



**BRAZILIAN NAVY  
DIRECTORATE OF PORTS AND COASTS**

**INVESTIGATION REPORT OF THE CAPSIZING  
OF THE CONVOY “NORSUL 12 AND NORSUL VITÓRIA”**

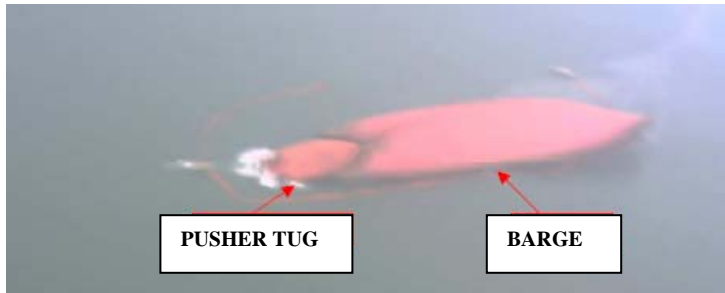
**SÃO FRANCISCO DO SUL - SANTA CATARINA**

**- JANUARY 30, 2008 -**



On 30 January 2008 the combined vessels pusher tug “Norsul Vitoria” and barge “Norsul 12”, laden with 340 tonnes steel coils, capsized in the entrance channel of Babitonga Bay, in São Francisco do Sul, at the position LAT 26° 09.8 S and LONG 048° 31.0 W.

## CONVOY “NORSUL 12” / “NORSUL VITÓRIA” CAPSIZED



### I) DATA OF THE VESSEL

#### (a) CHARACTERISTICS OF THE CONVOY

The convoy formed by the barge “NORSUL 12” and the pusher tug “NORSUL VITÓRIA”, is the type “Articulated Connection ITB” (Integrated Tug-Barge).

The connection between them is made by two hydraulically activated locking pins, installed one on each side of the pusher tug, which allows movement between the tug and the barge.

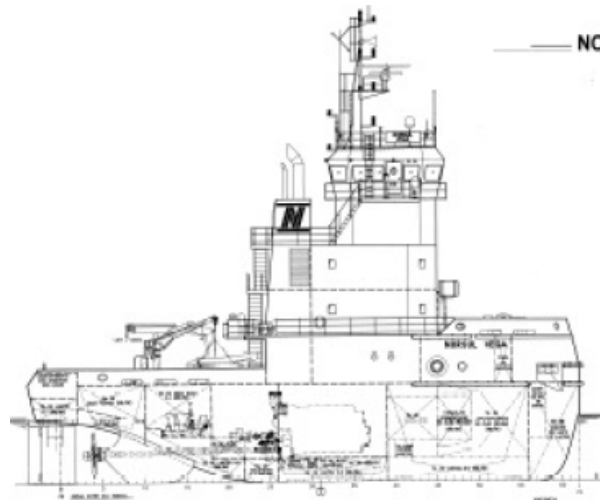
### CHARACTERISTICS OF THE VESSELS

#### **PUSHER TUG**

Name of vessel	<b>NORSUL VITÓRIA</b>
Name of Owner	Companhia de Navegação NORSUL
Name of Operator	Companhia de Navegação NORSUL
Builder	AKER PROMAR S.A.
No. of hull	PRO-15
Date of keel laying	11/03/05
Date of delivery	27/04/06
Type	Pusher tug
Registry in the Maritime Court	12778 DVA-C
Classification Society	American Bureau of Shipping (ABS)
Classification No.	06144805
Country of Registry	BRAZIL
Port of Registry	São Francisco do Sul
No. of Registry	442-020769-8
Call sign	PPTH

IMO No.	9318450
Length Overall	33.33 m
Length between perpendiculars	31.10 m
Breadth	12.00 m
Depth	6.00 m
Gross Tonnage	730
Nett Tonnage	219
Loaded draft (summer)	4.00m
Loaded Displacement (summer)	865.059 t
Gross Deadweight (summer)	197.70 t
Light Displacement	675.80 t
Navigational Area (radio-communication)	A1+A2+A3
MCP Power	2 x 7830 kilowatts
MCA Power	3 x 650 kilowatts

