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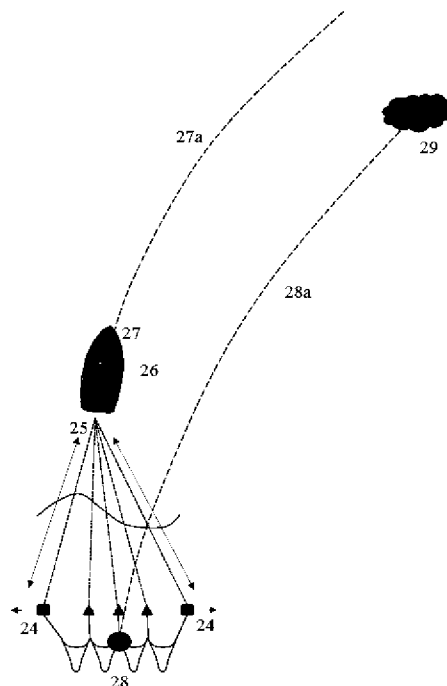
(54) **Title** **DYNAMIC TRAWL STEERING SYSTEM**

(56) **References**

Cited:
JP 2005046034 A
NO 334751 B1
NO 120174 B
NO 331304 B1
JP S5937416 A
JP S60155987 A

(57) **Abstract**

The present invention relates to a trawl steering system comprising a sea vessel and a trawl system. The system including a measuring unit for detecting and monitoring the position and movements of a target volume in the sea, the target volume constituted by a school, veil or haze of fish or shrimps to be caught in the trawl, and for monitoring the position of the trawl relative to said target volume. The system also comprises sampling means for sampling information including wind, current, and vessel and trawl characteristics and a route estimator for calculating an optimal trawl path and controller means for adjusting vessel and trawl parameters so as to provide a movement for the trawl toward the target volume along said optimal path and thus increase the catch and reducing the bunker consumption and associated environmental impact.



DYNAMIC TRAWL STEERING SYSTEM

The present invention relates to a steering system for maneuvering a trawl, or multiple trawls, or other towed equipment behind a vessel to a target volume
5 such as a school or a haze/veil of fish, shrimp or other target volumes, in an efficient manner.

Known trawling systems are based on controlling a vessel where an operator measures the position of a target volume as well as the position of the trawl and
10 steers the vessel in so as to move the trawl through the measured moving target volume. This is a complex operation and requires continuous monitoring of both trawl and target as well as environmental conditions such as wind and current. In addition, the trawl has to be controlled individually in order to maintain the wanted shape and orientation of the trawl and to avoid damage to
15 the trawl. Other uses of sensors for monitoring fish and trawl positions are also discussed in NO331304, JP S5937416 and JP S60155987.

Automatic systems have been suggested but are mainly aimed at controlling the vessel movements using traditional rudders, propulsion power and/or steerable
20 propellers, and through this the following trawl, according to the target position. This is, however, still based on the vessel steering as the main means to steer the trawl, including frequent course and velocity adjustments which increases energy consumption and wear on the equipment. An example of such a system is discussed in Japanese patent application JP 2005046034 where the focus is
25 on optimizing the trawl symmetry while using the vessel rudder and propulsion system to control the trawl movements. Norwegian patent NO334751 is related to trawl symmetry while Norwegian patent NO120174 describes a now well known solution for locating a school of fish.

30 It is an object of the present invention to provide a flexible and more efficient system, thus also reducing the fuel consumption, and hence reducing the environmental footprint. This is obtained as described in the accompanying claims.

The present invention is based on the realization that the vessel is only one of several components in a system for reaching the target volume, as for example the movement of the vessel may diverge in one direction due to wind while
5 current as well as the target movement may require another type of movement for the trawl.

The system utilizes several steering methods, including the potential use of movements in three dimensions of the trawl by actively adjusting length and
10 position of towing wires/leads, but also potentially actively using steerable doors, deflectors and/or weights, the system utilizes in addition the steering effects of the vessel movements by moving towing points at the stern of the vessel, and adjusting length of towing wires/leads, as discussed in Norwegian Patent Application NO20170593, the system utilizes in addition the potential
15 use of traditional vessel steering using rudders and propulsion. The individual steering methods are individually known but the present invention provides a system utilizing them to provide an improved system.

