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Burial depth requirements and experience with pipeline burial on the Dutch continental shelf.

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Abstract: English

In the Southern Bight of the North Sea the route selection for a pipeline should include a careful evaluation of the various activities of other users of the sea and the seabed along the route. In general it is necessary to protect the pipeline as well as the other users.
In most cases pipelin burial will provide an acceptable solution.
On the basis of the limited data available a cover of 2 m is considered necessary for the gaspipelines to the Dutch coast.
Except in specific areas, this requirement could not be met with the available burial techniques.

Abstract: French

La choix de la tracée des conduits de gaz dans la partie méridionale de la Mer du Nord oblige d'évaluer consciencieusement les intérêts des autres utilisateurs de la mer et de son fond.
En genéral on doit protéger non seulement le conduit de gaz, mais aussi les autres intérêts.
Dans la plupart des cas c'est l'enfouissement qui donne une solution acceptable.
A défaut de données suffisantes une converture de 2 mètres est considérée nécessaire pour les conduits croisant la côte hollandaise.

La technique moderne n'est pas encore si avancée qu'on peut satisfaire à cette exigence dans toutes les régions.

1. Introduction.

Due to the spectacular technical developments of the last century the sea and the seabottom are now accessible to mankind for various activities such as:

- shipping
- fishing
- communication cables
- defensive activities
- offshore mining
- land reclamation
- dumping of waste materials
- construction work for shipping or offshore mining.

Offschore pipelines can influence or limit some of these activities. With some of them a pipeline can be in direct conflict. Careful route selection is necessary in order to limit - as far as possible or acceptable - interference of the pipeline with other users of the seabottom.

Pipeline routes in the southern part of the North Sea cannot steer clear of all these users. They will encounter most of them. Therefore, protection of the other users as well as the pipeline is necessary.

2. Protection of the pipeline.

During its expected lifetime - 20 to 30 years - a pipeline has to be protected very carefully. Maintenance and repair work is very expensive and sometimes impossible.

Therefore, the protective measures are also designed for a lifetime of 20 to 30 years.

An offshore pipeline is normally protected by

- a corrosion coating.
- a cathodic protection.
- a concrete coating.
- burial.

With the corrosion coatings of to-day, when fully intact, an offshore pipeline is sufficiently protected against corrosion during its lifetime. However, damage during construction and during the lifetime of the pipeline are possible. For that reason a

cathodic protection is also provided.
For negative byoyancy and stability under wave influence the large diameter pipelines also need a weight coating, usually made of concrete.
This concrete coating also affords some protection for the corrosion coating.
Especially the older types of concrete coating hardly withstand mechanical impact forces.
Modern types of concrete coating however can to some extent withstand such impact forces. But also then additional protection is required.
Ships' anchors or heavy fishing gear can buckle or even totally destroy a pipeline.
In such a situation also the ship and her crew are exposed to real risk.
These risks, in combination with the possibility of sea pollution in the event of a leakage, call for measures by which the pipeline is placed beyond the reach of fishing gear and ships' anchors.
It is beyond dispute that in the southern part of the North Sea, with its heavy shipping and fishing, burial of the pipelines is essential.

3. Burial depth requirements.

3.1. General

Determination of the burial depth should be based on data regarding:

- the stability of the seabottom
- penetration depth of fishing gear
- penetration depth of ships' anchors
- probability and depth of soil liquefaction under storm conditions
- other dangers to the pipe in specific areas, such as those used for naval gunnery practice
- the possible environmental consequences in the case of a pipeline leak or break
- the possible economic loss to the pipeline owner in the case of damage
- the possible costs of repair.

In principle an increase in the burial depth will decrease the risk of damage.
In theory it must be possible to determine the optimum burial depth by reference to a risk analysis and a cost-benefit analysis.
In his paper "How to protect offshore pipelines", Brown mentions a method for such an analysis. See ref. 1.
In practice, however, it is very difficult, if not impossible, to obtain all the necessary input data.
Based on the available data, the Dutch Government has specified a cover of 2 m for the two pipelines to its coast.
Some important factors in this choice are discussed below.

