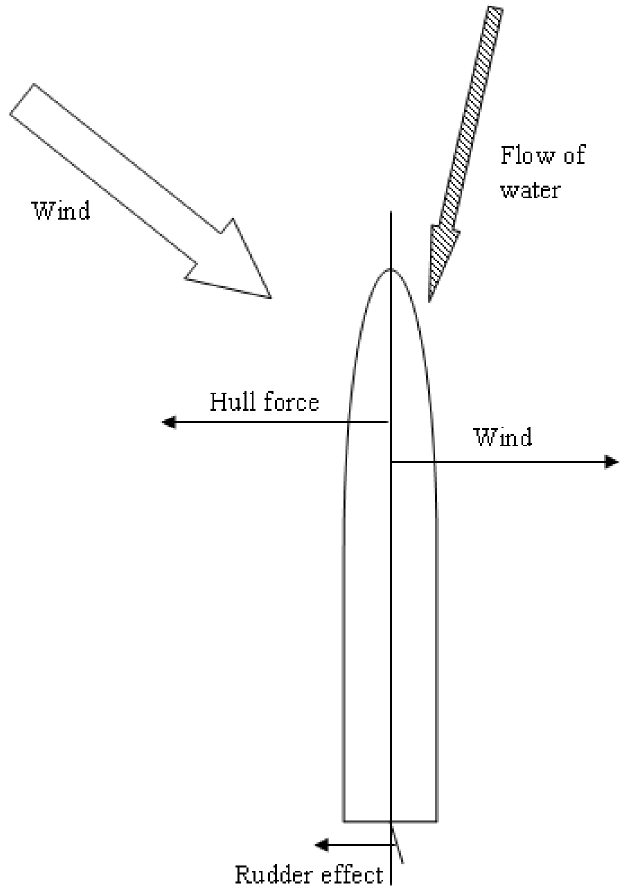



*Figure 10. On the passenger vessel the close-hauled wind direction causes a wind force, the point of application of which is located at the bow of the vessel. The wind force makes the vessel drift, and the flow of water generates a hull force, the point of application of which is also located at the bow of the vessel. The distance between the points of application of the wind and hull forces defines the rudder effect which is required to make the vessel proceed straight. On tankers and other cargo vessels, on which the superstructure is located at the aft of the vessel, the point of application of wind force is further back than illustrated in the figure. However, because the wind surface of these vessels is usually relatively small, the power of the rudder is adequate to compensate for the turning moment of the wind. Only the transverse components of the wind and hull forces are presented in the figure.*

As to the vessels which sail in quarterly wind, the point of application of wind force is located in the aft. Even though the side force generated by the wind is usually smaller compared to close-hauled wind, and the drift angle caused by the wind force is smaller, the distance between the points of application of the wind force and the hull force is now great, and the moment which turns the vessel against the wind is at its largest. The steering force of the rudder can remain inadequate especially in situations in which the vessel’s speed is reduced, and the vessel can start an unintentional turn against the wind.

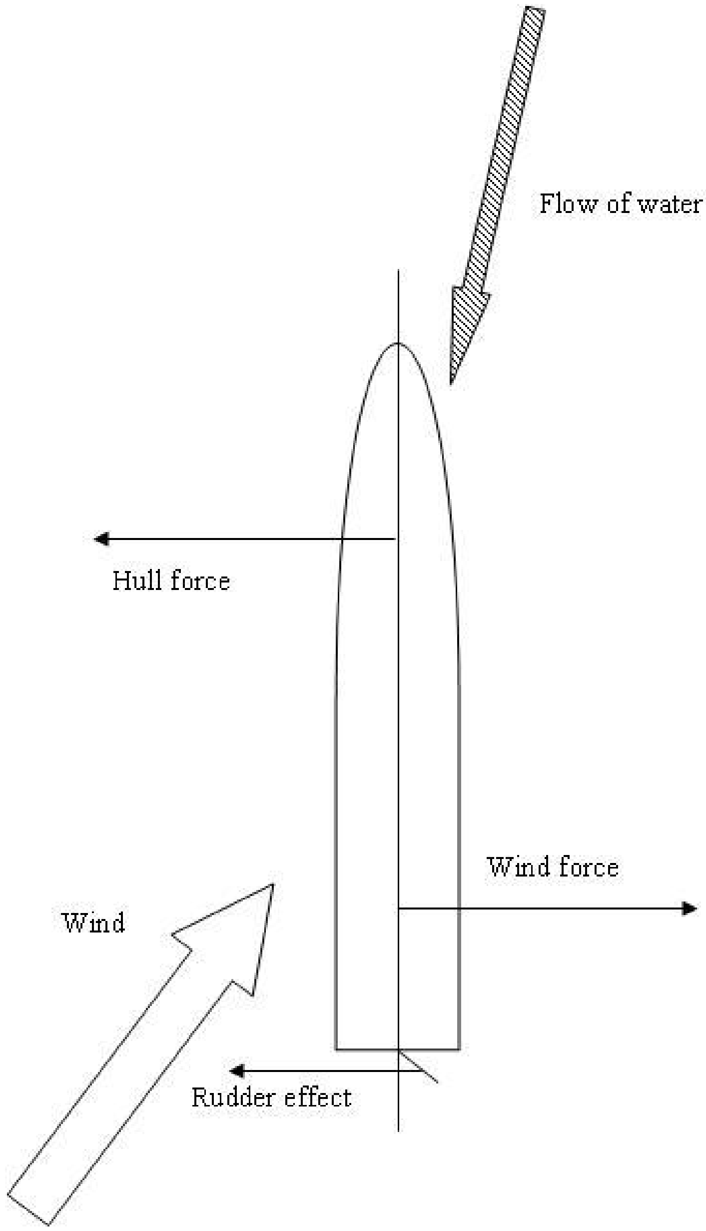



*Figure 11. Free wind generates a wind force, the point of application of which is located at the aft of the vessel. The wind force makes the vessel drift, and the flow of water generates a hull force, the point of application of which is located at the bow of the vessel. The distance between the points of application of the wind and hull forces is now great, and the rudder force, which makes the vessel proceed straight ahead, must be strong. If the speed of the vessel is quickly reduced, the propeller flow decreases so much that even a large rudder angle is no longer capable to keep the vessel on its course. The vessel starts to turn to port. Only the transverse components of the wind and hull forces are presented in the figure.*

The swell of sea can in the open parts of the fairway, together with the free wind, cause problems with respect to keeping the course. A wave which hits the vessel's aft diagonally heels the vessel towards leeward. This heeling force together with wind force tries to turn the vessel towards the wind. If the vessel proceeds almost at the speed of the swell and if the wave at the stern keeps the vessel heeled towards leeward for a long time, this can result in the vessel turning transversely in the wind, i.e. broaching, which is caused by the inadequate capacity of the rudder's steering effect. At the top of the wave, the water masses move in the following seas, and therefore the resistance of the aft of the vessel decreases. In addition, when the vessel sails 'downhill', its resistance decreases further and thus reduces the load on the propeller. If the bow of the vessel hits another crest of wave in this kind of a situation, the bow turns to the side towards the eye of the wind. When the water flow in the wave around the rudder goes in the same direction as the movement of the vessel, and when at the same time the stress of the propeller and thus also the amount of water it pushes to the rudder have increased, the manoeuvring power of the rudder can drop so low that it is impossible to control the turning of the vessel.

#### 4.1.6 Ice

Operating in ice conditions has traditionally been learnt through experience, but simulator technology will in the future add to the training. The effect of ice conditions on pilotage is a many-sided phenomenon, and it is not possible to describe all the effects ice has on e.g. radar work within the framework of this study. Manoeuvring in ice is shortly described next. With respect to ice conditions, this study does not deal with ice ridges, which are rare in coastal fairways, or with ice floes, for which the best manoeuvring technique is to try to pass around them. This is, however, often impossible in narrow fairways.

If the ice field is stationary, proceeding in an already open ice channel is fairly easy. The ice channel determines the track, and if there is not need to exit the lane due to e.g. meeting vessels, it is easy to manoeuvre the vessel. Even if the rudder order in the turn was not exactly the correct one, the channel steers the vessel, which usually stays in the path as by itself. If required, when the motion state allows it, it is also safe to stop the vessel, and there is no need to fear that it would drift to a shoal.

One problem related to ice manoeuvring has to do with ship design. Engine powers and the strength of the hull have increased during the last twenty years, and the risk of getting stuck in ice has decreased. The bow of the vessel operating in ice is, however, ever more often fitted with a bow bulb, which does not cut out from the ice lane that easily. At the same time the general optimization of hull shapes and especially the damage stability regulations on ro-ro vessels have changed the shapes of the stern in such a way that it has become broader. The waterline of the vessel can be fully broad up till the stern, and this efficiently makes the turning slower. In situations, in which the vessel with the help of fast initial speed must cut out from the channel e.g. in order to pass an icebound vessel or to cut it loose by proceeding close by, the design of the bow and the back corner of the stern can hamper the turn manoeuvre. This can result in a rear-end collision, several of which take place every winter.

Another factor worth paying attention to is related to the common way of steering the inner edge of the ice channel in turns so that the vessel does not drift out of the track by mistake. If the ice field stays where it is, the vessels move ice to the outer edge of the turn. In this way the channel gradually moves towards the inner edge, and it can finally lie outside the fairway area.

If the ice field moves, the ice channel moves away from its place. In that case it is safest, if possible, to open a new ice channel to an intact ice field in the correct position of the fairway. It is normally possible to check the position of the ice channel ahead in relation to the fairway area by radar.

### 4.1.7 Current

The currents on the coast of Finland are mainly return currents, which are formed after the wind has first moved water slowly to the bottom of the Gulf of Finland or the Bay of Bothnia. The speeds of currents are low, often less than two knots, usually less than one knot. Stronger currents caused by strong winds in the Quark can occur occasionally. It is often impossible to discern a weak current from the effects of wind, but the direction and strength of a current can be estimated by the wake left by navigation marks.

The current can, however, be locally significant, especially in lake districts. The knowledge of local conditions is in that case essential in order to guarantee safe pilotage.

### 4.1.8 Meeting vessels

In a meeting situation, the pressure fields around the vessels affect each other and generate forces which move sideways and turning moments on both vessels. The magnitude of the forces which affect the vessels depends strongly on the size of the vessels and their closing speeds as well as on the vessels' reciprocal distance longitudinally and transversely. If the vessels meet in confined waters, the shallow water and the bank effect of the fairway can further add to the interaction of the vessels.

If the head-on vessels are identical, they are also subject to identical interaction forces. When the bows of the vessels are abreast, the resistance of each vessel has already started to grow. At the same time the bows try to turn away from each other. Because the stern parts of the vessels are not yet within the pressure fields of the other vessel, the propulsive force affecting the vessels' bows moves them further away from each other. When the vessels' bows have reached amidships of the meeting vessel, the interaction force which pushed towards the side has disappeared, and the turning moment does not exist any longer. The resistance of the vessels has decreased. Immediately after this the vessels start to approach each other by suction, and especially the bows pull towards each other. When the vessels are fully abreast, the sterns abreast with the bows, the resistance has started to grow again and the suction effect is at its highest. The side forces then affect amidships, so that the turning moment disappears.

When the vessels' bows approach each other's mid-frames, the resistance continues to increase, and even though the suction effect decreases, the moment pulling the sterns of the vessels towards each other is at its highest. From here onwards the resistance of the vessels starts to normalize, the suction effect becomes a force which pushes the vessels apart, and the turning moment disappears almost entirely. When the vessels' sterns are abreast, the interaction forces start to decrease quickly. If the vessels are of different sizes, the interaction force is stronger for the smaller vessel. It is possible to sketch the influencing directions of the forces in one's mind, if one remembers that the wave pattern of the vessel is caused by the pressure field which is formed around the vessel. When e.g. bow waves meet, it is easy to understand the effect the pressure fields have on the increase of the resistance and the tendency of the bows to turn away from each other.

In a head-on situation, the interaction forces which concentrate on the smaller vessel can be stronger than its manoeuvring forces, i.e. the change in its motion state can be momentarily uncontrolled. Luckily a head-on situation usually passes quickly, and the manoeuvring control resumes.

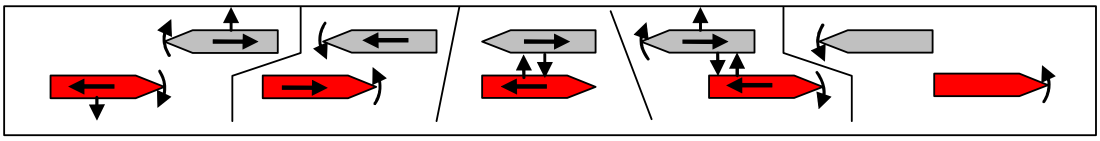


*Figure 12. The interaction forces between meeting vessels.*

### 4.1.9 Overtaking vessels

In overtaking situations, the interactions depend strongly not only on the overtaking distance between the vessels and their reciprocal dimensions, but also on the faster vessel's relative speed compared to the slower vessel. As in a head-on situation, in an overtaking situation the interaction forces also clearly increase in shallow water.

When the overtaking vessel approaches from abaft and its bow reaches the stern of the vessel which is being overtaken, both vessels are affected by a side force which moves them to the direction of the vessel which is being overtaken. If the faster vessel thus overtakes the slower one on the port side, the interaction force steers both vessels towards starboard. At the same time both vessels also try to turn to starboard. When the overtaking situation goes on, the resistance of the overtaking vessel decreases and the resistance of the vessel which is being overtaken increases. At this stage the overtaking seems to advance quickly. When the vessel with more speed reaches the slower one and is abreast with it, the resistance has changed to what it used to be, but now the vessels are pulled towards each other by suction. At the same time they try to turn away from each other. This situation is with respect to both vessels analogous with a single vessel proceeding in a canal. In the same way this vessel tries to change its motion state due to the bank effect.

When the overtaking vessel is getting ahead, the interaction starts to move both vessels towards the faster vessel and at the same time also to turn both vessels in the direction of the faster vessel. At the same time the resistance of the overtaking vessel increases and the resistance of the vessel being overtaken decreases. In this case the overtaking situation becomes prolonged. When the speed of the overtaking vessel decreases, its propeller performance perhaps has to be increased so that the interaction between the vessels does not have time to suck the bow of the vessel being overtaken to the side of the overtaking vessel. Unfortunately increasing propeller performance strongly increases resistance. The moments which turn the vessels can become so strong that it is not possible to reverse them by rudder manoeuvring. The situation can also get worse if the vessel being overtaken increases propeller performance in order to be able to manoeuvre better. If the overtaking situation is prolonged, the risk of collision is imminent. When the overtaking vessel finally manages to get ahead of the vessel being overtaken, the resistance of the vessels starts to return to normal and the bow of the overtaking vessel tends to turn in front of the vessel being overtaken. At the same time the faster vessel, however, turns away from the slower vessel.

Because the resistances of both vessels and thus their speeds of advance become more unfavourable during the second half of the overtaking situation, it is especially important that the seafarers providing pilotage know how vessels behave in overtaking situations. A prolonged overtaking situation often causes problems when the initial estimate of the length of the fairway section required for the operation is not adequate. In addition to this, the vessels' reciprocal difference in speed, which is typically one order of magnitude smaller than the absolute speed of the vessels, can give seafarers an incorrect idea of the intensity of the vessels' reciprocal resistance and lead to a situation in which the overtaking takes place too close. The problems connected with overtaking have been dealt with in closer detail e.g. in the Accident Investigation Board's report C1/2006 M *'MS ESTRADEN and MT WOLGASTERN, Collision in the Kiel-canal on 2.2.2006'*.

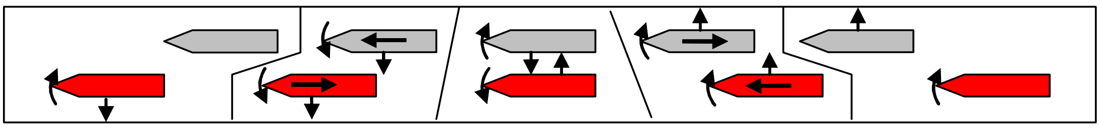


*Figure 13 The interaction forces caused by the overtaking vessel*

### 4.1.10 Sea trials

The IMO has defined minimum requirements with reference to the vessels' manoeuvring characteristics. The objective of sea trials is to describe the manoeuvrability of different types of vessels in a uniform way, but the sea trials, which have been agreed upon internationally, only partly give information which supports pilotage. The most common sea trials are described next, and the usefulness of the results in pilotage is estimated.

When the TURN CIRCLE is defined, the vessel is first steered straight ahead at a cruising speed. At the beginning of the test, the rudder is deflected 35 degrees to the side, and the vessel is allowed to turn a full circle. The initial part of the turn is interesting with respect to pilotage and navigation, i.e. at the most the first 90 degrees of the turn. The trial results show the vessel's initial speed of turn and the development of the drift angle at the beginning of the turn. According to the IMO requirements, the vessel should not be allowed to proceed more than 4.5 vessel lengths during the first 90 degrees of the turn (Figure 14, advance X), and sideways it should not proceed more than five vessel lengths during a turn of 180 degrees (Figure 14, lateral Y1).

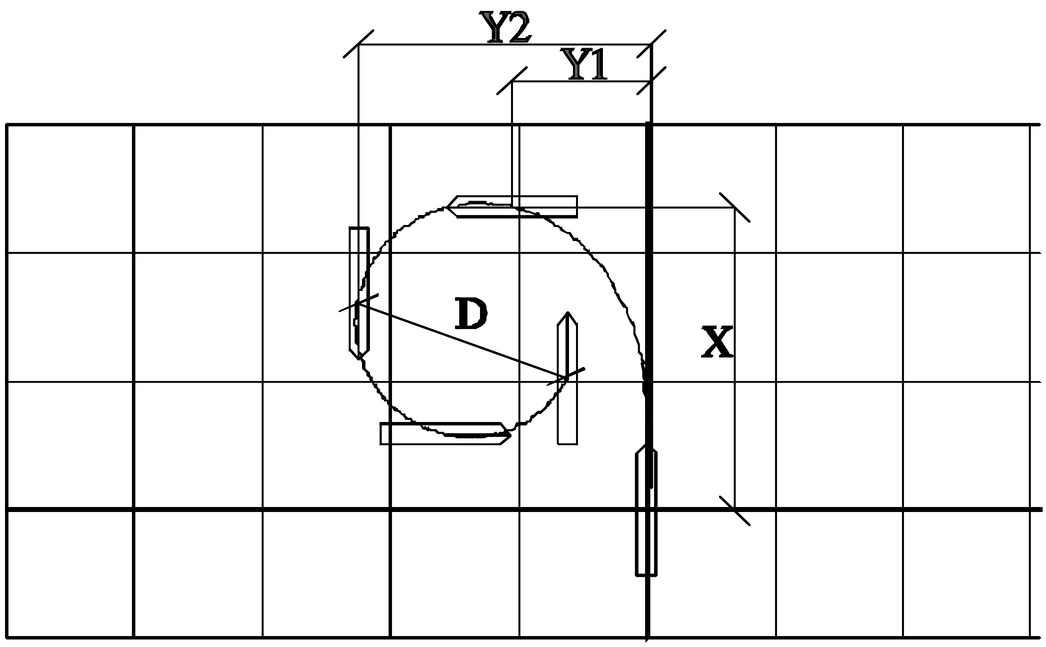



*Figure 14. Turn circle test. X = advance, Y1 = lateral, Y2 = tactical diameter, D = steady diameter*

The PULL-OUT TEST starts from the end of the turn circle test. After a full circle, the rudder is moved back to midships, and the turning speed of the vessel starts to decrease. The test is continued until the turn of a course-stable vessel stops or the turn speed of a course-instable vessel normalizes. The test gives an indication of the vessel’s course stability, and it gives an accurate result only if the wind speed during the test is low.

The Z TEST is carried out by turning the rudder from side to side. The test is started in a similar way as the turn circle test, i.e. by proceeding straight ahead. The test starts by a rudder order, the rudder angles most commonly used are 10 and 20 degrees. When the vessel has turned a pre-decided angle from its original course, counter rudder is applicable. The turn then gets slower and the vessel starts to turn in the opposite direction. The vessel passes the initial course, and the rudder is kept deflected until the course of the vessel has again deflected the chosen angle from the original course. After this, the rudder is again turned to the opposite side and the test is continued at least until the vessel passes the original course for the second time. Normally, the pre-decided angle of course alteration corresponds with the rudder angle, e.g. 10/10 yawing test stands for a test in which both the rudder angle and the position angle of the manoeuvre which deviates from the original course are 10 degrees. This test is used to find out the vessel’s initial turning ability and the straightening after a turn. The quantities describing the vessel’s manoeuvring characteristics include e.g. the time which passes from the beginning of the test to the first opposite wheel order (Figure 15, t1) and the overshoot (Figure 15, a1 and a2), i.e. how many degrees the vessel continues in the old turn direction after the opposite wheel order has been given. The results of this test illustrate the vessel's manoeuvring characteristics in a fairway in the archipelago better than the turn circle test. In the yawing test a rudder angle of 10 degrees corresponds perhaps best with the normal rudder use in pilotage. Earlier tests were done on rudder angles of 20 degrees, and the test is still used when estimating manoeuvring characteristics in order to obtain comprehensive reference material. According to the IMO, the overshoot llowed in the 10/10 yawing test can be as big as 40 degrees depending on the vessel type (Figure 15, a1 and a2), which is far too much when navigating in narrow fairways.

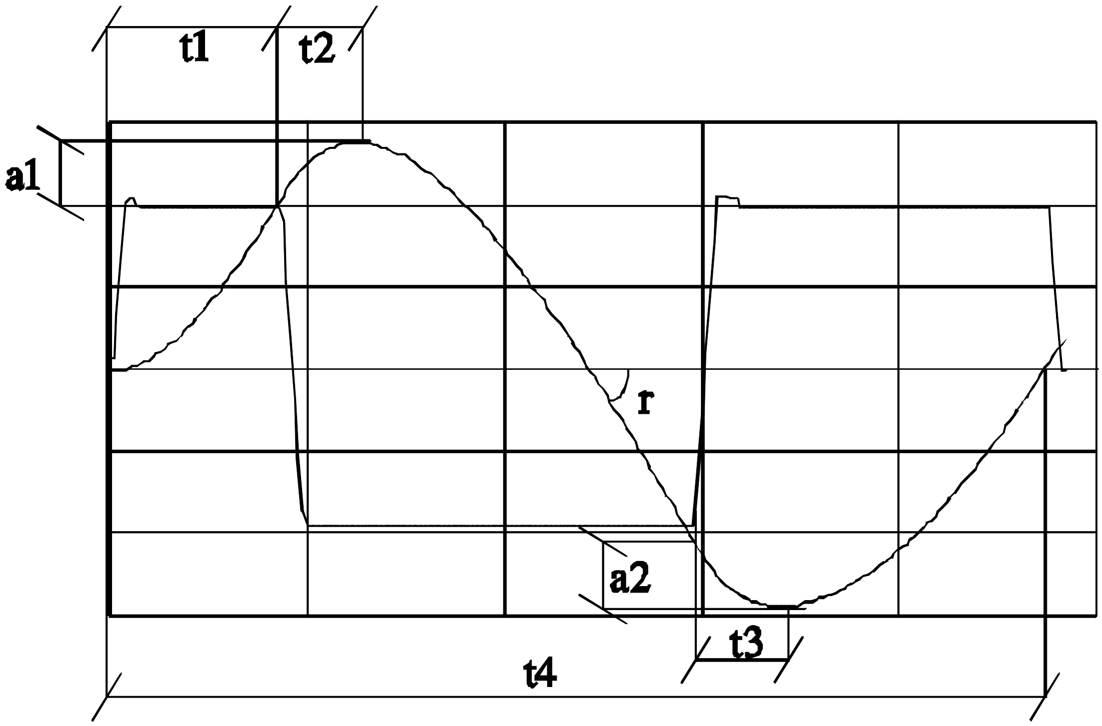



*Figure 15. Z test. a1 = the first overshoot angle, t1 = initial turning time, t2 = time to the first overshoot angle, r = turning speed, a2 = the second overshoot angle, t3 = time to the second overshoot angle, t4 = time of a full period.*

A SPIRAL TEST is like a series of turn circles and a pull-out test. It starts from a turn circle manoeuvred with a 35-degree rudder angle, which is continued until the rate of turn has been stabilized. This usually happens when a little more than half of the turn circle has been steered. The realized speeds of advance and turn are noted. After this the rudder angle is reduced e.g. by five degrees after this, and this is continued until the motion state becomes stable. When there are five degrees left of the rudder angle, the changes in the rudder angle can be reduced to e.g. one degree. This course of action provides accurate information about the vessel's course stability, i.e. about whether the vessel starts to proceed straight ahead when the rudder is midships or whether the stopping of the turn requires opposite helm. When the test has reached a stage in which the point zero of the rudder angle has been passed over to five degrees on the opposite side, the rudder angle can again be increased e.g. by steps of five degrees. The spiral test can be continued until enough measuring information has been gathered on the relationship between the rudder angle, speed of advance and speed of turn on a specific main engine setting. In the spiral test, rudder angles are usually used from both directions over the zero point. This is especially important for vessels with one propeller. Their proceeding straight requires a rudder angle different from zero. As in the pull-out test, the measuring results are sensitive to weather conditions, and the wind speed should be low during the test.

The CRASH STOP or stopping test is started in the same way as the turn circle test, i.e. by proceeding straight with cruising speed. The main propellers are set to full reversing power, and the rudder is kept midships. The test ends when the vessel is fully stopped. According to the IMO, the vessel should stop within the distance of 15 vessel lengths (Figure 16, progress X). In exceptional circumstances, large vessels can be allowed 20 vessel lengths. The crash stop test is a test which puts heavy strain on the vessel's main engines, and therefore performing this test is avoided. In a real emergency situation, the turn circle usually leads to a shorter advance in the direction of the initial course than the crash stop does, but on the other hand it requires so much lateral space that turning in the archipelago is not necessarily possible.

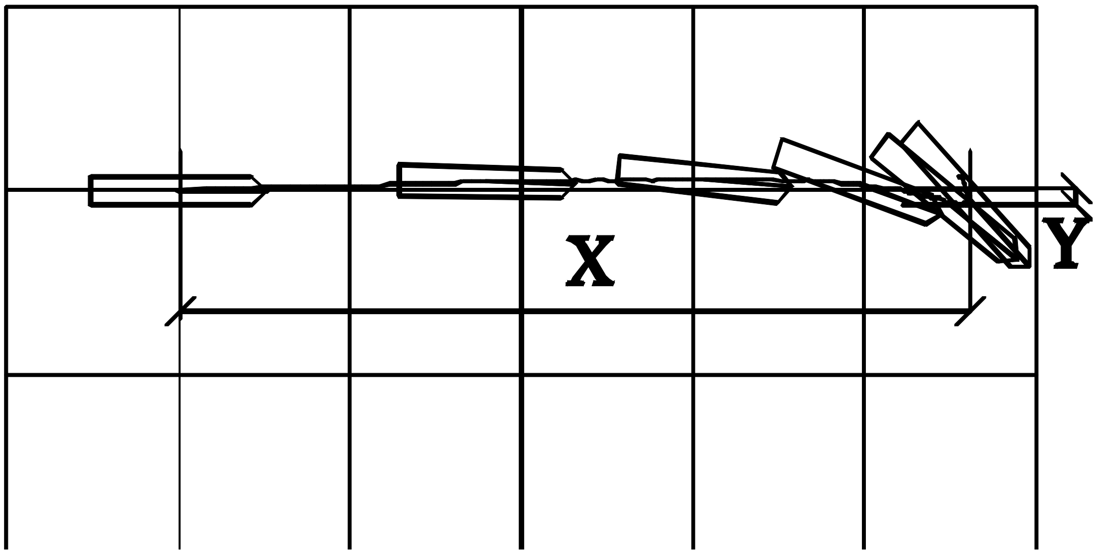



*Figure 16. Crash stop or stopping test. X = advance, Y = lateral*

## 4.2 The fairway

Of the investigation reports published by the Accident Investigation Board, 8 contain observations on fairway alignments, fairway areas, or buoyage that contributed to the accidents.

### 4.2.1 Fairway depth and channel alignment

Old nautical charts did not include any kind of depth classification with respect to fairways, so the masters had to estimate whether a fairway could be used on the basis of the depth information printed on the chart. In Finland the situation changed in the middle of the 19th century when the first fairway depth markings appeared on the charts. The planning grounds of fairways were developed when the National Board of Public Roads and Waterways started to participate in the planning of sea tracks after the Saimaa Canal had been completed in 1968. The Waterways Department of the National Board of Public Roads and Waterways stated in an article in 1975 that the Board had considered the planning criteria for as long as three years[106], and the work was not yet completed. The instructions for the planning of fairways[107] compiled by the National Board of Public Roads and Waterway were published in 1979.

The effect of shallow water, i.e. squat, became a matter of public knowledge among the seafarers in 1976 when the National Board of Public Roads and Waterways published field tests on the squats apparent on car ferries in the Åland Islands[108]. In the same year the University of Technology published a study on vessel's squat in shallow water caused by speed[109].

Squat has been explained in the Finnish Maritime Administration's fairway planning instruction[110]. The magnitude of squat can easily be estimated on the Finnish Maritime Administration's website. The spreadsheet programme uses the Huuska-Icorels method of calculus.

The following are added into the yellow fields of the spreadsheet:

- the length of the vessel's waterline (Lpp) m,
- the breadth of the vessel (B) m,
- the vessel's block coefficient (Cb)
- the vessel's draught (t) m
- the safe clearance depth of the fairway (hs) m,
- the water depth of the chart (mean, affecting water depth h m)
- the internationally required net underkeel clearance (0.5 m) and
- the added depth required by the vessel's list or the swell of the sea

[106] Kimmo Mannola, Uutta tekniikkaa meriväylien suunnittelussa, NAVIGATOR 2-3/1975.
[107] Laivaväylien suunnitteluohjeet, National Board of Public Roads and Waterways, Waterways Department, Helsinki 1979, TVH 752159
[108] Aimo Heiskanen, Timo Rekonen, Aluksen nopeuspainuma, Navigator 3/1976, p. 32
[109] Olavi Huuska, On the Evaluation of underkeel Clearances in Finnish Waterways. ISBN 951-750-768-2. Otaniemi 1976
[110] Laivaväylien suunnitteluohje, Finnish Maritime Administration 2001, ISSN 4156-9442. p. 26–31

*Table 6. An example of the initial values of the squat-spreadsheet. The programme calculates the gross underkeel clearance under the bottom of the vessel. In this example there is 0.9 m of water.*

| **INITIAL VALUES** | | |
|---|---|---|
| Vessel's breadth B = | 22.0m | A value given by the user |
| Vessel's length Lpp = | 138.0m | A value given by the user |
| Fill factor of the displacement[111] $C_B$ = | 0.525 | A value given by the user |
| $B / L_{pp}$ = | 0.16 | A value calculated by the programme |
| Vessel's draught T = | 5.7m | A value given by the user |
| Safe clearance depth hs = | 7.30m | A value given by the user |
| Water depth h = | 7.5m | A value given by the user |
| Gross underkeel clearance | 1.6m | A value calculated by the programme |
| - Net underkeel clearance * | 0.5m | A value given by the user |
| - Other motion allowance ** | 0.2m | A value given by the user |
| - Sag(squat)reserve allowance | 0.9m | A value calculated by the programme |

* The net underkeel clearance on sea tracks is usually 0.5 m

** Other motion allowance includes e.g. the movements caused by the sea and the vessel's heeling; these factors have to be taken into account on a case-to-case basis according to the circumstances

For calculating the effects of shallow water the formula in the Huuska-Icorels

$$\frac{\Delta t_{\max}}{t} = C_0 \frac{C_B b}{l_{pp}} \frac{F^2{}_{nh}}{\sqrt{1-F^2{}_{nh}}}$$

calculus method is the following:

Froude number, $F_{nh} = V/\sqrt{gh}$

Speed; $V = (m/s)$

*Normal acceleration due to gravity* , $g = 9.80665 m/s^2$

Water depth; $h(m)$

Squat: $\Delta t_{\max}$

Draught: $t$

*The length of the waterline:* $l_{pp}$ ,

[111] The ratio Block Coefficient $C_B$ equals with the ratio of the volume of the underwater part of the hull, i.e. the volume of the displacement to a hexahedron, the volume of which is the length of the waterline multiplied by draught multiplied by breadth.

The coefficient $C_0$ varies between 1.7-2.4. The results are given as three different values according to the vessel's block coefficient:

- $C_0$ = 1.7, when the block coefficient $C_B$ of the hull is under 0.7 (streamlined vessels)
- $C_0$ = 2.0, when $C_B$ is 0.7-0.8 (normal vessels)
- $C_0$ = 2.4, when $C_B$ is over 0.8 (full-bodies vessels)

For example low speed can be chosen as the speed of advance in the calculations. It can be noted from the table that in our example approximately 13.5 knots corresponds with the highest allowed shallow suction 0.9. It is easy to change the calculatory speed. In the example the highest allowed speed is 13.4 knots, which gives a squat of 0.88.

The programme shows a change in the Froude depth number as the speed increases. The Froude number 1.0 illustrates a critical wave formation in shallow water.

*Table 7. The chosen speed of 12 knots is fed into the yellow field.*

| | | | |
|---|---|---|---|
| Speed of the vessel v (kn) | 12.0 | 13.0 | 14.0 |
| Speed of the vessel v (m/s) | 6.2 | 6.7 | 7.2 |
| Froude number Fnh | 0.72 | 0.78 | 0.84 |
| **SQUAT (Co = 1,7)** | 0.61 | 0.79 | 1.05 |
| **SQUAT (Co = 2,0)** | 0.71 | 0.93 | 1.24 |
| **SQUAT (Co = 2,4)** | 0.85 | 1.11 | 1.49 |

The effect of the sea on the draught is estimated on the basis of the trough of a wave and especially on the basis of heeling. In inland waterways there is a wave allowance of 0.6 m and in outer passages 1.0 m.

The old fairway depth practice[112] was studied in 1995. It was impractical that depth had equalled with the draught of a vessel not making way. The old definition was changed at the end of 2005, and the change was published in an FMA Bulletin[113]. According to the new practice, the master could use a deeper depth than the value indicated in the chart when proceeding at a low speed. The master only had to know the safe clearance depth and the required net underkeel clearance in order to define a suitable speed. There is information about the safe clearance depth in the nautical chart or on the fairway information card. Fairway information cards are available on the Finnish Maritime Administration's website. According to the FMA's fairway planning instruction there should be half a metre of water between the safe clearance depth and the baseline of the vessel in fairways[114].

112 Timo Rekonen, National Board of Navigation, Fairways Department, Kulkusyvyyden vahvistaminen väylälle: byrokraattinen ja epätaloudellinen käytäntö. MEGAFONI 6/1995.
113 The Channel Depth Practice in Finland, FMA Bulletin, 8/12.7.2005.
114 Laivaväylien suunnitteluohje, Finnish Maritime Administration 2001, ISSN 4156-9442. p. 32.

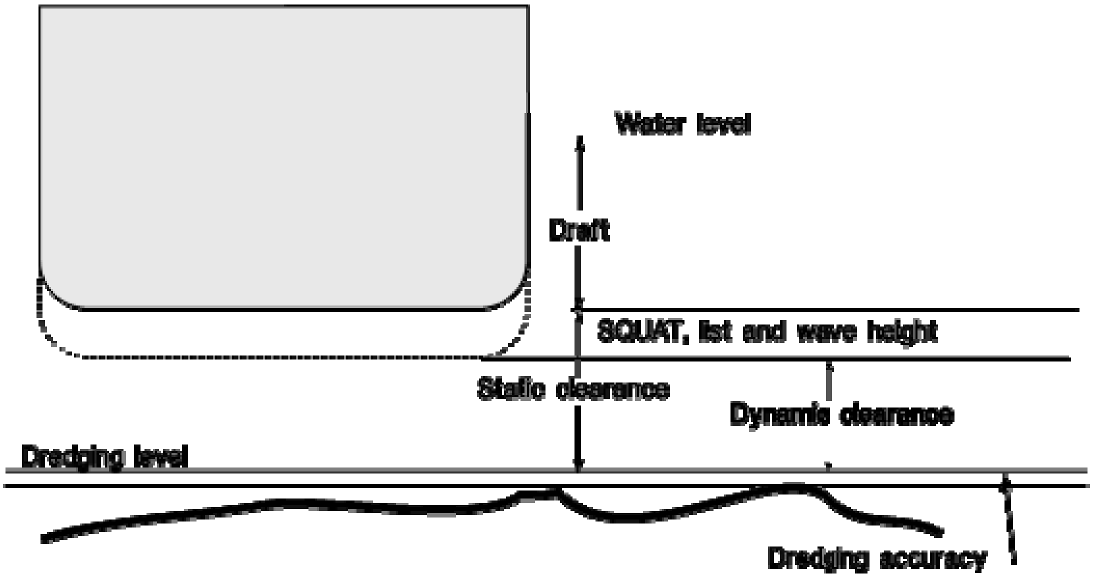



*Figure 17. How the depth of a fairway is determined.*

Squat is taken into account in the new channel depth practice[115]. The changed practice means that the crew should calculate the vessel's squat, and the highest speed allowed is marked in the route plan. At the time of writing the new channel depth practice has been adopted in some fairway entrances, and the practice is still expanding so that it will apply to all coastal fairways.

The Finnish fairway planning instruction is based on the recommendations given by the international PIANC organization (Permanent International Association of Navigation Congresses). According to these recommendations, the width of a single-lane fairway should in optimal circumstances be at least 3-4 vessel breadths, and that of a two-lane fairway should be 6-7 vessel breadths[116]. The total width of the fairway is the breadth of the dimension vessel, added for instance with the need for fairway area caused by unintentional yawing, inaccuracy of position determination, wind, current and the unevenness of the surrounding terrain. On the whole, 3-4 vessel breadths is such a narrow fairway space that the fatigue of the seafarer responsible for manoeuvring the vessel has an effect on the safety of the pilotage. The fairway planning instruction does not give any recommendations as to the maximum length of a narrow fairway section, but it is clear that when the fairway section requiring attentiveness is long, it is advisable from a safety perspective to use shorter watches than normally.

The IMO has not undertaken to publish any kind of a fairway planning instruction.

[115] Risto Lång, Väylien kulkusyvyyskäytäntö, Suomen Merenkulku 09/2005
[116] Laivaväylien suunnitteluohjeet, Section 4.3, Finnish Maritime Administration, Helsinki 2001, ISSN 1456-9442

According to the Finnish planning instruction, the radius of the bends should be five vessel lengths, and at the end of a turn there should be at least five vessel lengths of a straight leg so that there is enough time to stabilize the unintentional yawing caused by the turn. The turn should not terminate in such a way that the vessel must immediately after it must pass through a narrow gate. According to the instruction, each demanding manoeuvre requires five vessel lengths of straight tracks[117].

Fairway legs should be long enough so that the vessel would have time, after the turn, to settle on a straight course. When the section between two turns is shorter than five vessel lengths, we talk about an S-turn.