The present invention will be described more in detail below with reference to
20 the accompanying drawings, illustrating the invention by way of examples.

Figure 1 illustrates an overview of the system according to the invention.

Figure 2 illustrates details of a trawl that may be used in the system

Figure 3 illustrates the structure of the system.

25 Figure 4 illustrates the security margins relative to the trawl steering

Figure 1 illustrates a vessel 27 having a path of movement 27a while towing a trawl 28 to be moved in a path 28a toward a target volume 29 e.g. containing fish or shrimps. Depending on the environmental conditions such as drag,
30 current and wind, the trawl path of movement 28a may differ from the vessel path 27a and the relationship between these paths may be complex.

In addition there may be limitations to the freedom of maneuvering the vessel, and/or there might be limitations to the freedom of maneuvering the towed

equipment due to other vessels, other fishing equipment and subsea topographical restrictions, these factors will potentially be taken into consideration when the system calculates the actual modus operandi from case to case ensuring the minimum use of energy, and thus increasing effectivity in the fisheries and reducing negative environmental impact.

The vessel path 27a is determined by the sum of forces over time.

- Vessel thrust vector is determined by the propeller thrust and rudder angle.
- Vessel drag is determined by the sum of forces inflicted on the ship over time. This is determined by the shape and state of the hull, position of rudder and/or position and power of steerable propellers if being used.
- Wire drag is determined by the sum of forces inflicted from the towed equipment such as a trawl over time.
- Disturbance in the form of e.g surface current, waves and wind will affect the ship over time.

The trawl path is determined by the sum of forces over time.

- Trawl drag can be adjusted by changing the shape of the trawl by controlling doors, weights and wire tension and wire length. Trawl drag is also a result of trawl characteristics, filling of trawl and external disturbances like current.
- Trawl movement sideways to the wire drag is determined by sum of sideways forces inflicted by wire drag, trawl doors, trawl weights, seabed topography and current. This can be adjusted by direct control of adjustable doors and weights.
- Wire drag is determined by the sum of forces inflicted backwards from trawl drag, and forwards from the ship over time. Forward forces are controlled by throttle, pitch, rudder, and the point of attach of wire.
- Disturbance in the form of e.g sub surface current will also affect the trawl vector over time.

The forces discussed above regarding control of both the trawl and vessel path by adjusting the tension and momentum of the wire drag from the trawl to the vessel is also discussed in Norwegian Patent Application NO20170593.

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The forces affecting the vessel and trawl provide a number of variables that may be measured and used to move the trawl along an optimal and efficient path toward the target area. In addition, realizing that the main purpose of the movement is not the vessel path 27a but finding the optimal trawl path 28a
10 when considering both the speed and power consumption during the operation.

Figure 2 illustrates an embodiment of a trawl having a number of sensors, where

1-8 represents catch sensors, measuring the filling of trawl and thus the
15 weight of the trawl.

9,12 Measures trawl speed, pitch/roll, depth, distance to bottom, temperature and gives echogram of trawl.

10,11 Measures the pitch/roll, depth, distance to bottom, temperature and gives echogram of trawl.

20 14,17 Dual axis clump sensor, measuring distance to trawl door sensors.

13,16, 18,15 represents door sensors measuring the distance between paired doors and thus the width of the trawl, as well as pitch, roll, depth and temperature.

19-22 Catch sensor with echogram to provide detail information about the
25 catch passing into the codend, in addition to distance to bottom, pitch/roll, depth and temperature.

23-24 Trawl door sounder to provide rapid accurate distance to seabed, in addition to providing echogram to show catch passing underneath towards the trawl.

30 All of these measurements may be included in the calculation of the optimal trawl path along with the measurements of the target position and position of

the trawl relative to the target as well as the vessel.

When a target volume is detected, e.g. using a sonar or echosounder system, the calculation means estimates an optimal path based on the following:

- 5 1. The measured movement of the target volume.
2. The signals from the trawl sensors providing the true position of the trawl in three dimensions.
3. Signals from the trawl relating to symmetry, width, angle, doors, depth etc.
- 10 4. Signals from the vessel positioning system, e.g. GPS and autopilot, regarding the true position and course of the vessel.
5. Signal from the onboard radar and navigation system giving location, speed and course of surrounding vessels.
6. Signal from the onboard navigation systems giving information about other fixed or floating fishing equipment.
- 15 7. Signals from the onboard weather station regarding wind strength and direction.
8. Signals from doppler log regarding current velocity and direction in several layers in the water column.
- 20 9. Signals from the heave/pitch/roll sensors.
10. Prediction signal from the mapping machine which, based on the above, estimates about the topography and sea bottom conditions, indicates if it allows a trawl tow over a certain area without risking damages.