3.2. Stability of the seabottom.

A vital factor in deciding burial depth is the stability of the seabottom.
Erosion of the seabottom directly affects the burial depth.
However, on the high seas the data on seabottom stability are very inaccurate.
Differences of 0.50 to 1 m are still possible at present.
The inaccuracy of soundings is mainly due to the absence of a fixed datum.
Because of this inaccuracy, any trend in the changes of the seabed level is very difficult to show.
From the available data on the Dutch shelf, however, it may be concluded that changes in the bottom level outside surf zones are of minor importance.
Another problem of the Dutch coast is the large sand-wave area.
The height of the sand waves sometimes exceeds 10 m, and the data on the movement of these waves are also very poor. The problem is compounded by the inaccuracy of the depth soundings and of the horizontal positioning system.
Some authors suggest that there is a slow movement in a north easterly direction. See ref. 2 and 3.
Extensive surveys by the Dutch Public Works Department show that, on an annual basis, where there is movement, it is within the accuracy of the positioning systems. Via long term investigations, better

data will become available within some years.
Due to the height of the sand waves, their movement must be treated as a very important factor in determining the route and the burial depth of a pipeline.
The problems can be overcome by choosing a burial depth below the lowest points in the valleys. This leads to an unrealistic burial depth below the top of the sand waves.
Such far-reaching conclusions must not be drawn on the basis of incomplete data.
For these reasons possible changes in the seabottom level of the Dutch shelf are disregarded in the determination of the burial depth. Because of the unreliability of the data, maintenance of the prescribed burial depth is stipulated in the licence.

3.3. Effects of fishing gear on pipelines.

In his paper "The possible effects of beam and other trawls on submarine pipelines" (see ref. 4) de Groot describes the situation in the Dutch sector of the continental shelf in detail.
The following seabed fishing gear is used:
- beam trawl; total weight 4000 kg - 8000 kg.
- other trawl; weight of a board approx. 1200 kg.

The beam trawl is the most common seabed fishing gear of the Dutch fisheries. See annex. 1.

From the results of field tests in Trondheim it may be concluded that concrete coatings with chicken-wire reinforcement cannot withstand the impact forces of a Dutch beam trawl. In certain areas these impacts can be very frequent.
Annex 2 shows the number of fishing hours with beam trawls of the Dutch fleet. Given an average beam length of 10 m, a normal fishing velocity of 4 to 5 knots and the known number of fishing hours, a simple calculation shows that every point in some of the rectangles is fished 3 to 4 times each year.
Another interesting comparison is the strength of the fishing warps and the negative buoancy of the pipeline.

For example: Fishing warps with a tensile strength of 40,000 kg or more are not unusual.
The negative buoyancy of a 36" pipeline (specific gravity 1.25) is only 225 kg per meter.
In theory, a fishing vessel with these fishing warps can lift a length of more than 150 m.
In areas where such fishing gear is used burial of pipelines is necessary.
The necessary burial depth to protect a pipeline against the effects of fishing gear is limited. Normally they penetrate less than 0.10 to 0.30 m. In exceptional cases like hooking the penetration depth can be far more.

3.4. Anchor penetration.

To determine the risk for pipelines from ships' anchors we have to answer the following questions:
(a) What is the penetration depth of a certain anchor?
(b) What is the risk that such an anchor will hit the pipeline?

The answer to the first question is provided by the data mentioned in ref. 5, 6 and 7.
It appears that an anchor dropped on a sandy seabed is first dragged over the seabed and then penetrates until the required holding strength is reached.
If equilibrium is not reached, the dragging goes on. Due to unequal loading of the flukes - the soil is never homogeneous - the anchor will twist out of the bottom. Then penetration starts again.
For this penetration behaviour, see annex 3.
On the basis of this behaviour a relation can be derived between ship dimensions, anchor dimensions and penetration depth.
See annexes 4 and t.
The second question is more difficult to answer.
Lloyds Register of Shipping publishes all the shipping casualties and their positions. But nobody knows the relation between these casualties in a certain area and the number of dragging anchors.

Another problem is the effect of the pipeline on the behaviour of the seaman. The pipelines are shown on the seacharts.
It is reasonable to suppose that a pipeline route will be more or less respected by anchoring vessels. On the other hand, such a positive effect is doubtful in emergencies.
The probability of a dragging anchor crossing a pipeline route is still an unsolved problem.

From annexes 4 and 5 it appears that in a sandy seabottom

- a cover of 2 m gives a pipeline reasonable protection against dragging anchors of ships above 50,000 deadweight tonnes (d.w.t.)
- a cover of 1.50 m gives reasonable protection against anchors of ships over 10,000 d.w.t.
- with a cover of 4 m the pipeline remains within reach of the anchors of even small ships.

From the total world fleet 98% of the ships are smaller than 50,000 d.w.t., 80% are smaller than 10,000 d.w.t.
Lloyds' figures show that small ships are more susceptible to accidents than the large ones.