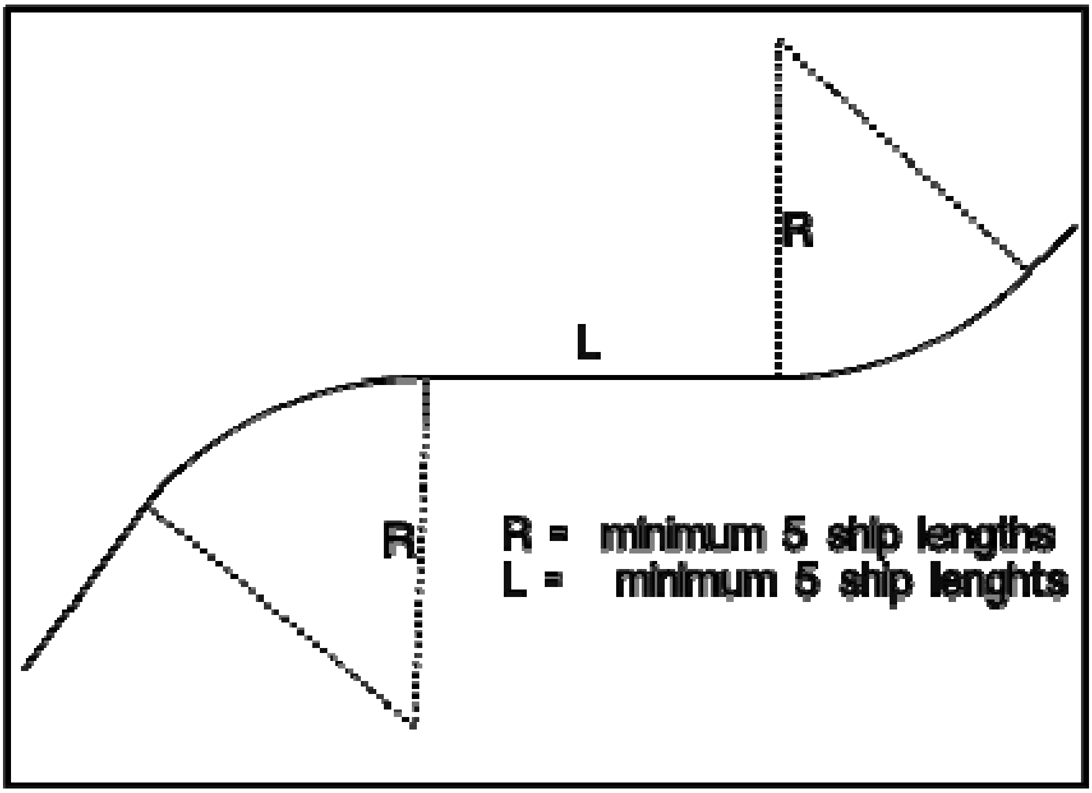



*Figure 18. Two successive turns according to the fairway planning instruction. The turning radius R should preferably be five vessel lengths, so that the rudder angle is not too big. There must be at least five vessel lengths between the bends of the straight section (L), so that it is possible to stop the unintentional yawing caused by the first turn.*

117 Laivaväylien suunnitteluohjeet, Section 3.1, Finnish Maritime Administration, Helsinki 2001, ISSN 1456-9442

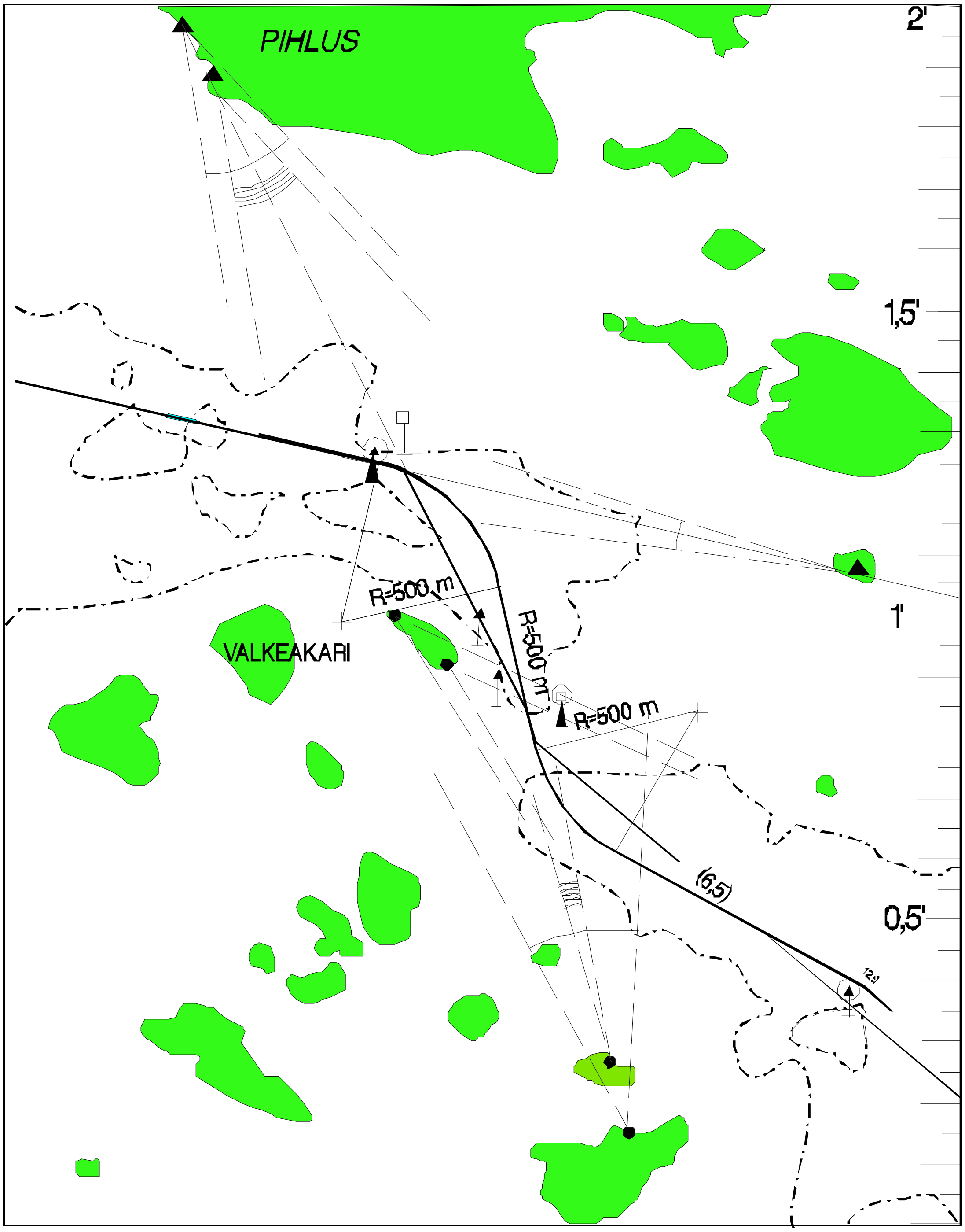



*Figure 19. The figure illustrates the fairway geometry of a 100-metre-long vessel drawn on a nautical chart according to the Finnish Maritime Administration's planning instructions. The geometry used for the old channel alignment does not correspond with the principles of a modern fairway planning instruction. The example is from the Valkeakari fairway leading to Rauma.*

The channel alignments of the Finnish coastal fairways do not always correspond with the requirements presented in the fairway planning instruction, since most fairways have been planned prior to 1979. Figure 19 illustrates the Valkeakari fairway leading to Rauma, for which the turn geometry in accordance with the fairway planning instruction could very well be used nowadays. The boards with the function of leading beacons have, however, been erected prior to 1979.

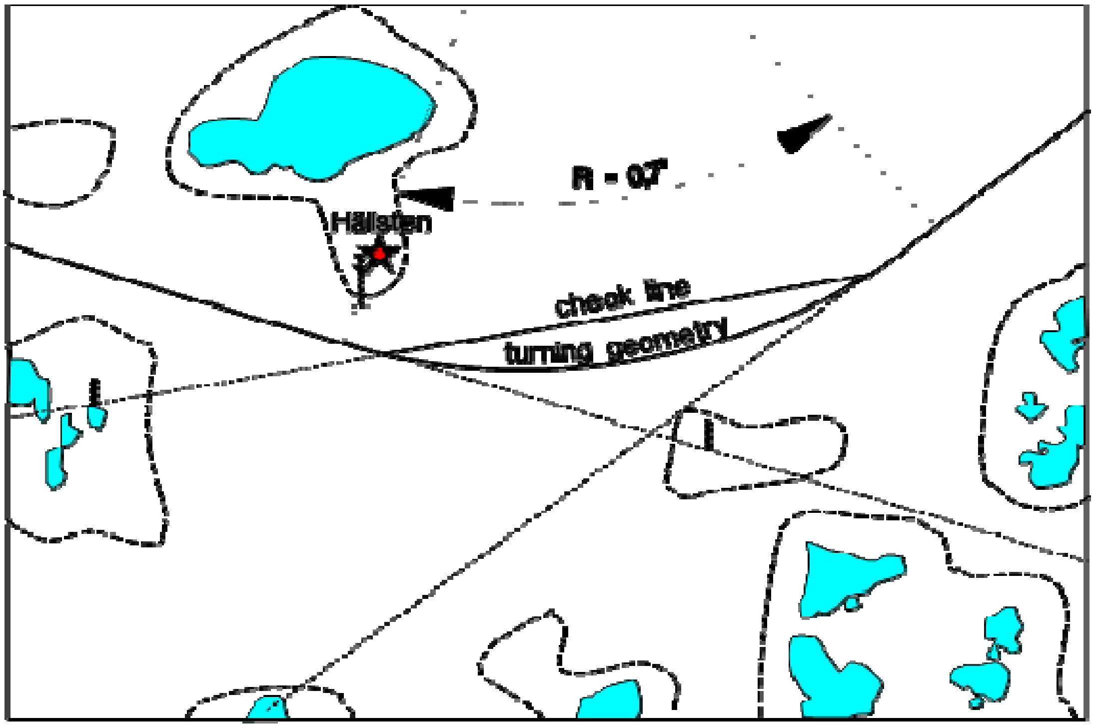



*Figure 20. The turn geometry of the present fairway planning compared with the alignment presented in the nautical chart. A checkline marked by boards shas been drawn between the tracks. The figure is from an area close to Rosala village.*

### 4.2.2 Fairway area

In earlier times marking the fairway on the nautical chart was done by using a simple navigation line. Later on navigation marks were adopted to mark off the navigable fairway areas. For hundreds of years, only the concept of fairway was used in maritime literature. The concept of fairway area has come into use only in recent history.

Nowadays at least the swept areas in the entrances are marked on the charts. The area outside the swept area is often only sounded, but it can still be deep and usable space. The sweeping of the area guarantees the minimum depth marked on the chart, but the navigable area can consequently be wider than the swept area. The borders between the swept areas are marked with navigation marks, so the navigable area can become narrower because of these aids to navigation.

In some cases fairways are marked with ‘gates’. In that case the navigation mark on one side of the fairway indicates a shoal, but the navigation mark on the opposite side at the same distance from the navigation line is placed in deep water. There can still be an old, traditional fairway area behind the mark. The crew’s local knowledge can lead to a situation, in which the vessel is steered on the 'wrong' side of the 'unnecessary’ navigation mark. Because the give-way obligations of the vessels proceeding in the official fairway area and outside it have been specifically defined in the Collision Regulations, the new way of marking, which is based on gates, has caused confusion as to the interpretation of give-way rules.

In 2005 the Finnish Maritime Administration gave a decision on fairway terminology[118]. The front page of the bulletin states that

> *‘... the purpose of the descriptions is to clarify the meaning of the terms connected with fairways/channels, their interpretation and the responsibility of the authorities providing fairways/channels.’*

As an exception to the old practice, this bulletin presents that

> *'The banks of the fairway area are marked by spar buoys, buoys and Edge Marks. All breakpoints of the fairway areas are not necessarily marked.’*

Because at the same time only some of the fairways are rastered on nautical charts, it can be unclear where the real sidelines of the fairway area are.

118 Fairway Terminology, FMA Bulletin 7/2005.

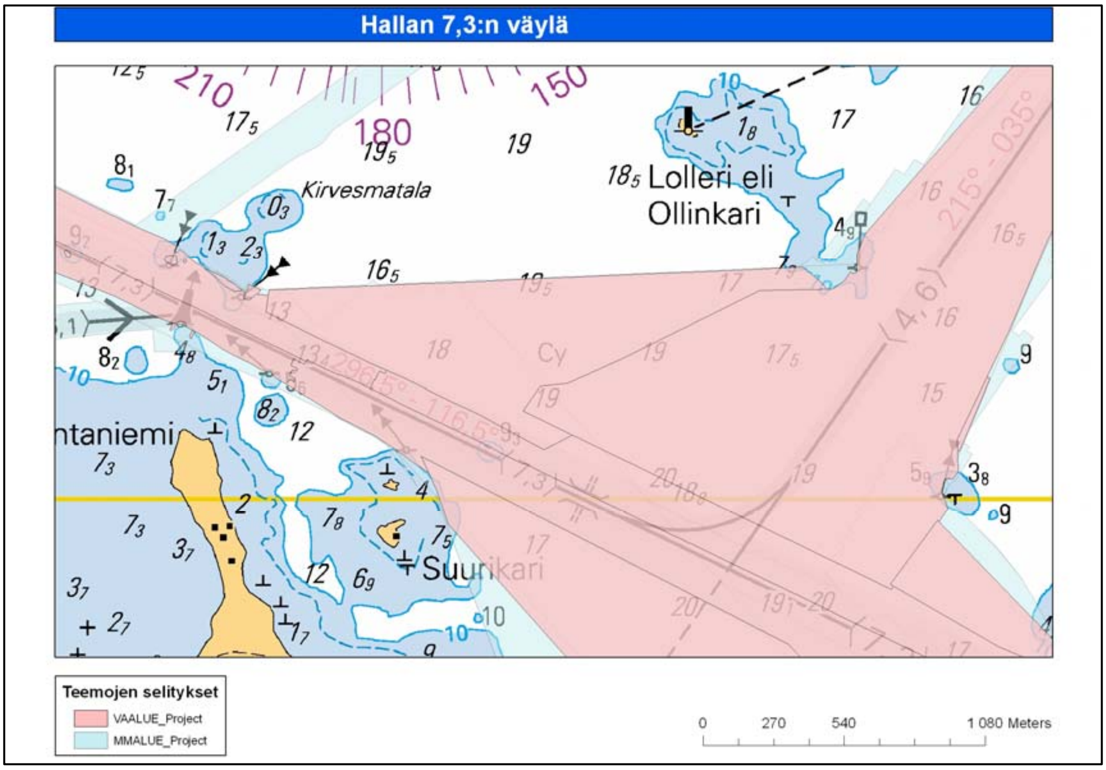



*Figure 21. An example of a supplementary area east of Ruotsinsalmi (Finnish Maritime Administration).*

The Supreme Court has based its decision on the fishermen's right to lay out nets on the old way to mark off the fairway. According to the decision, a fisherman can define the line from one navigation mark to another, and he/she can lay out nets 50 metres from this line towards the shallow water. The decision of the Supreme Court is clear. If e.g. the breakpoint of the outer sideline of the fairway turn is not marked, the fisherman can, according to the Supreme Court decision, lay out the nets inside the fairway area sketched out by the Finnish Maritime Administration. It is even more probable that fishermen lay out nets next to the fairway area, inside the supplementary areas, because the supplementary areas are not marked on the nautical charts usually used by fishermen nor are they marked in the fairway itself.

# 5 MANOEUVRING OF THE VESSEL IN FAIRWAYS AND PORTS

The IMO's STCW Code requires that masters and chief officers employed on vessels over 500 GT[119] have command of the manoeuvring of the vessel in fairways and ports in all conditions[120]. The literal requirement is the following:

> *'Manoeuvre and handle a ship in all conditions... in rivers, estuaries and restricted waters, berthing and unberthing under various condition of wind, tide and current with or without tugs …'*

This IMO requirement cannot be realized in practice in maritime education. The wording *'in all conditions'* sounds unconsidered, and it cannot be required in practice. The vessels have technical conditional limitations, which the seafarers and shipping companies must be aware of and which restrict operations in e.g. strong wind. Wind can set the lower limit to the vessel's speed, because the drift angle cannot be increased too much in a narrow fairway. If the depth of the fairway is also limited, shallow water can set the upper limit to the vessel's speed. The STCW Code requires the following:

> *'… manoevring in shallow waters, including the reduction in under keel clearance caused by squat, rolling and pitching'.*

A situation can arise, in which the vessel due to a strong wind should proceed at higher speed than what is possible with respect to squat.

Manoeuvring and handling a vessel in all conditions cannot be included in the maritime curricula. The requirement has to be interpreted in such a way that a seafarer must know the operational limits for manoeuvring and handling the vessel in a safe manner. So instead of the wording *'in all conditions'*, it would be sensible to apply the principle *'within the operational limits required by the SOLAS'.*

Because the IMO has not mentioned operational limits, the training in the maritime colleges concentrates on the theory of vessel manoeuvring. The forces affecting the vessel and manoeuvring theory are covered very well in the maritime colleges[121], but setting operational limits is not something the colleges should do, so the fulfilling of the IMO recommendation or regulation remains the shipping companies' task.

119 Gross tonnage

120 IMO, International Maritime Organization, London 1996. STCW CODE, Table A-II/2

121 This Safety Study has regarded the stencil "MANÖVRERING AV FARTYG I BEGRÄNSADE FARVATTEN", written by Martin Forsén (153 pages, 20 sources) and published by the Maritime Institute of Turku, as an exemplary instruction

Problems in manoeuvring the ship on the fairways and in ports contributed to the accidents in 30 of the cases studied. Of these, 20 cases were related to navigating in the fairway and starting a turn, 7 to port manoeuvring, and 3 to the operating conditions of a pilot who was not a part of the vessel's crew.

## 5.1 Preparations for pilotage

The IMO requires that the shipping companies give instructions to the officers to cover all dangerous situations[122]. Section 2.2.1.3 in the ISM Code puts forth the objective to create and continuously develop a safe working environment and safe working methods. The practical measures to meet the objectives are not defined in the Code.

However, this does not rule out that a shipping company could require concrete measures in order to create bridge cooperation in its Safety Management System (SMS). There is, however, a risk that instructions given by the shipping company only remain on the level of objectives. It is natural that terminology which is written down by authorities is used in SMS instructions. The maritime authority accepts the instructions issued by the shipping companies if they follow the wordings given in the regulations and the maritime traditions. In order for the SMS instructions not to remain too general, the description of concrete measures should originate from the vessels so that the objective set by the authorities and the shipping companies is met. For example the officer in charge of the navigational watch must, according to the regulations, take all necessary measures if the pilot does not provide him/her with an account of the pilot's intentions[123]. What should the officer in charge of the navigational watch do in that case? The officer in charge of the navigational watch acts as the master's substitute on the bridge when he/she is not there[124]. The officer in charge of the navigational watch cannot know what actions are appropriate in different situations if these operational models are not agreed upon and recorded in advance. The lacking cooperation must be added to the instructions on the officers' position – and this must also be done in cooperation.

Cooperation requires that the bridge personnel have weekly meetings, in which the division of work, training and operational routines are dealt with. The objective is that the members of the bridge team achieve a uniform performance level with respect to navigation and pilotage. It is good to rotate the tasks performed by the crew so that this objective can be reached.

[122] IMO Res. A.913 (22) 2001. Revised Guidelines on Implementation of the International Safety Management (ISM) Code by Administrations
[123] IMO, STCW CODE, 1995, Chapter VIII, paragraph 50
[124] IMO, STCW CODE, 1995, Chapter VIII, paragraph 12

Some pilotage-related measures taken to develop bridge cooperation are presented next. Especially crews who work with integrated navigation systems would benefit from taking these into consideration.

- The routes used by the vessel can be divided into parts. Functionally they are divided e.g. into port, fairway and open water areas. Decisions are made on the manning of the bridge, operational modes of the navigational equipment and operational procedures to be applied in the different areas. In order to make the division into areas clearer, charts, operational instructions etc. can be marked with identification colours, which are distinctly different from the colours used for check and work lists.

- The details of the route plans are decided together. For example the following are matters which should be agreed upon: tracks, turning radii, the locations of waypoints, the maximum speeds, and the operational modes of the automatic appliances in various parts of the fairway. Everyone must commit to use the same, commonly agreed route plan.

- In order to realize the effective monitoring of piloting work in practice, all deck officers must master the handling of the vessel in all parts of the fairway which are used. To meet this objective, the piloting and monitoring task must be changed during the watch in such a manner that all fairway areas and all tasks become familiar to each member of the deck officer team.

- The operational settings affecting the automatic steering are gone through, and set values are agreed upon.

- Manuals for navigational equipment are used to compile summaries on the important matters related to the use of appliances.

- Defects and illogical functions detected in the appliances are recorded during the watch. The findings are dealt with in weekly meetings.

- New navigational appliances are first used as test runs. They are taken into actual use only after phased test runs. Operational procedures are created to use the equipment.

- New regulations and changes in the operational environment are dealt with, and procedures are changed to meet the requirements.

- The objective of monitoring is to control the realization of the manoeuvring procedures and the functioning of the automation technology systems. The crew must be trained in such a way that the person doing the monitoring is able to intervene with the situation under special circumstances and, when needed, take over the manoeuvring responsibility.

- The crew is familiarized with the special characteristics of the vessel and with the effects environmental factors have on the manoeuvring and on the performance of automation systems. These vessel-specific characteristics can include large wind surface, poor manoeuvrability at low speeds or the difficulties to control the vessel in shallow water. Simulator technology has proved to be an efficient tool in illustrating the phenomena described above.

- Working with a pilot who comes from outside the vessel is taken into consideration. The pilot's duties in the bridge organization and the exchange of essential information between the pilot and the master are planned in advance.

- Deviations and incidents are recorded, and these documents are dealt with together and reported further to the shipping company.

All official records/minutes and jointly taken measures are documented. Written material is an important source of information when the crews change and when new crew members familiarize themselves with the work.

## 5.2 Navigating in the fairway and starting a turn

An erroneously defined starting moment of a turn was noted as one of the factors in 20 accidents. The following section discusses the various methods of defining the correct time to start a turn.

Traditionally a turn has been performed as a rudder angle order applied in a predetermined turning point. Figure 22 illustrates a turn which is realized in the traditional way near Sottunga in the Åland archipelago. The turning method described here remained similar from the 1940's till the beginning of the 1970's. Defining the starting point of the turn was geometrically difficult till the beginning of the 1970's, because the movable electronic bearing of the radar was not yet available. When the vessels' sizes increased, the starting point moved in 30 years so that the turn started 90 metres earlier. Otherwise the tracks have remained almost the same. The general directions marked on the chart were, according to the common practice of the 1930's, based on manoeuvring from one white sector of a sector light to another. In the example presented in Figure 22, the turn was started with a rudder angle 20° to port when the bearing to Enskär lighthouse was 250°. In the middle of the turn the rudder was returned amidships. The turn was sharp, and at the end of it a counter rudder as big as 30° had to be applied.

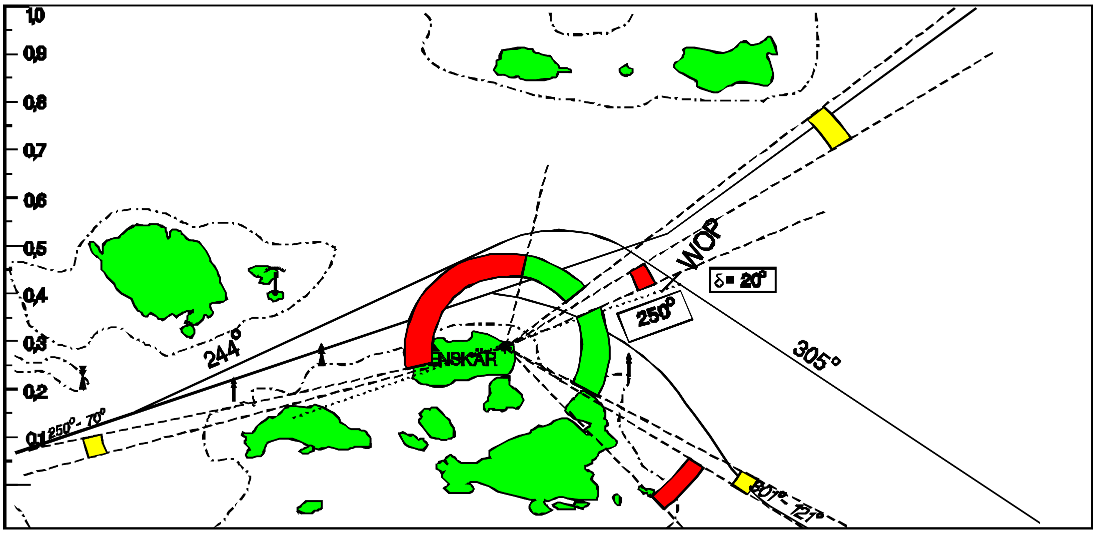



*Figure 22. A turn based on the rudder angle from course 305° to course 244° by order '20° to port' at the WOP (Wheel Over Point).*

Before a rudder angle command, one has to check that

- the starting course corresponds with the plan (305°)
- the bearing indicating the turning mark corresponds with the plan (250°)
- the helmsman must be told the initial rudder angle 20° to port

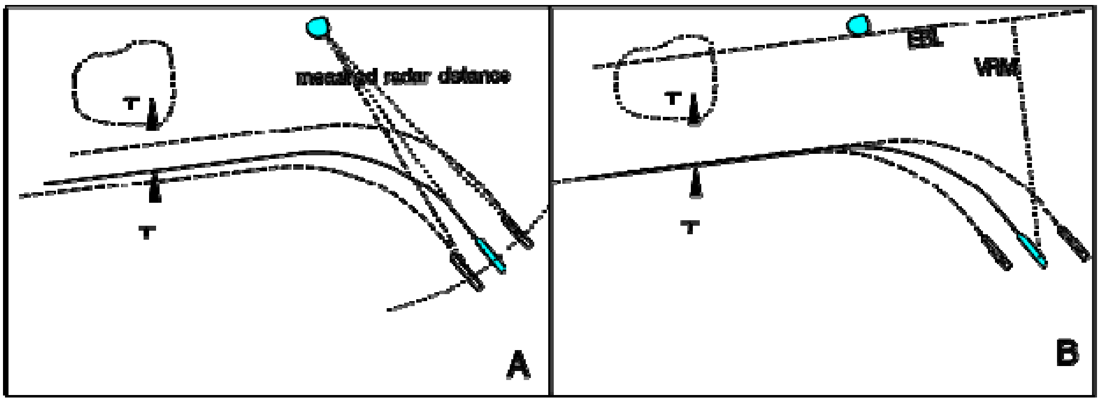



*Figure 23. Figure A illustrates a traditional turn applied to radar navigation. Figure B illustrates a method, which corrects the lateral deviation formed prior to the turn. A movable EBL and a VRM are needed for the measurements.*

The turning point has traditionally been defined with the help of a line of position, which is perpendicular to the track. In the early days of radar navigation there were no changes to this determination method (Figure 23 A), but the turning point was defined with the help of a range marker ring. The EBL together with the range marker ring (Figure 23 B) makes it possible to determine the turning point to the correct distance with reference to the new course. The lateral deviation, which has been formed before the turn, becomes automatically correct.

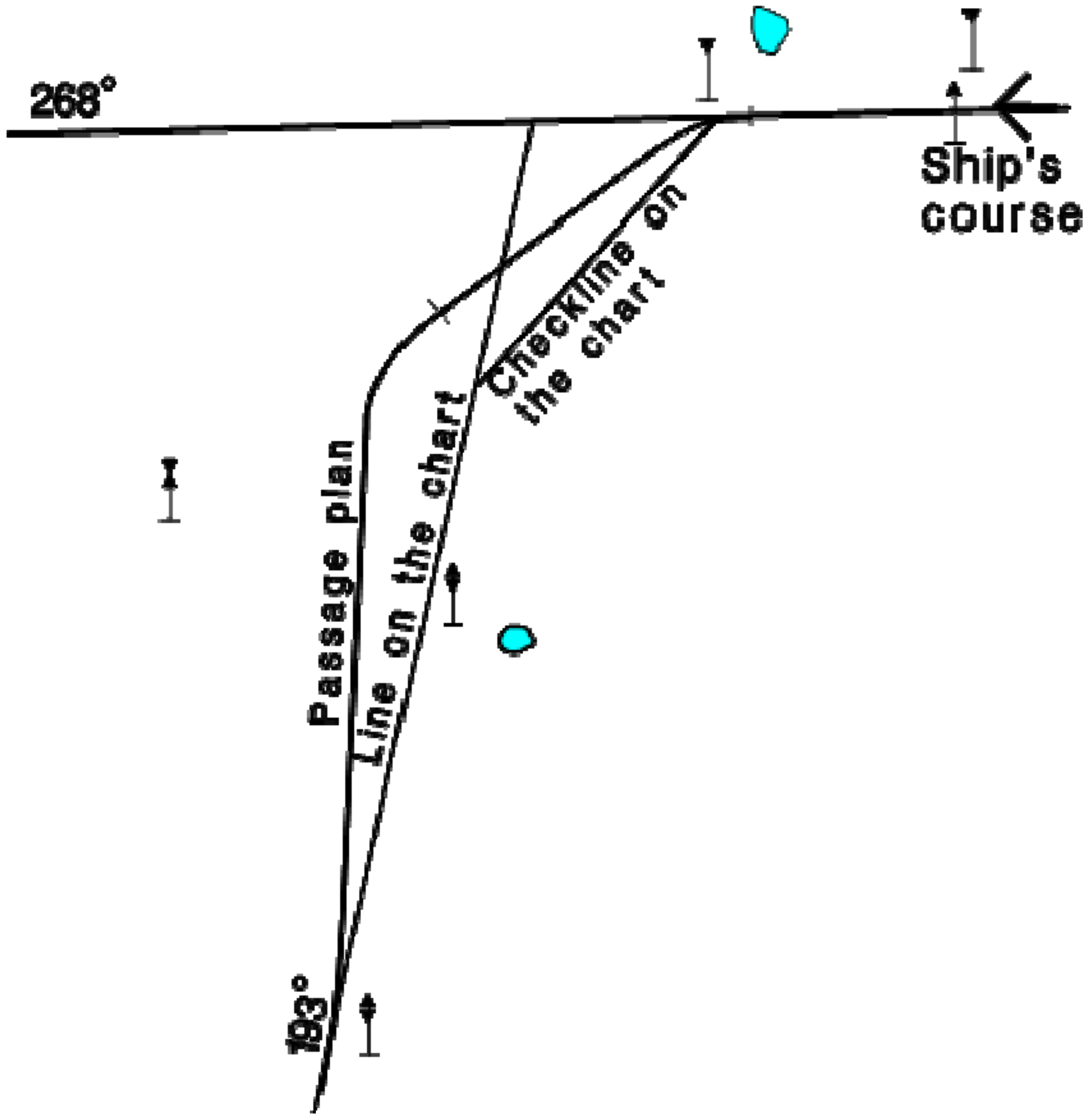



*Figure 24. A major course alteration has usually been divided into two parts on the chart. The pilotage plan somewhat differs from the chart alignment so that the tracks are positioned further away from the navigation marks.*

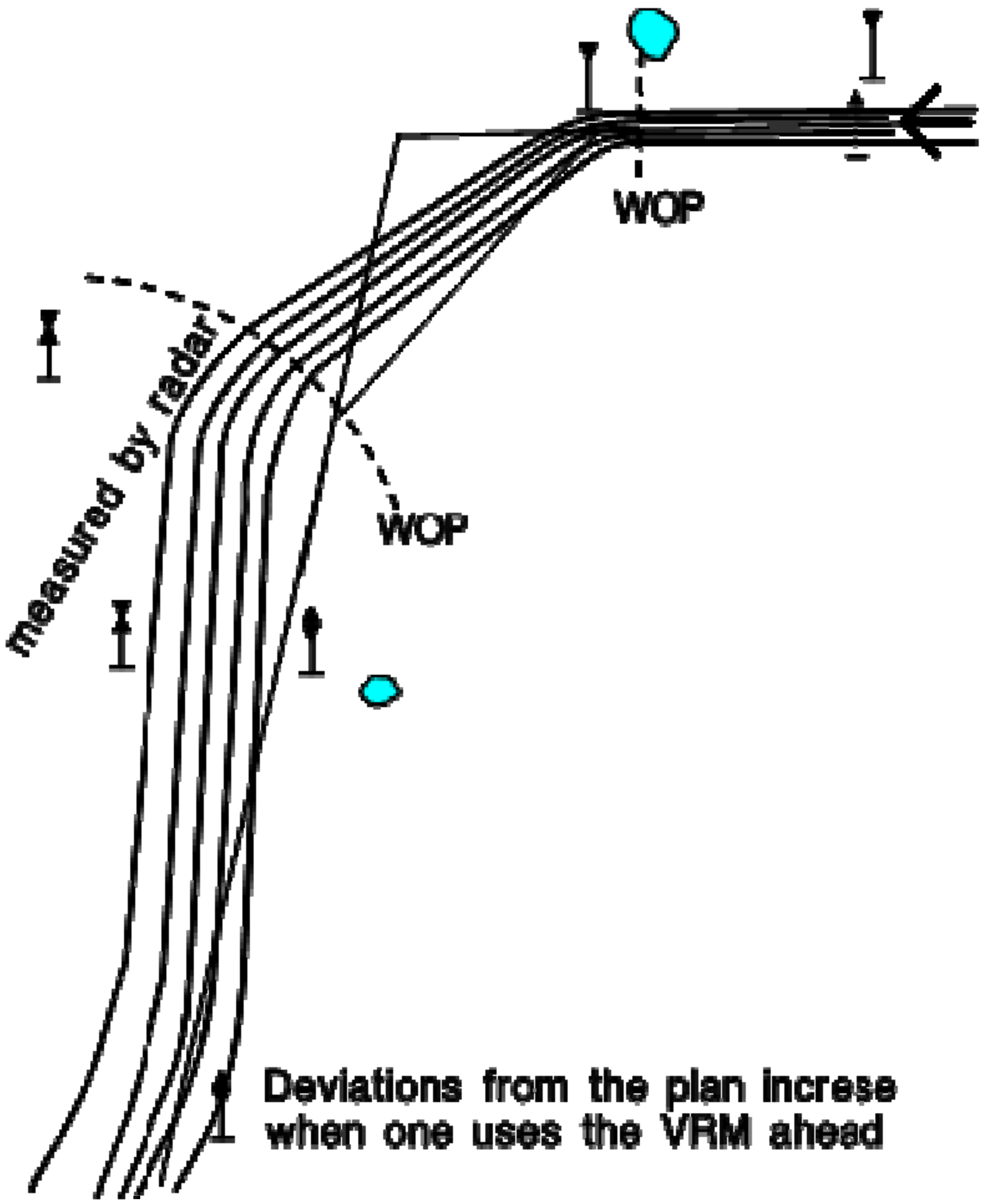



*Figure 25. When the turning points are chosen in such a way that the line of position is perpendicular to the track, the tracks disperse after the turn (WOP = Wheel Over Point). In the first turn the turning mark is directly on the side and in the second turn the radar distance has been taken straight ahead. Each turn increases the deviation from the route line.*

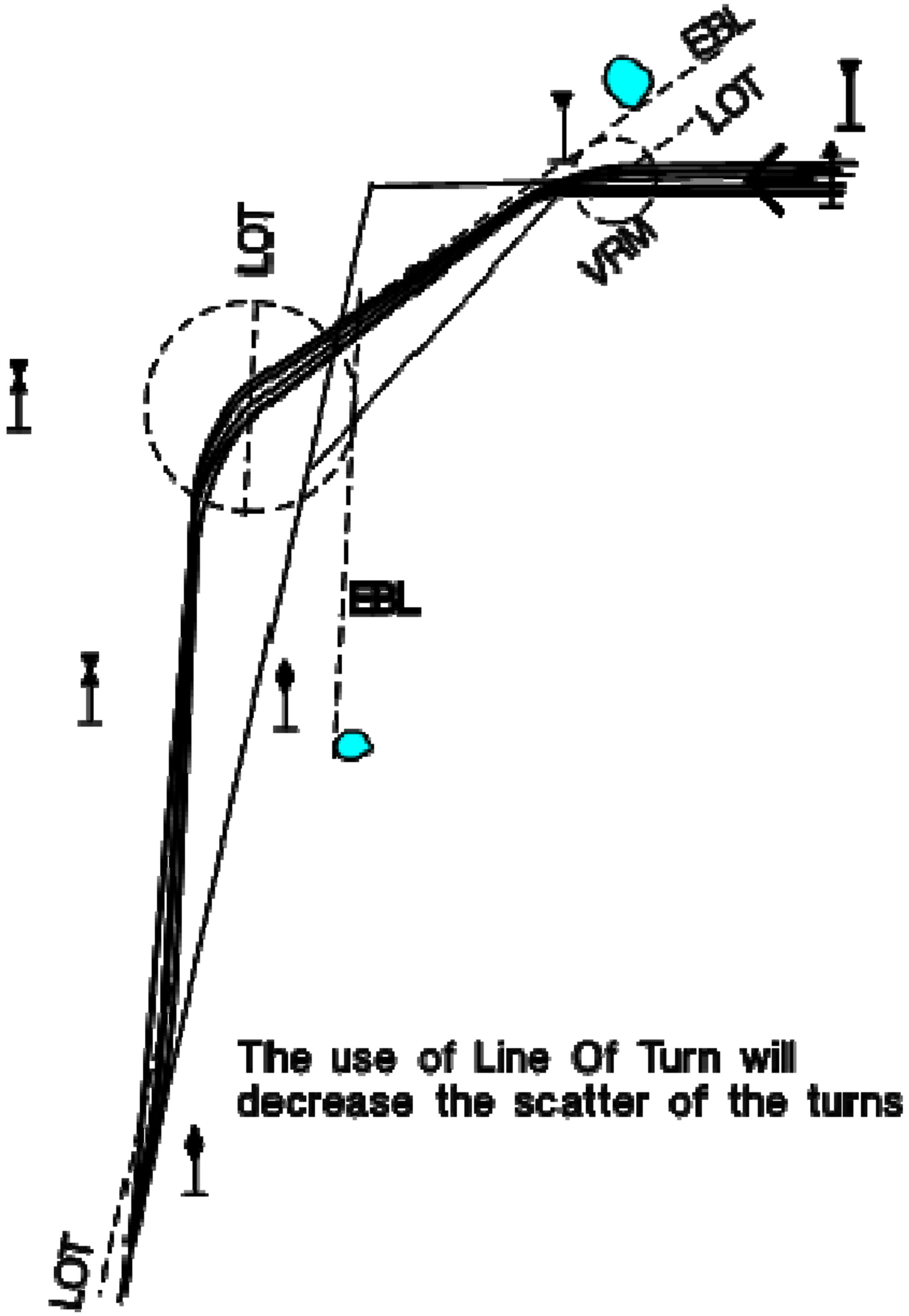



*Figure 26. The dispersion of the tracks decreases when the turning mark LOT (Line of Turn) corresponds with the course adopted after the new turn.*

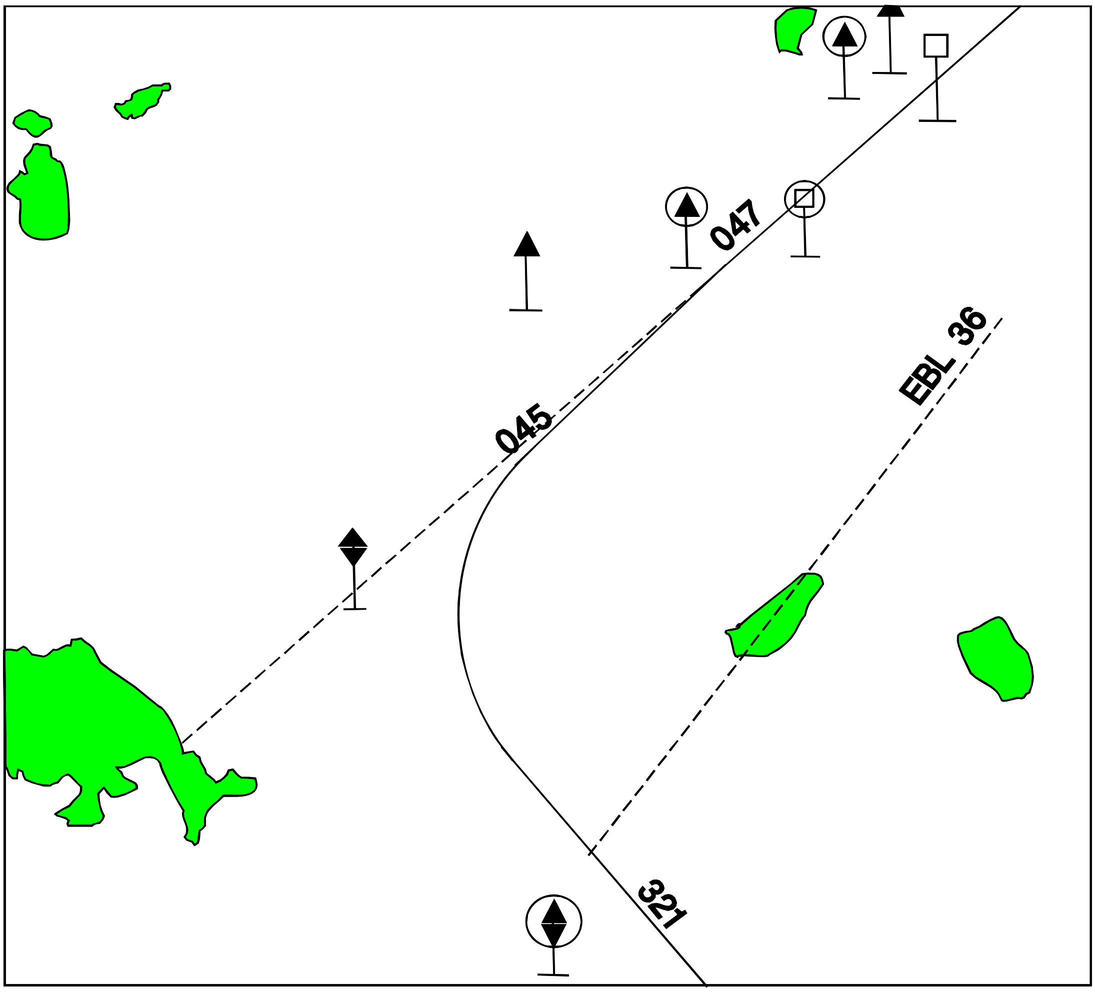



*Figure 27. In course alterations which require exactitude, the new course can be left somewhat short just to be on the safe side. The example is off Hanko.*

If a turn starts too late, it can be difficult to correct the error. Therefore turns which require accuracy are planned to be started a bit earlier, in which case the adjustment is easy to make at the end of the turn. The turn is stopped 2°–10° before the final course. When the safe course has been verified, the vessel is turned to the final track.

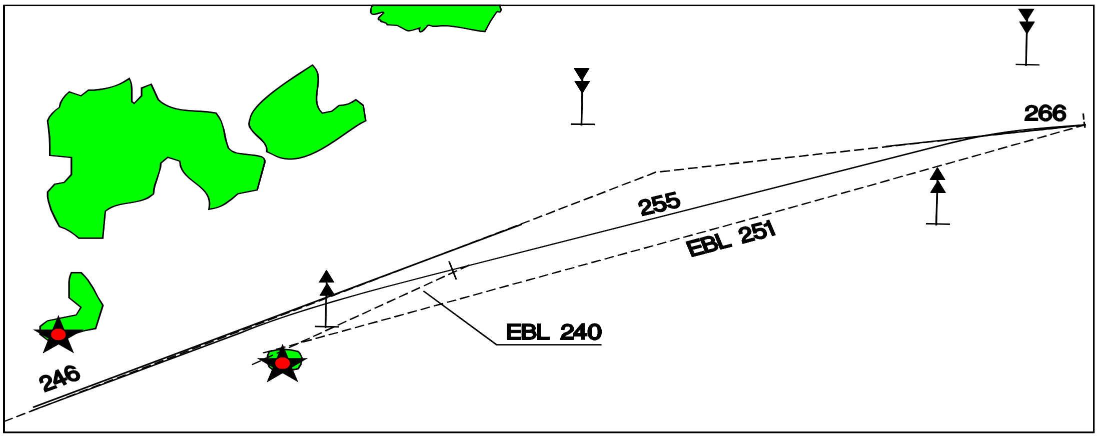



*Figure 28. The turn illustrated on this figure above is continuous, but in practice the turn before the narrow channel is performed as two separate course alterations so that the last correction is as accurate as possible.*

With modern technology it would be possible to control the vessel's motion state in bends with the help of ROT gyroscope. These are, however, rare on merchant vessels. Only vessels over 50,000 tonnes are required to carry an angular velocity gyroscope[125], and its objective then is to support the automatic steering device by eliminating unintentional yawing on a straight course. The angular velocity gyroscope is not required when pilotage is provided. It is, however, an important instrument, which would make it possible to make the turns safely as intended in fairway planning. The current IMO requirements on the vessels' compulsory equipment do not correspond with the principles of fairway planning.