- 25 Based on these signals it is possible for the system to decide how the different alternatives may be used to steer the trawl in the optimal way toward the target volume. This may be performed dynamically depending on the movements of the target volume and how the trawl will meet it.

- 30 This is illustrated in the system shown in figure 3 where a trawl pilot 30 with a trawl pilot control 31 receives a number of data 32 about the target volume fish school position, depth, size etc, as well as vessel parameters such as position, speed, rate of turn etc, current and wind data and other operational parameters.

The trawl pilot 30 includes a route estimator 35 proposing a towed path 36, e.g. based on economical priorities and based on this may provide necessary commands 34 to the trawl controller 40 including a trawl control unit 36 for adjusting parameters like angle of attach, trawl shape and trawl position.

5

These trawl movements are then achieved by providing suitable control signals 38 to the relevant steering means. This is done primarily by adjusting the weights and doors Ref Fig 1; 24 of the trawl 28 as is well known in the art. Secondly to adjust trawl gallows and blocks and winches 25 on the vessel, and finally to
10 sending signals 33 to the vessel 27 engaging changes to the rudder and propulsion power 26 on the vessel (ref Fig 3). In order to obtain this the trawl controller 40 may also utilize measured or known information 39 about wire tension, doors positions and the symmetry of the system in order to optimize the trawl control.

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The range of priority of above actions might vary in order to obtain the sum of actions ensuring the least use of energy and most effective route optimization. All of above while also taking into consideration the optimum shape of the complete trawl systems and the safest route regarding other vessels and other
20 fishing equipment.

In this operation there is also a feedback where the effects on the trawl movements are predicted by a trawl predictor 37 (ref Fig 3) in the trawl controller and fed back to the route estimator 35 so as to provide a continuous
25 adjustment of the trawl being added to the estimation model and thus influencing the estimated trawl trajectory.

In estimating the trawl trajectory some variations is allowed within an acceptable window of movements, so as to limited the need for fast and power consuming changes. This is illustrated in figure 4 where a safe envelop boundary 40
30 enclosing a safety margin is defined and within this an estimated boundary of controllability 41 of the trawl. As a safety precaution the operating boundary 40b is defined within this, wherein the route estimator and trawl control allows some variations in the trawl movements over a span of time 43.

The acceptable window may thus be based on a model involving the following calculations:

Calculate dynamic trawl system behavior

Calculate operating boundary

5 Calculate safety margins

Calculate trawl resistance

Calculate Angle of Attack of trawl system

Calculate effects of wind and current.

10 This may be achieved based on different estimator models such as :

«Trawl safety envelope» model defining the safe trajectory, e.g. avoiding sea bottom or other obstacles along the planned trajectory.

«Disturbance model» including currents and other dynamic disturbances actively changing the real trajectory.

15 «Trawl system dynamic model» describing the dynamic behaviour of the trawl during a operation. The real trawl movements should preferably be kept within the limits of these models while calculating the most efficient route and recommending means to achieve this route.

20 The precise nature of the models and calculations used by the route estimator will depend on the different types of trawls and vessels as well as the measurements provided by related sensors and instruments, as well as environments conditions, e.g. variations in sea floor, depth, currents, trawl size, vessel maneuverability, and safe vessel routes avoiding dangerous or

25 unwanted contacts with other vessels and other fishing equipment.

To summarize the present invention thus relates to a trawl steering system comprising a sea vessel and a trawl system, the system including a measuring unit such as a sonar or echosounder system for detecting and monitoring the
30 position and movements of a target volume in the sea where the target volume may be constituted by a school, veil or haze of fish or shrimps to be caught in the trawl. The vessel also includes means for monitoring the position of the trawl relative to said target volume. The system comprising sampling means for sampling information including wind, current, and vessel and trawl

characteristics and a route estimator for estimating the optimal route or path of the trawl. The system also comprises a trawl controller for adjusting vessel and trawl parameters so as to provide a movement for the trawl toward the target volume along said optimal path thus increasing the catch and reducing the
5 bunker consumption and associated environmental impact.