4. Experiences on the Dutch shelf.

At present there are two gas-pipelines to the Dutch coast:

- a 36"-pipeline from the Placid fields in block L 10, 50 km north west off Texel, to Uithuizermedum the pipeline is 178 km long and was laid in 1974
- a 36"-pipeline from the Pennzoil gasfields in block K 13 west of Texel to Callantsoog south of Den Helder; the pipeline is 120 km long and was laid in 1975.

See annex 6.

Because of the dense shipping and fishing in these areas, the Dutch government stipulated a cover of 2 m.
In spite of great efforts, the companies were not able to meet this requirement.
The only available burying method, jetting equipment, was found to be very inefficient in the fine, loosely packed sandy bottom of the Dutch shelf.

Immediately after the jetting equipment had passed, the trench was filled up again by distortion of the slopes. Consequently, the pipeline reached the bottom of a shallow trench with gentle slopes.
Only in a few specific areas could the pipeline be lowered to a level where the top of the pipeline was 2 m below the level of the seabottom.
With this burial method the cover on the pipeline is dependent on natural backfill.
The rate of this backfill supports the opinion mentioned under 3.2., viz. that changes in the level of the seabottom are very slow processes.
Berry reports (see ref. 8) that in 1967, during the burial of the Shell Esso pipeline from Leman Bank to the English coast near Bacton, the jetting equipment met the same trouble.
It is disappointing to find that today, 10 years after this experience, the offshore industry is still using the same techniques with the same disappointing results in a loose sandy bottom.
Methods based on the fluidisation principle are known, by which a pipeline can be buried and covered in a loose sandy bottom.
Field tests have shown that the principle of the fluidisation method produces good results.
However, due to some unfortunate experiences, the offshore industry is reluctant to develop this method further.

5. Conclusions.

5.1. For protection of offshore pipelines and their environment, burying of the pipelines in the southern North Sea is necessary.

5.2. Due to the lack of essential input data, optimalisation of the burial depth is impossible.

5.3. Data on the changes in the level of the seabottom are limited. However, they indicate that outside the surf zone the changes develop slowly and are of minor importance in the choice of burial depth.

5.4. Instances of a pipeline route in the southern part of the North Sea being crossed by heavy bottom-fishing gear can be very frequent. The penetration depth of fishing gear is limited and therefore not important in the choice of burial depth.

5.5. The available data on anchor penetration show that in a sandy bottom a cover of 1 m above a pipeline hardly gives protection.
A cover of 2 m places the pipe outside the reach of nearly all the penetrating anchors.

5.6. On the basis of the above-mentioned data, a cover of 2 m has been stipulated for the pipelines to the Dutch coast.
The jetting method has proved unsuitable for burying these pipelines to the required depth.

5.7. One may expect that burying equipment based on the fluidisation principle will give better results in comparable situations.
However, the development of such equipment has been delayed by some unfortunate experiences.