If a seafarer is uncertain about the vessel's motion state during the turn, he/she aims at steering a new course as quickly as possible. This often leads to bigger rudder angle orders and sharper turns than planned. A rudder angle of 20° increased the angular velocity to 80 degrees in a minute when the vessel was 100 metres long (MS NORDIA). In that case the vessel acquired a discomfortable heel. If the vessel is heeling too much, the rudder angle must be reduced. As a result, the angular velocity changes during the turn, the heeling of the vessel varies and the vessel's path in the bend becomes oscillatory. Figure 29 illustrates the time history of the turn used as an example. The curve to the left illustrates the realized angular velocity of the turn when the turn is realized with the help of wheel orders. The changes in the turning speed make the turn inaccurate.The turn geometry is normalized if angular velocity or constant ratio apparatus is used or, in the case of manual steering, if the angular velocity indicator is monitored. If the top of the angular velocity curve is cut and moved to the end of the turn (Figure 29), the area between the curve for the time history of the angular velocity and the axis remains the same, which means that the starting and ending points of the turn do not change.

125 SOLAS amendment 2000, Chapter V, Safety of Navigation, Regulation 19, Gyro-compass paragraph.2.5. Rate-Of-Turn Indicator paragraph 2.9.

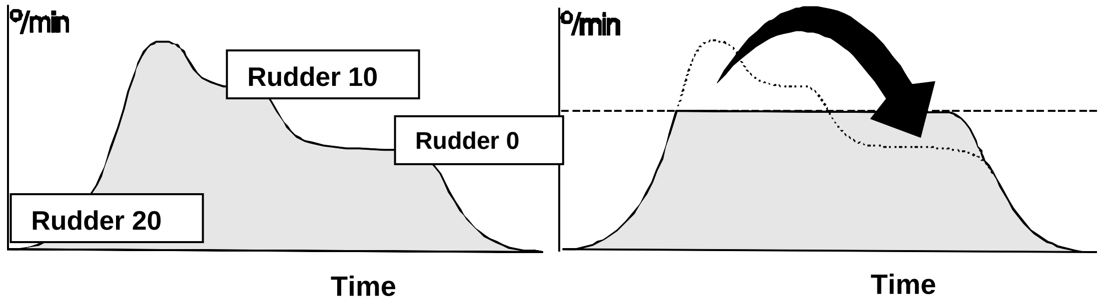



*Figure 29. The turn easily becomes sharp if only rudder angle orders are used. The ROT order cuts the top of the turn, and moves the cut area to the end of the turn. The total alteration of course equals with the integral of angular velocity in relation to time. In the figure the area remaining between the curve and the x-axis illustrates the alteration of course.*

Turning radius $R$ expressed in metres can be calculated with the formula;

$R = \dfrac{V}{\omega}$, in which

*V = speed*
*ω = angular velocity*

In this formula, the unit of angular velocity is radian/second and speed m/s according to SI-units.

Because the radian in degrees is:

$$\varphi(rad) = \frac{\alpha(asteet) \times 2\pi}{360}$$

The angular velocity is ω radians/second:

$$\omega(1/rad) = \frac{\alpha \times 2\pi}{\min \times 360} = \frac{\omega_0 \times 2\pi}{60 \times 360}(ast/\min)$$

in which the metre value $\omega_0$ is degrees/minute. Then;

$$R(mpk) = \frac{v}{\omega} = \frac{v_0 \times \frac{1}{3600s}}{\omega_0 \times \frac{2\pi}{360 \times 60}(1/h)} = \frac{3 \times v_0}{\pi \times \omega_0}(mpk)$$

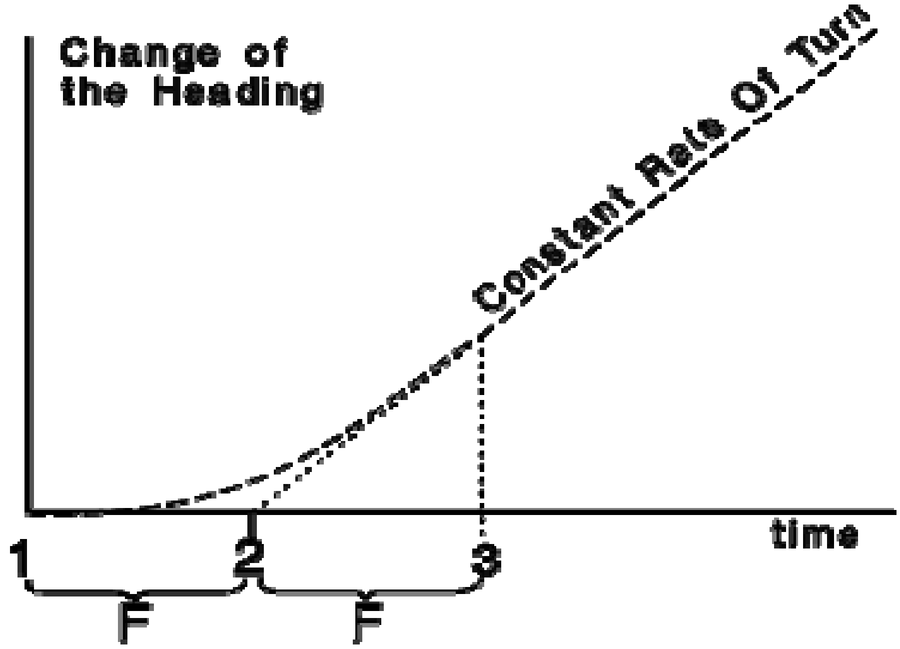
$$R \approx 0{,}955 \frac{v_0}{\omega_0}(mpk)$$

$$R \approx \frac{v_0}{\omega_0}(mpk);$$

*$v_0$ = speed in knots (nM/h) from the log,*
*$\omega_0$ = angular velocity (degrees/minute) from the gauge,*
*$R$ = turning radius in nautical miles (nM). This approximate value is adequate when manoeuvring in practice.*

The planning of the turn is first started by deciding the vessel’s speed of advance in the turn; the squat is taken into account. After this a geometric turning radius is measured from the chart. These values determine the angular velocity to be followed in the turn. For example in Figure 20, the correct speed is 15 knots and the turning radius 0.6 (nM). The angular velocity is then 15/0.7 = 22°/min.

At the beginning of the turn, when the rudder is deflected, the vessel actually moves straight ahead for a moment. After this the turn becomes sharper, and the vessel's trajectory stabilizes on an even arc. Starting major alterations of course is usually planned for rudder angles of 15°-20°.




**Example of F distances from a 200 meter long carferry**

| Turning Radius R nautical miles | The staraight path F cable lengts |
|---|---|
| 2.0' | 0.67 |
| 1.5' | 0.67 |
| 1.0' | 0.54 |
| 0.8' | 0.54 |
| 0.6' | 0.54 |
| 0.5' | 0.54 |

*Figure 30. F stands for the imaginary straight part of the turn at the beginning of the turn immediately after the wheel order. 2 × F is measured with a stopwatch and the F distance is drawn on the chart at the beginning of the turn.*

The vessel's angular velocity stabilizes to a value corresponding to the rudder angle when time t = 3 passes (Figure 30). The time interval 1-3 can be measured with a stopwatch. The broken line in the figure illustrates the fixed value of angular velocity. When the line is continued downwards, it cuts the time axis at point 2. Point 2 cannot be seen in the turn. Line segments 1–2 and 2–3 are approximately equally long. The line segment 1–2, i.e. F[126] is drawn on the chart at the beginning of the even bend.

It is not worth drawing the real trajectory on the chart, because the radius of the bend decreases until point 3. Point 2 halves the distance 1-3, and the beginning of the turn can be described on the chart as a straight line between points 1 and 2. An even arc to be followed in the turn is drawn from point 2. The vessel's true motion and the simplified trajectory drawn on the chart differ somewhat from each other. The error usually lies within the breadth of the vessel, so it does not make any practical difference.

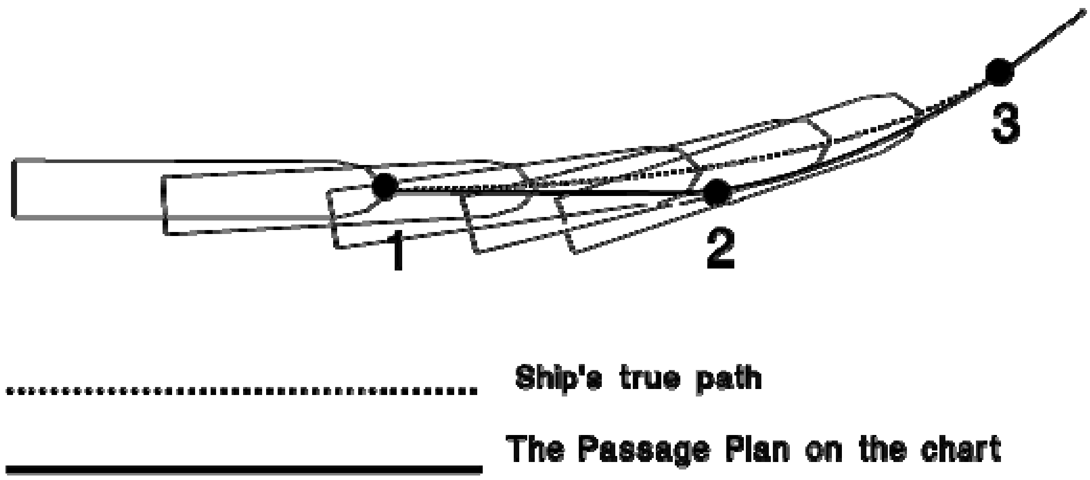



*Figure 31. The vessel reaches an even angular velocity at point 3, but the bend is drawn on the chart from point 2 onwards after the straight section. In reality the vessel moves along the broken line.*

[126] 'Framförsträcka'in the Swedish textbook NAVIGATION 3, Navigering med teletekniska hjälpmedel, 1984, Section 39, 46

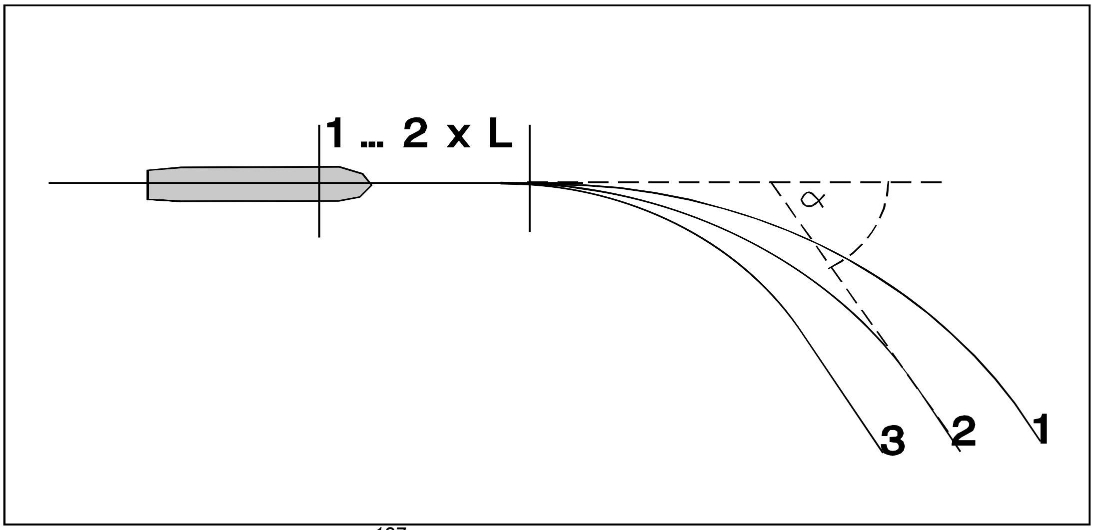



*Figure 32. Starting the turn[127] 1. A small rudder angle, i.e. the turn is prolonged. 2. The correct rudder angle 3. The rudder angle is too big and the vessel cuts inwards. The latter mistake is easier to correct.*

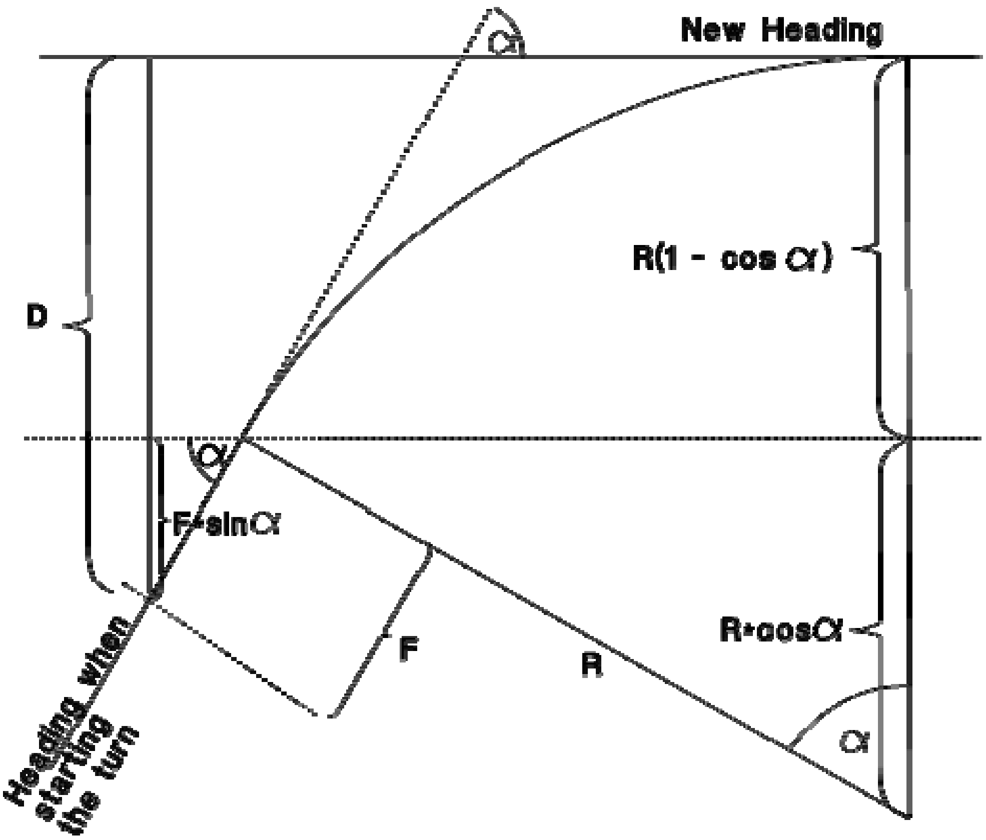



*Figure 33. Planning a turn.*

[127] Laivaväylien suunnitteluohjeet, Finnish Maritime Administration, Helsinki 2001, ISSN 1456-9442. Section 3.2.

When planning a turn, a starting line and the line to which one wants to turn are first drawn on the chart. The bend is measured with the help of a drawing triangle from the starting line to the new line. The F distance is placed at the beginning of an even bend (Figure 33).

The distance D describes the distance from the starting point of the turn to the new line perpendically. It can be calculated using the formula:

$$D = R(1 - \cos \alpha) + (F \times \sin \alpha)$$

The bend is drawn on the chart according to the initial starting course, the final course and the values *D* and *R.*

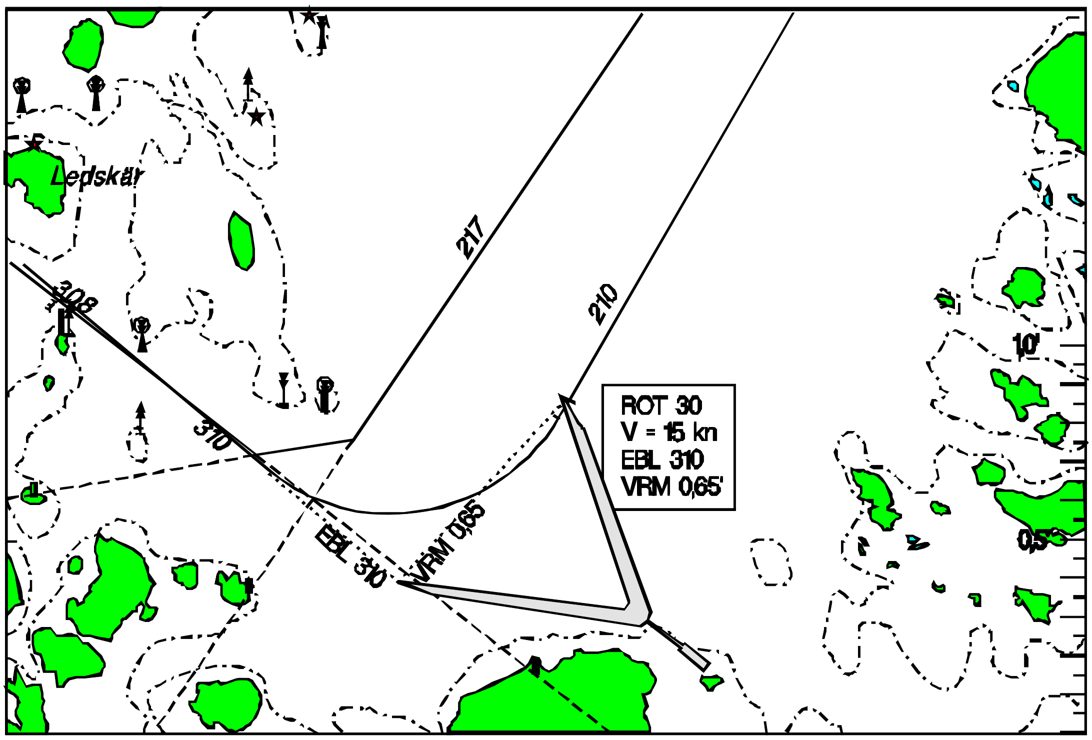



*Figure 34. Planning a turn on the chart. In this case the fairway alignment on the chart does not take into consideration the vessels' manoeuvring characteristics or the principles of modern fairway planning. The turn drawn on the chart from course 217° to course 308° must be planned divergent from the channel alignment. For example the turning radius from course 210° to course 310° is 0.5 (nM)', to which the F distance 0.15' is added.*

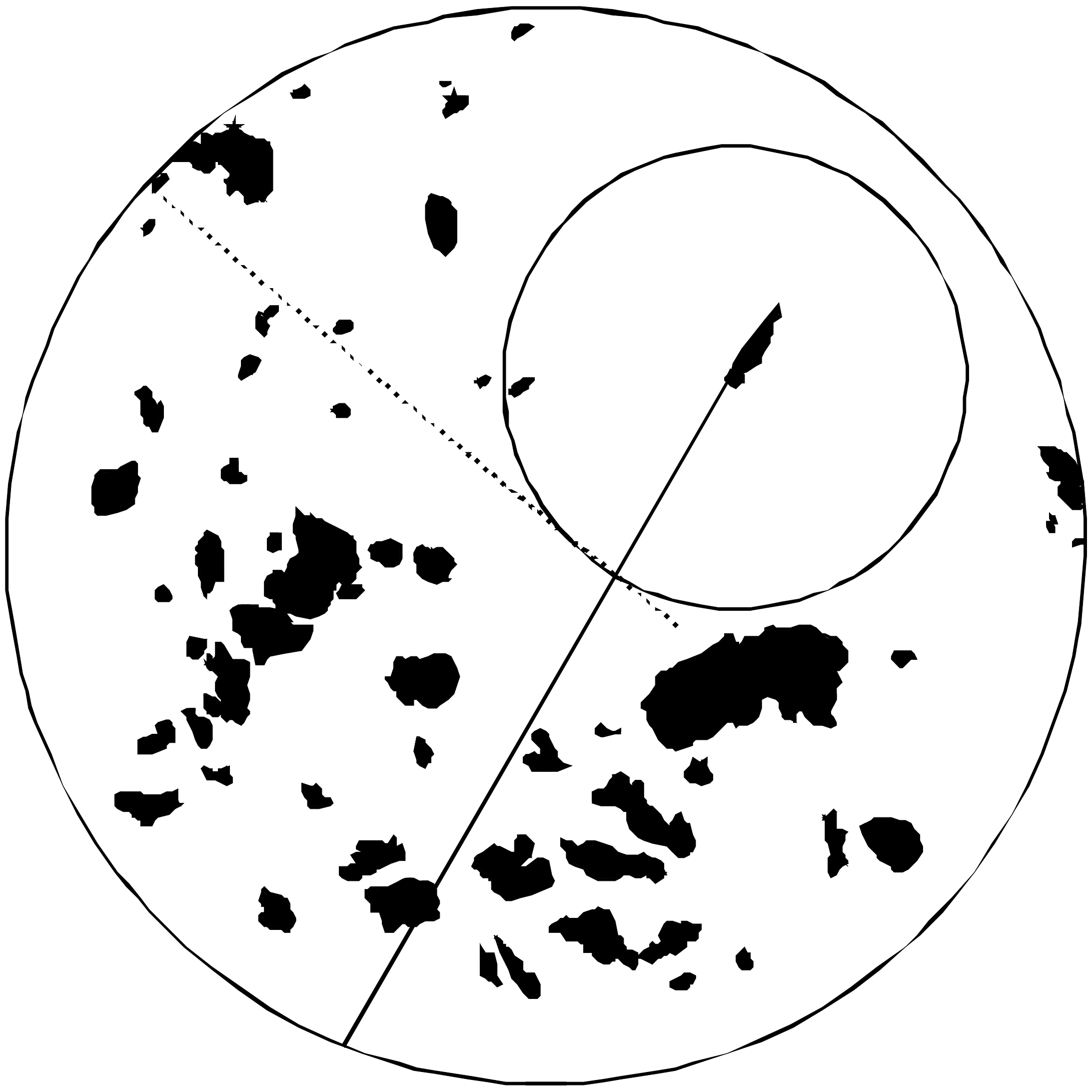


*Figure 35. The distance D = 0.65’ (turning radius + distance F) is set to the VRM ring of the radar. The EBL has been set to the new course 310° so that it is tangent to the VRM ring. The vessel is at the starting point of the turn when the EBL directs to the fairway space subsequent to the turn.*

Figure 34 illustrates the channel alignment of the Turku-Nyhamn fairway near Ledsund on the Åland Islands. On the chart the channel alignment runs at the side of a deep water area even though the water area is large. In addition, a checkline is marked on the chart. It cannot, however, be used in manoeuvring. In practice the tracks should be planned in such a way that the narrow passage is approached as straight as possible. In this case the track must be determined to the port side of the fairway, i.e. to the wrong side. This means that if two vessels are in a head-on situation in this fairway section, it has to be agreed upon on the radio telephone who gives way.

## 5.3 Port manoeuvring

According to the accident investigation commissions, errors in port manoeuvring contributed to the accident in 8 of the cases studied. This chapter will discuss the effect of wind on port manoeuvring.

The IMO has set high requirements with reference to port manoeuvring. The Masters and Chief Officers on vessels larger than 500 tonnes must have command of port manoeuvring *'in all conditions'*[128]. This requirement also applies to pilots not belonging to the vessel's crew as they are required to have a master's qualifications. According to the latest Finnish pilotage instruction, pilotage only ends when the vessel is moored to the quay[129].

Examples of port manoeuvring of modern passenger and ro-ro vessels are dealt with next. Because the vessel's behaviour in strong wind depends not only on the characteristics of the manoeuvring equipment but also on the shape of the superstructure and the cargo situation, the optimal manoeuvring can differ considerably from the one presented below.

Many modern vessels have streamlined superstructures. This weakens their manoeuvrability when the wind is strong. Because of this the power of bow thrusters has been increased. When it comes to passenger vessels, the lateral side force is at its highest when the relative wind direction is 30°- 60° from the bow and the wind revolves around the bow, past the streamlined superstructure to the leeward side of the vessel. At low speed the drift angle becomes big in strong wind. If the vessel's control devices, in addition to rudders and propellers, include separate manoeuvring levers, there is not enough time in the port operations to use all controls efficiently. Therefore the speed of advance is usually increased so that the side force of the hull compensates some of the power required from the steering units. If the rudders of a vessel equipped with two rudders can be steered independently from each other, both rudders are turned somewhat 'in' during the port manoeuvring or a helmsman is used, in which case the rudders can be steered synchronically. The vessel is steered by cross-running the main engines. The speed is, however, kept high. If bow thrusters are used in an attempt to try to improve manoeuvrability in this kind of a situation, the major speed nullifies their effect. The result is that port manoeuvring becomes difficult, and the reduction of speed when approaching the quay can happen too late.

[128] STCW CODE-95, Table A-II/2, page 47. *'Manoeuvre and handle a ship in all conditions.'*

[129] Pilotage Act (940/2003) and Goverment Decree on Pilotage (982/2003) do not indicate at which point pilotage ends. The pilotage instruction (FMA Bulletin 10/2000) however lays down provisions that pilotage ends when the vessel is moored or when departing from a port, at the pilot disembarkation place.

If the vessel is equipped with joystick-steering (Section 6.4.5), the situation is more controlled. When approaching the port area at a speed of 4 knots, the turn centre of the device is set to the bow, in which case the joystick lays emphasis on the use of the manoeuvring equipment located at the stern. There is no need to use the bow thrusters at this stage. The joystick control is set to push slowly forwards. The course is only maintained with the moment control of the device, in which case the pitches of a turn screw vessel are set independently, and one rudder turns inward whereas the rudder behind the backing propeller stays midships. If the vessel is equipped with a stern thruster, it functions in the direction indicated by the moment control (Figure 59).

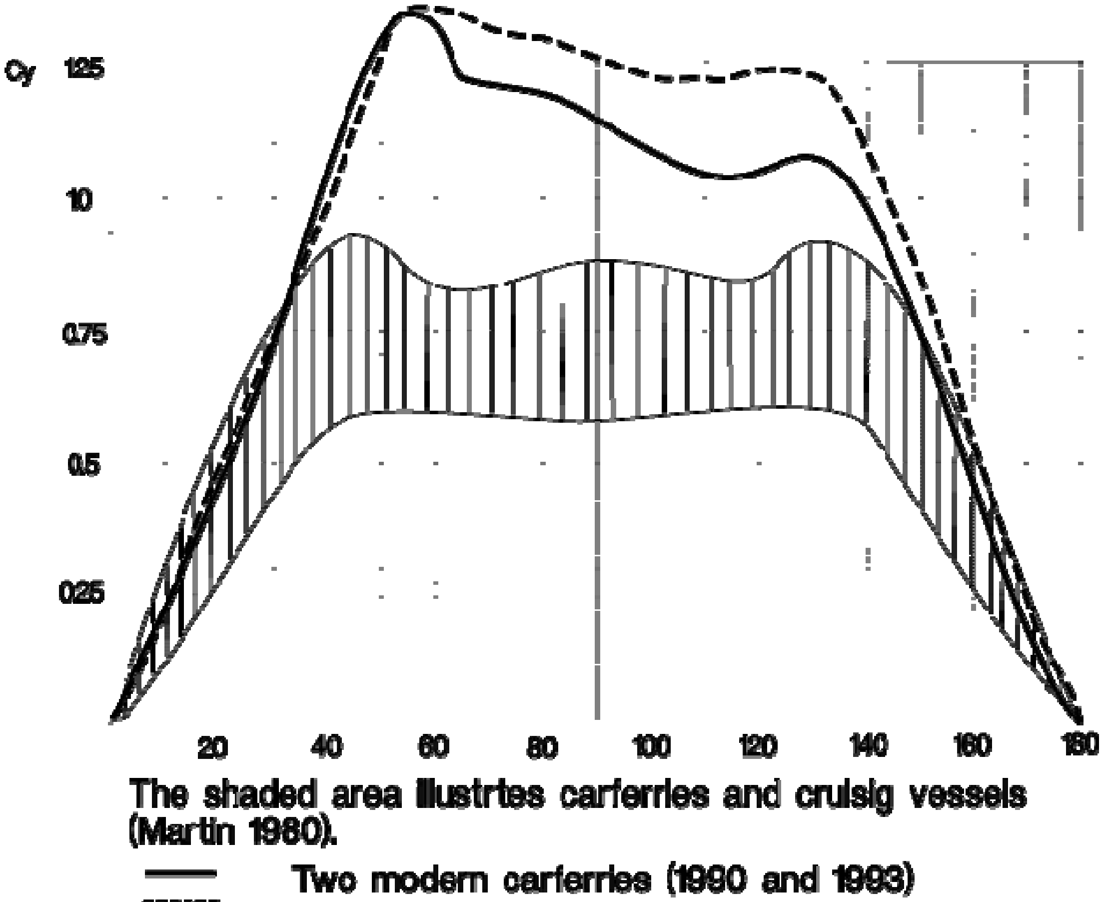



*Figure 36. The side force (Cy) generated by wind on the superstructures based on the relative wind speed[130].*

When it comes to passenger vessels, the wind force is at its highest when the relative wind speed is 30°- 60° from the bow. The wind revolves around the bow to the leeward side of the streamlined superstructure. Lift is formed at the bow of the vessel, and it lifts the vessel and often also slows the turning and may stop it altogether. The stern of the vessel can almost always be turned against the wind with the help of the strong manoeuvring force generated by the main engines.

130 L.L. Martin, Ship Manoeuvring in Wind, Annual Meeting, WTC, NY, Nov, 1980. SNAME Trans, Vol. 88

Turning the bow against the wind must be carefully calculated in different wind conditions, so that the manoeuvre is certain to succeed in a real situation.

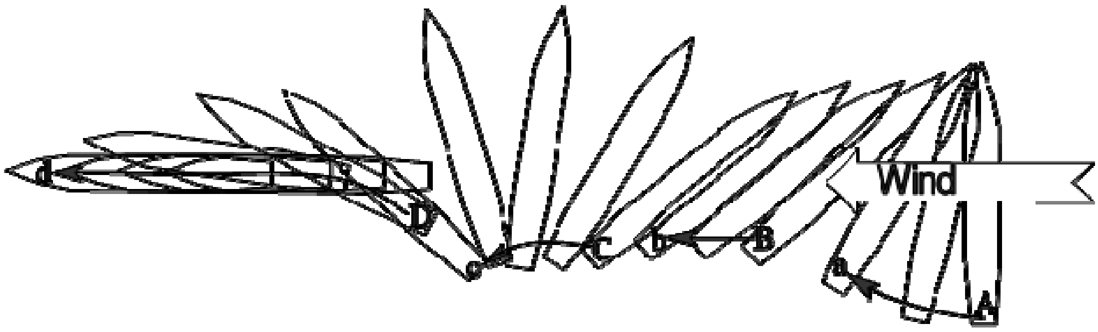



*Figure 37. An attempt to turn the bow against the wind when the wind forces exceed the manoeuvring powers which the vessel has at its disposal.*

In Figure 37 an attempt is made to turn the vessel the bow against the wind. Between A–a an attempt is made to turn the vessel by running the bow thrusters to starboard and the stern thrusters to port. In this example the turning of the vessel stops when the relative wind speed is over 30° from the bow. The vessel drifts with the wind without turning between B–b. The bow thrusters are run to port between the vessel symbols C–c, and stern thrusters are used in an attempt to stop the drifting of the stern. It is possible to turn the stern more easily towards the wind. Between the vessel symbols D–d the vessel is turned in the direction of the wind, stopped and backed against the wind.

Figures 38 and 39 illustrate some tracks in a narrow port with various wind directions. The effects of the wind and the manoeuvring powers which are at disposal are taken into account.

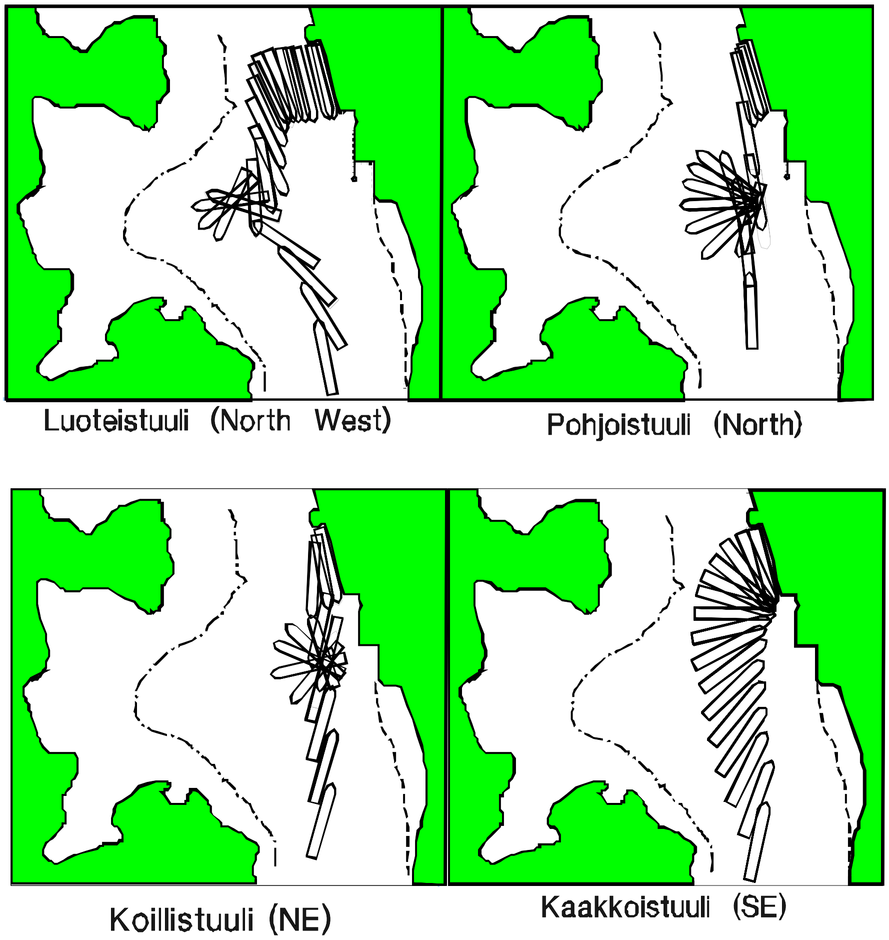



*Figure 38. The vessel approaches the port from south. The north-westerly wind is the most demanding one of the above mentioned winds.*

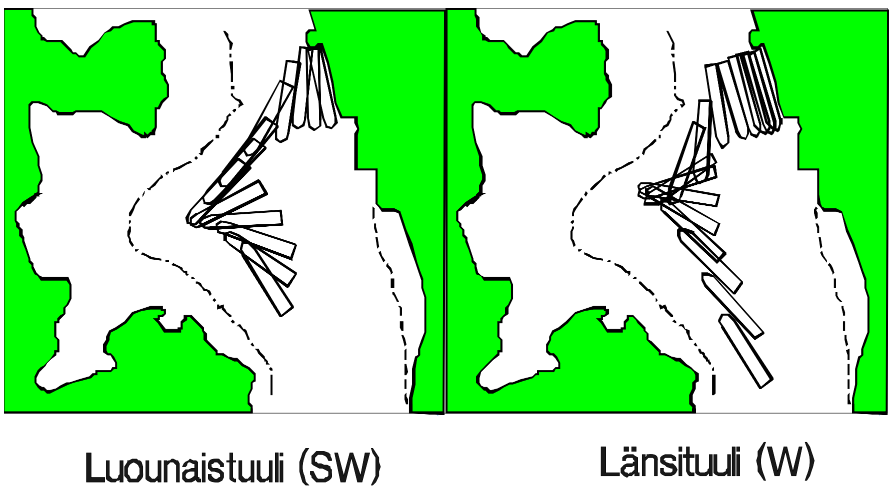



*Figure 39. The vessel approaches the port from south. The south-westerly and westerly winds are the most demanding ones of the above mentioned winds.*

In the first square of Figure 38 (the track at a north-westerly wind), the stern of the vessel has been held against the wind for as long as possible. The quay has been approached slowly, side first. The transverse force generated by the thrusters overcomes the wind force, because otherwise it is not possible to stop the vessel from drifting sideways. The swaying speed of the vessel has to be low enough, and the bigger the vessel is the slower the speed has to be when approaching the quay. When the wind blows from north or northeast, there are not any particular difficulties as to manoeuvring in the port used as the example.

At a south-westerly wind the wind hits the bow from an unfavourable direction when the vessel is turned parallel with the quay. The wind circles behind the hull and causes a strong lift (Figure 39). In this situation the technical wind limit of the operations cannot be exceeded.

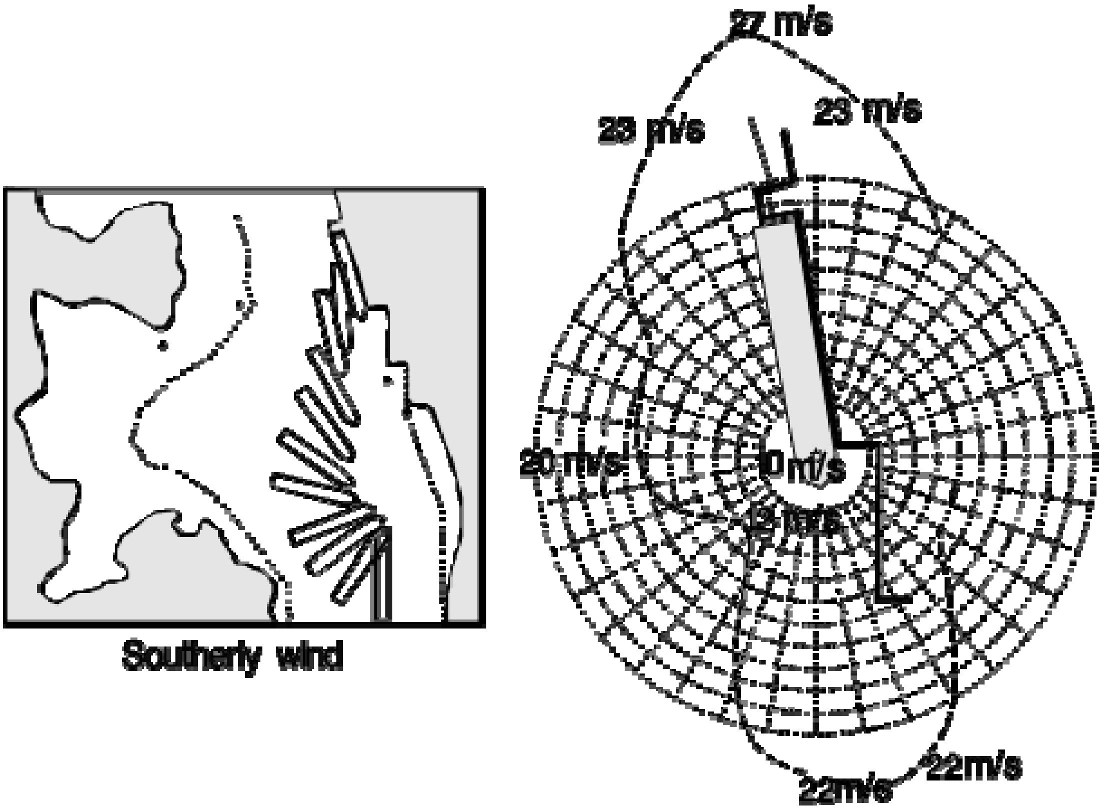



*Figure 40. Southerly wind and the calculated wind limit curve.*

At southerly wind the turn is started early so that there is time to make sure that the vessel is able to turn.

Figure 40 illustrates the wind limit curve of a modern passenger vessel in the port of the sample vessel. In the figure it can be seen that the wind limit is at its lowest at a south-westerly wind when the vessel can only take 12 m/s of wind. The limit curve illustrates the speed of the wind at the height of ten metres, which is the measuring height used in weather forecasts.

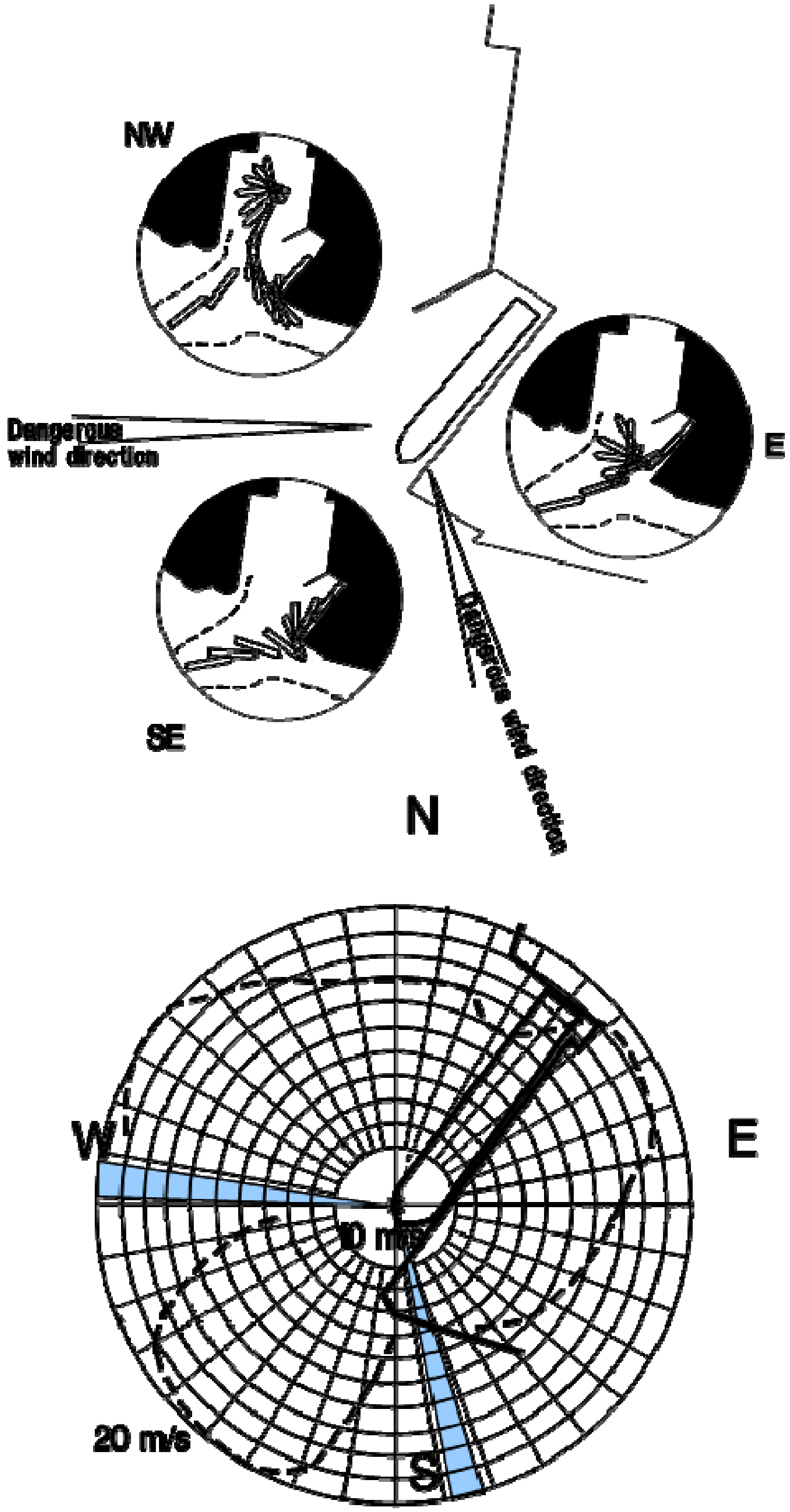



*Figure 41. An example of a narrow port.*

Even a narrow port can offer the possibility to alternative tracks in different circumstances. East is the most favourable wind direction in the example illustrated in Figure 41. At south-westerly wind (SW) the vessel can be turned by leaning on the corner of the quay for support. At north-westerly wind (NW) the vessel is turned north of the quay, after that it is steered to the corner of the quay and then turned with the help of the quay so that it becomes parallel with the quay.