The control means may include a vessel control unit calculating the vessel movements necessary to steer the trawl along the estimated route toward the target volume. The trawl may also comprise steering means that may be adapted to move the trawl relative to the vessel so as to move toward the target
10 area, wherein the steering means may include doors, deflectors or weights positioned at the trawl for adjusting the position in the lateral and/or vertical direction relative to said path along said trajectory.

The route estimator may include interfaces for receiving measurements from the environment, e.g. wind or current, measurements from the vessel and the
15 trawl, as well as the measured movement of the target area and to calculate the trawl trajectory based on said measurements.

The system may also include a navigation unit monitoring the global position of the vessel, the system being adapted to measure the position of the target volume and the trawl relative to the vessel.

20 The system might also include signals from one or several radar units onboard the vessel, and/or other navigational systems giving information about fixed or floating fishing equipment to be avoided.

The steering means may include interactive use of moving the trawl towing points on the vessel laterally and/or vertically, and in addition possibly also by
25 adjusting length of towing wires.

The system may also comprise automation systems, hardware and software systems, which might be based on artificial intelligence to provide an hierarchical list of actions comprising a priority of navigational means such as to
30 ensure safest trawl trajectory route using the least amount of energy. This might be based on a priority list of a first step to maneuver the trawl relative to the

vessel movements so as to move toward the target area and secondly to maneuver the vessel and trawl including interactive use of moving the trawl towing points on the vessel laterally and/or vertically, and in addition possibly also by adjusting length of towing wires, and thirdly to maneuver the vessel and

5 trawl using rudder and propulsion power, or any combination of the above.