### PROFILE “NORSUL VITÓRIA”

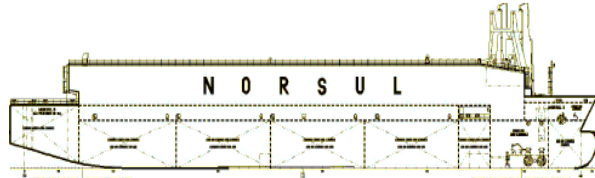


### BARGE

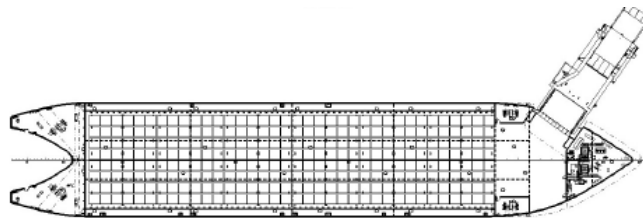
Name of vessel	<b>NORSUL 12</b>
Name of Owner	Companhia de Navegação NORSUL
Name of Operator	Companhia de Navegação NORSUL
Builder	EISA – Estaleiro Ilha S.A.
No.of hull	491
Date of keel laying	03/05/05
Date of delivery	24/10/06
Type	Barge
Registry in the Maritime Court	12880 DVA-W
Classification Society	American Bureau of Shipping (ABS)
Classification No.	06144810
Country of Registry	BRAZIL
Port of Registry	São Francisco do Sul

No. of Registration	442-020770-1
Call Sign	Does not possess
IMO No.	Does not possess
Length overall	123.40 m
Length between perpendiculars	117.00 m
Breadth	22.00 m
Depth	8.50 m
Gross Tonnage	11,089
Nett Tonnage	5,604
Loaded draft (summer)	6.50 m
Loaded displacement (summer)	13,513.574 t
Gross deadweight (summer)	10,352.074 t
Light displacement	3,161.50 t

### PROFILE “NORSUL 12”

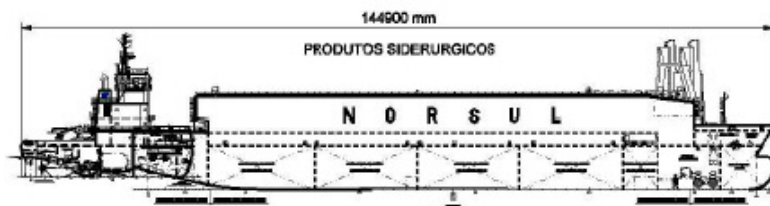


### DECK “NORSUL 12”



The length of the integrated Tug-Barge, when coupled, is 144.90 metres.

### PROFILE CONVOY “NORSUL VITÓRIA – NORSUL 12”



**UNITS EMPLOYED**

In almost all of this report units of the Internatopnal Metric System (SI) were employed excepting the dimensions of the nets and their accessories , which are easier to understand than the English System.

**GROSS DEADWEIGHT**

**PUSHER TUG NORSUL VITÓRIA**

On the voyage numbered 008/088, in which occurred the capsizing, the pusher tug at the moment of the capsizing had a quantity of 216. 15 tons of liquids in its tanks as shown in the table below:

Tanks	Quant (t)	Density (t/m3)
Ballast tanks	77.64	1,025
Diesel oil tanks	3.59	0.90
Lubricating oil tanks	7.30	0.89
Various tanks	8.48	0.90
Fresh Water tanks	31.26	1.00
Fuel Oil tanks	87.88	0.95
TOTAL	216.15	x

The weight of the stores and the so-called “Constants” also make up the gross deadweight of the pusher tug with the respective values of 0.50 t and 9.46 t. Thus the Gross Deadweight of the pusher tug totaled 226.11 tons.

In the above conditions the pusher tug NORSUL VITORIA sailed with:

Draft forward	4.059 m
Draft aft	4.148 m
Longitudinal position of the Centre of Gravity:	0.389 m
Vertical position of the Centre of Gravity:	5.088 m
Distance Metacentre – Centre of Gravity:	0.8666 m
Metacentric Height:	6.258 m
Tons per Centimetre of Immersion:	3.37 t

**BARGE NORSUL 12**

The Barge NORSUL 12 was loaded with 340 steel coils, totaling 9,014.315 t. The ballast tanks of the barge had a total of 183.15 t of seawater and 9.337 t of diesel oil., arranged as shown below:

Tanks	Quantity (t)	Dens (tm3)
Ballast tank 1.C	16.40	1.025
Ballast tank 2.C	37.93	1.025
Ballast tank 3.C	37.93	1.025
Ballast tank 4.Port	38.95	1.025
Ballast tank 4 Stbd	49.20	1.025
Ballast tank 5.C	11.28	1.025