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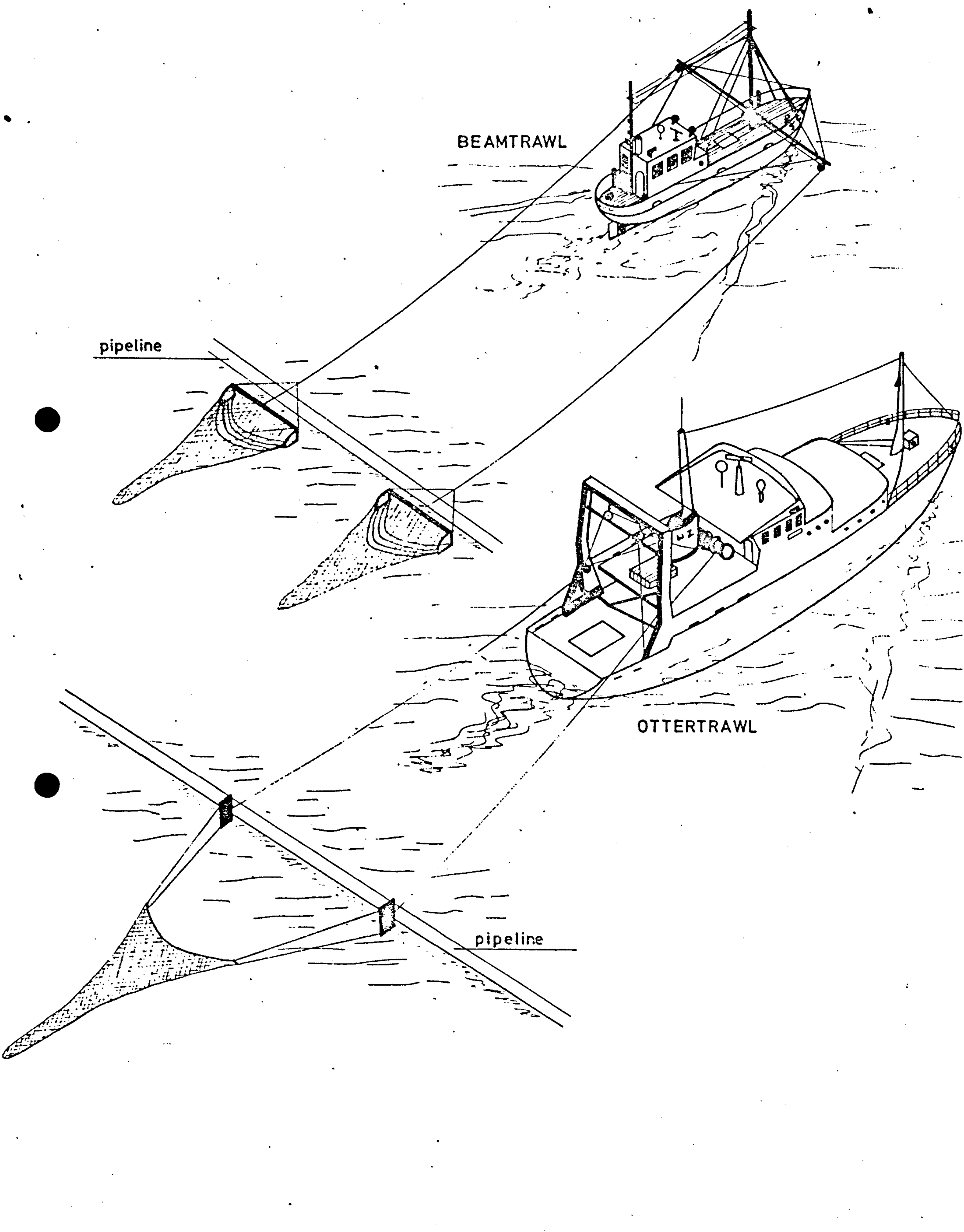