Claims

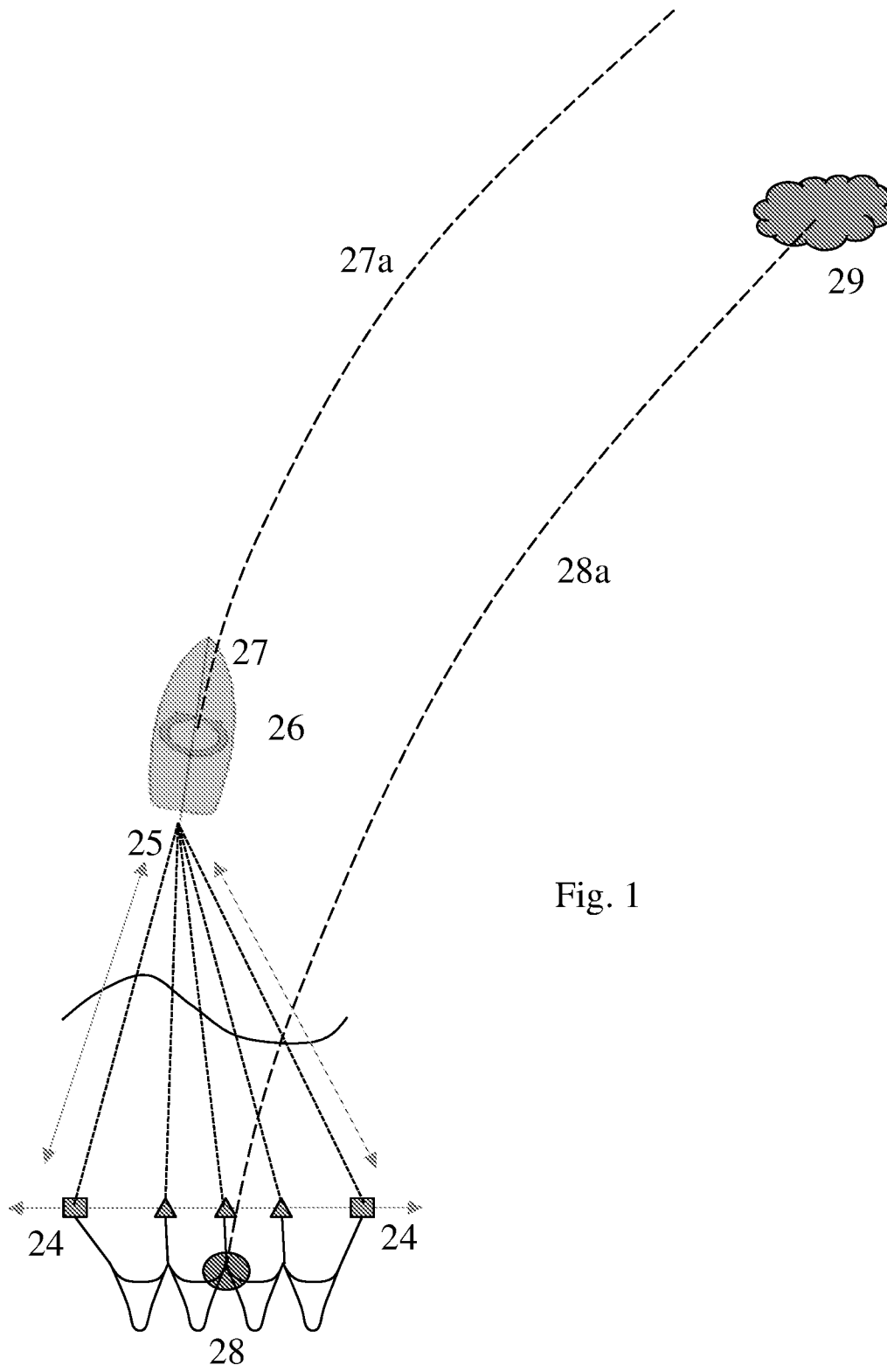
1. Trawl steering system comprising a sea vessel and a trawl system, the system including a measuring unit for detecting and monitoring the position and movements of a target volume in the sea, the target volume constituted by a school, veil or haze of fish or shrimps to be caught in the trawl, and for monitoring the position of the trawl relative to said target volume, the system also comprising sampling means for sampling information including wind, current, and vessel and trawl characteristics and a route estimator for calculating an optimal trawl path and controller means for adjusting vessel and trawl parameters so as to provide a movement for the trawl toward the target volume along said optimal path and thus increase the catch and reducing the bunker consumption and associated environmental impact.
2. System according to claim 1, wherein the control means includes a vessel control unit calculating the vessel movements necessary to steer the trawl according to the estimated route toward the target volume, while avoiding any danger of collision or unwanted interface with other vessels and other fishing equipment.
3. System according to claim 1, wherein the trawl comprises steering means adapted to move the trawl relative to the vessel movements so as to move toward the target area.
4. System according to claim 3, wherein the steering means includes doors or deflectors positioned at the trawl for adjusting the position in the lateral direction relative to said path along said route.
5. System according to claim 1, wherein said calculation means includes interfaces for receiving measurements from the environment, e.g. wind or current, measurements from the vessel and the trawl, as well as the measured movement of the target area and to calculate the trawl trajectory based on said measurements.
6. System according to claim 1, comprising a navigation unit monitoring

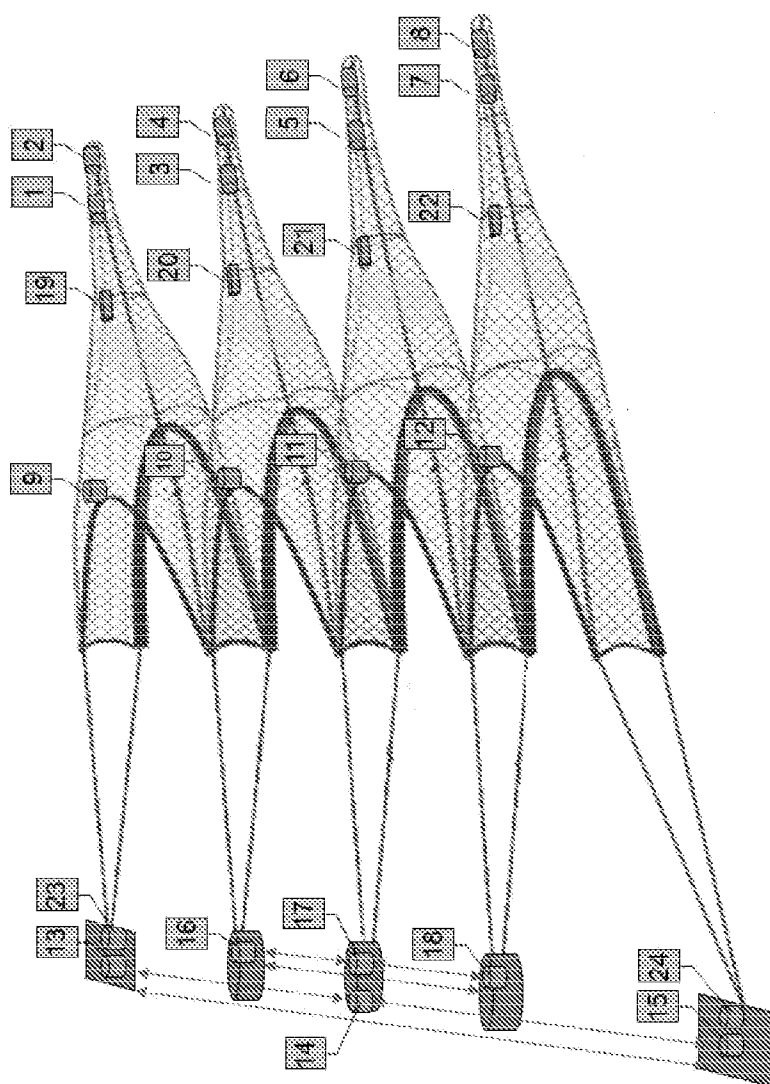
the global position of the vessel, the system being adapted to measure the position of the target volume and the trawl relative to the vessel.