## 5.4 Shiphandling simulators

The development of shiphandling i.e. manoeuvring simulators started as early as in the 1960's, but making use of simulator technology became familiar among seafarers only in the 1970's. At that time there were three well-known simulators in the Netherlands. The TNO simulator was working in Delfi as early as in 1970 and in Shosterberg[131] in 1971. The research institute NSMB[132] had a manoeuvring simulator in Wageningen in 1971. In Sweden the manoeuvring simulator of the SSPA was completed in 1974. The simulator of the USA Maritime Administration and Department of Commerce[133] started operating in 1976. It was technically the most advanced manoeuvring simulator of its time.

The first training simulator[134] in Finland became operational in 1985, which means that Finland was not far behind the great seafaring nations.

An example of what kind of an attitude a Swedish tanker company adopted towards simulators well describes the nature of simulator training. In the 1970's they sent officers to the Netherlands to be trained in a technically more limited Dutch simulator. When the shipping company was asked what made them make the choice, they answered that the simulator in question had the best trainers. Their answer illustrates the importance of the training personnel. If simulator training is considered to be some sort of a video game, the objective is bound to fail. Even a technically limited simulator can be effective if there is knowledge of how to use it in a correct way.

Modern data technology provides good possibilities to practice all kinds of shiphandling. Manoeuvring simulations can be technically realized on many different levels, and by utilizing these, a good and economical outcome is reached. For example the wind and other operational limits of safe operations can in principle be studied on four different levels:

- empirically
- by balance of power calculations

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131 TNO, Instituut voor Zintuigfysiologie, Holland
132 NSMB, Netherlands Ship Model Basin, P.O. Box 28, Wageningen. The Netherlands
133 Computer Aided Operations Research Facility (CAORF), U.S. Department of Commerce, Maritime Administration. Kings Point, New York. U.S.A.
134 Maritime College of Rauma. The simulator was located in the premises of the Technical Research Centre of Finland (VTT) in Otanniemi in Espoo.

- by work station simulations
- by using a manoeuvring simulator

In an analysis based on experience, simulation technology is not necessarily needed at all. The observations of the whole formed by the crew, vessel and environmental circumstances are the advantage of an experience-based analysis. It would be beneficial to always make this kind of a study. The disadvantages include certain subjectivity and a low frequency of extreme circumstances, in which case the experience basis can remain rather thin.

Balance of power calculations quickly demonstrate the magnitude of safe operational limits. These calculations do not require an actual simulator system and they do not take into account the dynamics of the manoeuvring motions nor the manoeuvres performed by the crew. Depending on the observed situation, this can lead either to over- or underestimation of the operational limits.

Work station simulations are performed in order to calculate the vessel's dynamic motion state on a digital chart. The symbol chart formed for the radar display (user chart) can also be used. This simulation method makes it possible to numerically take into account all the factors affecting manoeuvring except for the crew’s reactions. When determining wind limits, the work is usually commenced on work station simulators, and the more advanced training of the crew is carried out in a manoeuvring simulator.

The crew can first be familiarized both with the manoeuvring characteristics of a certain vessel type on a more general level and more specifically with those of the own vessel by using the work station simulator.

The development of technically more advanced control systems puts special demands on the training, and the use of simulator technology is motivated. The new navigation and steering devices such as joystick, dynamic positioning and azimuth thruster systems require that the users have undergone simulator training. With the help of a simulator, it is possible to solve problems more quickly and concretely than in theoretical teaching.

The efficiency of equipment usage training can be increased in a simulator by reducing the information provided by the visual system. When the visibility is reduced in the virtual landscape or when the landscape is deleted entirely, the manoeuvring decisions must be made based on the technical information provided by the technical devices.

The shipping companies train their seafarers to control emergency situations in accordance with the ISM system. The shipping companies usually compile the curricula themselves, and the training is based on the reconstruction of dangerous situations which have been experienced.

With the help of manoeuvring simulations it is possible to get information about extreme situations in a systematic way if the arrangements for the experiment are realized in such a way that it is possible to specify the learning process affecting the results of those seafarers who participate in the study.

It is worth paying attention to the documentation of the simulator training and the analysis of the results. It is important not only to hold a briefing prior to the exercise, but also to go through the realized manoeuvring performance in a debriefing. It is a good idea to document the manoeuvring performances in the form of chart pictures and numerical lists. The operational wind limits are usually also illustrated as polar diagrams, in which the maximum value of real wind for the various directions and different parts of the fairway is presented. Experience has shown that the vessels' officers find the documentation of simulator exercises more useful than the printouts from the manoeuvring tests since it is more difficult to apply their results to practical operations.

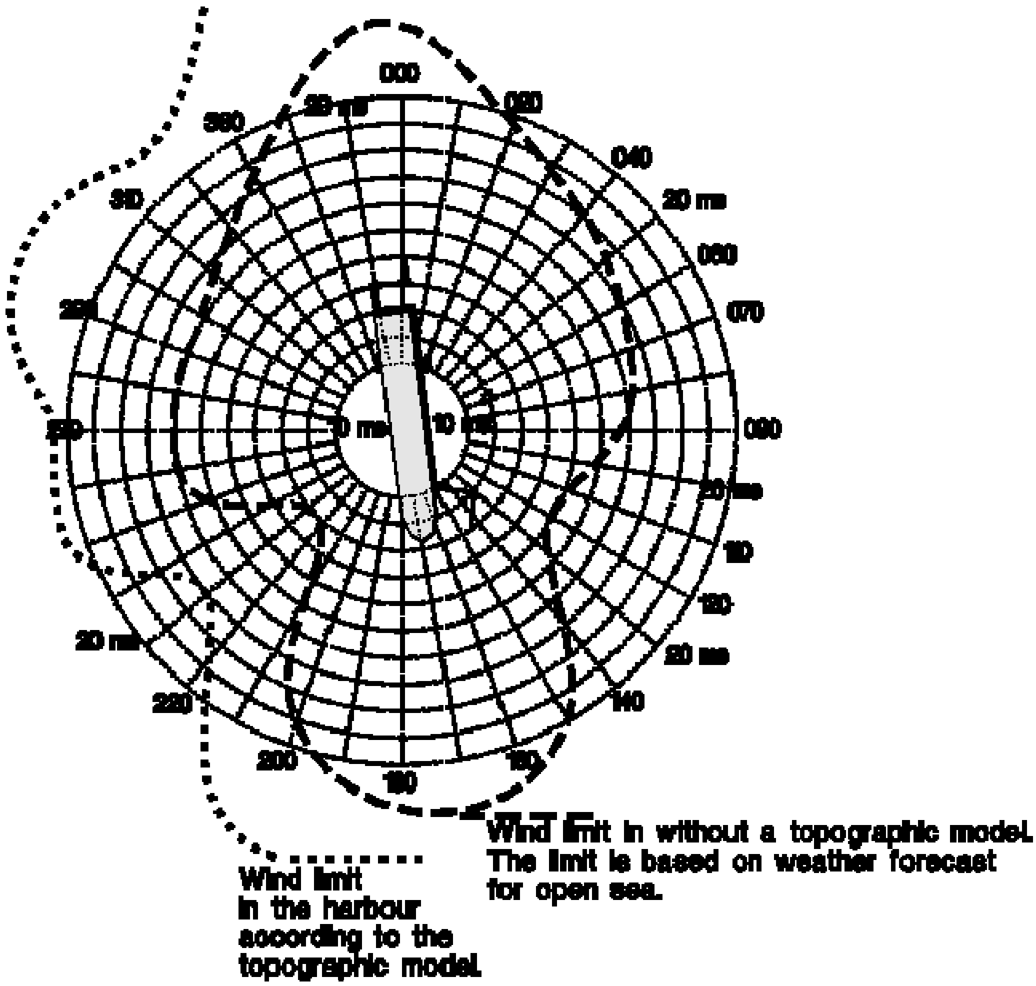


*Figure 42. The numerical wind limit is illustrated both without the effects of the terrain and corrected using the terrain model. The area between the curves illustrates the shelter provided by the terrain.*

Figure 42 illustrates a wind limit curve calculated with the help of simulations. For the studied vessel it suggests an upper wind speed limit at the height of 10 metres in the port area. When operating a vessel, the plan for the details of port manoeuvring or on the whole for the decision to manoeuvre into the port area has to be made on the basis of a weather forecast.

In order to define wind conditions for the port area, it is possible to make a scale model of the terrain. This model is then placed in a wind tunnel. The model is turned in the tunnel e.g. 10 degrees at a time and measurements are made as to how the terrain changes the direction, speed and gustiness of the average wind. Making this kind of an investigation could naturally fall to the port operator, but port operators are of the opinion that this problem is something the masters of the vessels have to solve[135]. The Port of Helsinki has had a wind study made for the South Harbour. Some shipping companies have also ordered wind studies for certain ports[136]. The wind model of a port can reveal which is the most dangerous wind direction for the vessels. This is something which otherwise can go undetected. For example the wind study made on the Strait of Kustaanmiekka revealed rather surprisingly that a north-westerly wind (NW) was the most dangerous one for a ro-ro vessel entering the harbour. When the vessel approaches the strait, the vessel's drift angle is wide due to the relative wind direction. When the vessel proceeds closer to the strait and enters into the calm conditions provided by the Suomenlinna Fortress, the side force generated by the wind on the superstructure vanishes and the drifting of the vessel stops. Before the strait the crew only has a short time to react to the vessel's rapidly changed course over ground.

It is possible to find suitable tracks for different wind directions by using simulations, and at the same time it can be seen how much drift area the vessel requires. Simulations are efficient in illustrating how an unnecessarily high speed makes manoeuvring more difficult in strong wind. When the seafarer moves from one vessel to another, he/she often unconsciously moves the routines from a smaller vessel to a bigger one. When the vessel size increases, the manoeuvring speed in port should be reduced. The vessel can get out of control if too high engine powers are used to operate it. Simulations make it possible to learn manoeuvring at slow speed and a wide drift angle, when controlling the vessel is the easiest.

It is possible to define the technical operational limits of complicated port manoeuvres with the help of a work station simulator. If the simulations are not realized under full automatic control but controlled by the seafarer, learning is achieved during the simulator runs. This learning is of the kind which is otherwise impossible for the seafarer to get on the field. In connection with each

[135] The Accident Investigation Report MS CITY OF SUNDERLAND (IoM), Grounding off Hanko on 1.1.2002 (2/2002 M) can be regarded as an example of this. The statement given by the Port of Hanko

[136] For example Silja Line and Royal Caribbean International

simulator run, he/she learns something new about the vessel's behaviour, and this knowledge can be applied to the following simulation.

The wind limit for safe operations can be settled also by accelerated *'fast time'* simulations. In this method the vessel's optimal track is defined first, and after that the simulation programme can perform a large number of fast time runs in automatic steering, which follows the determined track. In this system the automatic steering must also be able to handle the vessel's thrusters in a joystick or DP mode. The wind speed is changed e.g. at an interval of 1 m/s until it is no longer possible to follow the track. After this the system changes the wind direction e.g. 10° and repeats the variation of wind speed until a full compass circle is calculated. The system can manage to complete the whole task in a few of hours, considerably faster than real time simulation based on a seafarer's steering.

Even though it would be good for the simulation systems to take into account the impact shallow water has on manoeuvring, it is often difficult to model the bank effects of islands, which means that they can often remain undefined. It is of course possible to act in this way, but in that case it is, however, important to understand and estimate the effect this exclusion has on the simulation results. Manoeuvring speeds are usually low in the actual port area, and bank effects can also remain minor. However, almost inevitably the system has to deal with the gustiness of the wind, because it is the gustiness which lowers the wind limit of safe operations.

A manoeuvring simulator can be used in research in a many-sided way when deciding upon new displays, display modes, control devices, tracks for port manoeuvring, wind limits, channel alignments, ports and vessel types. Utilizing simulator technology is an essential part of seafaring.

Simulations are used frequently in accident investigations. Even though vessels have VDR registering devices, investigators do not always obtain VDR recordings from the vessels. In that case the coherence of statements can be examined with the help of simulation results. In some cases interested parties have visited manoeuvring simulators.

Overtaking another vessel in a narrow fairway is a demanding manoeuvre. It forces the overtaking vessel to reduce its speed in order to reduce the interaction forces of the vessels, and therefore the procedure can take so long that the vessels can run out of fairway space. The risks of an overtaking situation can be demonstrated in a simulator, and the effects various measures have on the vessels' behaviour can be illustrated.

In simulator training, the route or pilotage plan also functions as the curriculum. Learning the chart by heart is replaced by extensive documentation. In manoeuvring training the turn parameters are checked from the route plan, and it would be good if each vessel only had one common route plan for the fairway. If there are not any ready route plans when the simulator training begins, the simulator instructor should draw the route plan which is used in the training. However, if this is not done and the student has to draw the plan himself/herself, this means a reversion to the old method in which the person training pilotage trains himself/herself.

Using a simulator is more effective than practicing onboard a vessel, because it is possible to change the environmental conditions in a controlled way. If needed, it is possible to retake a certain simulator run. As to the less frequently used fairways, simulator training offers the only way to obtain enough training experience. It would be fully possible to realize the fairway training required for the pilot's certificate and the actual piloting examination with the help of simulation technology. A simulation run through the Strait of Kustaanmiekka has been part of the Helsinki fairway test piloting for years.

### 5.5 Work rhythm of pilotage

Work rhythm and factors affecting the state of alertness have been dealt with more extensively in the Safety Study S3/2004 M *'Factors contributing to fatigue and its frequency in bridge work'* published by the Accident Investigation Board. Even though the study does not deal with pilotage specifically, the matters which are taken up in the report also relate to pilotage.

Pilotage requires timely and exact observation and anticipation, interpretation and understanding of the situation as well as ability to take required action on the basis of correct decision-making. The lowered alertness caused by fatigue affects all these contributing factors of a performance.

### 5.6 Bridge cooperation

According to the regulations, a seafarer providing pilotage is never allowed to be alone on the bridge. Even if the person was the vessel's officer in charge of the navigational watch, it has been made sure by regulations that there are other persons present on the bridge so that the person providing pilotage can concentrate on the piloting.

In order to improve the safety of navigation, it is appropriate that also the other crew member present on the bridge monitors the pilotage and makes sure that the manoeuvres are correct. To make this possible, bridge cooperation is needed (BRM, Bridge Resource Management).

In an ideal situation both persons participating in the manoeuvring of the vessel are capable of the same performance level. This makes the monitoring of pilotage is efficient. The monitoring works best when the person responsible for the monitoring gives feedback on the actions performed by the person who is in charge of the manoeuvring, and the person who is in charge of the manoeuvring takes this feedback into consideration in his/her actions.

Bridge cooperation is best realized e.g. in such a way that the seafarer providing pilotage informs about the approach and starting of a turn when the vessel proceeds in the fairway. The person who is in charge of the monitoring checks the intentions of the pilotage provider, and acknowledges that the intended measure is understood. In order for the monitoring to be possible, the manoeuvring orders have to follow a certain route plan known to both parties. The route plan is also used to check that the manoeuvring order to be given is correct. The same procedure also applies to changes to be made to the propulsion settings.

### 5.7 The duties of the pilot not belonging to the crew

When providing pilotage, the state-employed pilot applies the navigation theory which has been described earlier in this Safety Study. However, on the vessels he/she mainly has to use such equipment which is not developed for pilotage. In addition to this, after arriving on the bridge the pilot has to quickly take in the placing of the equipment on the bridge which is unfamiliar to him/her.

Preparations for pilotage start in good time before the pilot's arrival on the vessel or the vessel's departure to the piloted area. The pilot familiarizes himself/herself with the vessel's technical characteristics, its manoeuvring characteristics and the possible need for tug assistance. The weather forecast has a significant effect on the pilot boarding and disembarkation places.

The pilot's task starts when a pilot request is made. The Pilot Order Centre sees to it that the vessel promptly gets its requested pilot. When the vessel approaches the coast from the sea, it is important that the location where the pilot boards the vessel is agreed upon in advance. A VTS operator is an integral party in this cooperation. It must be possible for the vessel to safely arrive at the agreed position, where it is safe for the pilot to board the vessel.

The pilotage itself starts when the pilot has boarded the vessel, and the vessel in making way in the fairway or it has set off from the quay. The pilot's and master's common objective is to navigate the vessel safely through the fairway. According to the current regulations, the master is responsible for the navigation of his/her vessel, and therefore he/she defines the routines on the bridge. At the beginning of the pilotage the master and pilot exchange the necessary information about the vessel, fairway, route plan, port and other conditions.

Various information packages put in writing have been compiled in order to guarantee the necessary exchange of information between the master and the pilot. It is clear that it is not possible for the pilot to quickly absorb a comprehensive information package in the often stressful initial phase of pilotage. In reality the pilot's signature only confirms that he/she has handled such a document. A few pieces of basic information about the vessel provided by the master enable the safe starting of pilotage, and after that the pilot can become more acquainted with the information about the vessel. It is equally clear that communications in connection with navigation cannot be replaced by only a quick reading of the documents and signing them.

The nature of the pilot’s work varies depending on the master of the vessel. The pilot's role can vary from being a mere observer to comprehensive navigation and use of appliances. The nature of pilotage often becomes clear only after pilotage has already begun. Even though piloting work has centuries-old traditions, manoeuvring situations which can change very quickly require special readiness among the cultures and actors unfamiliar to each other. It is especially important that the communication works in such a way that there are no risks of mistakes or misinterpretations. At the same time, the way of work which encourages the expression of open and important information must be remembered.

The vessel’s crew is responsible for the manoeuvring. The regulations forbid assigning that duty to the pilot. The pilot can, however, manoeuvre the vessel if he/she so wishes. The pilot should then be able to use FU steering (FU, Follow Up, see Section 6.4.2). The pilot cannot be forbidden to manoeuvre in such a situation in which it increases safety. In that case the pilot has to inform the officer in charge of the navigational watch of the objective of the manoeuvring, i.e. how he/she intends to manoeuvre the vessel. In a narrow fairway it is easier for the pilot to manoeuvre himself/herself, because in such a situation the helmsman would have to be given several rudder angle orders and the steering would then be less accurate. The course alteration orders given to the helmsman should not be given as compass orders only, but it would be good to always add the rudder angle to the order.

The Pilotage Act defines the pilot as an advisor. It can be presumed than in the advisor’s role the pilot would only be responsible for the correctness of his/her advice. While the pilot is onboard the vessel, he/she must get information about the environment with the help of the radar in order to be able to give advice, so following the radar image is necessary when defining the advice. Adjusting the radar image equals with using the radar, which strictly defined then belongs to the vessel's officers. Determining turning marks with the help of the electronic bearing line of the radar and its variable range marker ring is the pilot's task, because in order to be able to give advice, he/she must know the vessel's position in relation to the turning mark. It is difficult to define the roles of the advisor and the user of the radar.

# 6 TECHNOLOGY REQUIRED IN PILOTAGE

This chapter describes the navigation and control technology used on vessels. The functioning of basic systems is first dealt with, and after that the principles of automatic steering and joystick as well as integrated systems are discussed.

The national pilotage instruction cannot require that such equipment, upon which there are no international agreements, are installed on vessels. The lack of definition of pilotage and the technology utilized in it has led to practical ways to do the work. These ways differ significantly from the pilotage principles which are used as the basis of fairway planning. The seafarers who perform pilotage rely on traditional piloting methods.

The minimum prerequisites in order to perform pilotage are an engine order telegraph, a radar and a helmsman or the manual steering device used by the pilot himself/herself. Because the optical lookout performed by the pilot in practice requires that he/she moves around the bridge in order to ensure proper view and because there can be several manoeuvring places on the bridge, this chapter also deals with the transfer of control between the manoeuvring places.

## 6.1 Sensor technology

The capacity of a navigational system or a single navigation device largely depends on the reliability of the sensors which are coupled to it. Nowadays even integrated navigation systems rely on the position determination and movement sensors. This means that these appliances are at present not yet fully integrated wholes. One can talk about a fully integrated system only when the information sent by the sensors is compared and filtered inside the equipment.

Sensor technology and the ways in which sensors really could be coupled as a part of an integrated system are dealt with next.

### 6.1.1 Position determination

Satellite positioning has started a new technical era in the history of navigation. The new technology has replaced the devices working on the basis of hyperbolic position determination, and the current navigation systems are able to tell the position of the vessel with the accuracy of a couple of metres. Other devices expressing information about the motion state have also become more accurate than before.

Position determination on merchant vessels is nowadays in practice based solely on satellites. The deliberate weakening of the positioning determination signal of the GPS system, which was initially developed for military use, was removed in 2000, and that particular moment can in practice be regarded as the beginning of a new technical phase in navigation. In the future the functioning of satellite positioning will be secured with the help of three different systems. The new Russian GLONASS system[137] will be completed in 2009. It has been estimated that the European GALILEO system will be completed between the years 2010-2011[138]. However, according to some sources the GALILEO will be at least 18 months late due to management problems[139]. China has already launched two satellites of its BEIDOU system.

One source of errors disturbing satellite positioning is the so-called *multipath error*. It is generated when the antenna of the GPS receives a signal directly from a satellite, but at the same time it receives the same signal also reflected via the structures nearby, e.g. the vessel's funnel. The satellite signal disturbed by the multipath error can be excluded from the computation of the device by a RAIM programme (Receiver Autonomous Integrity Monitoring). The RAIM needs the signals from at least five different satellites in order to find the incorrect distance measuring. For the time being the RAIM is a very expensive solution.

Differential GPS (DGPS) means a correction system of satellite position determination, in which an independent system transmits a signal which is separate from the satellite either with the help of an own satellite or ground station. The differential system was originally created to fix the errors of an inexact GPS signal. The differential systems which are developed for the needs of shipping are based on ground stations which know their own position accurately and which calculate the difference of their GPS position and exact position, and send it on HF radio frequencies to vessels. The differential receivers on the vessels then correct the GPS position with the value calculated by the ground station. Within aviation the transmission of differential messages has been solved with the help of communication satellites. The system used in North America is called the WAAS (Wide Area Augmentation System). The corresponding European system is called the EGNOS (European Geostationary Overlay System). The WAAS and EGNOS satellites are located at the equator, so their signal can no longer be reliably received on the latitude 60° of Southern Finland. Therefore Finland will probably also in the future rely on the traditional differential beacons. The differential beacons in the Baltic Sea have functioned extremely well already for 16 years. Even though the accuracy of satellite positioning has increased along with the change made in 2000, differential correction is still necessary in modern pilotage.

137 International Herald Tribune, 4 April 2007. Russia’s Reply to GPS. An effort to end America’s monopoly.

138 The Institute of Navigation, Newsletter, Fall 2005, p. 5, U.S.A.

139 International Herald Tribune, 19 April 2007. In satellite navigation, EU can’t find its way.

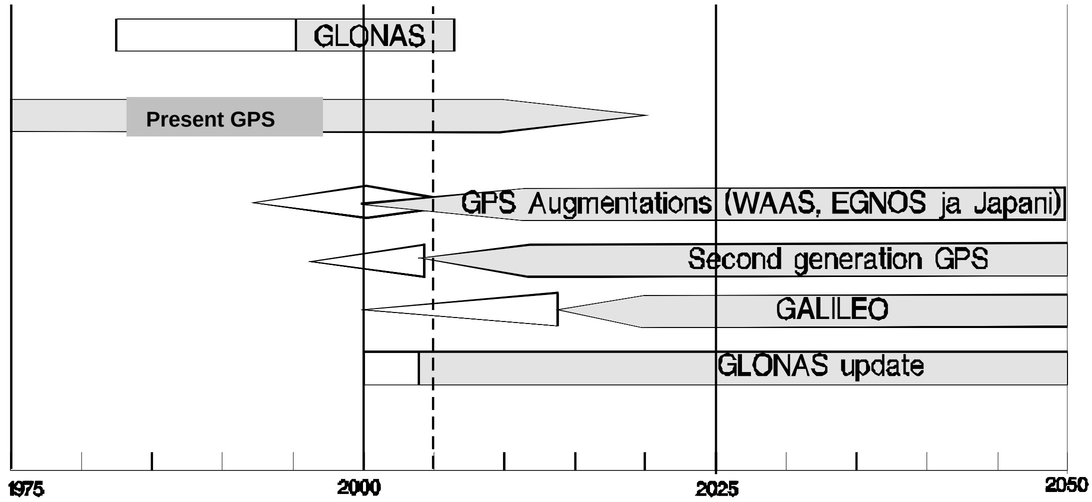


*Figure 43. A publication by the British Royal Institute of Navigation presented a prediction for the future of satellite navigation in May 2000. The Chinese BEIDOU system will probably become global in 2010. The EU's GALILEO system[140] will be completed in 2013.*

In order to increase the reliability of position information, it would be good to check satellite positioning with the help of two receivers. In this case both receivers are connected to a filter, which removes the jump in position information which may be caused by the change of receiver. This is of outmost importance for e.g. the trackpilot that automatically follows the route line. The position information is taken from the filter further to the navigation system. Information from the movement sensors is led to the same filter, and the position marking can be calculated based on this information. In other words the GPS updates the position marking and a disturbance in the satellite receiver does not cause an interruption in the position determination. The other receiver continues the position determination from the moment when this disturbance takes place. If the position determination breaks off altogether, the equipment continues with the help of dead reckoning. The device must give a clear alarm when the position information generated is based on dead reckoning only.

[140] Navigation News Jan-Febr. 2008, p. 4, ISN 0268 6317

### 6.1.2 Heading measurement

The IMO requires that vessels have a gyrocompass. The compass must form a uniform whole independent of external systems[141]. Integrated pilotage systems put harder demands than normally on the gyrocompass. In order for the radar image presentation to work satisfactorily in the same display with an electronic chart, the compass must follow true course very accurately. The IMO allows a compass error of 2.0-2.5 degrees on latitude 60°[142]. This is not accurate enough for the radar image to be moved on the chart image. The minimum accuracy should be within one degree.

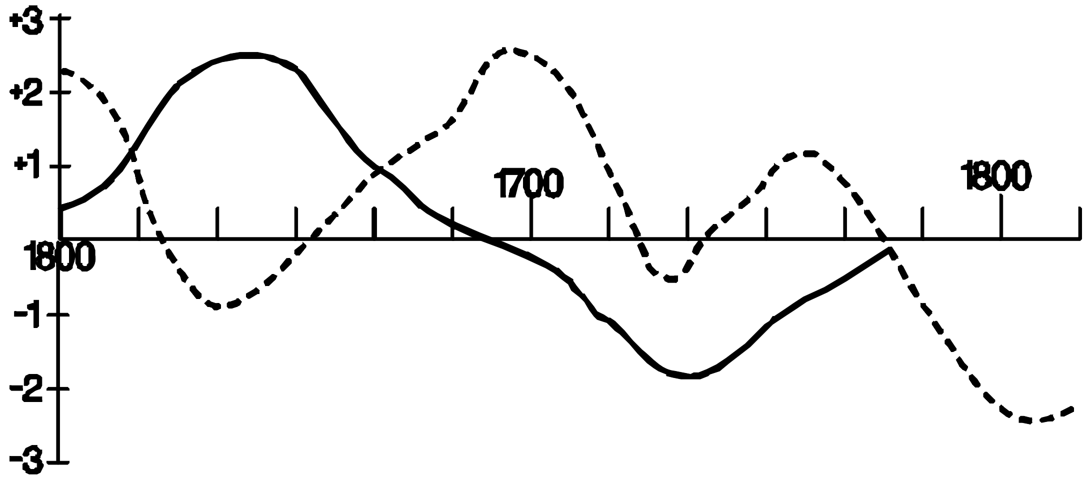


*Figure 44. The figure illustrates the ballistic error curve of two conventional gyrocompasses on a curving fairway in the archipelago of the Åland Islands.*

It is easy to check a gyrocompass error with the help of the AIS system[143]. If the echo of a vessel nearby and the AIS symbol are not in overlay on the radar screen, the difference is probably caused by a compass error. The bearing to the AIS target illustrates the true bearing, whereas the bearing to the radar echo of the same target corresponds with the bearing measured with the gyrocompass. It is easy to measure the difference of the bearing on the radar screen. After this the correction can be made slowly in a couple of minutes 0.1°–0.2° at a time because the automatic steering does not approve a correction which is too quick or big. The correction is made on the radar and navigation equipment without affecting the zero setting of the gyrocompass itself.

[141] IMO Res. A.434 (XI) 1979. Performance Standards for Gyro-Compasses, Definitions: *'The term gyro-compass comprises the complete equipment and includes all elements of the complete design.'*

[142] IMO Res. A.434(XI) 1979. par, 5.2.

[143] AIS, Automatic Identification System, see Chapter 6.3

*Table 8. The gyrocompass errors allowed by the IMO.*

| Regulat ion section | **The allowed GYROCOMPASS errors** Performance Standards for Gyro Compasses **Resolution A.424(XI), November 1979** | **Allowed errors on latitude 60°** |
|---|---|---|
| 5.2.2 | Settle point error on ± 1° secant latitude | ± 2° |
| 5.2.3.1 | Turn and alteration of speed at the speed of 20 knots does not cause a bigger error than ± 0.25° x secant latitude | ± 0.5° |
| 5.2.3.2 | A speed alteration of 20 knots | ± 2° |
| 5.2.3.3 | A 180° turn at the speed of 20 knots | ± 3° |
| 5.2.3.4 | In the swell of sea, the error is not allowed to be more than ± 1° x secant latitude | ± 2° |
| 5.2.4 | The allowed difference between the main compass and the daughter compass. | ± 0,5° |

The SOLAS Convention changed radically with reference to the compass in 2004. Rule 19 (Section 2.5.1) in Chapter 5, *Safety of Navigation*, changed in such a way that on a vessel there can be

'*Gyro compass <u>or other means</u> to determine and display their heading by ship borne <u>non-magnetic means</u>, being clearly readable by the helmsman at the main steering position. These means shall also transmit heading information for input to the equipment referred in paragraphs 2.3.2 (radar), 2.4 (AIS) and 2.5.5 (ARPA).*'[144]

On the basis of this, a fibre optic compass can replace conventional gyrocompass. A fibre optic compass is a whole formed by three optical fibre coils, and it measures acceleration in relation to the three axes of spatial coordinates. The light is conducted to the fibre coils from their both ends. The wavelength of the ray of light changes when the coil is turned and the change in the phase difference of light offers an opportunity to calculate how much the compass has been turned.

The fibre optic compass is so far the only device which can replace the conventional gyrocompass. In theory the accuracy of the device is 0.7° x secant latitude. On latitude 60° the accuracy is therefore 1.4°. An accuracy of approximately one degree has been observed in practical tests performed on the compass. This accuracy clearly fulfils the IMO requirements.

[144] IMO, Resolution MSC. 170(79), 9 December 2004, Chapter V, Reg. 19

A satellite compass is a device, which can be used to measure the heading based on the signal sent by satellites. It includes two antennas, which calculate the heading in the global coordinate system by measuring the difference in distance to the satellites with the help of the phase differences of the signals. The calculated course is prone to disturbances in the measurements, which means that the information must be filtered. The filtering can be performed e.g. with the help of a sensor, which measures the angular acceleration of a turn. When this acceleration information is integrated, the angular velocity of the turn and further, by using integration, the alteration of the course can be determined. This calculated alteration of course is compared with the heading calculated from the satellite, and the result is a stable compass display. A satellite compass cannot be used as the main device, because it is not independent from the external system as it uses the satellite network. The functional errors in the satellite network have a direct effect on the accuracy of the device.

With the help of the satellite compass equipped with three antennas it is also possible to determine the heeling of the vessel, in which case the location given by the antennas can be corrected to the reference point used in the navigation system. In the same way it is also possible to correct the motion over ground to the same reference point. Tilt compensated COG (Course Over Ground) is comparable with the result from a double-component Doppler log. In ice conditions the satellite receiver is a good way to check the Doppler log when the hull presses ice blocks ahead of it. This may cause disturbance in the functioning of the log.

Several course sensors could be connected to the navigation system through a filter unit in order to guarantee accurate and reliable information about the heading. A programme like e.g. the Kalman filter[145] can be used when filtering information received from the sensors. It compares the course of the satellite compass with the values obtained from gyrocompass and directional gyroscope. The filtering calculates a forecast for all the sensors, and this forecast is compared with the actual value given by a sensor, and major error alterations can be deleted. The system estimates the reliability of the sensors and according to this deduces the true heading, which is statistically the most probable one. With the help of the angular velocity gyroscope it is possible to monitor the realization of the preplanned turns. The directional gyroscope on the other hand makes it possible to secure the continuity of the compass information, even though the north-seeking compass would halt.

[145] The Kalman filter gathers information on e.g. the vessel's motion state. From this information it deletes noise apparent in measuring results, and on the basis of this it predicts future changes in the motion state.

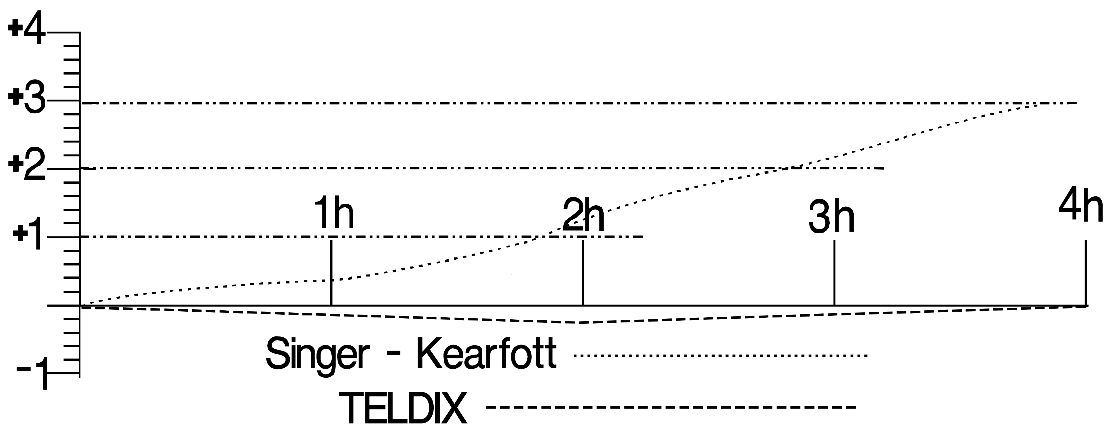


*Figure 45. The error of two mechanical directional gyroscopes expressed as the function of time while the vessel is at port.*

Figure 45 illustrates the accuracy of two mechanical directional gyroscopes. The Robertson compass uses the Singer-Kerfott directional gyroscope which is popular in aviation. It wanders approximately one degree in two hours. If this gyroscope got external correction information a couple of times an hour, the error would remain under half a degree. The Teldix tank gyroscope includes a processor, which after receiving a couple of external correction values is able to keep the error very small, only 1/4 degree in two hours. When the external correction value is entered into the device, the correction takes place automatically within two hours. For example on a vessel en route from Stockholm to Helsinki, the gyro can be given three corrections and the device still shows accurate true heading when it arrives in Helsinki. This shows that the directional gyroscope could be used as a compass as to its accuracy if the correction took place automatically on the basis of the course information which has been calculated e.g. from the satellite.

The traditional north-seeking gyrocompass can be connected to an integrated navigation system, but in that case it should include a ballistic error correction, which corrects the reading to an accuracy of one degree.

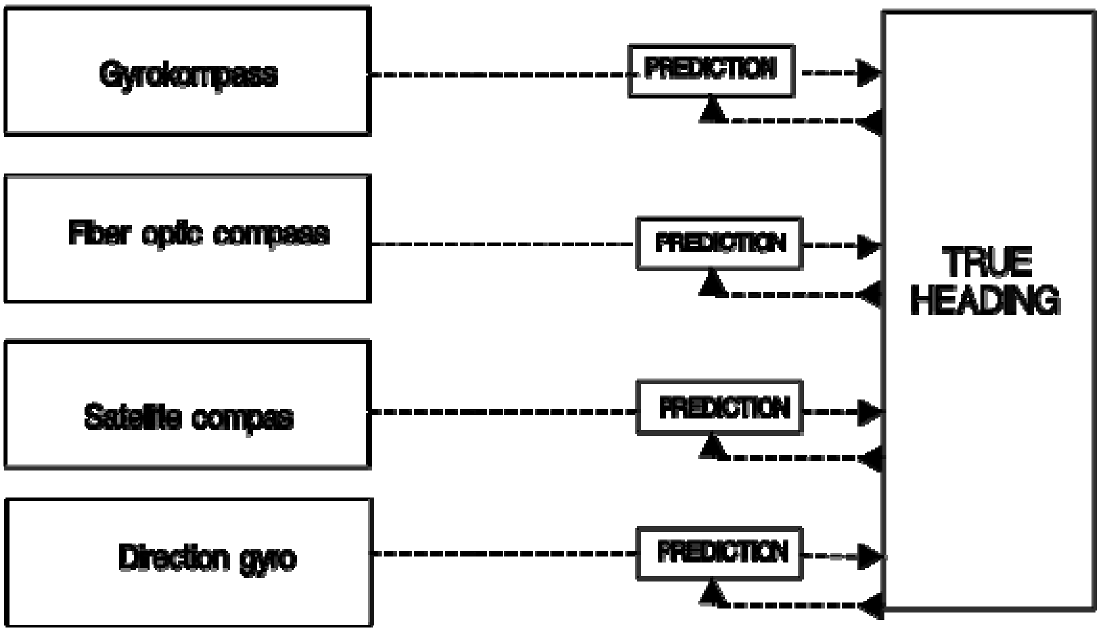


*Figure 46. An example of a filter used in integrated navigation. The filter connects the satellite compass, the gyrocompass and the directional gyroscope to true course. The magnetic compass (TMC) must, according to the regulations, be a separate device, which cannot be connected to an integrated navigation device.*

The SOLAS Convention forbids connecting the magnetic compass to the radar and the AIS system. The accuracy of a magnetic compass is of the magnitude ±2 degrees. The speed with which the magnetic compass sways is the problem. The error could be compensated with the help of a comparison value obtained from the directional gyroscope.

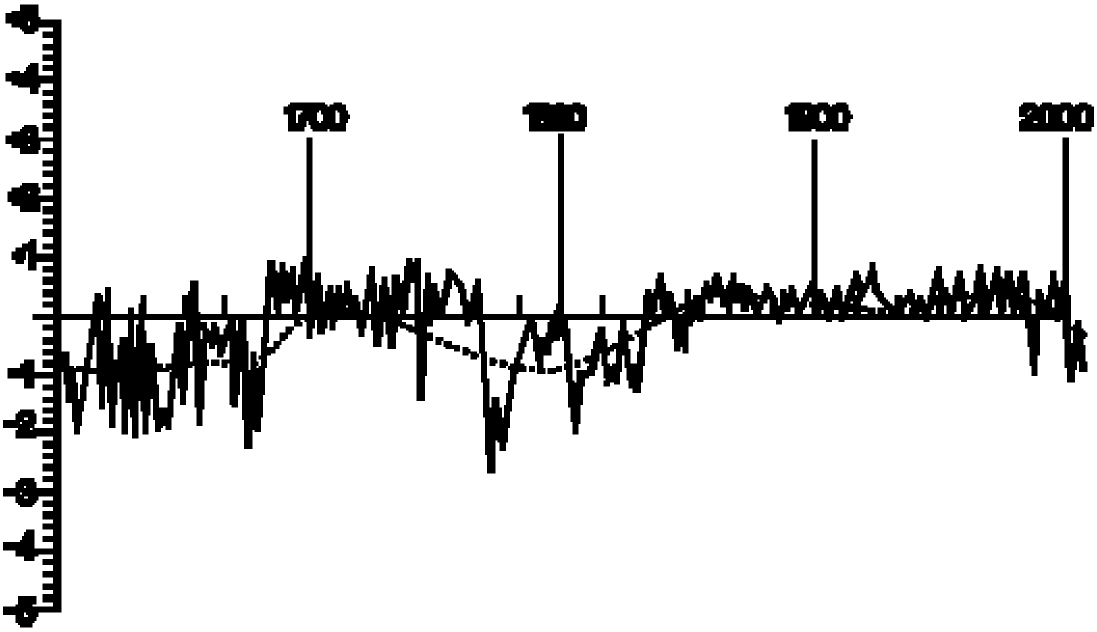


*Figure 47. The error curve of the magnetic compass in a curving fairway. The broken line illustrates the mean value of the error, which is only one degree.*

Figure 47 illustrates the error of the magnetic compass of MS WELLAMO en route between Mariehamn and Turku in 1989. The mean value of the error of a magnetic compass is smaller than the error of a gyrocompass, but the weak point of the magnetic compass is that it sways quickly and after turns it still continues to turn.


*Figure 48. A magnetic compass is a good emergency system if it is stabilized with the help of a directional gyroscope.*

The sway of a magnetic compass can be dampened with the help of a directional gyroscope. This has been done in aviation since the 1940's. The dampening was done mechanically in such a way that the magnetic compass tried to turn the directional gyroscope towards the course it showed. The gyro force of the directional gyroscope filtered the sways of the magnetic compass. It is not permitted to use a magnetic compass in integrated navigation, but in emergency situations it is rather useful together with manual steering. A magnetic compass therefore makes a reliable emergency compass.