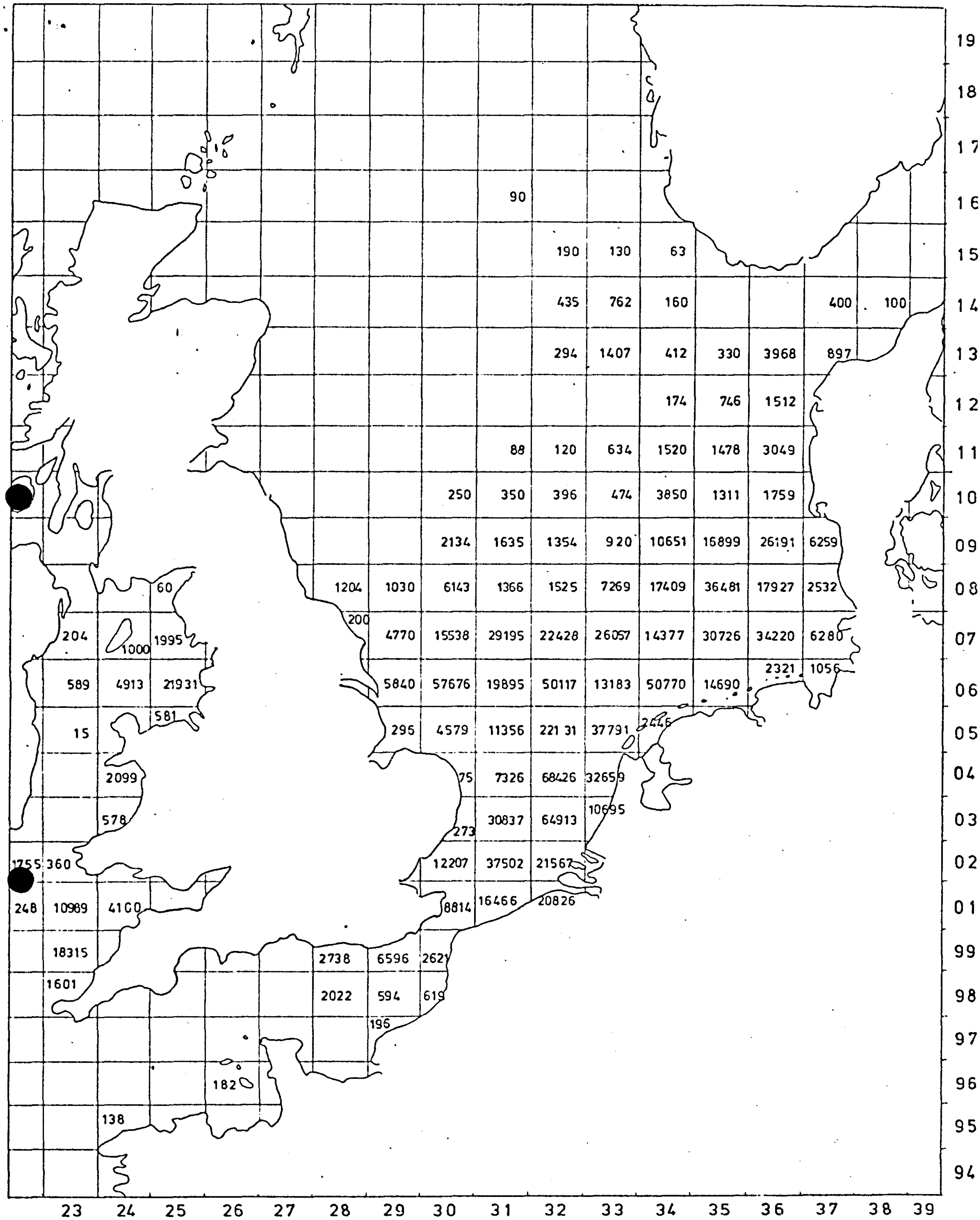
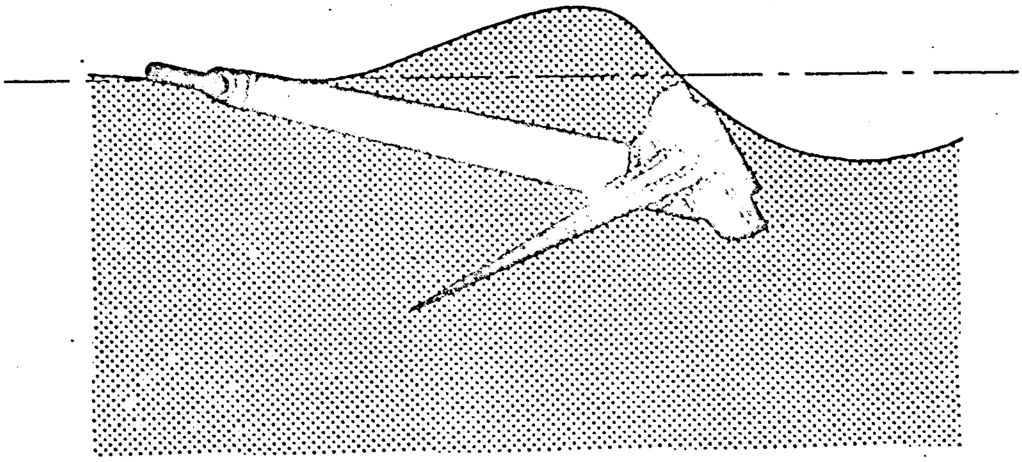