Tank Diesel Oil C	9.37	0.90
TOTAL	201.06	X

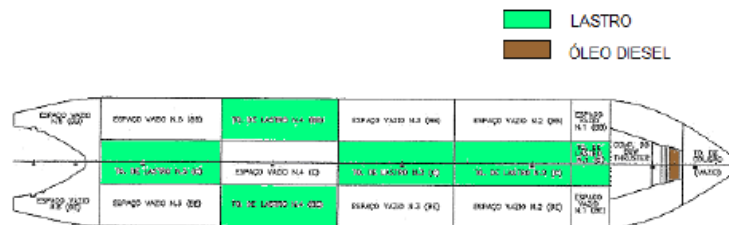
The gross deadweight of the barge is complemented by the weight of the cradles and the so-called “Constants”, whose values are 254.52 t and 0.80 t respectively.

Thus the gross deadweight of the barge totaled 9,452.785 t.

In the above conditions, the barge sailed with:

Draft forward:	6.105 m
Draft Aft	6.141 m
Longitudinal position of the Centre of Gravity	2.506 m.
Vertical Position of the Centre of Gravity	9.478 m
Distance Metacentre – Centre of Gravity	0.618 m.
Metacentric Height:	10.317 m
Tons per Centimetre of immersion	23.37 t

Below is a sketch with the arrangement of ballast and diesel oil, it is observed that the major part of the ballast is placed on the Centre Line of the barge and only the ballast tanks No.4, which serve the anti-heeling systems are placed at the sides.



Lastro = Ballast  
 Óleo Diesel = Diesel Oil

The above information was also supplied by the owner in a document issued by PROJEMAR S.A. “Investigation of the Accident with the Convoy “NORSUL 12” / “NORSUL VITÓRIA”.

The information referring to the gross deadweight of these vessels was considered by the executors of this survey as being well consistent and the Captain of the convoy, and Chief Engineer and the Sub-Chief Engineer, in their testimonies confirmed that there was not any alteration in the conditions of ballast of the convoy. Such data also could not be confirmed by the survey, seeing that during the capsizing and the salvage, the oil was taken off the vessels and it was necessary to supply and transfer ballast, making impracticable the confirmation of the data.

## **THE CARGO**

The cargo of the barge was made up exclusively of steel coils, of a cylindrical format, with a weight varying between 12.185 and 37.725 t and with diameters varying between 1.529 and 2.021 m and height between 1.013 and 1.850 m in a total 9014.315 t

## **THE STOWAGE OF THE CARGO**

The above-mentioned coils were stowed on cradles, made of laminated steel ASTM-A131 Degree “A” or higher, of welded manufacture, on the main deck of the barge. The axle of the cylinder of the coils is positioned in a direction transversal to the centre line of the barge.

Of the 340 coils, 04 were stowed on Level II and 336 on Level I (main deck). The fastening of these cradles, which are in number of 84, on the main deck of the barge, is done by means if accessories employed in the fastening of containers.

These cradles have the following characteristics:

Length	6.524 m
Width	2.438 m
Height	0.932 m
Maximum load	180 t
Weight	3.254 t
Fastening points in the deck	04 points

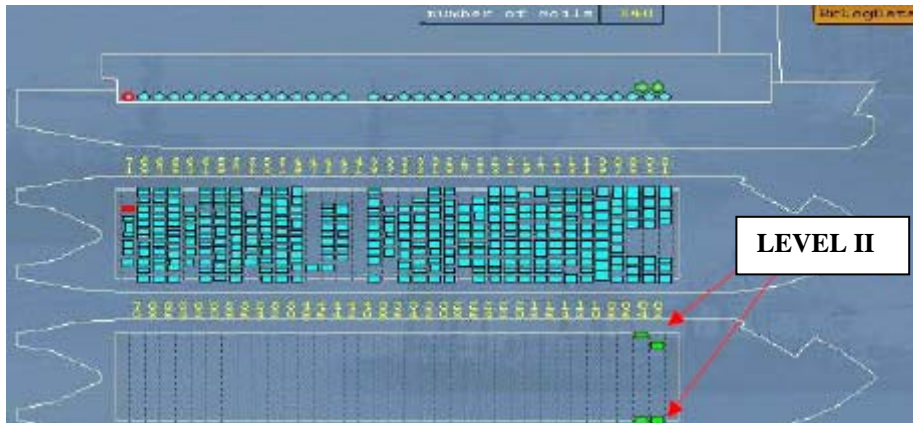
The above information was taken from the drawing of PROJEMAR S.A., “Cradle of the Coils”. No. 1D28-002, Rev, D Through filming carried out immediately after the accident, it was observed that same cradles were suspended a number inferior to the fastening points and others presented their fastening by means of welding on the deck.