### 6.1.3 Measuring speed

It is possible to measure the speed of the vessel over ground with a double-component Doppler log or with a GPS receiver. Doppler is faster as to its response, but there is some fluctuation in the measuring result. In addition, the functioning of the log is disturbed by ice and in port by the backwash of the bow thrusters. The GPS speed on the other hand includes the motion component of the receiver's antenna in the swell. Filtering it requires the comparison information of speed e.g. from the Doppler log or measuring the heeling and pitching angles for the compensation calculation. The accurate speed information of the vessel can also be deduced from the speed information obtained from several measuring devices and by filtering this information.

In addition to preventing grounding, the objective of pilotage is to avoid collision with another vessel. The give-way rules are based on the sectors of the vessels' navigation lights. A decree on navigation lights was issued in England in 1846[146]. The Rules of the Road at Sea were renewed in 1851 and again in 1856. According to the give-way rules, when the courses of the head-on vessels cross each other, the vessel showing red light must be given way to (the left-hand side of Figure 49). On the other hand, if the green navigation light of the other vessel can be seen, one's own course has to be maintained. The visibility sectors of these side lights are in seafaring called the aspect. Earlier the IMO's ARPA regulation required that the speed information was measured through water, because according to the aspect definition, the target had to be visible on the radar in the same way as it was visible by naked eye. The disagreements about the way to measure speed culminated in the 1990's when the satellite positioning devices became more common. The differential corrected GPS became standard equipment and it gave an accurate course and speed over ground. The conflict about measuring the speed through water or over ground was solved in 2004 when the IMO Resolution[147] suggested that AIS information should replace ARPA information on the radar screen. This change was so important that it is quoted in full below:

*'An automatic target association function serves to avoid the presentation of two target symbols for the same physical target. If target data from AIS and radar tracking are both available and if the AIS and radar information are both available and if the AIS and radar information are considered as one target, than <u>as a default condition, the activated AIS target symbol and the alphanumeric AIS target data should be automatically selected and displayed.</u> The user should have the option to change the default condition to the display tracked radar targets and should be permitted to select either radar tracking or AIS alphanumeric data.'*

[146] J. Kemp, The COLREGS and the *Princess Alice*. The Journal of Navigation, UK. No. 2, 2008
[147] Performance standard for the presentation of navigation-related information on shipborne Navigational Displays. MSC.191 (79) 2004, paragraph 6.4.8.1

The speed information measured through water is necessary in river estuaries or in tidal currents. Many automatic steering devices use flow rate as the calculation information when defining the rudder angle needed for manoeuvring. The speed through water can be measured by a water pressure or electromagnetic log. Doppler logs can also include a setting for measuring the speed through water. In that case the speed information is obtained as reflections of the measurement impulse from plankton and from the interfaces of temperature differences of water. In shallow water the effect of the measurement impulse is however usually so strong that the strongest reflection reflects back from the sea bed and it is not possible to obtain the measurement through water.

## 6.2 Radar display

The Rules of the Road of Sea still require that in radar positioning the speed of the own vessel has to be measured as speed through water. This requirement is based on the fact that in a head-on situation the speed measured through water gives on the radar display a converging close-up of the situation with the visual observation based on navigation lights. Therefore the ARPA Resolution from 1995 defined the log which measured speed over water to be the primary speed sensor.

On the other hand GPS and ECDIS utilizing GPS show the vessel’s motion over ground. The obligation to give way can go unnoticed if speed over ground is used in the calculations of the ARPA radar (the right-hand side of Figure 49).

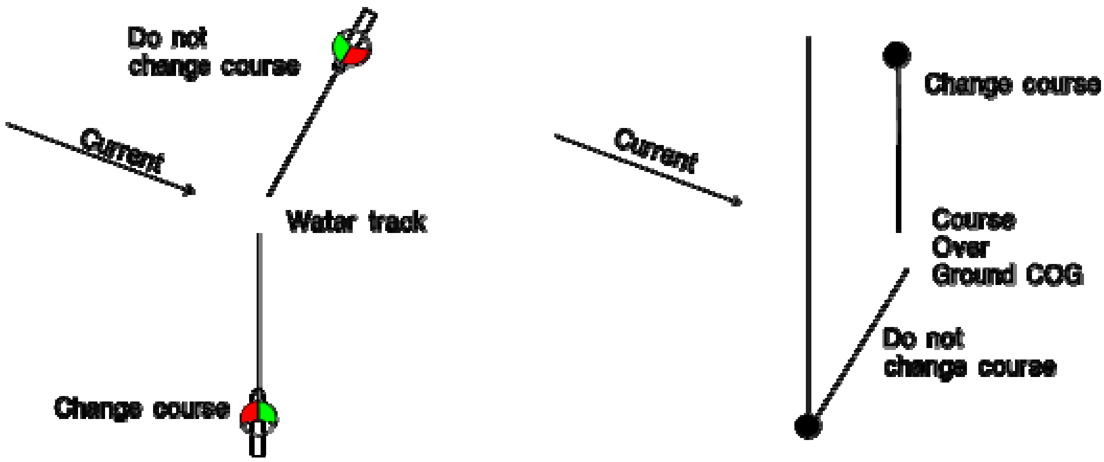


*Figure 49. Measuring speed over ground can cause an incorrect interpretation of Rule 15 of the Rules of the Road at Sea. If the northbound vessel (the vessel at the bottom) estimates its obligation to give way based on the ARPA function of the radar, the speed information of which is obtained from a log measuring the speed over ground (the case on the right-hand side), a situation may arise in which the vessel aims at keeping its course and speed instead of giving way in accordance with the regulations.*

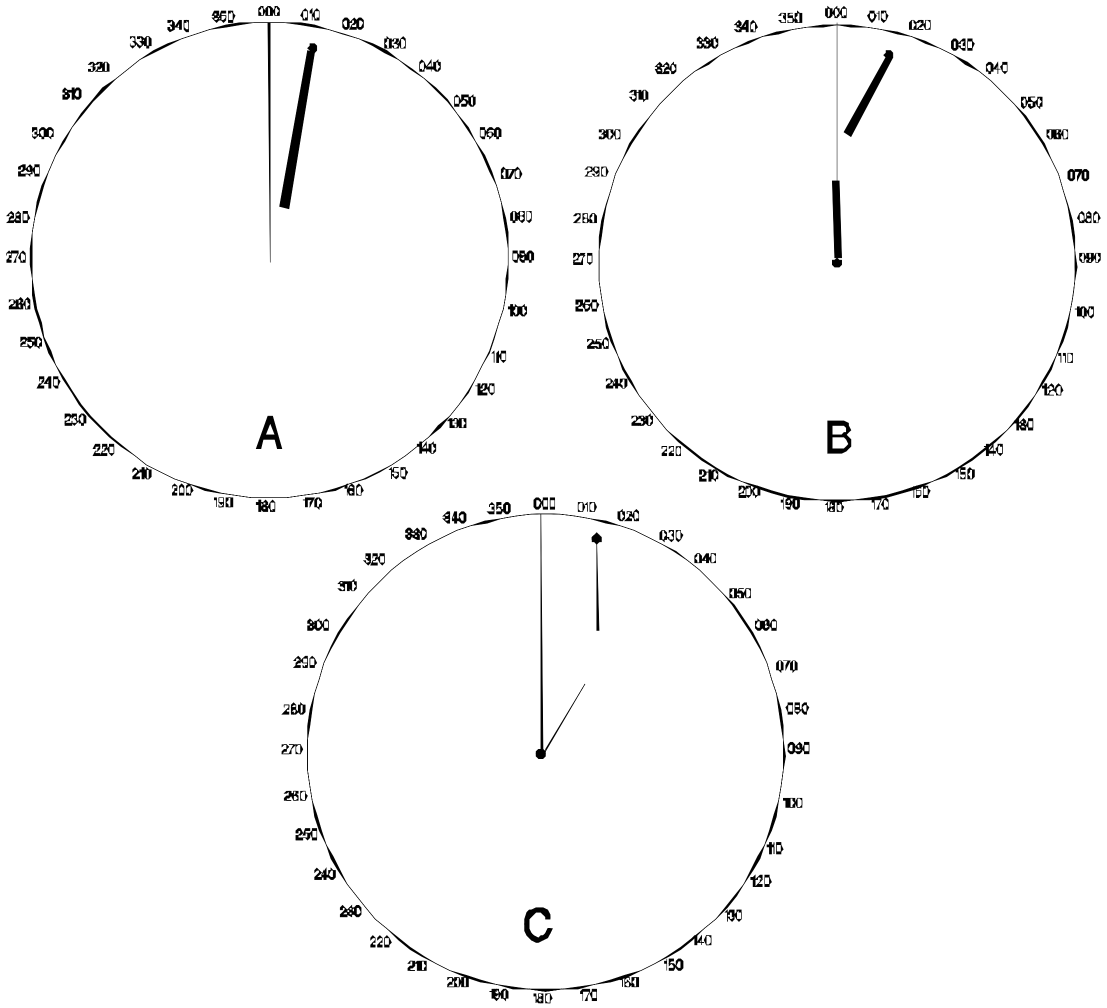


*Figure 50. The radar in the figure is compass-stabilized, and the own vessel is northbound. A strong current takes the vessel eastwards. Display A illustrates the relative movement of the target. Display B presents true motion through water when the effect of the current is not evident. Display C illustrates true motion over ground, in which case the drift can be seen.*

According to the regulations, in all ARPA radar equipment it must be possible to show the route plan and the safety limit of shallow water, which has to be locked over ground on the radar screen. Bernhard Berking and Joachim Pfeifer[148] have taken up effects of measuring speed in different traffic situations in Figures 51-53. The figures illustrate COURSE UP display mode, in which the bow of the own vessel is upwards. Motion is presented as true motion.

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[148] Bernhard Berking and Joachim Pfeifer, Stabilizing the Radar image and ARPA Data. The Journal of Navigation, UK, 1/1995, p. 18

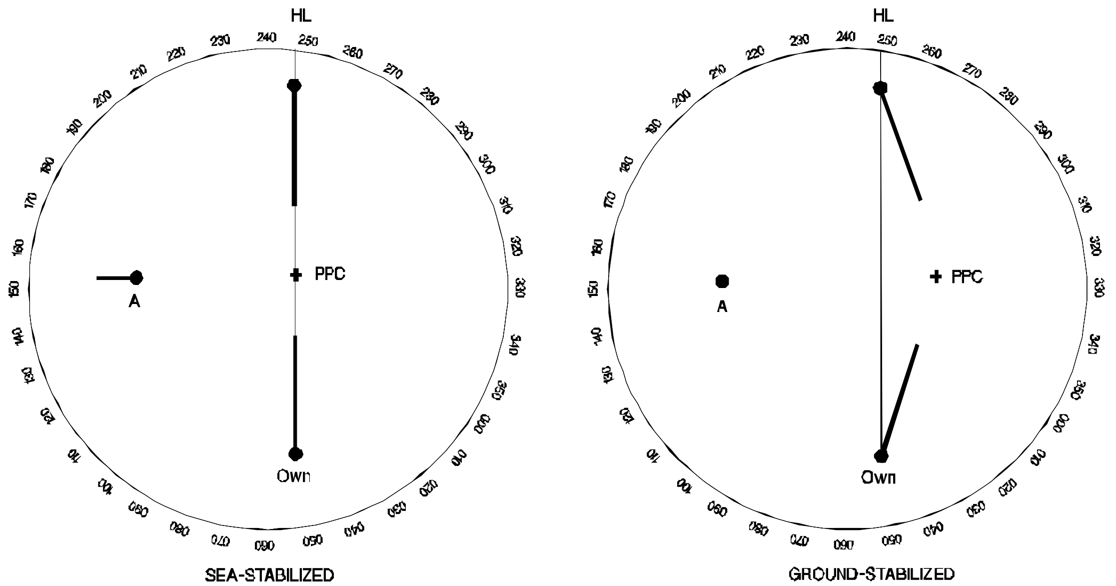


*Figure 51. A transverse current takes to starboard. A is a fixed target. PCC (Point of Possible Collision) is the collision point defined by the ARPA.*

On the SEA-STABILIZED display, i.e. a log measuring through water:

- Fixed targets move on the radar screen against the current.
- The aspect of the meeting vessel is shown correctly.
- The danger of collision is clear, but the point of collision on the radar screen is incorrect.

On the GROUND STABILIZED display, i.e. a log measuring over ground:

- The fixed targets do not move.
- The aspect is misleading, but on the other hand, when visibility is restricted, it is forbidden to base the decision on the aspect[149]. When visibility is good, visual information replaces the aspect of the radar. The person using the radar must understand that the motion vector of the target is not the heading of the meeting vessel.
- The place of collision is correct.
- The danger of grounding becomes evident.

Wind affects the radar image in a different way than current.

[149] Rule 19 in the Collision Regulations deals with giving way when the visibility is restricted

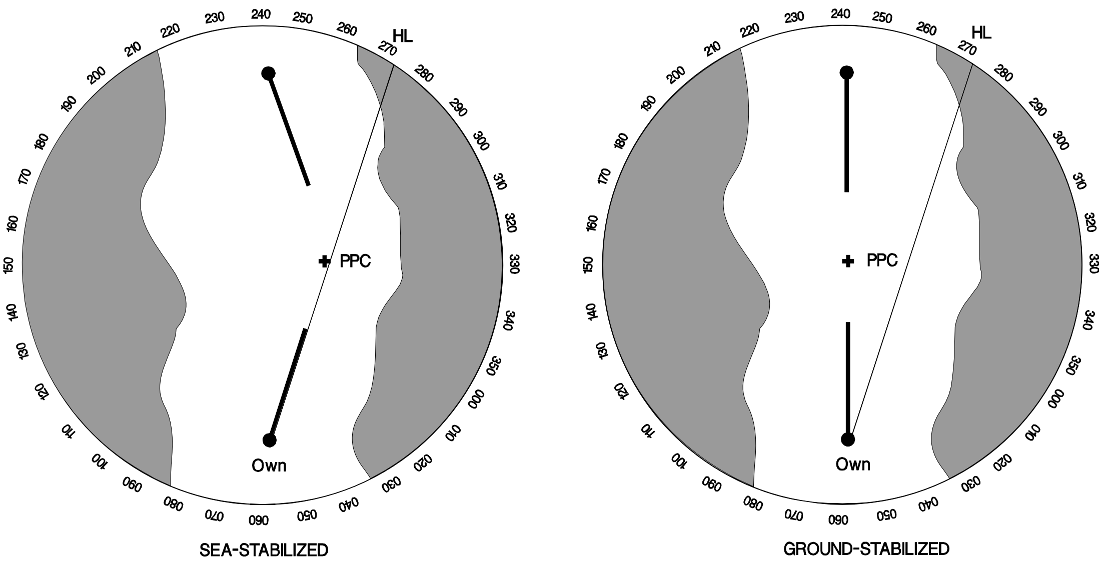


*Figure 52. In the example the wind blows from starboard. Both vessels take the drift angle into account. There is no current.*

On a SEA-STABILIZED display, i.e. a log measuring through water:

- Movement of the own vessel is parallel with the bow line. True motion through water is not visible.
- The danger of collision becomes apparent
- The aspect is shown correctly. The true motion of the target over ground is not visible.

On the GROUND STABILIZED display, i.e. a log measuring over ground:

- The motion of the vessels is over ground. The drift of the own vessel is visible as presented by the motion vector of the bow line
- The danger of collision is clearly visible.
- The aspect is incorrect.

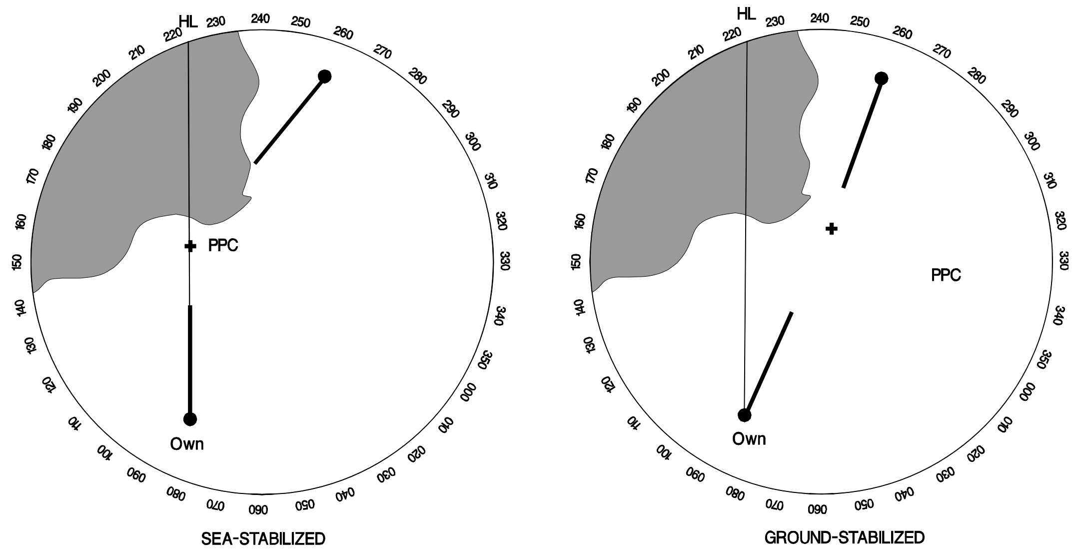


*Figure 53. The tide affects the own vessel (Own). The meeting vessel is protected from the current. This kind of a situation is possible but unusual.*

On a SEA-STABILIZED display, i.e. a log measuring through water:

- The aspect is wrong and misleading despite the fact that the measuring of speed is done through water.
- The vector of the target is incorrect. It seems as if the vessel is steering ashore, even if its course is clearly away from the point of land.
- The danger of collision is apparent, but the position for it is incorrect

On the GROUND STABILIZED display, i.e. a log measuring over ground:

- The aspect is correct.
- The motion of the vessels is indicated correctly.
- The future position of collision is predicted correctly.

It can be concluded on the basis of the examples above that the motion state measured over ground gives a more realistic picture of both the danger of collision and danger of grounding than the motion state measured through water. The conflict between the Rules of the Road at Sea and ARPA/AIS instructions has to do with the aspect defined by the navigation light sectors. The aspect does not show correctly in the traffic situation measured over ground.

The importance of different ways to measure speed in pilotage is examined next.

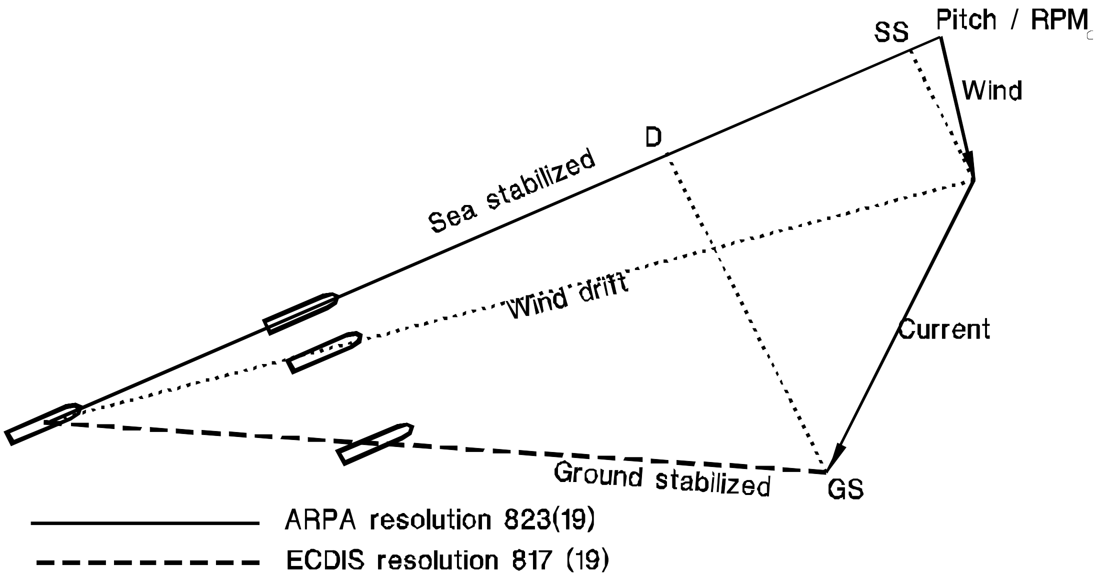


*Figure 54. The figure illustrates speed vectors measured by different types of logs.*
*SS = Sea Stabilized, i.e. speed through water*
*SS + wind = the drift caused by the wind, i.e. motion through water and*
*GS = Ground Stabilized, i.e. motion over ground*
*Pitch/RPM$_C$ = the calculatory speed based on the propeller performance*

The SS vector (SEA STABILIZED) shows the speed information generated by the electromagnetic log of the water pressure log and the single-axis Doppler log which measures through water.

The SS + wind resultant vector shows the true motion through water. The vector can be measured with a double-axis Doppler log, when it is in the mode which measures through water.

The GS vector (GROUND STABILIZED) shows the motion over ground. It takes the effects of both wind and current into account. It can be measured with e.g. the Reference Target function of the ARPA by locking the fixed target into follow-up, in which case the ARPA calculates the course and speed of the own vessel. The result is inaccurate and using it is not recommended, but regulations do not forbid its use.

The GPS gives the COG and SOG directly. The disadvantage with the GPS can be the location of its receiver in the mast of the antenna. When the vessel rolls, the trajectory of the mast causes the COG vector to sway. As a result of this, the ARPA vectors calculated by the radar devices connected to the GPS also sway.

Point D in Figure 54 illustrates the measurement result of a single-axis Doppler log. The measurement has been made over ground only in the direction of the keel. This is not true motion, neither through water nor over ground, but the use of it distorts with radar positioning.

A single-axis Doppler log can be used to measure speed through water e.g. for the speed information required by the automatic steering.

Measuring speed over ground is according to seamen's general view the clearest alternative. There are, however, situations when measuring speed through water provides necessary extra information. In strong tidal current the automatic steering must know the flow rate of water around the rudder. If there is not any log which measures through water, a helmsman must be used when proceeding in flowing water. In the proximity of shoals, the radar must obtain the speed over ground.

It is useful for a seafarer providing pilotage if the motion state of the own vessel is shown on the radar screen. In order to do this, at least speed and course measured over ground are needed. Showing the outline of the vessel on the radar screen makes it further easier to identify the position of the vessel especially in narrow sections of the fairway. The predictor display, which is described later in this study, relies among other things on this information about the motion data.

Authorities do not require that the turning radii of the route plan are shown on the radar, but showing this information is required in ECDIS appliances. In pilotage it becomes easier to monitor the vessel's position in the fairway area if the route plan with its turning radii and the borders of the navigable area are visible on the radar screen. These display characteristics are very useful in preventing groundings, and it is recommended that the use of them would become more common on the bridges.

## 6.3 AIS

The Automatic Identification System, AIS[150] is a system which makes it possible to get real-time information on vessels and their movements from a wide area. The AIS is based on a radio working on the VHF frequency. The system automatically and continuously sends information about the own vessel and its motion state and receives corresponding information sent by other vessels. The range of the device corresponds with the range of a VHF radio transmission, and it is not affected by e.g. natural obstacles or visual obstructions which have an effect on the proceeding of the radar wave. Two VHF frequencies, AIS1 and AIS2, have been reserved globally for the transmission activities[151].

150 SOLAS Consolidated edition, 2004, Chapter V, Regulation 19 (Carriage Requirements), paragraph 2.4.

151 Finnish Maritime Administration's Internet pages

The IMO has made the system mandatory[152] on all vessels engaged in domestic traffic the gross tonnage of which is over 500, and on all vessels engaged in international traffic the gross tonnage of which is over 300. It is good to remember that all vessels do not necessarily have an AIS device or it may be switched off. The AIS transmission must be active unless the authority has given permission to hold back position information.

The AIS device sends two types of information, i.e. static and dynamic information. The static information includes the vessel's IMO number, call sign, name, type of vessel and cargo, the vessel's main dimensions and draught, the source of the position information, the port of destination and the estimated time of arrival. The device sends this information every six minutes.

The dynamic information illustrates motion state, and its transmission frequency varies according to the vessel's own speed. When the vessel is moored or anchored, the transmission interval is three minutes, and from that it gradually decreases and is two seconds at its shortest, which applies to a vessel proceeding at the speed of 23 knots. The dynamic information in its most complete form includes the vessel's MMSI number, navigational status, position, heading, turning speed, course and speed over ground and the accuracy of the position determination.

The IMO's MSC has published a technical standard for the AIS device[153]. According to this, the vessel should send information about its angular velocity *'where available'* through the AIS system. The receiver on the other hand can choose the display mode of the information showing the movement of the AIS targets, and it is interesting that there is no obligation to make use of the received angular velocity information. The IMO requires that information about the motion state is sent through the AIS system to others, but it does not require that the motion state of the own vessel is shown on the radar.

The received information can be shown clearly on the displays of the radar or the electronic chart, and it can therefore be used as a part of an integrated navigation system to prevent a collision. The user must regularly check that especially the information about the vessel's motion state sent by the own AIS device is reliable, and make sure that the voyage-specific information is correct. The AIS device can be connected to a separate GPS receiver, which is not used for any other purpose on the vessel. The course information used by the AIS device can also originate from the separate reproducer of the gyrocompass. At least in one accident, the incorrect information sent by the meeting vessel has been a contributing factor when heading reset of the compass reproducer presumably has not been done.

[152] A 22/Res917 Guidelines for the onboard operational use of shipborne Automatic Identification System (AIS)

[153] IMO, MSC, 74(69) 1998, (ANNEX 3)

Nowadays the AIS system has become an indispensable part of navigation. The GPS and the electronic chart prevent grounding and the AIS warns about the danger of collision. Radar is needed to make observations on the vessels which do not have an AIS transmitter. In some cases the target cannot be seen on radar. For example a timber barge which is being towed is perhaps not visible on radar, in which case the only possibility to prevent accidents is to equip such barges with AIS transmitters[154].

AIS must have been connected to all new radars since June 2008[155]. It will certainly take till the middle of the next decade before old radars have been replaced by new ones in the merchant fleet. At the moment approximately one fourth of the vessels have an electronic chart, to which AIS has been connected[156]. The significance of the radar will decrease in the future, but it will not become useless. The combination formed by an electronic chart and the AIS is not considered adequate to prevent collisions. The combination of radar and AIS is most effective for this purpose. The IMO will define the AIS as an official collision prevention device in the near future[157].

## 6.4 Control devices

The IMO has not issued that many technical recommendations on control devices. The regulations only deal with rudder gear and autopilots. The control devices divided according to their functioning principles are presented next. The usability of control and navigation devices have been dealt with in Mikko Kallas's thesis *'Komentosiltalaitteiden käytettävyys luotsauksessa'* (2008) [The usability of bridge instruments in pilotage].

### 6.4.1 Non Follow Up

The simplest and cheapest manual steering control is Non Follow UP, NFU (Figure 55). It is a switch that steers the electrical current to the steering wheel pump. When the switch or the push button is released, the switch returns to its initial position, the pump stops and the rudder remains in the deflected angle. The NFU lever can be recognized by the fact that there is a string returning the switch to its original position immediately when you let go of it. Push buttons are always NFU controls. This way of steering is used as emergency steering because of its reliability.

154 The Accident Investigation Board C 1/2007/M, M/S KRISTINA REGINA and barge CARRIER 5, collision in Danish territorial waters at Kadetrenden 29.5.2007

155 Resolution MSC.192.(79) 2004. Adoption of the Revised Performance Standards for Radar equipment. December 2004.

156 Andy Norris. Automatic For The People, Navigation News September/October 2008. © RIN. ISSN 0268 6317

157 Guidelines for the On-Board operational use of shipborne Automatic Identification Systems (AIS). Resolution A. 917(22) 2001, ANNEX, paragraph 39: *'The potential of AIS as an anti-collision device recognized and AIS may be recommended as such a device in due time.'*

Usually the identification text of the NFU steering control is marked next to the lever or the push buttons. This is, however, not always the case. Because of its low price, the NFU control is the only manual steering method on many cargo vessels. The manoeuvring places on the bridge can easily be connected electrically in a series, in which case all the NFU controls of a bridge can be available without the steering control being moved separately from one manoeuvring point to another. Electrical connection in a series is a recommended way in emergency steering, but on some vessels each NFU control has to be connected separately into use. The control device itself does not indicate whether it is functioning or not, which means that this always has to be checked from the rudder angle indicator. Therefore using the NFU control should always be directed to the helmsman.

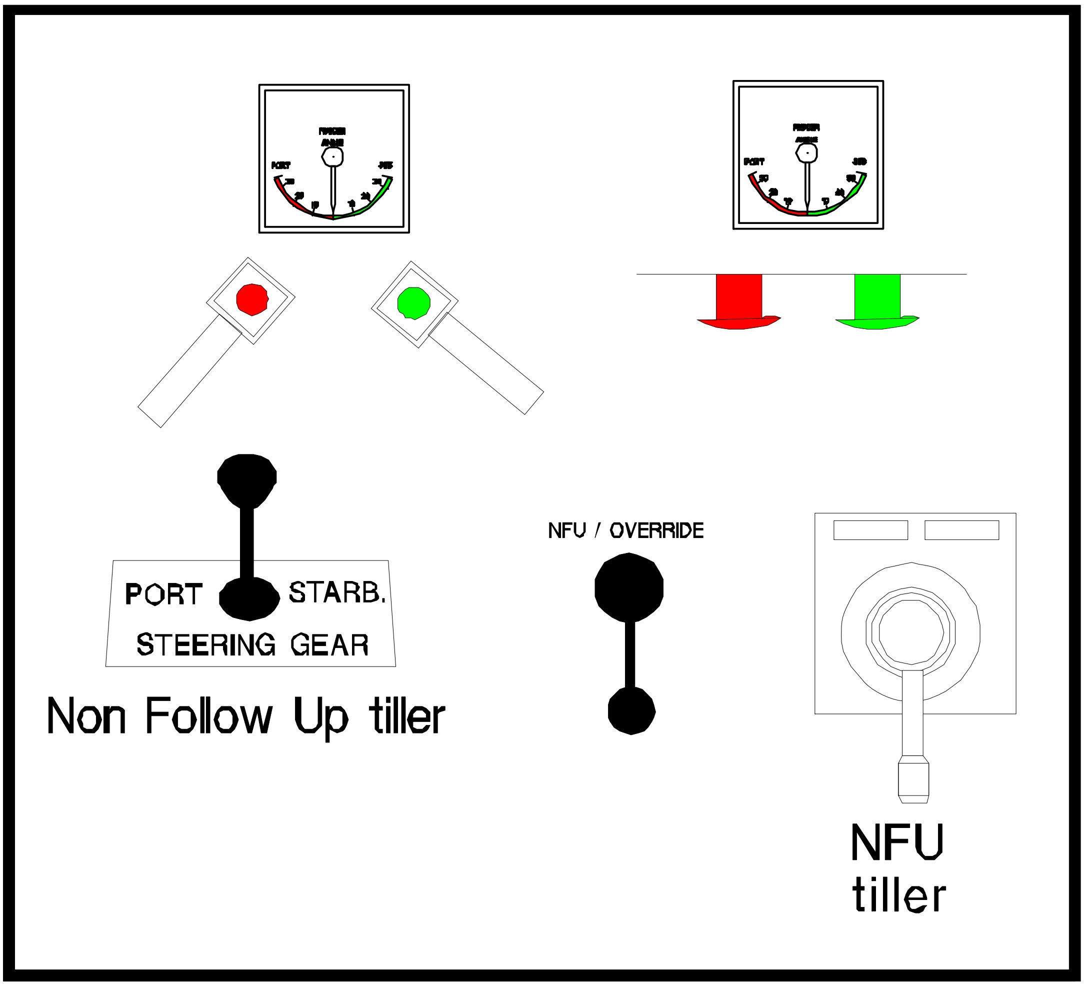


*Figure 55. Different NFU control devices. The NFU lever to the right is misleadingly similar to the FU lever (FOLLOW UP, Section 6.4.2).*

### 6.4.2 Follow Up

The FU (FOLLOW UP) moves the rudder to an angle corresponding with the position of the control lever. FU control lever can be recognized by the fact that the spring does not return it to the middle. The pilot can, when necessary, use the FU control himself/herself and at the same time concentrate on monitoring the radar image, but prolonged manual steering is not part of the pilotage provider's job description.

Using a FU control is usually easier than using a NFU control, but it is, however, not necessarily fully uncomplicated. The ease of using the FU control depends on the ergonomics of the control. Figure 56 illustrates turning the rudder lever with the help of three different types of FU controls. The movement of the arm is clockwise in the device on the left, and both the rudder and of course the rudder angle indicator also turn clockwise. The angle scales of the rudder angle indicator and the control lever are stretched on many devices in order to improve clarity. The FU control lever directly describes the position of the rudder. By turning the lever to port, the vessel's rudder and course turn to port.

In the FU control discs in the middle, the colouring of the rudder angle scale, which has been fixed to the disc, increases confusion. Turning the disc anticlockwise turns the rudder clockwise. The green indicating sector of the disc is in this case to the left.

The angle scale of the control shown on the right is fixed, and its colouring illustrates logically the direction of the turn, but the rudder turns to the opposite direction in relation to the control.

The rudder control order and rudder position should be described in a uniform way so that the system works according to a clear logic both on routes and in port manoeuvring. When the vessel proceeds forward, there is little risk of confusion, but when it moves astern, the direction of the rudder force can remain unclear to the user.

There is no requirement in the IMO regulations that the pilot should be able to use a FU control lever which corresponds with the movement direction of the rudder. The control in Figure 56 A works according to this principle.

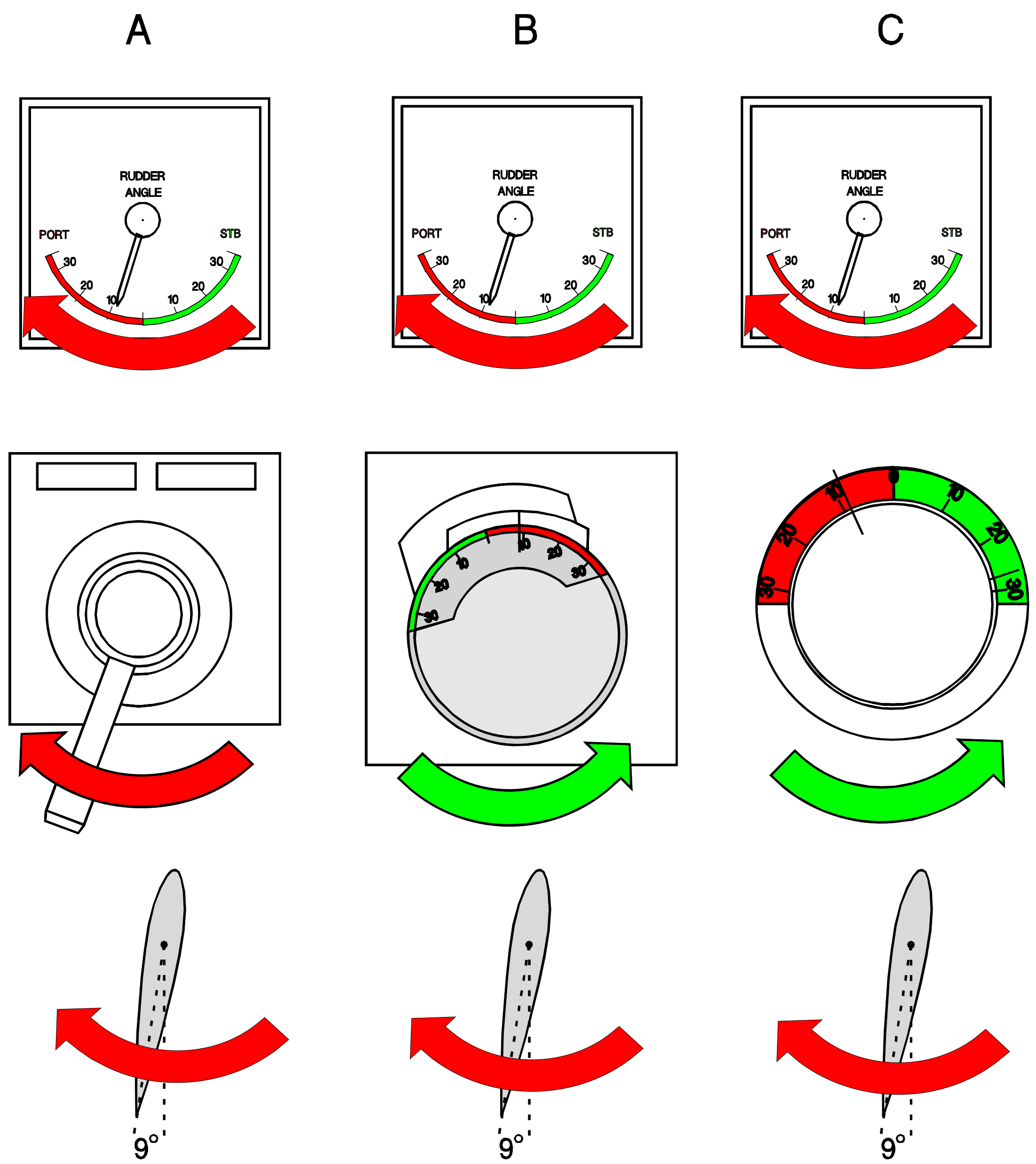


*Figure 56. Three different FU controls. Switch A is logical for the understanding of the movement of the rudder. When the discs B and C are turned anticlockwise, the rudders turn clockwise. As long as the vessel proceeds forward, there is little risk of confusion. When the vessel is manoeuvred in port, the deflection course of the rudder is not clear with reference to controls B and C.*

### 6.4.3 Engine order telegraph

The way an engine order telegraph functions has not been described in detail in the SOLAS regulations. Such a practice has, however, been formed that engine order telegraphs almost always function according to the Follow Up principle. Emergency steering devices are, conversely, almost always devices using Non Follow Up.

The engine order telegraph changes the number of revolutions of the main engine on vessels equipped with a fixed-pitch propeller. In the case of a controllable pitch propeller, the telegraph changes both the number of revolutions of the main engine and the propeller pitch according to a combination curve. This is done in order to protect the main engines from racing and to improve fuel economy, when the ratio of the propeller pitch and number of revolutions corresponds with the optimized design-point of the propeller. In the same way the number of revolutions of the main engine and the twisting moment required by the propeller are in the correct ratio with reference to each other. On some vessels such engine order telegraphs are used, in which the propeller pitch and the number of revolutions of the main engine can be independently adjusted. The automatic speed control, SPEED PILOT, is dealt with later in this study.

### 6.4.4 Autopilot

The pilot may perhaps have to use autopilot when providing pilotage. Because of the broadness of the regulations, the user interfaces of the automatic steering devices differ considerably from each other. This makes the work of the external pilot considerably more difficult. It cannot be required that persons providing pilotage would master the use of several different automatic steering devices. Even though the manuals of automatic steering devices normally include a rather comprehensive description of the use of the device in question, the performance of the steering system in different weather conditions has not been dealt with in them.

The lowest level of automation of an autopilot is control according to the compass heading. At its simplest the control device is electrically connected only to the compass and the steering gear. This control mode is commonly called HEADING MODE. The autopilot can also take the vessel's drift angle into consideration on the basis of the double-component log or the information about the transverse speed provided by the GPS receiver. This kind of steering mode can be called e.g. AUTODRIFT or COURSE MODE. Other functioning modes of autopilots have been dealt with later in Section 7.2.

The safest way to use an unfamiliar autopilot is to use it on straight fairway sections and make the actual turns by using FU manual steering. There are several different manoeuvring modes often available in automatic steering devices, and therefore the pilot should find out in which mode the autopilot follows the heading information only.

The autopilot can be used to perform turns in open fairway legs, but using the autopilot in narrower fairway sections requires knowledge of its setting parameters. The typical effects of various control values on the behaviour of the systems are described next. It is, however, important to remember that completely reliable information about the controls is available only in the documentation provided by the particular manufacturer.

A usual control value for automatic controls is RUDDER LIMIT. The autopilot does not turn the rudder over this limiting value. In some autopilots also the speed information from the log limits the rudder angle automatically in such a way that the largest allowed rudder angle decreases while ship speed increases.

The RUDDER LIMIT setting is problematic in the respect that it reduces the vessel's capacity to perform. In one accident the autopilot had not been able to turn the vessel quickly enough because of the low RUDDER LIMIT value set by the user. In an ideal situation the autopilot has been designed and set in such a way that it does not cause the vessel to make too sudden movements but, when necessary, uses the full steering angle area if e.g. the bank effect of a shoal reduces the vessel's ability to turn in the fairway.

The manufacturers of automatic controls give users different possibilities to influence how their systems perform e.g. when the weather conditions change. The realizations can be divided into three major groups.

The user can have full rights to set the control values of the control system or the manufacturer can allow only a change of a certain range to the default settings defined at the installation and sea trial stage. The third alternative is to allow the user to choose between prenamed control settings.

The right to change the parameters completely, which was mentioned first, is the most hazardous alternative. If changes to the default values are made without expertise, the performance capacity of the automatic steering can collapse. The number and impact method of the adjustable parameters vary from one manufacturer to another, and there is no general rule. YAWING, RUDDER and COUNTER RUDDER are established and typical default settings. Their default values are normally eigenvalues between zero or one to five or ten. The value area varies from one manufacturer to another, and it has to be noted that in some systems a low reading corresponds with strong control and in others the system is the opposite. The control is not necessarily linear, and changing the setting from e.g. value three to value seven does not change the steering of the system twice as much as the change from value three to value five. If, in addition to this, the behaviour of the vessel is unlinear, is impossible to estimate the total effect of a change of a certain control value in practice in any other way than by trying out new settings in small steps.

YAWING affects the total activity of the system with respect to the control of the course or heading. In pilotage the coefficient should be chosen in such a way that accurate steering can be achieved, and there is no oscilliating yawing. An accurate steering setting e.g. at open sea can in the long run put too much strain on the rudder gear.

RUDDER affects the starting of a turn and the rudder angle of the whole turn. The default value applicable in pilotage is approximately in the middle of the range of the coefficient.

COUNTER RUDDER first and foremost affects the ending of a turn. A strong COUNTER RUDDER correction may stop the turn too early. A small correction allows the turn to overshoot over the new course. In pilotage the correction should preferably be stronger than average so that the turn does not overshoot over the desired course.

The vessel's officers should explain to the pilot not belonging to the crew which default values should be used in the autopilot when piloting and change the settings so that they fit. If the officers have never piloted the vessel in narrow fairways, it is unlikely that the pilot receives the help he needs. If the steering accuracy of the automatic system remains inadequate, the pilot has a justified reason to demand the helmsman to the bridge.