Krav

1. System for styring av trål omfattende et sjøgående fartøy og et trålsystem, der systemet omfatter en måleenhet for deteksjon og overvåking av av posisjon og bevegelser for et målvolum i havet, der målvolumet utgjøres av en stim, slør eller dis av fisk eller reker som skal fanges i trålen, og for overvåking av posisjonen til trålen i forhold til målvolumet, der systemet også omfatter samplingsmidler for innhenting av informasjon om inklusive vind, strøm og fartøy og trålkarakteristika og en ruteestimator for å beregne en optimal trålbane og kontrollmidler for å justere fartøyets og tråls parametere for å tilveiebringe en bevegelse for trålen mot målvolumet langs den optimale banen og dermed øke fangsten og redusere bunkersforbruket og assosiert påvirkning av miljøet.
2. System ifølge krav 1, der kontrollmidlene inkluderer en fartøykontrollenhet som beregner fartøyets bevegelser som er nødvendige for å styre trålen i forhold til den estimerte ruten mot målvolumet, mens fare for kollisjon eller uønsket kontakty med andre fartøy eller fiskeutstyr unngås.
3. System ifølge krav 1, der trålen omfatter styremidler innrettet til å bevege trålen i forhold til fartøyets bevegelser for derved å bevege seg mot målområdet.
4. System ifølge krav 3, der styringsmidlene inkluderer grensnitt for dører eller deflektorer plassert ved trålen for justering av posisjonen i lateral retning i forhold til banen langs nevnte rute.
5. System ifølge krav 1, der nevnte beregningsmidler inkluderer grensesnitt for mottak av målinger fra miljøet, for eksempel vind eller strøm, målinger fra fartøyet og trålen, i tillegg til den målte bevegelsen til målområdet og beregne trålbanen basert på nevnte målinger.
6. System ifølge krav 1, omfattende en navigasjonsenhet som overvåker

den globale posisjonen til fartøyet, der systemet er innrettet til å måle posisjonen til målvolumet og trålen i forhold til fartøyet.





- 1-8 MAR-NFS-5-00
Catch sensor, measures filling of trawl
- 9 & 12 MAR-SPE-155W
Measures trawl speed, pitch / roll, depth, distance to bottom, temperature and gives echogram of trawl
- 10 & 11 MAR-TE-155W
Measures pitch / roll, depth, distance to bottom, temperature and gives echogram of trawl
- 14 & 17 MAR-SSC-18-00
Dual axis clump sensor, measuring distance to trawl door sensors
- 13, 16, 18, 15 MAR-SS-15/16-00
Door sensor measures distance between paired doors, pitch, roll, depth and temperature
- 19-22 MAR-OE-150-W
Catch sensor with echogram to provide detail information about the catch passing into the codend, in addition to distance to bottom, pitch / roll, depth and temperature
- 23-24 DS-155-W
Trawl door sounder to provide rapid accurate distance to seabed, in addition to providing echogram to show catch passing underneath towards the trawl