It should also be registered that, even though that in the document “Leaflet of Trim and Stability”, no. 1D10-110, issued by PROJEMAR S.A. it is informed by this company in item 4 NOTES ABOUT THE LOADING, that “coils destined for road transport, with a maximum of 13 t can be transported in two layers”, furthermore the conditions of loading in 11 TYPICAL CONDITIONS OF LOADING do not contemplate coils with weight above 13 t on Level II, the barge “NORSUL12” carried 04 coils with unitary weight higher than 13t on Level II, as presented below:

<b>POSITION</b>	<b>WEIGHT (KG)</b>
2-25	34105
2-170	36285
4 -5	23945
4-170	27015

It was also observed that there existed various row with vacant spaces between the coils and as presented in the document “Leaflet of Trim and Stability”, no. 1D10-110, that not one of the loading conditions presented there allows the existence of empty spaces between coils stowed in no.1 Level.

## **DISPOSITION OF THE COILS**



## **THE LOADING/DISCHARGING**

The vessel “NORSUL12” is loaded/discharged with lorries, with the appropriate frames for coils on their bodies. These lorries embark one at a time by the access ramp, up to a maneuvering area existing on the bow, where a travelling crane with a capacity for up to 40 tons takes out a coil from the cradle where it is stowed and places it on the body of the lorry. The convoys employed in the traffic between Vitoria and São Francisco do Sul carry only steel coils.

## **THE ANTI-HEELING SYSTEM**

This system has the purpose of compensating, during the loading of coils, in port, the small heeling resulting from this loading. It consists of sensors that inform the heeling to a computerized system, which with the help of pumps transfers the ballast of one of the tanks no. 4 Pt or Stbd, to the other in order to maintain the barge without any heeling that prejudices the loading.

## **(b) DOCUMENTS OF THE VESSELS** **THE STATUTORY CERTIFICATES**

The Statutory Certificates were received by the Delegation of the Port Captaincy in São Francisco do Sul on 28/03/08, with all being verified as to their conformity in relation to the applicable Conventions and the fulfillment of the surveys prescribed in these Conventions. After analysis, the certification of the ship presented was considered in conformity with the Conventions. Below is a list of the certificates, their dates of issue, expiration and surveys, presented just as in the Formulary A, usually employed by the Naval Inspectors during their inspections of ships.



**“NORSUL VITÓRIA”**

<b>Certificates</b>	<b>Issuing Authority</b>	<b>Date of Issue</b>	<b>Date of Expiration</b>
Safety of Building	ABS	23/09/06	26/04/11
Safety of Equipment	ABS	23/09/06	26/04/11
Safety Radio	ABS	23/09/06	26/04/11
IOPP	ABS	23/09/06	26/04/11
Load Line	ABS	30/10/06	26/04/11
DOC/ISM	DNV	07/08/03	18/12/07
SMC/ISM	DNV	07/11/06	07/11/11
Safety Crew	DeISFSul	30/06/06	X
IAPP	ABS	23/09/06	26/04/11
Tonnage Measurement	ABS	27/07/06	X
Registry	Flag Country	10/08/06	X
IAPP	ABS	23/01/08	26/04/11
Class Certificate	ABS	23/01/08	26/04/11
SEWAGE	ABS	23/01/08	26/04/11

It was observed that, although the technical documents of the pusher tug “NORSUL VITÓRIA” register the capacity and the function of eventually towing the barge, this vessel does not possess the respective Certificate of Static Traction required by NORMAM 01/DPC in its item 0308.