The turn command given to the automatic steering should be as simple as possible. This is, however, not always possible. In some popular steering systems the alteration of course is given as a standard procedure of three orders, which are the choice of angular velocity, the desired course after the turn and the wheel order itself, but the order must be given within 15 seconds after the turn parameters have been entered or otherwise the settings will reset to zero. There is a risk that the vessel continues to proceed straight ahead after the wheel order because the user has exceeded the time limit of 15 seconds. The turn can be made by the device in question by using only one order, but in that case it is a question of an emergency manoeuvre, in which the rudder angle is only controlled by the RUDDER LIMIT limiting value. An automatic user interface does not clearly express the difference in these methods of application in a pilotage situation.

It would be an advantage if the desired angular velocity of the automatic steering or the radius of the turn circle could be set by using only one order. The new course could be preset in good time before the turn starts. After that the pilot could concentrate on the turning mark of the radar and start the planned turn at one push of a button.

The IMO does not require the automatic steering to be able to perform turns when the vessel is in angular velocity steering[158], but on the other hand the IMO sets forth the view that if the steering system supports that a pre-programmed route is followed, the system must be able to steer a planned turning radius or angular velocity[159]. In other words, the regulations do not guarantee that the turning radius of the future turn which has been programmed in the autopilot is presented on the radar display. Further, the IMO's ECDIS standard requires that the turning radius of the route plan must be presented on the electronic chart[160].

[158] IMO MSC 64(79) 1996, Annex 3, Recommendation on performance standards for Heading Control systems, Sections 2.5 and 3.2
[159] MSC resolution A.74(69) 1998, Annex 2, Recommendation on performance standards for Track keeping systems
[160] IMO Resolution A. 817(19) 1995, Annex Performance standards for Electronic Chart Display and Information Systems (ECDIS). Section 10.4.1

As pilotage is not mentioned in the IMO regulations as a task of its own, this has allowed the above described incoherent technical requirements from the point of view of pilotage.

Some automatic controls have been equipped with a separate control lever for angular velocity navigation. This kind of angular velocity autopilot is suitable for pilotage because it is easy to use. This principle of application is usually the same regardless of the manufacturer. Of the automatic steering ROT Tiller (Figure 57) is chosen as the steering mode form. The choice activates the control lever of angular velocity, and the directional steering based on the compass disconnects. The angular velocity 0°/minute means 'steady as she goes'. If the vessel is not equipped with an angular velocity gyroscope, the automatic steering can calculate the angular velocity on the basis of the information obtained from the gyrocompass. The above described coefficients of automatic controls (YAWING, RUDDER, COUNTER RUDDER) also work in angular velocity control.

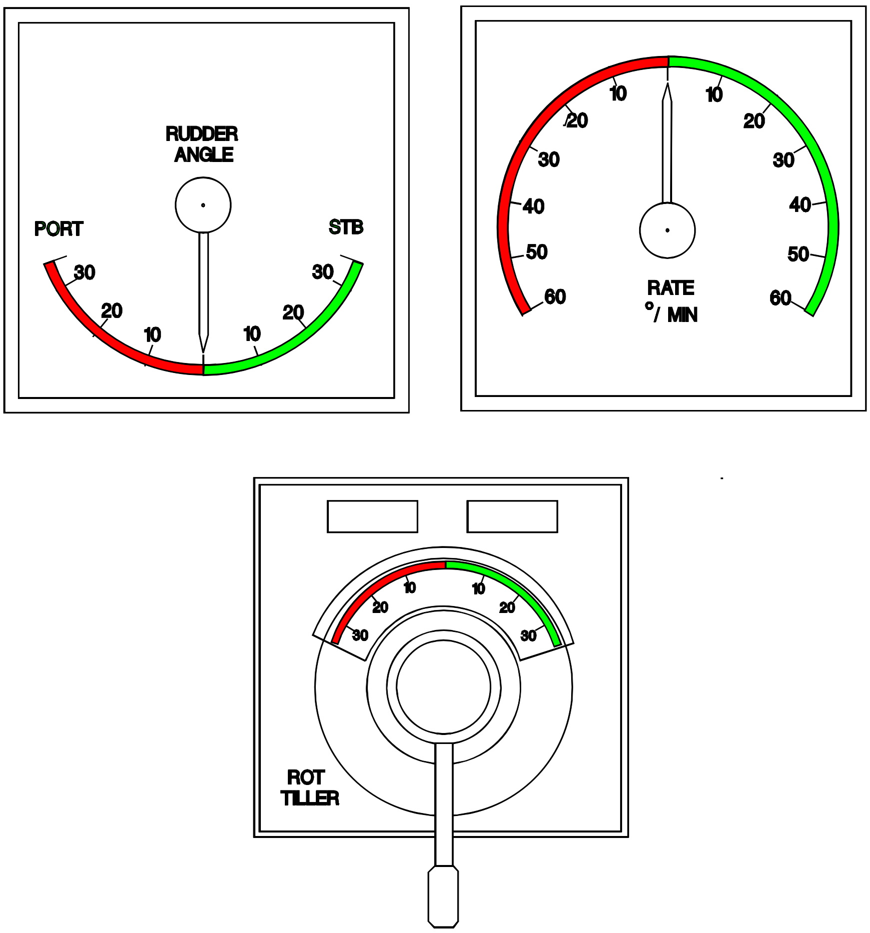


*Figure 57. The ROT (Rate Of Turn) lever of the angular velocity steering. In addition to the rudder angle indicator, the pilot must follow the angular velocity gauge.*

At the beginning of the turn the movement direction of the angular velocity control corresponds with the movement direction of the rudder. When the lever is turned to port the bow is intended to turn to port. The ROT Tiller control described in the figure allows a maximum wheel order of 35°/minute. This control area is adequate for speeds up to 12-13 knots. At higher speeds the turn often becomes too gentle, which can be seen from the table below.

*Table 9. The ratio of the turn circle radius to speed. The angular velocity is 35°/minute. The radius is presented in nautical miles and the speed in knots. R ≈ 0,955( V / ω ), ω = °/minute.*

| | | | | | | |
|---|---|---|---|---|---|---|
| **Radius, R** | 0.27’ | 0.3’ | 0.33’ | 0.35’ | 0.38’ | 0.41’ |
| **Speed, V** | 10 | 11 | 12 | 13 | 14 | 15 |

The angular velocity autopilot and the FU manual steering form a working whole in pilotage. It would be helpful from the external pilot’s point of view if this kind of standard steering arrangement became more common on vessels, because there can be as many as tens of different steering modes of the manual and automatic systems on the bridge of a modern vessel.

### 6.4.5 Joystick

When thrusters became more common on vessels in the 1970's, the number of control levers on the bridge increased. There could be as many as seven separate steering levers at the manoeuvring place of the bridge. This led to a situation where there was not necessarily enough time to use all control devices efficiently in e.g. port manoeuvres. There were attempts to control the situation by proceeding faster in port areas, because low speed would have increased the drift angle of the vessel and led to the loss of control. The risk level of the operations got higher, and integrated control systems for port manoeuvring were started to be developed.

In port manoeuvring the separate levers of control devices are replaced by joystick-steering, in which there are only two control levers. The actual joystick-lever is used to indicate the course (360°) and the output of the resultant force desired for the steering of the vessel. The desired turn moment is adjusted by a round rotation knob, and the desired revolving motion with reference to the programmed turn point is set. On the basis of these orders, the logic of the joystick steering calculates optimal default values for each control device, bow and stern thrusters, the main propeller and rudders, so that the required motion state is achieved.

In its default state the system does not pay attention to external forces, so if e.g. a sidewind tries to turn the vessel, the user must turn the rotation knob of the joystick control to the opposite direction so that the vessel proceeds straight ahead. The joystick system can also include half or fully automatic steering modes, in which case it approaches as to its functioning the DP systems which are described next.

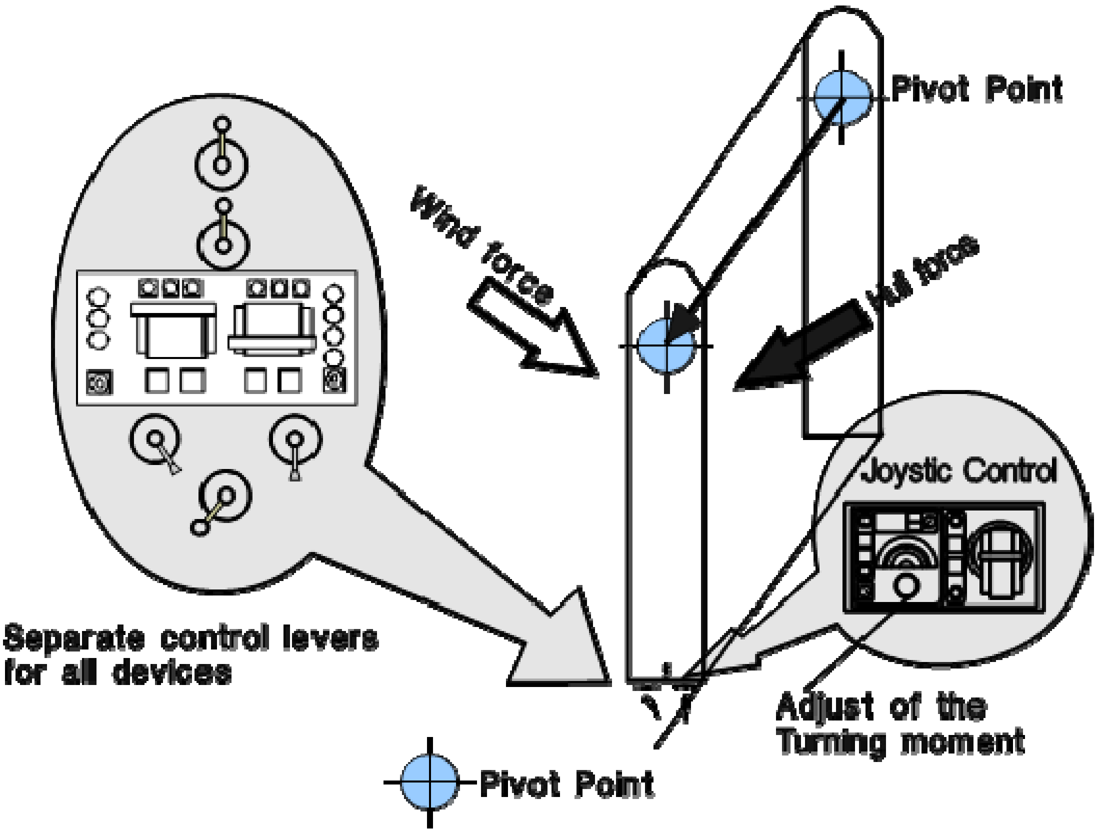


*Figure 58. The conventional levers and the joystick control device.*

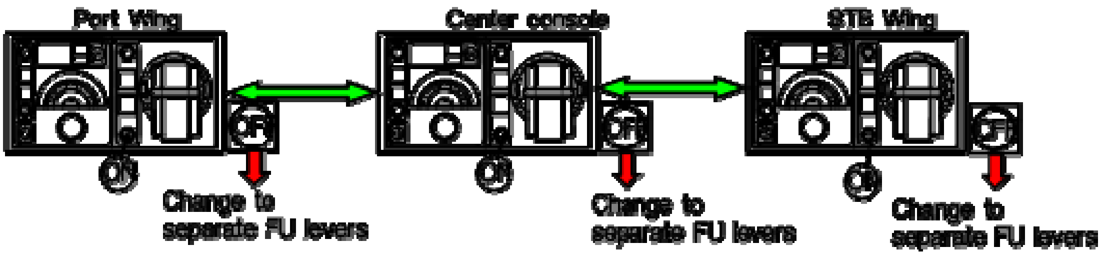


*Figure 59. The KaMeWa joystick steering is activated when the ON button is pressed, and when the OFF button is pressed, the steering switches over to FU manual steering*

### 6.4.6 DP systems

Several cruising vessels, ro-ro vessels and multipurpose icebreakers, which have efficient and versatile propeller devices, use DP (Dynamic Positioning) systems which have originally been designed for cable-laying and supply vessels. With the help of the DP system it is possible to move the vessel efficiently in the desired motion state, or it is possible to keep it completely still in a certain position. The vessel can be turned in the basin in e.g. such a way that the centre of the vessel remains stationary. After this it is possible to move the vessel to the quay by locking the steering of the DP system so that it keeps the vessel's keel line parallel with the quay and the vessel's longitudinal place with reference to the quay in its place. After that it is possible to manoeuvre the vessel sideways to the quay. There are several steering modes in the DP systems, most of which are of little use on an ordinary merchant vessel. It is, however, important that the various steering modes are gone through on the vessel and that a decision is made on which ones are best suited for the port manoeuvres of the vessel in question. The selection which has been made should then be followed.

### 6.4.7 The use and usability of control devices

One of the manoeuvring places on the bridges of modern vessels is usually located amidships next to the radar display and two other on the bridge wings. The FU control is often located only at the helmsman's separate manoeuvring place, and activating the manoeuvring places is usually done by a mechanical switch. The activating of the autopilot is usually done using the same switch, which means that there can be four or five selection modes on the switch. An activating logic which is realized in this way is dangerous in the light of accident statistics, because in a surprising manoeuvring situation nobody is in the immediate vicinity of the switch, and if the switch is in a wrong position, the desired control device does not work.

The safest and clearest arrangement for switching over from one manoeuvring system to another is a push button placed next to each control device. Pressing this button activates the adjacent control device and at the same time other control devices are switched off. This *'command request'* arrangement requires more cabling than the selector switch realization described above, and traditional selector switches are used because installation is cheaper. It would take an IMO resolution to get rid of dangerous selector switches.

A SOLAS Regulation[161] requires that a vessel's officers must know the vessel's manoeuvring systems and the measures which are needed to switch over from one system to another. The IMO's Pilot Card and Wheelhouse Poster[162] do not include any description of the vessel's control devices, their activation or the standard procedures required in manoeuvring[163]. In practice the pilot has to ask the officer in charge of the navigational watch where the selector switch of the control devices is located, how the autopilot is switched off and how the FU steering is activated. The manoeuvring modes which should be used in port manoeuvring, fairway navigation and at open sea should be entered into the vessel's standard procedures in order to avoid misunderstandings.

161 SOLAS, 01/07 2004, Chapter V, Regulation 26, paragraph 3.2
162 IMO Res. A.601(15) 1987. Pilot Card and Wheelhouse Poster
163 IMO Res. A. 960(23) 2003. Pilot Training, Certification and Operational Procedures

## 6.5 Laptop chart computer

It is difficult for the pilot, who is employed by the state and only visits the vessel, to use the navigation equipment installed on the bridge efficiently if he/she has not earlier been trained to use the system in question. On the other hand it is possible that there is no suitable equipment for coastal navigation on the vessel which is being piloted. If difficult weather or ice conditions are encountered on a vessel which is equipped only in such a way that it fulfils the minimum navigational requirements, the pilot's own portable position determination device equipped with a chart display is very useful. Weather conditions can affect the ability of the vessel's radar to distinguish targets in the environment, or there can be a wider open area on the fairway section which is being piloted and where it is difficult to get proper radar echoes. Portable equipment is also useful as an aid in decision-making in surprising navigational situations. The same applies to fairways and ports in which there are seldom operations. The display of the device makes it easier for the pilot to illustrate his/her intentions and to improve the situational awareness of the crew.

Electronic chart programmes which are installed in palmtops or laptops have developed together with GPS devices. There are programmes on the market for the use of mobile devices which vary from a standard display to complete ECDIS equipment. The development of position determination devices and applications has been strong during the last years. The common factor is that the majority of them have not been developed specifically for pilotage. A chart programme must be clear and easy-to-use ECDIS-approved software, which uses S57 chart information. All programmes naturally include the same or similar functions, but according to a study, the use of interfaces can vary considerably. There are for example major differences in the visuality and functioning of route tracking. An estimate on the reliability of position determination should be clearly visible in the programme. Getting used to the functioning of a certain programme often affects its use. Many pilots have individually familiarized themselves with many different programmes and devices. Thus they have gained fairly substantial experience of portable devices used for position determination over the years. This experience has not been compiled, but the information has spread by word of mouth among the pilots.

The State Pilotage Enterprise has realized a project to acquire portable chart displays to the pilots' use. The project has compiled experience of the programmes and appliances of several manufacturers. All programmes were equipped with electronic charts corresponding with the S57 chart standard, and it was possible to connect the devices to several different position determination sources. A portable chart display has been used by the State Pilotage Enterprise since autumn 2008.

Usually a GPS is connected to the programme as the position determination device, and it generates information about the position as well as the course and speed over ground. In addition, it is possible to some extent to obtain estimates on the reliability of the calculated position through GPS devices. Position information can also come to the use of the programme through the AIS device connected to it if the pilot connects his/her electronic chart computer to the output of the navigation information of the AIS device, i.e. the so-called Pilot Plug. That way it is possible for the pilot to get all the information received and sent by the vessel being piloted to his/her chart programme. In that case the information about the heading and important information about the CPA (Closest Point of Approach) and TCPA (Time to the Closest Point of Approach) values calculated to AIS targets are also available. The weak point of the Pilot Plug connection is its dependence on one source of information. Using the own GPS receiver together with the Pilot Plug increases the functional reliability of the system. Nowadays the Pilot Plug is a compulsory function of an AIS device, and its reliability has increased further.

Connecting a GPS device to a portable device can be problematic with reference to the availibility of satellites. In an ideal situation, there is free visibility from the GPS antenna to the sky. This is, however, seldom possible in practice. On the other hand, in most cases it is enough if the GPS antenna is locatednext to a window. Sometimes the heating units of the windows can, however, disturb or altogether prevent the reception of the GPS signal. However, if the receiver is stationarily fixed to the pilot's device or at the distance of a short cable, the usability of the system is somewhat limited. Wireless solutions can be useful as they speed up the initialization of the system when commencing pilotage and make the user free to choose the location of his/her display practically anywhere on the bridge.

Wireless data transfer between a GPS receiver and a portable navigation computer has proved reliable, but it requires cabled solutions more than battery capacity. The availability of electricity is one of the problems connected with portable appliances. The fully-charged batteries of the modern systems allow uninterrupted use for the duration of 2-3 hours. In practical pilotage this is not necessarily enough, and at some stage the devices must get their electricity from the vessel's power-distribution network. In an ideal situation a portable position determination device could function without external power source during the whole pilotage.

The small size of the display restricts the amount of information which can be presented and affects the consumption of electricity. The smallest size of display is in practice 12 inches if actual navigational measures are to be shown on the device. A computer of this size weighs less than 3 kg with all its accessories. Transferring equipment which weighs more than three kilos from the pilot boat to the ship and back becomes somewhat difficult. Palmtops usually weigh less than a kilo, but the small size of their memories limits the navigational characteristics of the device and the display.

If the number of the accessories connected to the computer is limited, a device has to be used between them. It gathers information from several different sources and moulds this information into one input for the navigation programme of the computer. Only user experience gives full certainty on the functioning of this kind of configurations.

The development of the GPS compass and angular velocity sensor will considerably increase the usability of a portable system both in port manoeuvring and in controlling turns. Information about course and angular velocity is required in order to present the prediction of the motion state, i.e. the predictor.

It has to be remembered that portable navigation instruments must be used together with the vessel's own systems. The safe navigation of a vessel is a whole, which is naturally affected by the reliability and functioning of the devices which are used, but not least by the extent of the bridge cooperation when estimating the vessel's future position and movement.

# 7 INTEGRATED PILOTING DEVICES

An integrated pilotage device provides the easiest way to support the requirements on pilotage expressed in the IMO's STCW Code. An integrated piloting device is in its most complete form a compact, integrated whole formed by motion state sensors, radar, electronic chart, autopilot and other control devices. Its features include motion state information which is received from several sources, and the system constantly assesses the reliability and accuracy of the data. An integrated navigation device is not necessarily required at open sea, but at a heavily trafficked coast and in pilotage its advantages are considerable. An integrated navigation device can thus with good reason be called an integrated piloting device.

The IMO's technical regulations from the year 1998 on integrated navigation equipment do not mention the significance of cooperation when using the system[164]. The recommendation simply states that an Integrated Navigation System (INS) only provides the functions and information of navigation with added value. The Resolution does not come forth with any technical objectives of the INS, and the importance of cooperation in the usage of the equipment is not emphasized. As there are no international instructions, the shipping companies themselves must set the functional requirements on the equipment.

The requirements which fall on shipping companies mainly deal with standard procedures. The IMO requires the shipping company to draw up a safety system corresponding with the ISM Code. All dangerous situations are taken into consideration in such a system[165]. The Code does not, however, define the basic tasks which are performed on the bridge, but these have to be defined by the shipping company itself. This has proved to be difficult as there are no clear authority instructions on bridge operations.

There are usually several alternative manoeuvring modes in an integrated navigation device. In addition to manual steering, steering corresponding with the Heading Mode on the basic automation level is in use. The manufacturers have their own names for this manoeuvring mode. AUTO, COURSE CONTROL or HEADING MODE are the most usual names used. The IMO calls this manoeuvring mode HEADING CONTROL MODE[166]. The term HEADING MODE is used in this safety study. It is an abbreviation of the IMO terminology employed in everyday language usage. The systems usually include a possibility to manoeuvre also by an automatic compensation of the vessel's drift angle. In that case the course settings of the autopilot stand for Course Over Ground, COG. This manoeuvring mode is, depending on the manufacturer, called e.g. AUTO DRIFT or COURSE MODE. The compensation of the drift angle is

[164] IMO MSC.86 (70) 1998, Annex 3, Recommendation on Performance Standards for an Integrated Navigation System

[165] ISM Code, Resolution A.913 (22) 2001, Annex, paragraph 2.2.1

[166] IMO Resolution, MSC 74(69) 1998 as amended 2000, Annex 2, paragraph 5.1.12

calculated with the help of the lateral speed of the double-axis Doppler log or of a COG vector calculated by the GPS receiver.

The most versatile manoeuvring state is track control, in which the control system tries to follow the electronic route plan line. The IMO calls this TRACK CONTROL MODE. The manufacturers use e.g. the terms TRACK CONTROL or TRACK MODE.

## 7.1 Preparing for pilotage

### 7.1.1 Route plans

Route plans are drawn electronically in integrated navigation. The STCW Convention requires that it must be possible to verify the plans with the help of charts[167]. In practice route planning is first done in the navigation system and after that the plan is printed out as a paper document. The ECDIS standard requires that the turns of the route plan are expressed as turning radii[168]. In addition to this, it must be possible to program the route plan and the border lines of shallow water for the radar[169]. The route is planned in such a way that it follows the fairway line drawn on the chart or it is drawn on the right side of the fairway line. It is good to name the set waypoints so that it is easy to read the route file.

The starting points of turns and turn points (VRM, EBL) are drawn on the route plan in accordance with the LOT (Line Of Turn) principle. The IMO accepts this geometry in defining the starting point of a turn[170]. The route plan is printed out in the form of a booklet or a leaflet so that it is easy to handle when located next to the radar. There is no need to learn the plan separately, as the person providing pilotage learns it by heart when performing the piloting, which makes using the route plan documents easier.

During the examination for the fairway certificate, a route plan in paper form is gone through. The pilot student also presents it to the pilot trainer during the practical training. In accident investigation a route plan is a proof showing that no negligence has occurred in connection with the planning of pilotage. In court cases an error in navigation is not punishable, but neglecting route planning is. A route plan is a central instrument in maritime education and in avoiding mistakes. A route plan on paper is a document which remains when the technical methods change. It is a good practice to keep the old plans as reference material.

[167] STCW CODE –95, Table A-II/2, Voyage planning

[168] IMO Res. A.817 (19) 1995, Performance Standards for Electronic Chart Display and Information Display (ECDIS), paragraph Route Planning, 10.4

[169] Res. MSC.192(79) 2004, Revised Performance Standards for Radar Equipment. Par, 5.32.2

[170] Resolution MSC.64(67) 1996, Annex 3 as amended 2000,paragraph 5.1.6 (1)

The examples in Figure 60 illustrate the turning of a vessel. When the course is 30° and the speed is 15 knots, the navigation device is given the order to turn to course 90° with a turning radius 0.5’. The turning of the vessel starts almost immediately, and the start of the turn is determined by the control settings of the navigation device and by the manoeuvring characteristics of the vessel. In route planning geometry the straight section F is marked at the beginning of the turn after the turning point. The lateral defelction of the vessel at the end of the turn can be taken into consideration in this F distance. The distance is, depending on the vessel, usually about half the length of the vessel.

The even arc in route geometry is of the same shape for all vessels regardless of their type or size. In route planning it is an advantage to use so large turning radii that the basic plan is always the same regardless of the vessel's size, and that the rudder angle remains reasonable. In addition to this, the ability of the autopilot to follow route plan is better in gentle turns.

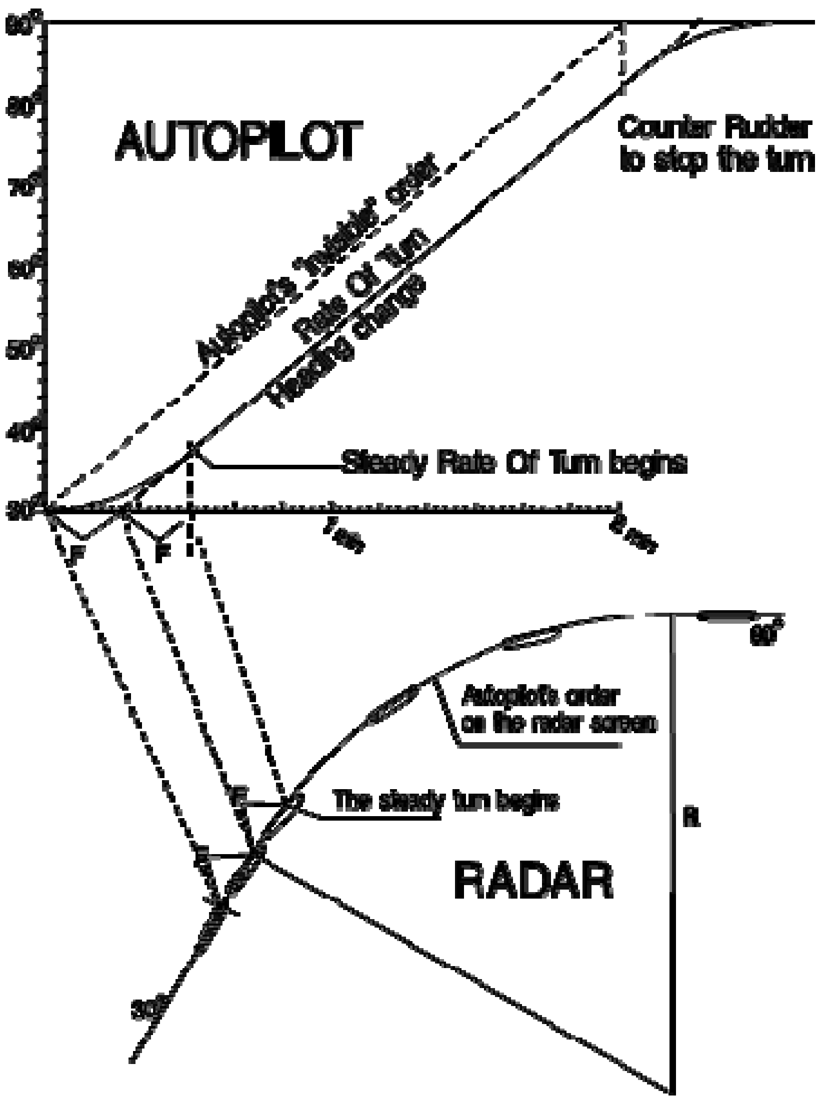


*Figure 60. An order from the autopilot draws the future track of the turn on the radar.*

Modern route plans can include e.g. the following information:

| | |
|---|---|
| 1 | Number of the waypoint, given by the route plan. |
| 2 | Waypoint coordinates according to the WGS-84 system. |
| 3 | The name of the waypoint given by the user based on the name of a nearby lighthouse or island. |
| 4 | The type of navigation line chosen by the user (dotted line, broken line, etc.) |
| 5 | Waypoint, can define the point of change of either the turning point or the speed of advance. |
| 6 | Turning radius, which is defined as large as possible within the limits of the fairway space. |
| 7 | The speed between the waypoints to calculate schedule and to adjust the speed. |
| 8 | A coefficient given by the user. It adjusts the sensitivity of the automatic steering. The coefficient is defined according to the width of the fairway. |
| 9 | TRACK LIMIT, i.e. the allowed maximum deviation from the route in automatic track control. The value is determined based on the width of the fairway space. |
| 10 | If there are deviations from the navigation line, there are usually two alternative ways in track control to steer the vessel back to the route. At open sea the vessel is steered directly to the following waypoint. In a fairway the vessel is steered immediately back to the fairway line. |
| 11 | Short instructions in connection with the waypoint. They become visible on the radar screen before the vessel arrives at the waypoint. These instructions can include e.g. standard procedures, the maximum allowed speed of advance and the EBL and VRM used in determining the turn line. |

The route plan file controls the functioning of the automatic system on the different parts of the route. The system generates a route schedule, which shows the time of passing waypoints, the standard procedures to follow at the waypoints and the speeds of advance which are used.

It is good to state the vessel’s maximum speed between the waypoints in the route plan. The areas of speed restrictions should be marked clearly. In addition to this, the speed must often be restricted in such fairway sections in which shallow water affects the proceeding of the vessel (Section 4.1.3, squat). In narrow passages the speed must be reduced because of the bank suctions of the fairway so that the manoeuvrability of the vessel does not decrease.

*Table 10. Excerpts from the route schedule of a route plan. The realized times, the weather and other observations are registered along the voyage. The list is kept within arm's reach, and after the voyage has been completed it is recorded as an appendix in the ship's log.*

| Speed | Calculated time | Realised time | Waypoint | Weather and notes |
|---|---|---|---|---|
| | 09:30 | - : - | Departure Helsinki | |
| 0,7 | 09:42 | - : - | South Harbour | |
| 4,0 | 09:47 | - : - | Katajanokka | |
| 12,0 | 09:51 | - : - | Lonna | |
| 12,0 | 09:55 | - : - | Kustaanmiekka | |
| ------- | ------- | -------- | -------- | |
| 12,0 | 11:27 | - : - | Smultrongrund | |
| 14,0 | 11:32 | - : - | Muntersgrund | |
| 20,0 | 11:43 | - : - | Sommarö | |
| ------ | ------- | ------- | -------- | |
| 15,0 | 16:39 | - : - | Utö | |
| 13,0 | 16:46 | - : - | Stenharun | |
| 13,0 | 16:52 | - : - | Knivskår Edge Mark | |
| ------ | ------- | ------- | ------- | |
| 1,0 | 20:36 | - : - | The corner of the dock | |
| 0,7 | 20:46 | - : - | The gate to the basin | |
| 0,5 | 20:59 | - : - | Quay | |
| VOYAGE | = 186,2' | TIME = | 11:29 | |

A route schedule is useful when the vessel has to agree upon a meeting place with an oncoming vessel or when the VTS centre is informed about the future times of passing waypoints.

## 7.2 Fairway navigation

### 7.2.1 Manual steering

In the past the rudder angle was the only indicator of how a turn proceeded to be systematically monitored in turns performed with the help of a rudder angle order. The rudder angle was then monitored during the whole turn.

There lies a danger in this method of manoeuvring, i.e. there can be variation in the turn which means that it is difficult to repeat the turn geometry. This was earlier eliminated by a large initial rudder angle and a sharp turn so that the new straight course could be reached quickly. The sharp turn decreased the effect of the corrective measures during the turn and caused hazardous lists. A small error at the start of the turn easily caused the risk that the turn would become too long.

However, in integrated navigation the situation is not this bad. The information about the motion state presented by the equipment and especially the predictive display of the motion state (predictor) make it easier to steer the vessel according to the route plan. If the predictor is utilized, the manual steering is a very accurate manoeuvring mode when proceeding at low speed in difficult fairway sections. The time a person providing pilotage is able to concentrate intensively is, however, limited, so during longer piloted tracks the assistance provided by automatic steering has to be used.

### 7.2.2 Angular velocity navigation, Rate-Of-Turn navigation

In Figure 61 the Sottunga Enskär turn is performed with an angular velocity of 30°/min while the speed is 17 knots. The starting line of the turn is drawn with the help of the variable range marker ring (VRM distance 0.57') and the electronic bearing line (EBL bearing 244°).

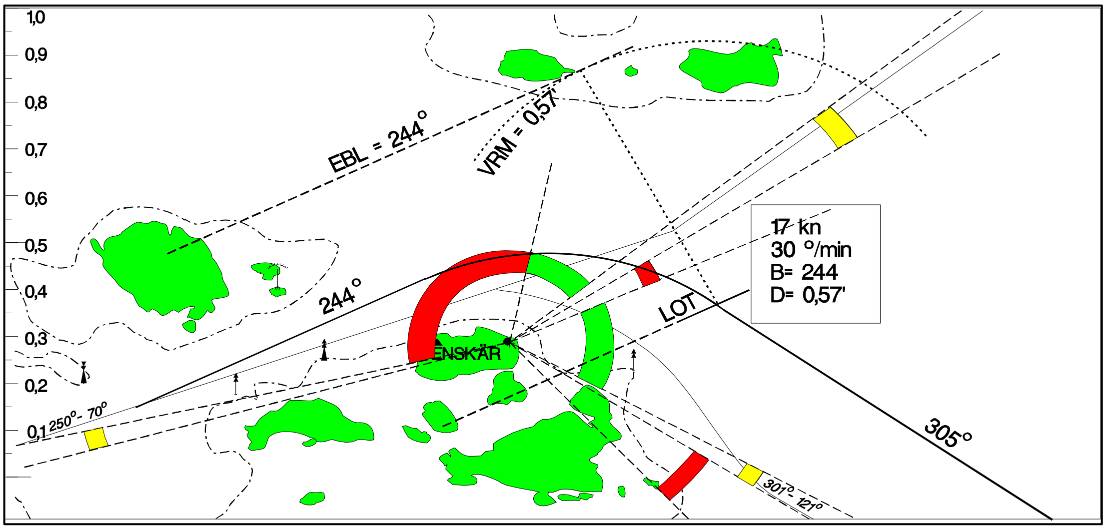


*Figure 61. A turn performed by using angular velocity.*

Using a helmsman in angular velocity steering is considered to be difficult, because at least four different orders have to be given when executing a turn. The starting of the turn commences with a normal rudder angle order, and when the turn has started and the turn speed is close to the target value, the helmsman is given the actual turn speed order. An adequate pause has to be left between the orders so that the helmsman can concentrate on one indicator reading at a time.

*Table 11. Angular velocity navigation is a systematic method. If the turn is not realized in the desired way, one of the factors listed in the table has been performed incorrectly.*

| Instructions for an angular velocity turn | |
|---|---|
| **Manual steering**<br><br>**A separate helmsman has to be used** | **Automatic steering** |
| **The speed** has to be adjusted in good time to correspond with the plan. | **The speed** has to be adjusted in good time to correspond with the plan. |
| **The vessel's Course Over Ground** has to correspond with the starting | **The vessel's Course Over Ground** has to correspond with the starting |
| **The turn bearing** has to be chosen according to the plan. | **The turn bearing** has to be chosen according to the plan. |
| ***Ruder angle order***<br>*After this the helmsman only monitors the rudder angle indicator.* | **The planned angular velocity is entered into the autopilot** |
| ***Angular velocity order***<br>*The helmsman only monitors the angular velocity gauge.* | **Setting the heading and the order to turn** |
| **Rudder midships** at the end of the turn | |
| ***New compass course***<br>*After this the helmsman only concentrates on the compass.* | |

In automatic steering a turn performed with angular velocity decreases the dispersion of the tracks, and some of the effects of the external circumstances on the turning disappear.

When the vessel approaches a turning point, the speed has to be adjusted in such a way that it corresponds with the plan, and the vessel's Course Over Ground has to correspond with the planned starting course. The turn is commenced at the correct point, and the bearing line has to be parallel with the new track (LOT, Line Of Turn).

The vessel's speed has to be monitored during the turn and it should not be allowed to decrease. A drop in the speed turns the vessel's track inside the planned track. Then again, too high speed is more dangerous, because in that case the vessel drifts out in the turn, and it might be more difficult to correct this error.

The HEADING MODE of the autopilot, which controls the heading and angular velocity of the automatic steering, is at the minimum able to function on only compass information. Information from the position determination device or log is not necessarily needed. The vessel’s drift angle and the speed can, when needed, be entered manually for the autopilot.

### 7.2.3 Turning radius steering

The turning radius is one of the basic parameters of fairway planning. The IMO standard on electronic chart display (ECDIS) clearly demands that turns are planned as radii[171]. It is also a better adjustment value of a turn than angular velocity, because a change in the speed does not affect the vessel's path of motion.

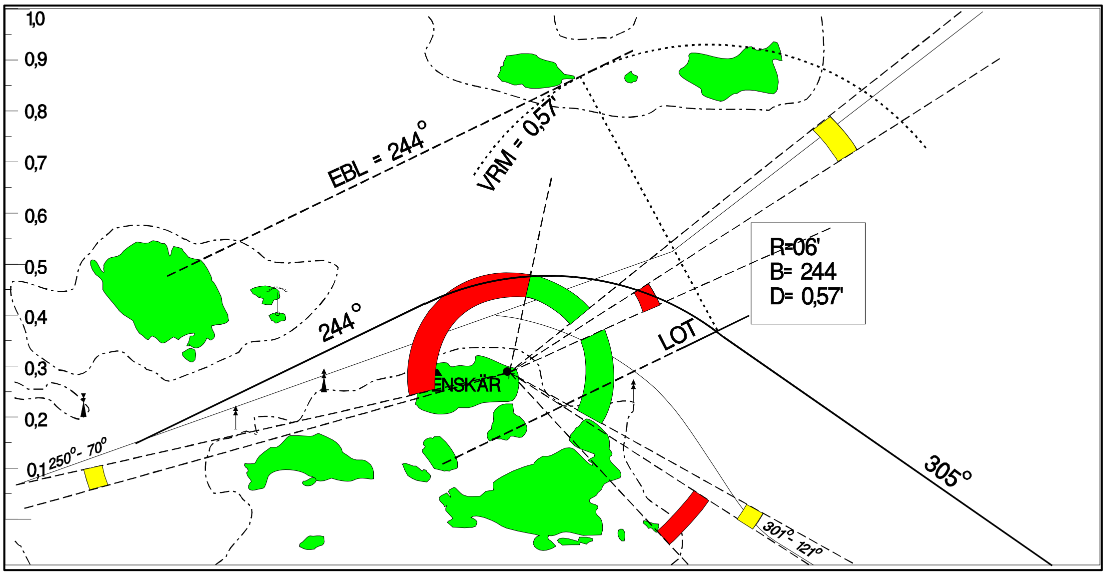


*Figure 62. A turn at the arch of a turn circle measured with the basic tools of a radar.*

Individual turning radius indicators can usually be obtained only by a special order, which means that turning radius steering cannot usually be controlled in manual steering. Several modern autopilots, however, include a mode to perform a turn by using turning radius steering.

As to the turns realized with the help of the rudder angle and turn speed order (see above), the success of the measure depends to a large extent on the correct starting point of the turn. The starting point of a turn is traditionally determined with the help of an electronic bearing and a variable range marker ring. The situation changes when the radar, route plan and automatic steering are integrated so that they function together. The vessel symbol on the radar screen pushes the planned turn geometry ahead of it (Figure 63).

171 IMO, Performance Standards for Electronic Chart Display and Information System (ECDIS), Res.A.817(19) 1995, Annex 10.4.1. (curved segments)

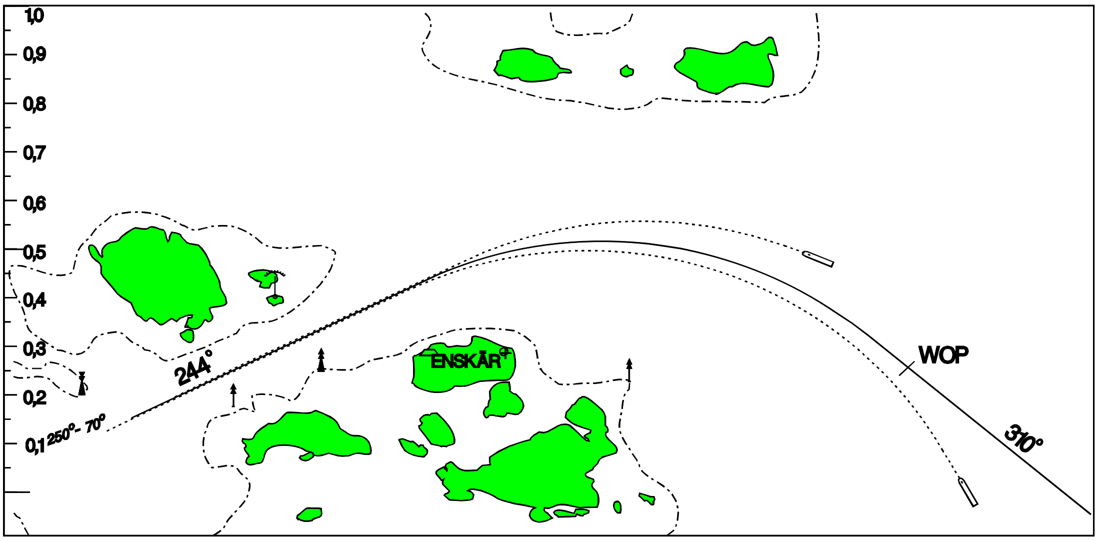


*Figure 63. A turning plan in integrated navigation. The solid line illustrates the route plan. The broken lines illustrate situations in which the turn is entered from different directions, in which case the starting point of the turn changes.*

The turn is started when the track of the turning plan meets the target track, on which one wants to turn. It becomes unnecessary to calculate the starting point of the turn. In integrated navigation there is no need to start the turn from a preplanned course, and the turning radius does not even need to correspond with the plan (Figure 64). Thus the realization of the turn differs from the traditional way in which the starting point of the turn had to be determined first in order for the desired target track to be reached. In this way integrated navigation well supports the natural way of pilotage, in which the seafarer primarily concentrates on the vessel's future position in the fairway.