BEAMTRAWL
pipeline
OTTERTRAWL
pipeline



Fishinghours with beamtrawl 1975

Source: RIVO IJmuiden, Holland
Oostende, België

annex 2



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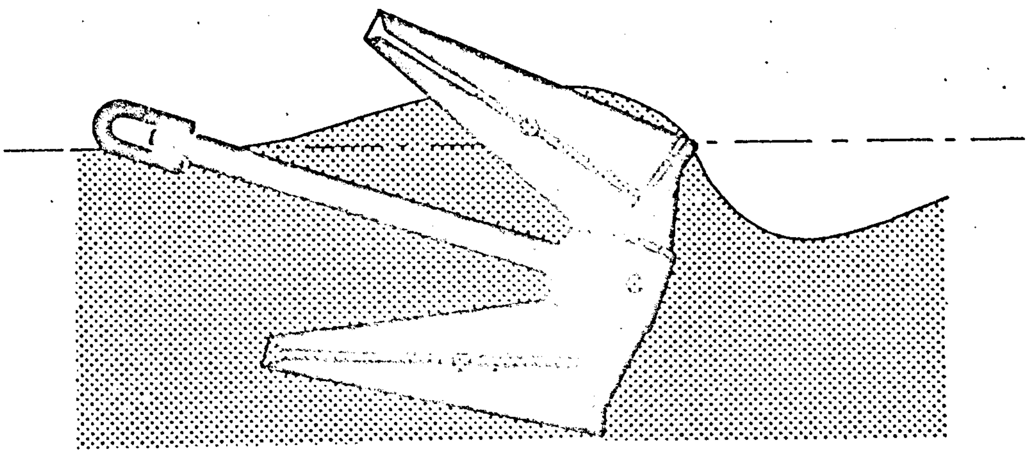