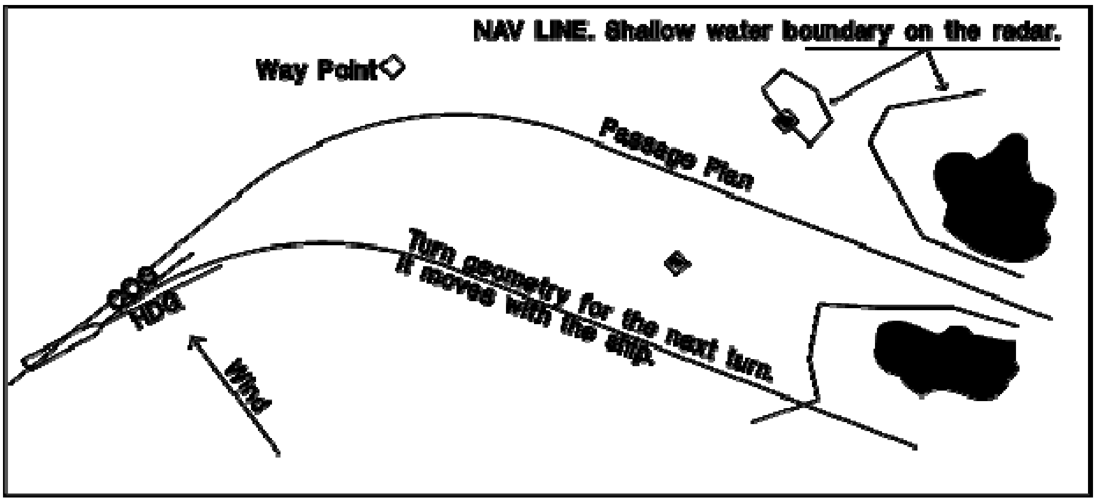


*Figure 64. On the radar screen the vessel symbol pushes the turn geometry ahead of it. The route plan can also be seen on the radar screen. The turn is started when the new course of the turn geometry (111°) meets the next track of the route plan. (HDG = compass course COG = Course Over Ground).*

The turn in Figure 64 is performed in an area where there are no fixed turning marks of radar navigation. For the turn to succeed it is essential to start the turn when the calculated turn geometry points to the strait. The navigator concentrates on where the turn ends, not on where it is started. This is perhaps the biggest difference of principle of integrated navigation when compared to traditional pilotage by radar.

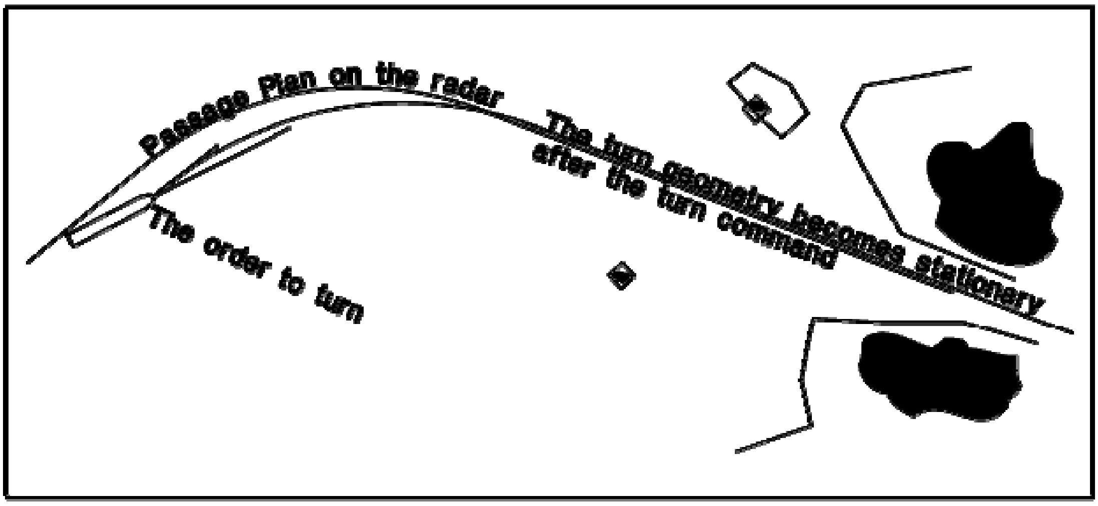


*Figure 65. The turn is started when the turn geometry points to the strait. Figures 64 and 65 show that the starting marks of the traditional route plan are no longer necessary.*

When the turn order has been given in turning radius steering and the turning has started but the vessel's path of motion does not correspond with the planned turning radius, it is sensible to change the set value during the first half of the turn. In the corresponding situation it is safest to switch over to manual steering on the second half of the turn.

In some navigation systems the automatic steering reacts to the changes of turning radius and the desired course given by the user by recalculating the path of the turn ahead from the vessel's present position. In that case the vessel's deviation from the programmed track, which affects rudder steering and which the system calculates internally, becomes zero (Cross Track Error, XTE). If the system works in this way, it is good to make the correction at the earliest possible stage of the turn, and the correction has to be adequate. Several small corrections are ineffective, and in fact they only lower the performance of the automatic steering.

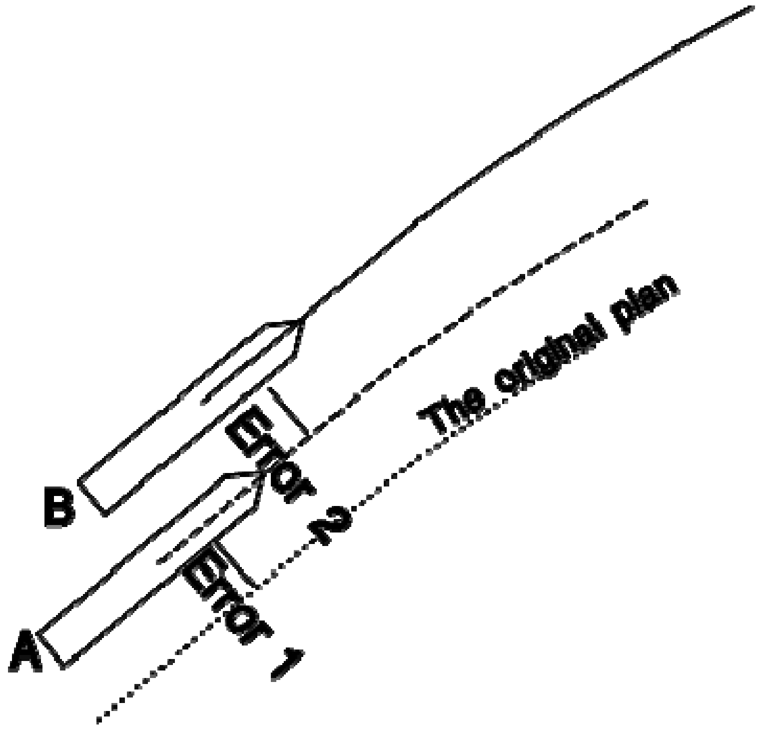


*Figure 66. Because of the functioning logic of some control systems several manually performed corrections prevent the automatic steering from making corrections in the planned way.*

The broken line in Figure 66 illustrates the original curve line, which corresponds with the route plan. Let us presume that during the beginning of the turn the vessel has, due to external factors, drifted to port, to the broken line to point A. The XTE error 1 has thus come about. If the directional value of the automatic steering is then corrected e.g. one degree to starboard, the calculator error 1 may reset to zero, and the automatic steering does no longer try to correct the error 1. If the vessel proceeds ahead, the external factors can still move the vessel to port and XTE error 2 is a fact. If the user again corrects the directional value, the error 2 disappears. As a result the vessel drifts further away from the original route plan. The changes in the turning radius setting can also affect the autopilot in the same way. It may feel natural for the user to try to correct a small error by a small correction, but in reality the deviation increases. This mistake can be avoided by using correct standard procedures. The corrections must be made at the beginning of the turn as adequate reductions of the turning radius. If the measure does not help, a switch over to manual steering has to be made. The steering logics of this kind of an autopilot result in the end of the turn moving further away, if the vessel after passing halfway through the turn is drifting outwards and if attempts are made to affect the error by changing the desired course after the turn inwards. The desired correction is thus not achieved.

In integrated navigation the objective is usually to make the turning radius gentle. In that case the vessel does not heel, the speed does not decrease and the transverse deviation is easy to correct. When the turning plan is visible on the radar, steering in the turn is as easy as on a straight leg. Turn commands are simple. By comparing Figures 22 and 65 it can be stated that as to the orders there is a return to the initial situation when the turn only had one adjustment value. Earlier the control value of the turn was the rudder angle, in integrated navigation it is now the turning radius.

### 7.2.4 Automatic track control

The most advanced control state of integrated navigation equipment is TRACK CONTROL. The most important control magnitude is Cross Track Error (XTE), i.e. the vessel's deviation from the intended track. The correction sensitivity of automatic steering can usually also be defined waypoint by waypoint in the route plan file. In fairway navigation it is natural to correct the lateral deviation XTE immediately, but at open sea there is no need for that.

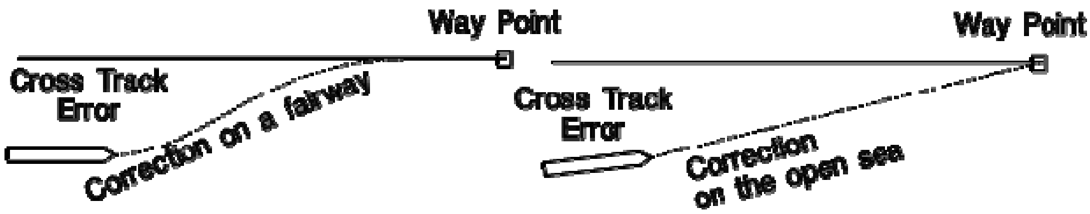


*Figure 67. A method for correcting transverse deviation (Cross Track Error) to the waypoint can be programmed.*

The maximum allowed transverse deviation of a track section is defined with the help of Track Limit (Figure 68). If the vessel drifts to this limit, the automatic system gives an alarm and strongly corrects the course closer to the track. The limiting value saved in the route plan file for areas located in the proximity of narrow passages is usually smaller in the way shown in Figure 68.

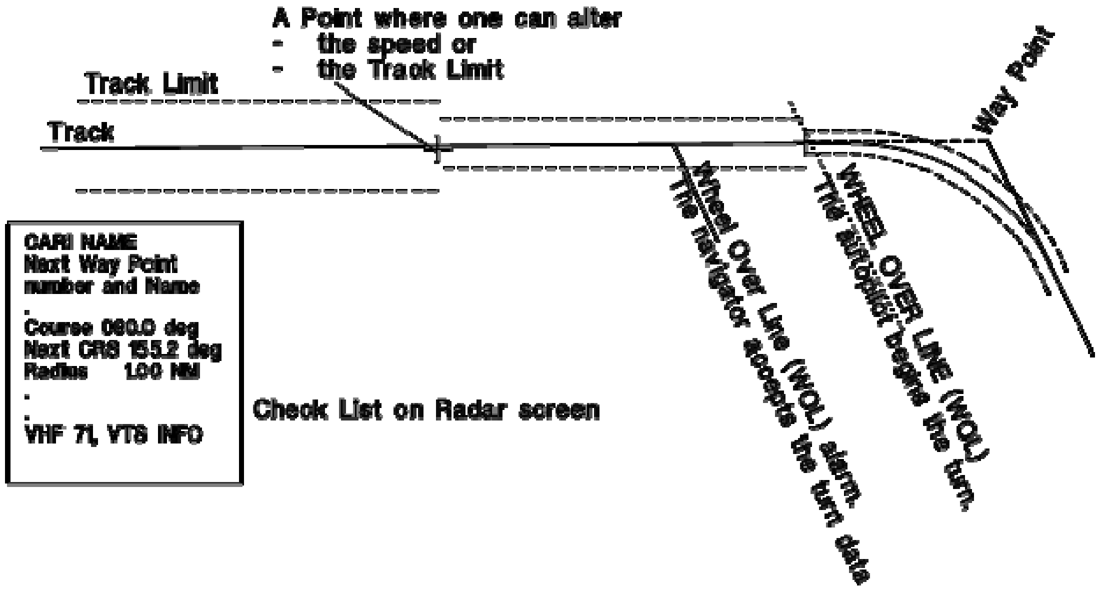


*Figure 68. When the automatic track control gives the start alarm of a turn, the user acknowledges the alarm and after that approves that the autopilot performs the turn independently. At the IMO's request the turn nowadays takes place automatically anyway even if the alarm is not acknowledged.*

Technically the TRACK CONTROL monitors the realization of the route plan better than other control modes. If the vessel is heading-unstable as to its manoeuvring characteristics, the track control can steer the vessel without getting tired and more accurately than a human being. Track control requires high-quality sensor signals and the filtering of them. It is not possible to train pilotage in fully automatic track control.

### 7.2.5 Standard procedures of automatic steering

Automatic steering is always activated to its lowest control state i.e. the HEADING CONTROL steering, which at its simplest only depends on the heading information. In the display of the autopilot there should always be information about the state of the sensors, which are connected to the autopilot. The information must always be checked when the control mode is changed.

HEADING CONTROL is started by checking that

- the vessel is on a straight course and does not have angular velocity
- the compass and log or the GPS show correct readings
- there is enough fairway space

Changing to COURSE CONTROL

- the Course Over Ground is checked from the Doppler and the satellite navigator
- the vessel is on a straight course and it does not have angular velocity
- there is enough fairway space

Changing to TRACK CONTROL

- the vessel must be inside the TRACK LIMIT limit
- the vessel's Course Over Ground must be towards the navigation line
- there is enough fairway space

It must be possible to choose manual steering anytime at one push of a button[172].

The choice between the control modes presented above can be made when the vessel is proceeding on a straight course and there is enough fairway space. In the COURSE CONTROL mode the autopilot uses the drift angle measured by the Doppler log or the COG from the GPS. In the HEADING CONTROL mode the drift angle can be compensated by changing the directional value (Figure 69).

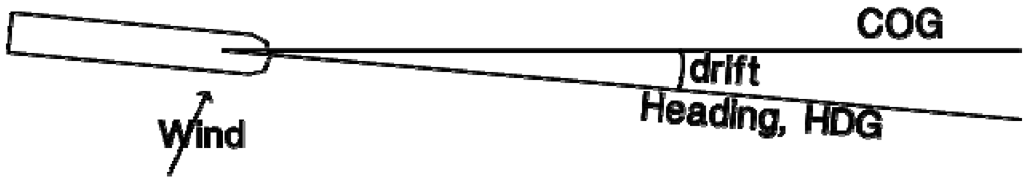


*Figure 69. It is possible to switch between the COG and HDG control modes on a straight course.*

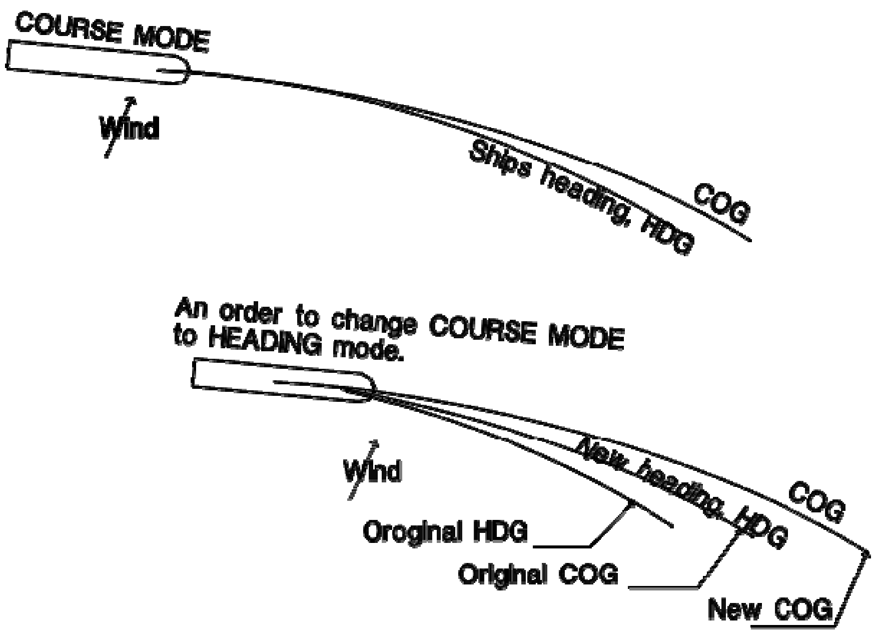


*Figure 70. Course control mode (COG) must not be switched to Heading control mode (HDG) in the middle of a turn because the initial steering order changes with the extent of the drift angle.*

[172] IMO, MSC. 64(67) 1996, Annex 2, par, 4.1, allows a three-second delay when switching over to manual steering

In the example in Figure 70, the steering has received a new steering order over ground in the COURSE CONTROL mode. The wind forces the vessel to port. If the control mode is changed in the middle of the turn to HEADING CONTROL steering, the numerical value of the steering order does not change but the Course Over Ground changes to port as many degrees as the drift angle is. Even if the vessel proceeded on a straight section of the route, it is forbidden to change into automatic steering in a narrow section of the fairway. A switch over to manual steering is always safe, but it is good if the predictor of the motion state is then available for use.

### 7.2.6 Automatic speed control

The integrated navigation equipment often includes the automatic speed control of the vessel. There are usually two automatic speed control modes in integrated navigation equipment. The most common control mode is the setting of the standard speed, and it can e.g. be called *Set Speed mode*, which refers to the speed set by the user. When the speed control is activated, the automatic system chooses the vessel's instantaneous speed as the set value. In addition to this, the integrated navigation system can follow e.g. the speed profile saved in the pre-programmed route plan.

The own control systems of the propeller equipment and the main engines partly affect the changes in the speed. When the speed is increased on modern vessels, the main engines' own load control automation delays the increase of the propeller pitch and the number of revolutions. In this way the user can usually safely ask for the propeller performance to be increased without this leading to an overload of the main engines. This also applies to the automatic speed control. In a speed profile saved in the route plan, the increase of speed can vary e.g. from twelve knots to twenty knots when one point of definition is used (Figure 71). In an acceleration situation the flow rate of water over the rudder increases, and this has a positive effect on the manoeuvrability of the vessel. Thus it is safe to increase speed if it only is possible with respect to the fairway area and traffic situation.

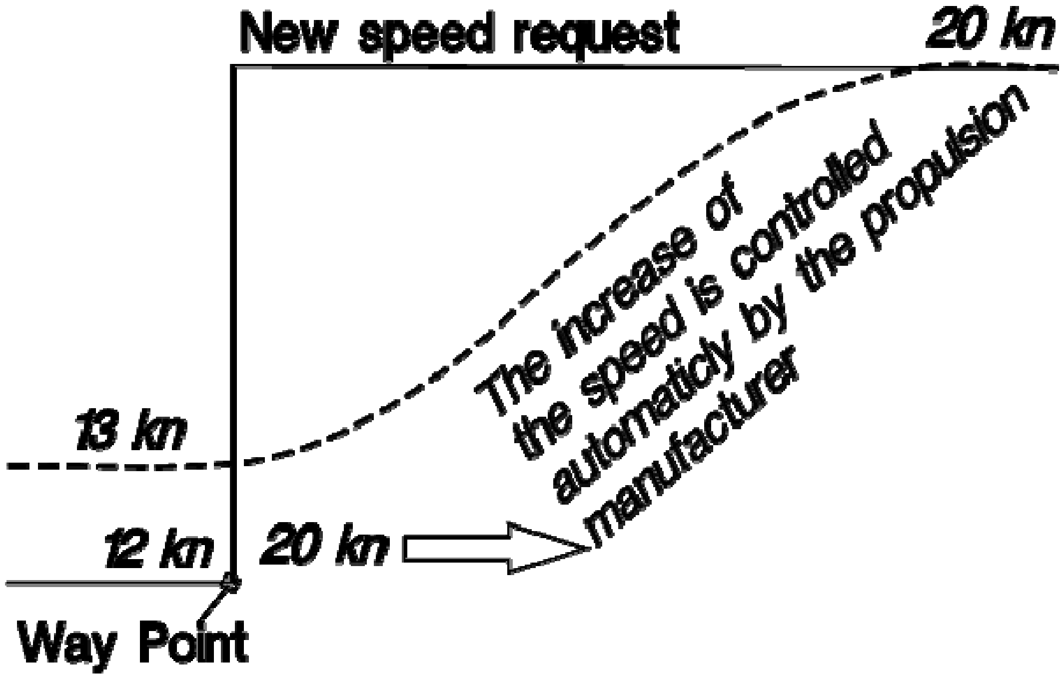


*Figure 71. The speed setting in the waypoint is 20 knots. It is possible to increase speed from twelve knots to for example twenty knots by one change.*

The situation is different when the speed is reduced. Because decreasing propeller performance does not cause overload problems to the main engines, reduction of the propeller pitch and number of revolutions only depends on the response of the control mechanics. When the speed is reduced, the propeller thrust can drop to zero in a couple of seconds. The manoeuvrability of the vessel must thus always be taken into consideration when reducing speed and speed must be reduced carefully. This factor must be taken into consideration also when defining the speed profile in the route plan. If the automatic speed control of the route plan does not include protection logic to change the track speed, the speed must be reduced gradually along the track (Figure 72). This can happen by adding into the route plan several successive points of definition, in which the speed is changed by small steps. It is safest to determine the change points of speed on the straight sections of the route. The system can also include a parameter, which is set separately. It determines the rate of reduction of propeller performance. One single waypoint is enough to change speed in that case, and the automatic system takes care of reducing the speed of advance gradually in such a way that the vessel does not lose its manoeuvrability.

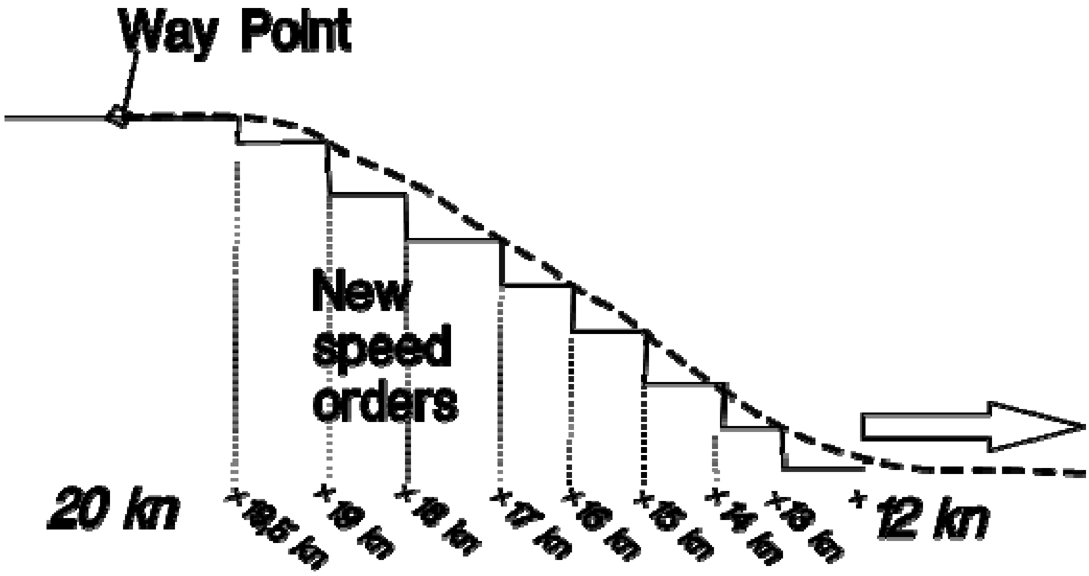


*Figure 72. The speed of the vessel is reduced in the route plan first by e.g. half a knot and then with the intervals of one knot. The distance between the point of definition is e.g. on a ro-ro vessel approximately one vessel length. The distances defined for tankers are longer.*

All the levers of the engine order telegraph located on the bridge usually follow the changes in setting of the active manoeuvring place or the automatic speed control. In that case it is possible to follow the functioning of the automatic system easily by monitoring the movement of the levers of the engine order telegraph. In that case it is easy to switch off from automatic control, because the switch should never generate a change from one speed mode to another.

The control mode which controls the speed according to the schedule is called e.g. *Arrival Mode*. The desired time of arrival to the port of destination is fed into the system, and the programme calculates the target speeds for different track legs by taking the speed restrictions into account. If the time of arrival is set too early, the programme calculates the schedule at the maximum allowed speed profile, and tells the user how much the vessel will be late. The automatic system thus always follows the speed restrictions which are saved in the route plan despite the schedule.

It is usually possible to set the limiting values to the automatic speed regulator; the regulator functions within the limiting values. The appropriate regulating limit is ± 0.2 knots in sheltered fairways and ± 2.0 knots at open sea. It is also possible to set the maximum value of speed restrictions. Moreover, it is useful to set the alarm limit of low speed, because it gives a pre-warning of too low a speed, which would cause the loss of manoeuvrability.

It is difficult to follow the changing speed restrictions of a fairway in the archipelago, because the changes in the propulsion performance slowly affect the vessel's speed of advance. The major advantage of the automatic speed control system is how easy it is to follow the speed limits. The automatic speed control allows the person providing pilotage to concentrate on keeping the course and monitoring position determination. Quick reduction of speed in special situations must always be done by using manual steering.

## 7.3 Development of pilotage

### 7.3.1 Display modes of radar and automatic steering

The IMO has defined the minimum requirements for radar displays, but these requirements have not been written bearing the foundations of the pilotage in mind. As to the displays of the automatic steering devices, the IMO has so far not come forth with any kind of requirements.

The IMO's NAV Sub-Committee has delegated the design of the displays of navigation systems to the IEC (International Electrotechnical Commission). The IEC working group number 13 has worked with this task already for several years. The sole responsibility of the IMO member states is with respect to maritime experts participating in the working group.

One pilot expressed his view of radar display by saying that he looks at it as if it were landscape. This well describes the character of pilotage. Relative navigation has earlier come up in the description of pilotage, i.e. the person providing pilotage has not defined the vessel's position and motion state as absolute with reference to the coordinates of the globe, but rather as relative with respect to the surrounding terrain. The landscape has provided the necessary information about the vessel's position and motion state. The observation has therefore been away from oneself (inside-out), and the piloting work has not been perceived as a chart picture (outside-in), even though the pilot has had to know the chart by heart. Determining the vessel's motion state has been based on observing the relative movement of fixed targets, and understanding the motion state has helped to identify the vessel's future position. The display mode of the radar display which is described next is also based on this natural course of action. In this study this mode is called PILOT MODE.

What the pilot said about comparing the radar and outside with each other refers to the fact that pilots wish the orientation of the radar image to be the same as the view which can be seen from the window. Pilots want to see the targets on the radar screen in the same relative bearing as in the window. PILOT MODE can be well realized by the double-stabilization of the radar (Figure 12). When the vessel turns to starboard, the bow line turns to starboard. But at the same time the radar turns the whole picture an equal degree to port. The bow line thus remains in its position, and the targets move to port as does the scenery seen from the window. The own vessel symbol on the radar screen remains stationary. This corresponds with the HEAD UP display. In addition to this, another stabilization with reference to true motion is done. True motion is also realized normally: the vessel's speed, i.e. the distance it proceeds, is stabilized.

The vessel moves forward on the radar screen, but at the same time the image is drawn backward the same distance. In that case the own vessel remains stationary on the radar screen, and the fixed targets are met without afterglow. The moving targets leave an afterglow which corresponds with true motion. The radar image then corresponds with the view from the window. This display mode can be realized within the framework of the IMO's technical requirements[173].

The IMO requires that radar equipment must be able to display the navigation lines[174]. In its simplest form it is a broken line, which lacks the turning radii of the route plan. The broken line of the PILOT MODE helps the pilot to perceive the vessel's deviation from the fairway line. The fairway line can be locked at the correct place in the radar image with the help of the position information obtained from the satellite navigator. The fairway line is presented on the radar display according to the graduation representing true motion.

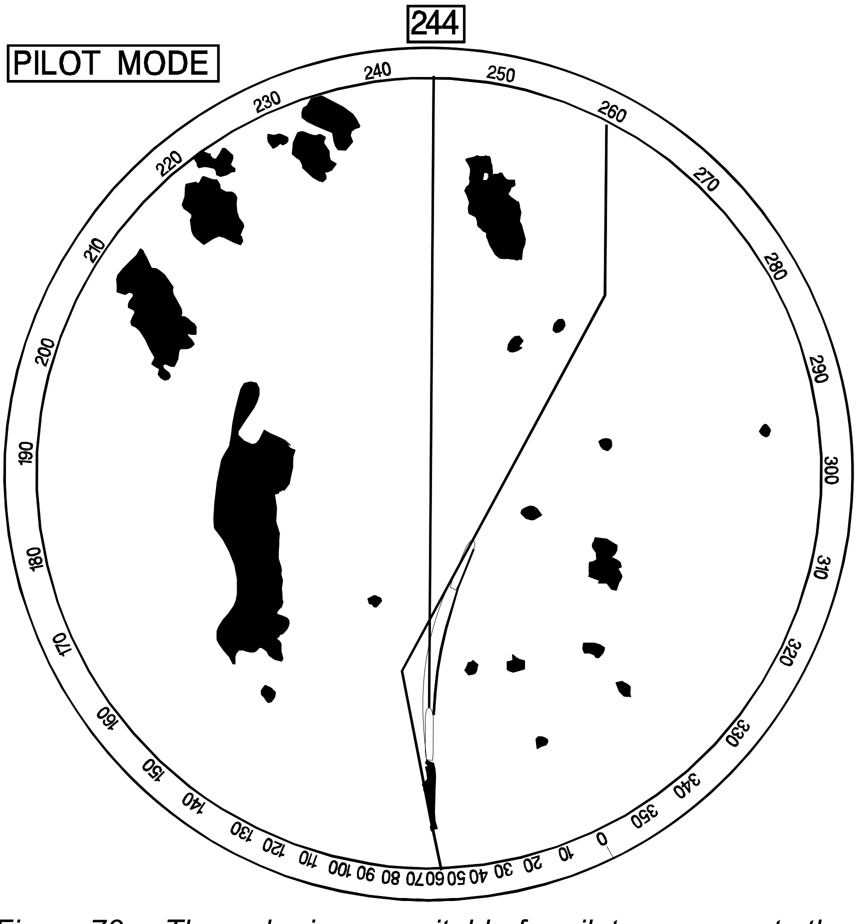


*Figure 73. The radar image suitable for pilotage supports the traditional way of piloting and illustrates the vessel's motion state graphically.*

[173] IMO resolution 192(79) 2004, Annex, paragraph 5.20.2: *Head-Up may be provided when the display mode is equivalent to True Motion with a fixed origin (in practice, equivalent the previous relative motion Head-Up mode).*

[174] IMO resolution 192(79) 2004, Annex, paragraph 5.32

Perceiving the motion state is made easier in PILOT MODE by showing the temporary motion state graphically with the help of the predictor.

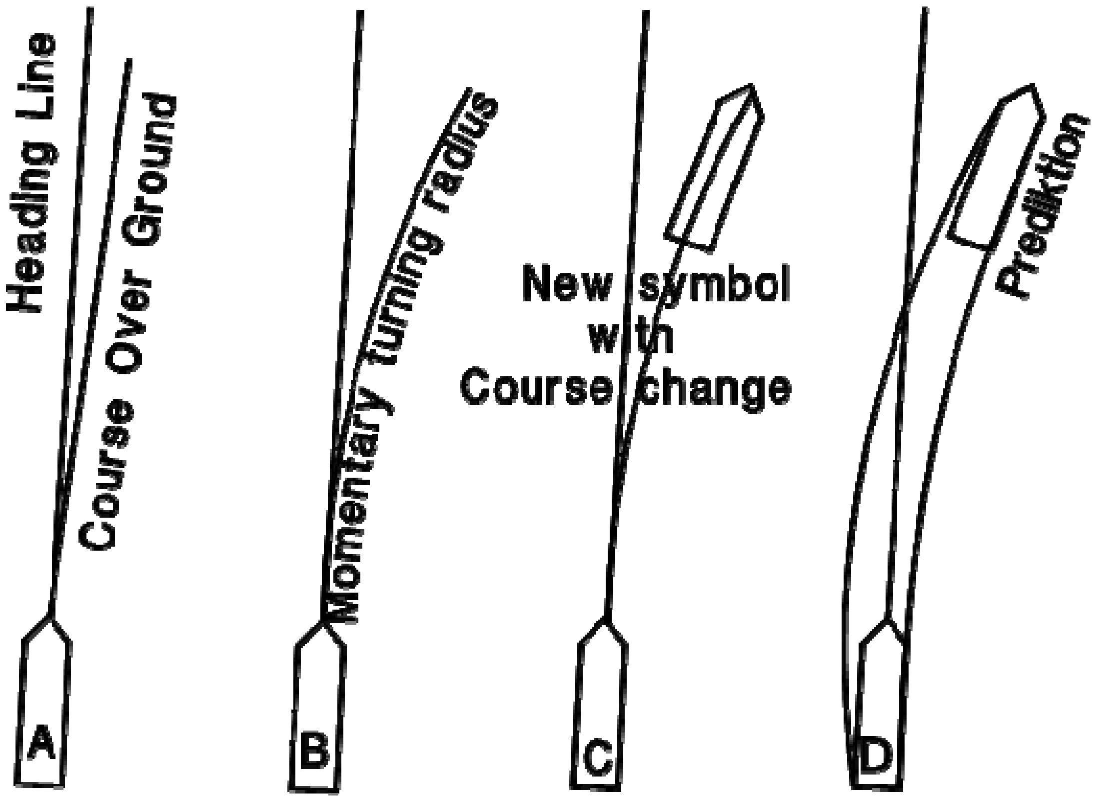


*Figure 74. The structure of the predictor.*

Point A in Figure 74 illustrates the vessel's motion vector in relation to the ground (COG, Course Over Ground). The vessel's instantaneous turning radius is tangeant to the motion vector, Figure 74 B.

A suitable time period must be chosen for the prediction. The suitable time usually varies between 30 and 60 seconds. The vessel's predicted position and heading are drawn at the end of the prediction (Figure 74 C). Finally, the swept path used by the vessel is drawn. The curved line has been removed from Figure 74 D for the sake of clarity.

The PILOT MODE display can be installed on all modern radars. New sensor connections are not needed, because the display mode can be realized by programming. New radar equipment includes at least the HEAD UP, STABILIZED RELATIVE and TRUE MOTION display modes. Many devices also include the COURSE UP display mode. PILOT MODE could be one display mode option alongside with the others.

When working on PILOT MODE, the pilot only adjusts the screen of the radar display and the length of the predictor. The control of the predictor's length could be combined with the control of the length of the traditional speed vector.

A simulator study has been carried out on the principle of the PILOT MODE display mode. The objective of the study was to find out the effects of the radar display on the accuracy of manoeuvring. The simulator test was realized in cooperation with the State Pilotage Enterprise (Finnpilot), Sydväst Sjöfart (present Aboa Mare) and the Accident Investigation Board. It was carried out in the Sydväst Sjöfart premises in Turku, Finland. Nine pilots and six Sydväst Sjöfart students acted as test subjects.

The simulator test included 90 simulations in five days, and each participant took altogether six tests in three different fairway sections using two different display modes. The test subjects were told the vessel's type and size and the wind conditions and they were given the information that there was no other traffic in the area. After each simulation run the participants were asked about their sentiments and about their experiences on how the simulator test had gone and how the display mode had affected the test. The runs were recorded in a database for more detailed analysis. The ship model of a 170-metre-long passenger-vessel was used in the simulation.

The information about the vessel's motion state was available for the test subjects in all the simulations. The steering of the vessel was carried out by using the FU lever. The persons providing pilotage acted themselves as helmsmen. The fairway line with its turning radius was presented on the radar display. This was used to make it easier for the test subjects to determine the route in the unfamiliar radar scenery. In this respect the test arrangements differed from the situation which the external pilot typically encounters when arriving on the bridge.

The other display mode used in the test was the normal, traditional gyrostabilized NORTH UP display with a TRUE MOTION setting. This is nowadays the most usual display mode employed when using the radar. It is easy to compare this kind of radar image with the chart, because in both of them the north direction is presented upwards. The usual speed vector presenting the vessel's speed over ground was presented on the radar display.

The pilotage display was imitated in these test arrangements with the help of the HEAD UP display. The problems connected with the HEAD UP display in observing moving targets were not a problem in the test, because the test subjects were aware of the fact that in the simulator runs there was no other traffic in the fairways.

A predictor was presented on the pilotage display to make it easier to perceive the vessel's motion state. The predictor pointed out the vessel's presumed position and the swept area after one minute calculated from a momentary motion state. Because the predictor takes into account the turning of the vessel, it also gives a more accurate and illustrative prediction about the vessel's future movement than the traditional double-component vector.

The fairway sections were first navigated by using the PILOT MODE display, after which the same three fairways were navigated by using the normal display. This order was used to ensure that if some learning occurred with reference to the fairways or the vessel during the simulator runs, it would improve the performance especially when using the traditional display mode. The test results were analysed for each fairway with the help of the time history of the track logs and rudder angle.

As to the time history of the Rate-Of-Turn, it can be concluded that the intensity of yawing is lesser when using the PILOT MODE than when using the traditional display. The most probable factor affecting this was the predictor, which quickly displayed the changes in the vessel's tendency to turn. Another influencing factor might have been the clear difference between port and starboard caused by the HEAD UP display mode. It made it easier to identify the correct course of the corrective order when the vessel turned.

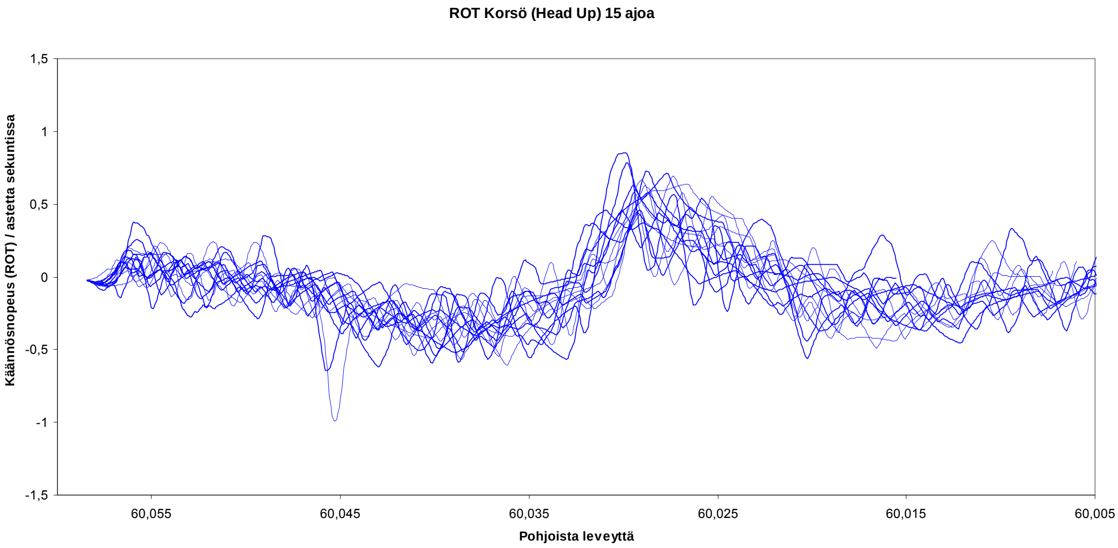


*Figure 75. The time histories of turn speeds recorded in the simulator runs when using the display mode imitating the PILOT MODE display.*

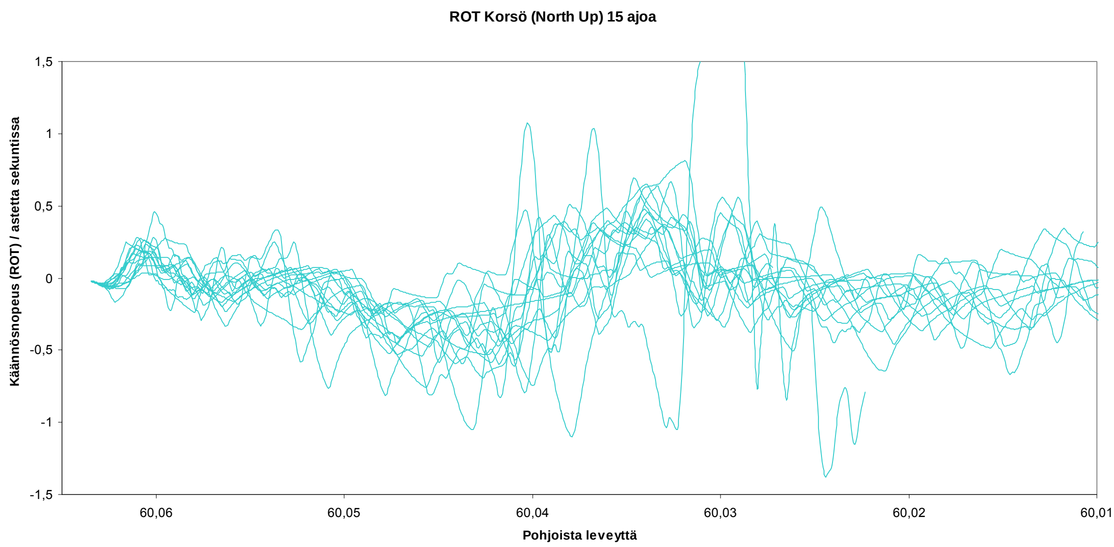


*Figure 76. The time histories recorded in the simulator runs when using the traditional display mode.*

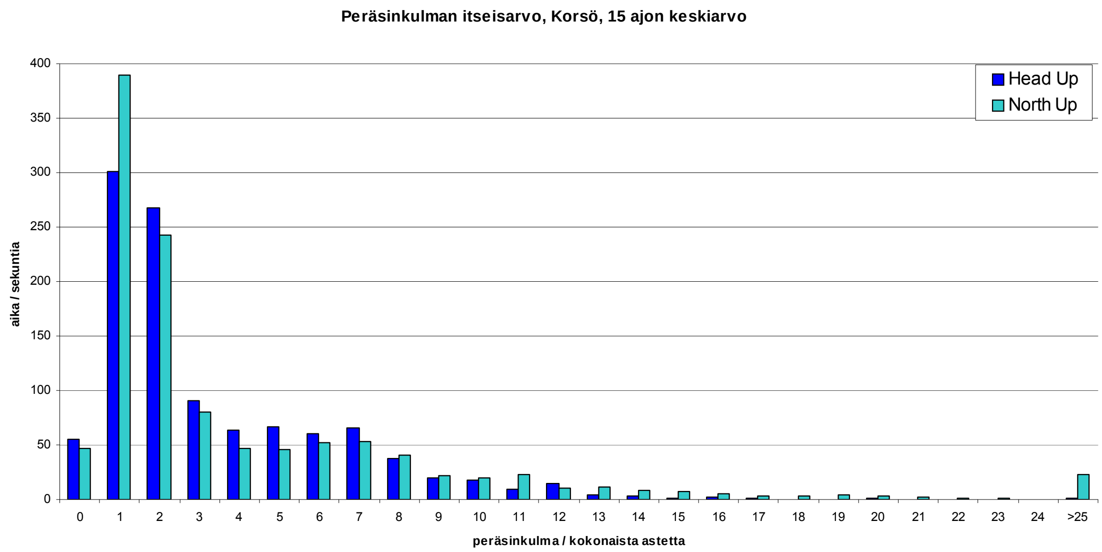


*Figure 77. Comparison of the rudder angles used in simulator runs. The Head Up definition in the figure refers to the PILOT MODE display.*

To summarize the findings about rudder angles it can be said that in the runs in which the normal display was used the rudder was held more midships than when the pilotage display was used. When the pilotage display was used, the manoeuvres were clearly more concentrated close to the rudder angle of approximately 7°. The most typical rudder angle used with the normal display was somewhat bigger, and the variation of rudder angles was higher. When the normal display was used, large rudder angles were also used more.