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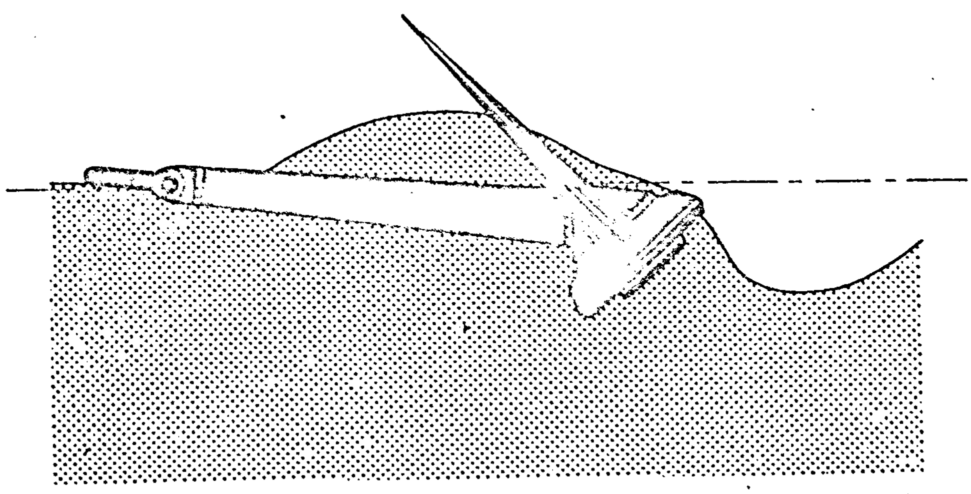
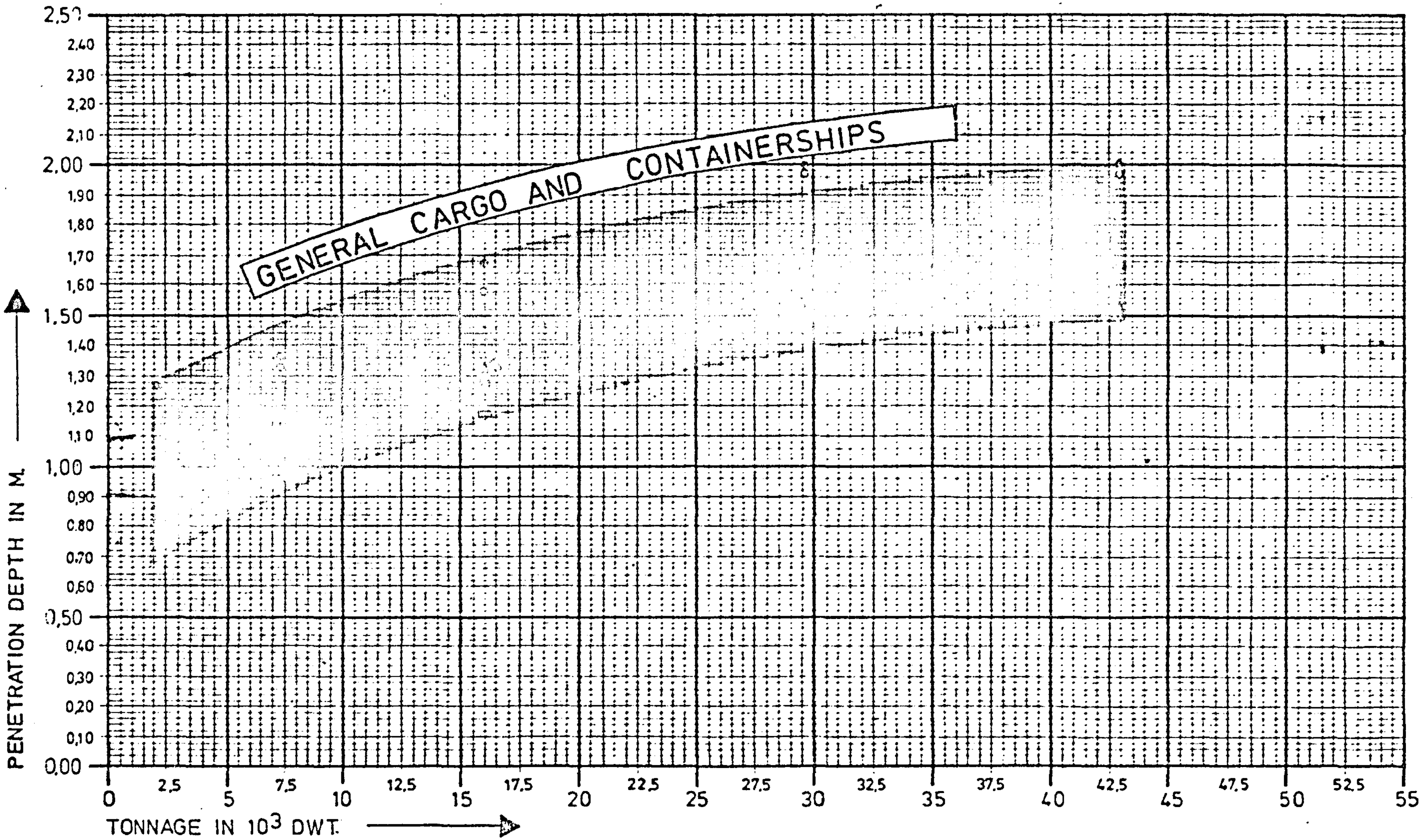