Using the PILOT MODE seemed to be more reliable, and there were less course errors than when the normal display was used. However, the test subjects also did better than had been expected when using the traditional display. This may be an indication of the fact that the adaptability of the human being is good also when it comes to apparently inferior systems. The facts that the test subjects had years of experience of the characteristics of the traditional display mode and that they usually use it in their work had an effect on the results of the test. Some of the test subjects also admitted that '*in a tight, narrow passage*' they sometimes use a Head Up display mode similar to the pilotage display, others said that they had used it only '*when forced to'*. The distrust of the reliability of the predictor affected the results – at least when it came to some of the test subjects: *'I only used it every now and then'* and *'I did not follow the predictor as I don't trust them on vessels either'* were some of the comments. Some test subjects compared using the predictor with playing on a computer: *'You don't have extra lives, but everything goes well if you remain in the black area away from the coloured area.'*

Despite several years' experience, most of the test subjects were surprised at how difficult it was to switch from the pilotage display to the normal display and how much mental effort it required. Many of them felt that in real pilotage performed on a vessel they did not have to think as much about the direction of the port and starboard as in the simulator. Some of the test subjects, however, felt that this was due to the fact that they had not paid attention to this matter before as there had not been any point of comparison, but it had been normal when working with radar. Almost all the test subjects were of the opinion that the pilotage display could provide much assistance in pilotage.

The PILOT MODE described above is easy to realize technically in the current radar devices, and according to the study it constitutes a clear improvement in pilotage. The computing capacity of navigation equipment is also adequate to create increasingly versatile display modes. The suggestions as to the interfaces of the future integrated navigation equipment are dealt with next.

Radar displays could include the possibility to present chart information needed by the user. The contents of this information vary according to the sea area in question. It is usually not possible to show a complete chart image, as the echo areas of the radar are not discernible from the dense chart information. Figure 78 illustrates a situation in which Utö is approached from north along a 15-metre fairway. The chart information of the display device is rather simplified, but it is adequate to give a clear picture of the situation, and excessive amount of information does not interfere with the image.

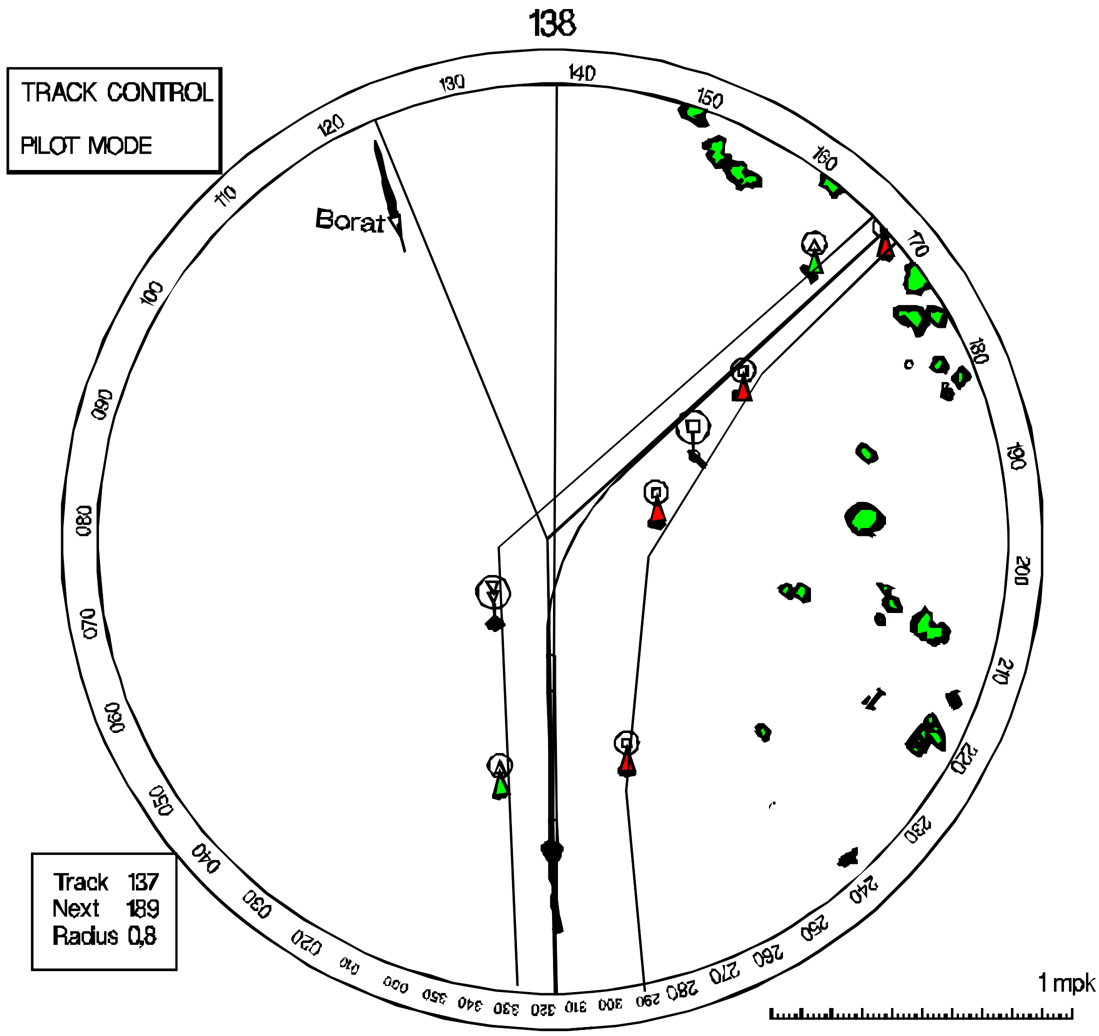


*Figure 78. Integrated radar display, where information from an electronic chart and route plan has been incorporated.*

The radar display in Figure 78 is from a scope of 1.5 nautical miles. In the PILOT MODE display the moving targets present true motion, and fixed targets do not leave afterglow. The automatic control steers according to the route plan (Track Control). There are less than two minutes to the beginning of the turn in the situation illustrated in the figure above. The course is 137°. The turning radius is 0.8 nautical miles and the following course is 189°.

The display mode (PILOT MODE) and the control mode of the automatic control (TRACK CONTROL) are marked on the side of the radar image. The most important information of the waypoint is the turning radius and the desired course which follows the turn. A waypoint can also include standard procedures belonging to the route plan, e.g. a speed restriction or VHF announcement.

The electronic chart information presents the islands on top of the radar echoes. As to the islands the radar echoes can be seen somewhat bigger than the chart information, because the antenna signal of the radar makes the targets wider.

The user can monitor the errors of the compass and the position determination device by comparing the transition between the chart information and the radar targets. In the example the course information obtained from the compass is correct (no angle of deviation) and the position determination is accurate (no directional glide).

The fairway area, which had been swept to 15.6 metres, clearly marks off an area, the edge of which should not be crossed. There is no need for depth contours, because the swept area clearly defines the fairway space which can be used. The fairway line, the floating navigation marks, the Edge Marks and AIS targets should be displayed. The figure also shows the vessel's own route plan.

The displays of automatic steering devices are usually full of numbers. The number of digits has only increased along with the development of the devices. The information related to steering could also be presented in the form of an illustrative graphical figure, which could replace most of the numerical information. The display orientation of the autopilot illustrated in Figure 79 is Head Up as on the radar. The figure is three-dimensional, and the viewing point is diagonally above behind the vessel. This display mode illustrates well the fairway space around the vessel, and at the same time it shows the vessel's own movement. The global coordinate system is presented as a grid, which moves according to the vessel's speed towards the bottom of the image. Several alternative scales can be chosen to the image. The grid clearly shows the vessel's transverse deviation with reference to the navigation line and the distance to the nearest fairway limit or track limit.

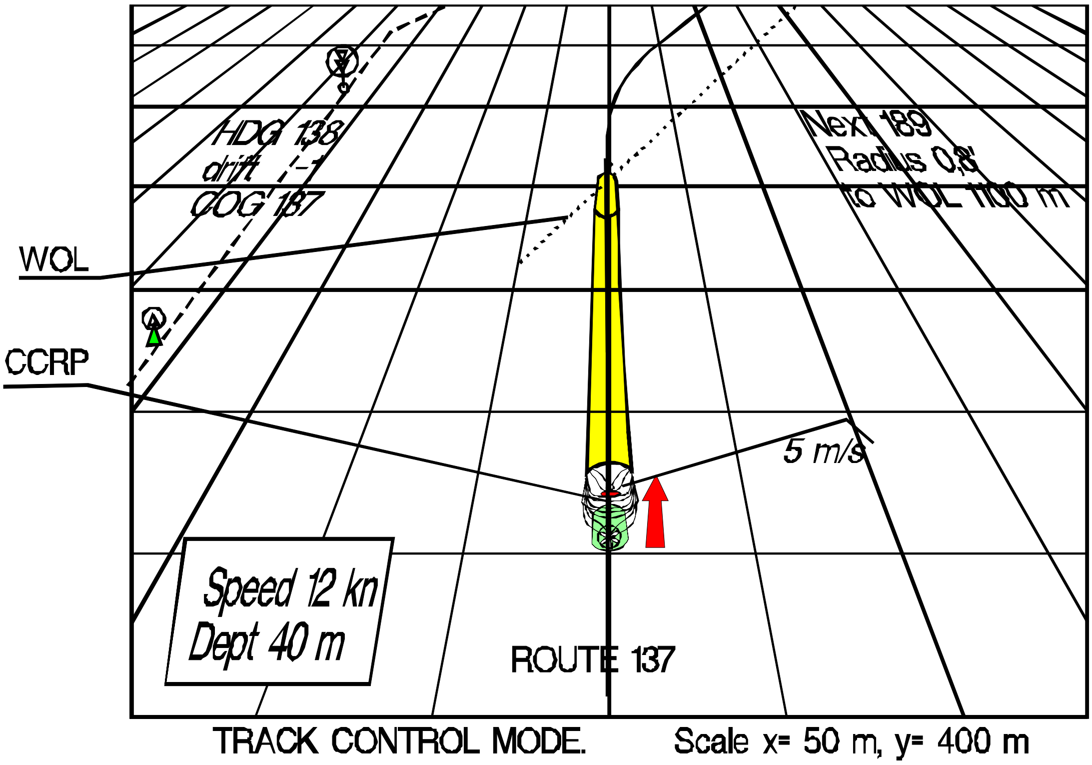


*Figure 79. The three-dimensional display of the automatic steering. The display orientation is Head Up.*

In the figure the vessel is presented as a simple, transparent body plan. The animated rudder moves according to the information given by the rudder angle indicator. The image can be zoomed in in such a way that the movement of the rudder is clearly visible. In that case the image can also be used in manual steering. It is easy to illustrate the rotation or the stopping of the propeller. The vessel's shadow is shown in perspective so that it is visible against the sea bed, in which case the size of the shadow changes according to the depth of the water. The engine power is presented with a red arrow next to the vessel. In this display the predictor is reproduced graphically.

The CCRP (Consistent Common Reference Point) is a point defined by the IMO[175]. All the information from the position determination antennas and sensors is presented in relation to this point. Figure 79 illustrates the display of TRACK CONTROL automatic steering in the control mode. The automatic steering starts the turn when the CCRP meets the WOL (Wheel Over Line).

The graphical display mode may require some numerical information as its support. The most important realized information about the motion state includes compass heading (HDG), course over ground (COG) and drift angle. Another group is the most important planned route information, i.e. the new desired course, turning radius and distance to the following turn. It is also good to present the depth of water and speed as alphanumerical information.

[175] IMO, Resolution MSC.192 (79), 2004 amendments, par. 5.9 Radar measurements - CCRP

Figures 80 and 81 illustrate display devices when the vessel is steered manually after the departure from the port of Turku. In Figure 80 there is a lot of chart information but very little radar information. In the display of the autopilot (Figure 81) the water area is illustrated by the chart information about the dredged fairway. The EBL taken from the radar illustrates the starting point of the turn in a situation, in which it is tangeant to the point of Ruissalo. The predictor shows that the vessel is starting to turn. The objective in the figures is to navigate close to the starboard buoy.

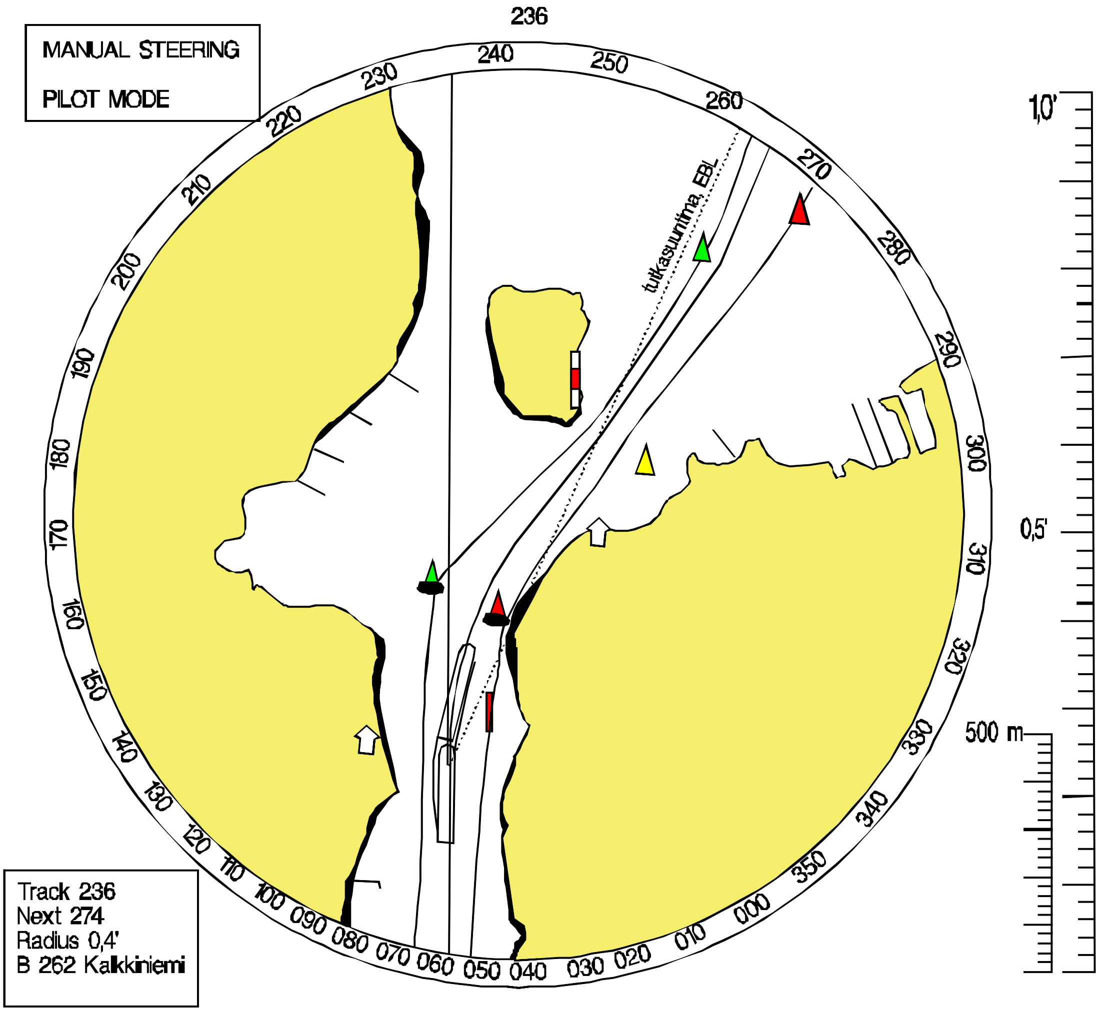


*Figure 80. An example of a radar display from along the fairway leading out from the port of Turku.*

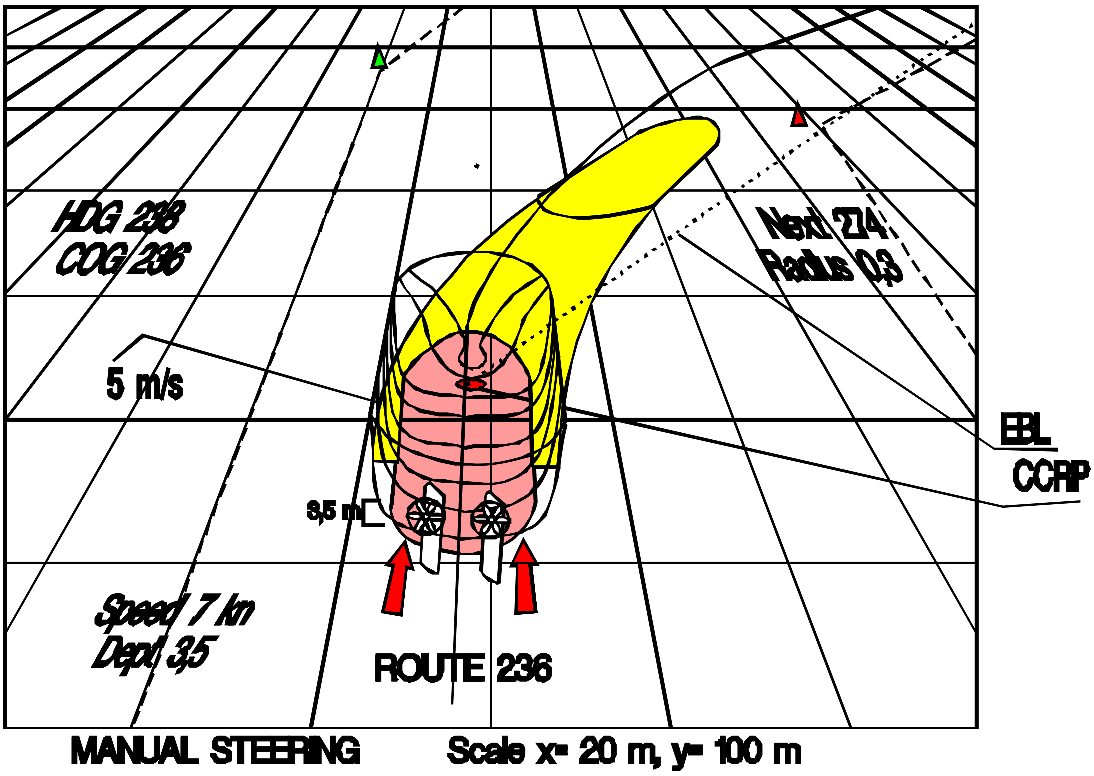


*Figure 81. The display of an automatic steering device when in manual steering.*

In this pilotage situation the scale of the display of the automatic steering has been chosen small so that the space required by the vessel is clearly visible. The red arrows illustrate the thrust of the main propellers. In the figure the rudders turn according to the rudder angle, which means that their display also shows the rudder angle. The numerical values of the heading and the true motion are secondary in this manoeuvring situation, because only the edge lines and the navigation line affect the manoeuvring. The vessel is steered with FU manual steering, and the monitoring seafarer adjusts the power of the main engines and the speed of the vessel. A wind arrow can also be brought to the image to show the direction from which the wind blows. The water depth measured by the echo sounder is presented between the vessel's bottom and the shadow under the vessel (Figure 81).

Presenting depth information requires a more detailed study. Only how the measured information from the echo sounder can be used to illustrate depth has been outlined here. The grid can, however, give a misleading conception that the water area continues to be of the same depth in the fairway. Figure 81 also gives the impression that the depth of the water is the same also outside the fairway area. The image must, however, be interpreted in such a way that the depth measured by the echo sounder only applies to the fairway area at the place where the vessel is.

The chart information obtained from chart institutes does not support presenting depth contours three-dimensionally, because the normal S-57 chart information is not comprehensive enough, even if sounding information had been gathered at frequent intervals at sea. As to the swept areas there is e.g. so much certainty that it would be possible to use chart information about them in a three-dimensional form. All the sounded depth information cannot be fitted to be presented on nautical charts, so the amount of information is reduced by leaving out less essential data.

### 7.3.2 Bridge design

The objective of modern bridge design is to create prerequisites for efficient bridge work at a high safety level. In addition to technical arrangements, integration of equipment design can also be extended to pilotage in such a way that operational preconditions are created for a closely cooperating team of two persons. The objective of teamwork is that these two persons can reach an equal level of performance. Pilotage and its monitoring are most efficiently carried out if the workplaces of the persons are situated close to each other.

In practice the person providing pilotage is simultaneously able to concentrate on operating a maximum of two devices. The radar and automatic steering are the most important ones. Radar displays are situated in front of both workplaces, and the automatic steering display is placed between the radars (Figure 82). The electronic chart or ECDIS can be placed in the middle of the console above the display of the automatic steering. The visibility straight ahead must, however, be taken into consideration in these arrangements. This is especially important in winter conditions when the changes in the ice coating have to be observed visually. If the automatic steering display is located high, a chart display cannot be installed above it without impairing the visibility straight ahead. In that case the chart display must be placed to the side.

The equipment console, in which the automatic steering display is built, should be as narrow as possible, only approximately 40-45 cm in width. This is due to two factors: firstly the persons working as a pair must be able to compare the images on the radar screens with each other, and secondly it must be possible to use the control devices from both workplaces. If the person who provides pilotage is left-handed, he/she must have equal work conditions with the persons who are right-handed. This is only achieved if the middle console is narrow enough.

There should be enough space in front of the navigation console so that there is space to service the equipment which is installed in the console. Another reason for installing the console at an adequate distance from the windows is that the sun cannot shine directly on the displays of the navigation equipment. A compact navigation console which is designed around two workplaces does not provide space to install all indicators. Therefore a separate instrument panel is needed. It is placed in the ceiling of the bridge, in a place which can easily be monitored from both workplaces. This *overhead* panel is usually installed on top of the windows, and as it should be easy to monitor the indicators in it, this provides another reason for placing the navigation console at an adequate distance from the front windows.

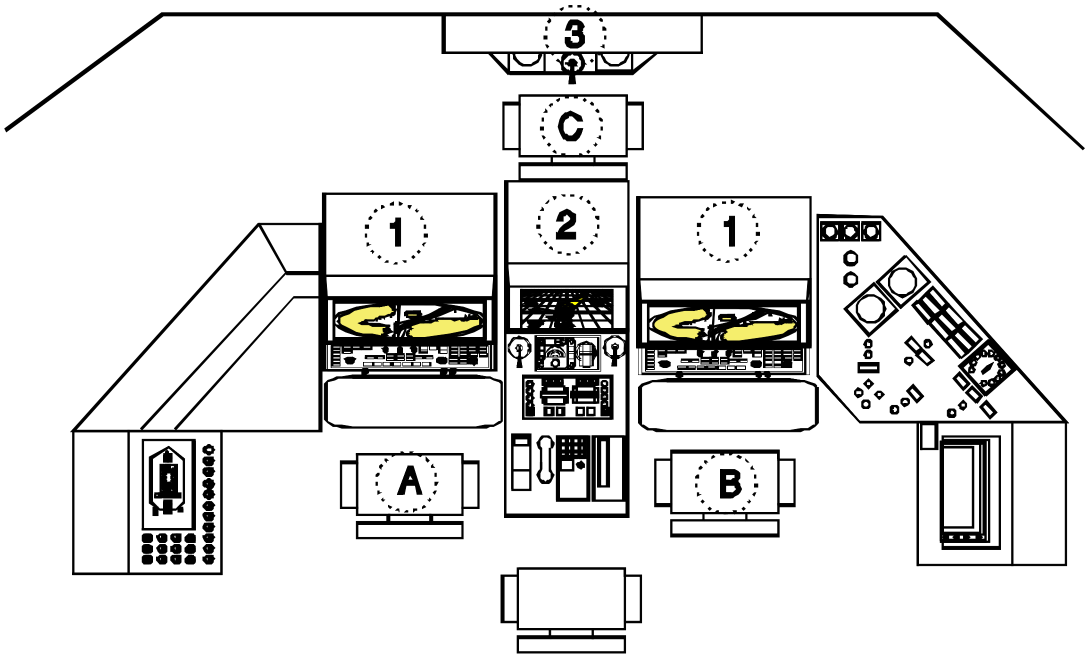


*Figure 82. The objective of the design of the control and navigation console is to realize both the technical integration and the integration of the pair work in piloting.*

The workplaces of integrated navigation equipment are defined as follows:

A. A pilotage workplace for a right-handed person. The control devices are within the reach of the right hand. The workplace can be used by a state pilot, the master or the officer practising pilotage.

B. Normally pilotage is monitored from workplace B, but a left-handed person can perform pilotage in this workplace.

C. The helmsman's workplace is in front of the console. The windows must reach low enough so that the helmsman can e.g. see the edges of an ice channel as well as possible. It must be possible to see over the helmsman from the workplaces A and B.

The usage of the workplaces A and B should not be tied to the rank of the crew members. One advantage of the bridge arrangement is the possibility to give efficient pilotage training, because the uniform performance level among the bridge officers constitutes the basis for safe navigation. On the basis of this principle, all the officers of the vessel must learn to provide pilotage even though they are not taking the pilot examination. The international requirement, according to which the officer in charge of the navigational watch must be able to monitor pilotage, also aims at this objective. It is impossible to fulfil the objective if the OOW cannot provide pilotage himself/herself.

Arranging the navigation equipment around the workplaces:

- Two identical radar displays; the control of automatic steering is included in their user interfaces. The important information from the electronic chart is displayed on the radar screens. The route plan should always be displayed.

- The middle console must be as narrow as possible. It includes the NFU and FU controls of the rudders and propellers as well as the VHF radio telephone. The joystick control integrates all the control devices into a small space in an excellent way. Because of the restricted space, the FU levers of the bow thrusters and the control levers of the servo-motors of the floodlights can be placed in the ceiling above the console. The automatic steering display is located between the radar screens.

- Rudder angle indicators and the angular velocity gauge are located in the middle of the overhead panel above the windows. The engine meters are placed on the other side. These include for example the main engine revolutions, the propeller pitch and the ammeters of the bow thrusters. The anemometer, the compass display, the Doppler log and the echo sounder are placed on the opposite side.

Bridge wings have traditionally been designed without taking pilotage adequately into account in a situation when the vessel is reversing. It may be impossible to turn a large vessel in a confined harbour basin. Therefore the vessel is perhaps backed for long distances before it reaches an area where it is possible to perform the turn. It would be a good idea to design the bridge wing in such a way that the control device console would be as close as possible to the outer edge of the wing. It would be a definite improvement if it was possible to steer from both sides of the console in such a way that it would be possible to stand on the bow side of the console when reversing. It is advisable to place the control devices, the electronic chart and the meters in such a way that they are equally visible both when reversing and when sailing ahead.

If the visibility astern is poor, an officer must be present at the stern when reversing. He/she then informs the bridge about possible obstructions. The reversing manoeuvre must be preceded by a short discussion, in which it has to be explained to the officer that the reversing takes place according to the information he/she provides.

# 8 SUMMARY

The word navigation is used to mean simultaneous position determination, manoeuvring and control of the vessel's dynamic state. Navigation starts when the vessel begins to move and ends at the port of destination. The objective during the whole voyage is to stay on the pre-planned route. Meeting this objective includes the simultaneous control of position determination and steering.

When the vessel makes way at open sea, the measures described above are adequate in order to guarantee a safe voyage and arrival at the destination. When the vessel approaches a coast, the narrowing of the fairway space forces the navigator to estimate the developments in the motion state of the vessel in closer detail. At the same time the significance of position determination decreases, and predicting the vessel’s motion state in the fairway becomes the most important duty. This means that the position and the movement of the vessel are estimated with reference to the surrounding terrain. This task consisting of precision navigation in limited fairway space is pilotage. Pilotage has traditionally been carried out by a pilot not belonging to the crew, i.e. an outsider.

The development of legislation during several centuries makes it clear that the state and the authority have never taken responsibility for the pilot’s work. When accidents happened in the past, the pilot had full liability for damages. The sentences passed on pilots have also been much harder than the sentences passed on other seafarers. During the Swedish rule a pilot was an important government official within the armed forces. He swore an oath to the king not to reveal his information about the fairways to outsiders. Fairways were marked inaccurately on the charts, and only pilots knew the fairways well. The pilots were the king’s trusted men, and they had to remember the fairway by heart.

Even today pilotage is an act of safety, but no longer to guarantee national security. Instead its objective is to make transportation safe, i.e. to secure human lives, property and environment. The old way to use the recollection of the chart has, however, continued until our day. Still today pilots are required to know the chart from memory in the pilotage examination, even though the fundamental reason with reference to securing national safety ceased to exist as early as during the period of Finnish autonomy. The old method is considered as the prevailing good seamanship, *'ordinary practice of seaman'*, without really realizing the real origin of this way of working. In today’s society the documentation of procedures and methods of work is considered absolutely necessary. One exception to this is, however, the concept of good seamanship, which does not have a jointly drawn, objective definition.

During the first years of Finnish independence, the responsibility for pilotage was transferred to the shipping companies, as if the shipping company had inducted the pilot into office and trained him/her. The pilot's responsibilities and liabilities were defined in the 1998 Pilotage Act[176]. In the bill to the government, the pilot's responsibilities were not explained otherwise than by referring to the Tort Liability Act. The Parliament decided that the pilot is responsible for pilotage. The Ministry of Justice was not, however, fully satisfied with the bill and stated as follows:

*'It can, however, be presumed that in pilotage there are more specified liability provisions with reference to pilotage, which have developed in the course of long-standing practice and which could now be entered in the legislation.'*

The Ministry of Justice stated as follows on the liability distribution of the master and the pilot:

*'The compactness of the Pilotage Act Bill is apparent e.g. in the provision dealing with the division of duties and responsibilities between the master and the pilot. This is problematic, because the limitation of liabilities can be regarded as one of the principal main problems of the Pilotage Act, and it is important especially when it comes to the application of the liability and penalty provisions.'*

In 2006 the Accident Investigation Board published a study called *Piloting Practices and Culture in the Light of Accidents*[177]. It concluded that the development tensions present in pilotage are caused among other things by the power and liability relationships, which are contradictory to the prescribed responsibilities and liabilities but necessary in practical pilotage.

When the legislation is studied, it is found that the instructions describing bridge work in connection with pilotage which used to be in force have been removed. The pilotage instruction and the route planning instruction would be important for performing the work, but they have been revoked. In the regulations pilotage has remained a separate part of bridge work, and there is no accurate official definition of pilotage. There is no textbook on pilotage, and defining it is not a part of maritime education. There are no instructions as to performing pilotage, and how the pilotage has succeeded is estimated afterwards only through good seamanship.

176 FMA Bulletin 7/1998, Pilotage Act 90/1998, Section 7.

177 Safety Study S1/2004M (Leena Norros, Maaria Nuutinen, Kari Larjo) [only available in Finnish]

# 9 CONCLUSIONS

The lack of national regulations on pilotage does not support the development of modern operating methods. In operating without instructions, the pilot has to make decisions in his/her work that would usually be left for the employer, which also means that the pilot has had to take on some of the employer's responsibilities. For pilotage, this situation is separately regulated. This lack of instructions is the result of the extra responsibility taken on by the pilot, and it has repeatedly been observed in the investigation of pilotage accidents.

According to the modern liability regulations, the master of the vessel is responsible for the manoeuvring of the vessel also when he/she follows the instructions that the pilot gives in the role of an advisor. Because of this, the master should be able to estimate whether the pilot's instructions are correct – in other words the master should be a better expert than the pilot.

Pilots used to object to having to take the position as advisors and being the responsibility of an unfamiliar employer. There has not been enough discussion about the option that the pilot's own employer would be responsible for the work which she/he performs, as is the praxis when it comes to other employers. This change would break the distortion which has continued for over 300 years within pilotage services. One can ask if the change of liability would bring along more detailed instructions. If the answer is "yes", would these instructions have a positive effect on the safety related to operating a vessel?

If the responsibility for providing pilotage is transferred from the employee to the employer, it certainly lies within the employer's interests to clearly define on which kind of terms it is possible to bear responsibility and which conditions limit the liability during the pilotage.

As a positive consequence of assuming this responsibility, the pilot arriving at the vessel would check the vessel's route plan and the condition of the steering and navigation equipment. In light of the accidents discussed, this kind of exact checking is in practice not always carried out. The pilots would have the clear operational preconditions for checking the condition of the bridge equipment used in pilotage when they use the equipment. Only in such cases in which the vessel being piloted fulfils the conditions set by the IMO, the employer would be responsible for pilotage. This would motivate the shipping companies to take adequate care of the maintenance of the equipment.

The new definition of responsibility would thus create clear instructions on which kind of vessels and with what kind of navigation equipment pilotage is safe. This would again create a clear need to accurately define the weather conditions, in which it is possible to navigate the vessel in the fairways in the archipelago and how the vessel's crew and the pilot should prepare themselves for pilotage. As a consequence of this, defining pilot boarding and disembarkation places would become more accurate, as it would lie in the interests of both parties to clearly know, because of liability issues, when the pilotage task begins and when it ends.

Pilotage and preparing for it would thus be described, and in order to meet the objectives of this description, the training required for pilotage would also be defined in a clear manner. This definition would include the training programme, training material and the qualification requirement.

From the shipping company’s perspective, transferring the responsibility to the employer of the pilot would mean giving the pilot insurance for the duration of the pilotage. This would make using a pilot a desired option. The pilots’ opinion in this matter would certainly be the same as the shipping companies’. The pilotage fee would also be better motivated, and it would not be considered a gratuitous expense resembling a tax.

From the point of view of the pilot’s employer, the likelihood of having to pay direct compensations would grow, but as in all other functions of the society, the total safety level would increase due to training, instructions and control. This result again would lead to a reduction of the total level of expenses.

When it comes to pilotage, there could be clearer instructions on at least route planning, VTS operations and the temporary moving of pilot boarding and/or disembarkation place. In addition to this, the criteria for interrupting pilotage and the registration of dangerous situations performed at the VTS stations would require instructions. Checking the route plans could be incorporated in the annual inspections of the vessels. Also a theoretical textbook on pilotage would help in achieving qualifications in accordance with regulations. Including it in the curriculum of masters would also be worthwhile.

In the current situation, the lack of instructions with reference to pilotage certainly lowers the threshold to found new companies which offer pilotage services as the responsibility for pilotage and the possible expenses caused by accidents are to be borne by the shipping companies. Competition in itself certainly makes the supply of services more diverse, and in the long run in the end increases the level of services, which can be seen in the history of the Western democracies. But as the safety and security requirements quickly increase, can we afford the luxury to wait for the matters to improve without national instructions?

Referring to the division of liabilities presented in the conclusions of this Safety Study and to the Ministry of Justice's pronouncement on the Pilotage Act Bill[178], the Accident Investigation Board finds that it is of outmost importance that the Ministry of Transport and Communications set up a working group to compile a report on the measures required if the pilot's liability is transferred onto the employer.

Helsinki 18 May 2010

Kari Larjo

Jaakko Lehtosalo

Karl Loveson

[178] The Ministry of Justice's pronouncement to the Ministry of Transport 19.9.1995, record number 2307/43/95.

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**INVESTIGATION REPORTS CONNECTED TO PILOTAGE**

| *Number* | *Accident or incident* |
|---|---|
| B 1/1997 M | Inland Passenger Vessel ms UKKO, Grounding in Lake Kallavesi |
| B 1/1998 M | Passenger Hydrofoil LAURA, Grounding off Helsinki |
| B 1/2001 M | Passenger-car ferry MS ISABELLA (FIN), grounding near Staholm in Åland archipelago |
| B 1/2004 M | M/V FINNCLIPPER (FIN), Grounding off Kapellskär |
| B 5/2004 M | M/S GLOBAL FREIGHTER (FIN), Grounding at Kalvholmsgrundet |
| B 7/2004 M | Ms SUPERFAST VII (GRE), Grounding off Hanko |
| B 8/2004 M | Passengercarferry MS ALANDIA (FIN), Grounding near Uumaja |
| B1/2008M | M/S TALI (FIN), grounding in Jössingfjord, Norway |

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|---|---|
| C 1/1997 M | Training Vessel ms KATARINA, Grounding off Kotka |
| C 2/1997 M | General Cargo Vessel ms MARJESCO, Grounding at Puumala |
| C 4/1997 M | Ro-ro Passenger Vessel ms FINNMAID and Road Ferry ms MERGUS, Collision at Smörgrund |
| C 5/1997 M | Inland Passenger Vessel ss LEPPÄVIRTA, Grounding in Lake Saimaa |
| C 6/1997 M | General Cargo Vessel ms HÄLSINGLAND, Grounding off Kalajoki |
| C 11/1997 M | General Cargo Vessel ms GRIMM, Grounding Outside Port of Kotka |
| C 15/1997 M | General Cargo Vessel ms MARIE LEHMAN, Grounding on the Fairway to Tammisaari |
| C 16/1997 M | Chemical Tanker mt CRYSTAL AMETHYST, Grounding off Mussalo Harbour in Kotka |
| C 2/1998 M | General Cargo Vessel ms JULIA, Grounding in Kustaanmiekka Sound off Helsinki |
| C 4/1998 M | General Cargo Vessel ms GERDA, Grounding Outside Port of Kotka |
| C 5/1998 M | General Cargo Vessel ms BALTIC MERCHANT, Grounding in Puumala at Hätinvirta |
| C 9/1998 M | General Cargo Vessel ms CHRISTA, Grounding off Kotka |
| C 11/1998 M | General Cargo Vessel ms GARDWIND, Grounding off Kotka |
| C 13/1998 M | General Cargo Vessel ms TRENDEN, Grounding off Rauma |
| C 1/2000 M | MS OCEAN PRIDE (NOR), Grounding at Orrengrund |
| C 2/2000 M | Ro-ro Vessel ms AURORA (NOR), Dangerous Incident and Grounding South off Helsinki Pilot Station Harmaja |
| C 4/2000 M | M/AUX ASTRID, Grounding off Helsinki |
| C 6/2000 M | MS TUULISPÄÄ, Grounding off Helsinki |
| C 9/2001 M | Ms CINDY (FIN), Grounding South of Järsö in Ahvenanmaa |
| C 2/2002 M | Ms CITY OF SUNDERLAND (IoM), Grounding off Hanko |
| C 3/2002 M | DOURO CHEMIST (POR), Grounding at Lövskär Junction area |
| C 4/2002 M | Pusher STEEL and Barge BOARD (FIN), Grounding at Nordvalen in the Gulf of Bothnia |
| C 7/2002 M | Pusher Barge PÖLLI 7 (FIN), Grounding at Kyrönsalmi near Savonlinna |
| C 11/2002 M | Ro-Ro Vessel ms GARDEN (FIN) and General Cargo Vessel ms VINGAREN (SWE), Collision at Drogden in Southern Baltic Sea |

| | |
|---|---|
| C 12/2002 M | Cargo Vessel ms TRAVEBERG (FIN), Grounding in Ruotsinsalmi, off Port of Kotka |
| C 13/2002 M | Cargo Vessel ms KAJEN (GER), Grounding in Ruotsinsalmi, off Port of Kotka |
| C 3/2003 M | General Cargo Vessel ms BIANCA (FIN), Grounding outside Gävle in the Bay of Bothnia |
| C 8/2003 M | ms SILJA OPERA (SWE), Collision with Three Cargo Vessels at St. Peterburg Harbour |
| C 9/2003 M | Passenger Vessel ms SPOVEN (FIN), Two Groundings off Brändö |
| C 3/2004 M | The Navy Allweather Craft HÖGSÅRA and Archipelago Ferry ROSALA II, Collision in the Narrow Fairway on the North Side of Örö |
| C 4/2004 M | Passenger Vessel SUOMENLINNA II (FIN), Grounding in Helsinki on 5.7.2004 and Seven Other Incidents |
| C 5/2004 M | MS KRASNOVIDOVO, collision with pontoon bridge in Kyrönsalmi strait Savonlinna |
| C 6/2004 M | Ketch VALBORG, grounding in Porvoo archipelago |
| C 1/2005 M | M/S PAULINE RUSS (AG), grounding in Hanko Port |
| C 2/2005 M | S/S HEIKKI PEURANEN, Grounding at Saimaa |
| C 3/2005 M | M/S TRANSLANDIA (FIN), Collision with a Quay in the Port of Tallinn |
| C 5/2005 M | M/T OMEGA AF DONSÖ (SWE), grounding in the fairway to Porvoo |
| C 1/2006 M | MS ESTRADEN (FIN) and MT WOLGASTERN (IOM), Collision in the Kiel-Canal |
| C6 /2006 M | Passenger Vessel MS NORDLANDIA (FIN), Collision with Quay in Tallinn |
| C1/2008M | M/S OOCL NEVSKIY (LUX), grounding south of Helsinki Pilot Station Harmaja |
| C3/2008M | MS ANNE SIBUM (CYP), grounding near Orrengrund |