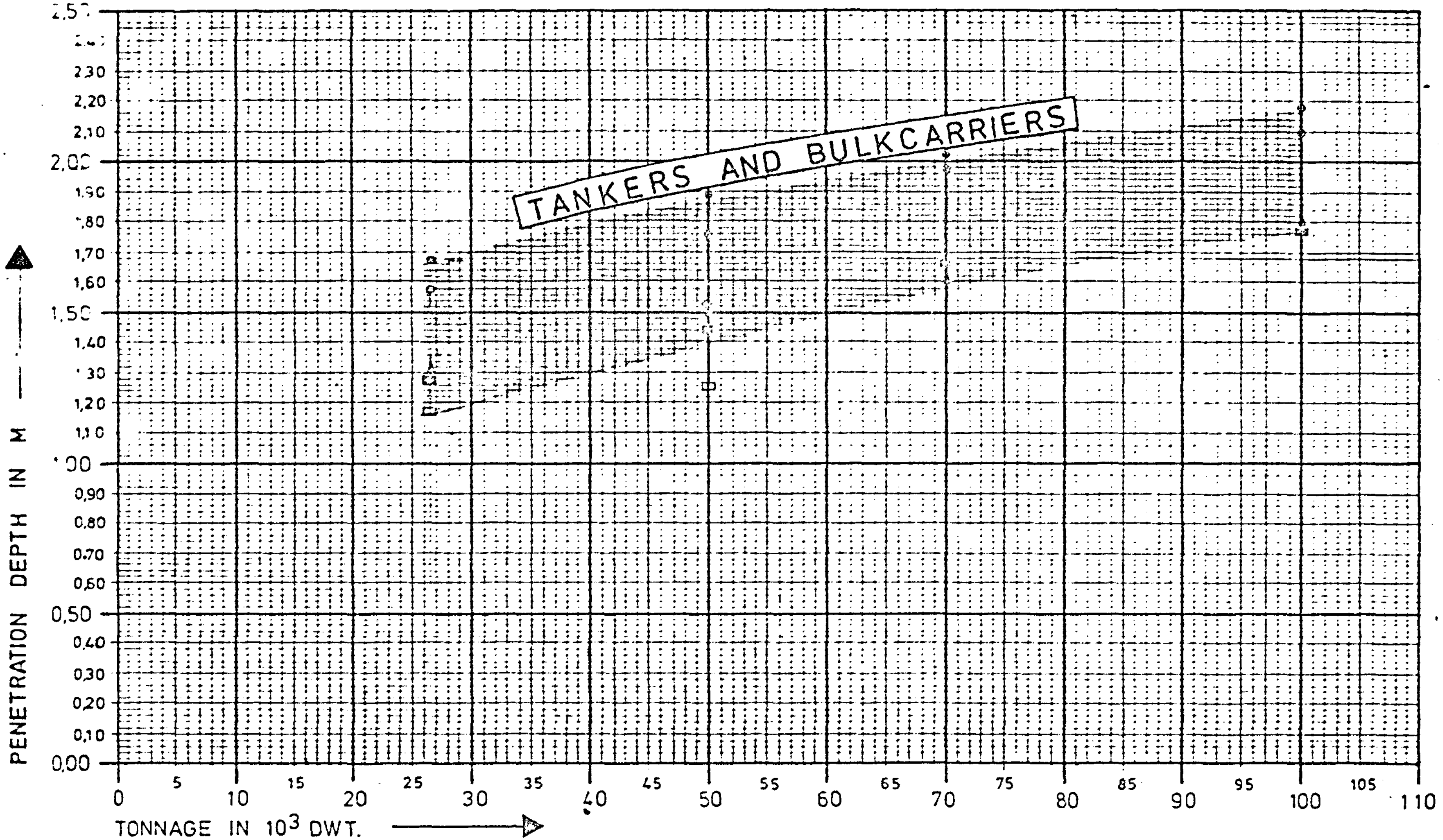
DRAGGING



ANCHOR TYPES

- o STOKES
- ▭ HALL'S
- Δ UNION
- ◇ BYERS
- ▨ BALDT
- • POOLANKER

Relation between ship tonnage and penetration depth of anchors in a sandy bottom



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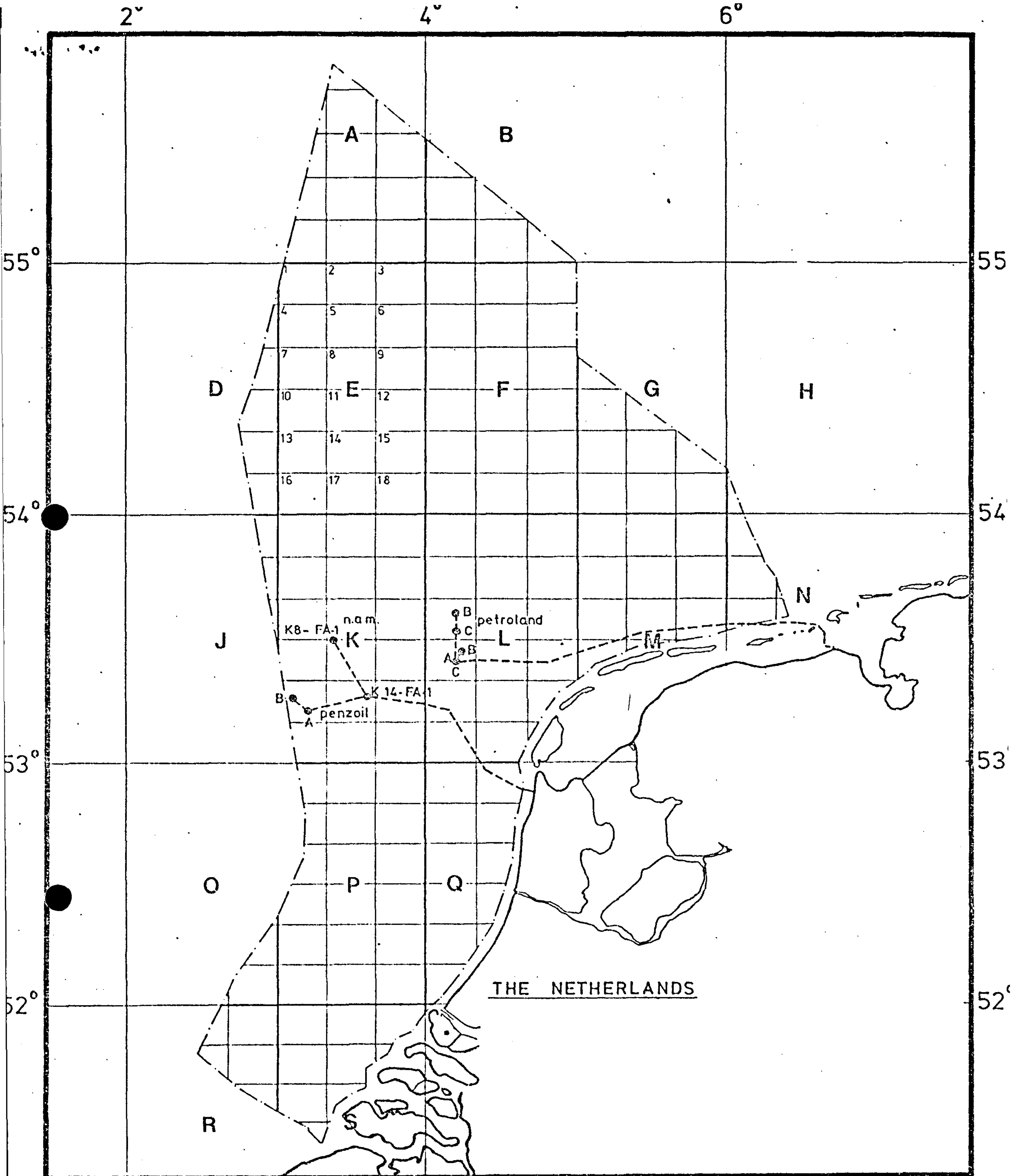

Pipelines on the dutch continental shelf