**“NORSUL 12”**

<b>Certificate</b>	<b>Issuing Authority</b>	<b>Date of Issue</b>	<b>Date of Expiration</b>
Safety of Building	ABS	23/09/06	26/04/11
Safety of Equipment	ABS	23/09/06	26/04/11
IOPP	ABS	14/05/07	23/11/11
Load Line	ABS	14/05/07	23/10/11
DOC/ISM	DNV	07/08/03	18/12/07
SMC/ISM	DNV	07/11/06	07/11/11
Tonnage Measurement	ABS	11/10/06	
Registry	Flag Country		
Class Certificate	ABS	24/04/07	23/10/11

ABS: American Bureau of Shipping  
DNV: Det Norske Veritas

### **LAST FLAG STATE CONTROL**

The last inspection made in conformity with the Viña del Mar Agreement was made by the Naval Inspectors of the Port Captaincy of Espírito Santo, on 16/07/07, in the port of Vitória – ES, on the pusher tug "NORSUL VITÓRIA". The report of this inspection (Form B) registers 08 (eight) deficiencies. The last deficiencies of the vessel were remedied on 19/08/2007. There does not exist registries of naval inspections on the barge "NORSUL 12".

### **THE CLASSIFICATION SOCIETY AMERICAN BUREAU OF SHIPPING (ABS)**

The Classification Society of the vessels is the AMERICAN BUREAU OF SHIPPING (ABS), it has maintained the vessels "NORSUL VITÓRIA" and "NORSUL 12" in class since their keel laying. The annotations of class of the vessels denote that the vessels and their systems were built in conformity with the rules of the Classification Society and their building was also accompanied by it.

#### **Pusher tug "NORSUL VITÓRIA":**



#### **Barge "NORSUL 12"**



### **THE CLASSIFICATION SOCIETY DET NORSKE VERITAS (DNV)**

The Classification Society DET NORSKE VERITAS (DNV), has issued the certificates referring to the International Safety Management Code (ISM Code) both the Document of Compliance (DOC/ISM) and the Safety Management Compliance (SMC/ISM ) applicable to the Companhia de Navegação NORSUL and the vessels "NORSUL VITÓRIA" and "NORSUL 12" respectively.

#### **(c) CONDITION IN WHICH THE VESSEL WAS FOUND**

#### **THE LIFESAVING MATERIAL**

During the survey made on the ship, it was verified that the lifesaving material was not used by the crew in view of the difficulty in launching and the availability of small craft in the area for the abandonment.

Various crewmember were flung into the sea during the capsizing and afterwards recovered .

The Pilotage craft “PILOT4” called by the pilot, through the VHF, was the first to arrive at the place of the capsizing and collected all the shipwrecked crew. As stated by the Certificate of Safety of Equipment and by the last naval inspection carried out, it may be stated that the lifesaving material was found on good condition for use

### **THE DOCUMENT PROJEMAR S.A. – “INVESTIGATION OF THE ACCIDENT WITH THE CONVOY “NORSUL 12” – “NORSUL VITÓRIA”**

On the 20/05/08 the document “Investigation of the Accident with the Convoy “NORSUL 12” – NORSUL VITÓRIA”, was presented by the company NORSUL. This document was drawn up by the company PROJEMAR S.A. the designer of the craft components of the convoy, and reflects the conditions in which the craft found themselves and simulates diverse situations through the use of the programme Autohydro, created by the company AUTOSHIP CORPORATION.

PROJEMAR S.A. is a national company, with a wide experience in projects of vessels of diverse sizes. It should also be registered that, in view of the values of the data of entry of the programme cited above, the quantities of ballast of the barge “NORSUL 12” differ in around 0.57% with the quantities of ballast informed by the Cia. De Navegação NORSUL, in Vitória. Such variation does not influence the results obtained throughout this report.

The document delivered presented considerations about the topics listed below:

a) The loaded condition of the pusher tug and of the barge at the moment of the accident.

This topic consists of the raising of the data necessary for the definition of the loaded conditions and, consequently the hydrostatic condition of the convoy.

b) The verification of the intact stability of the pusher tug, the barge and of the convoy. With the conditions of loading at the moment of the accident, the stability of the convoy was calculated without there being observed any abnormality as to the compliance with the requisites preconized in the ‘RULES OF THE MARITIME AUTHORITY’ in force.

c) the static effect of the cargo (coils) contemplating the displacement of the coils stowed in Level II and of all the coils to port.

d) The static effect on the movement of the trolley. This hypothesis was analyzed, however it was discarded seeing that the stowage os this trolley is to Port.

e) The static effect of an accidental transfer of ballast by the anti-heeling system.

f) The effect of a hypothetical flooding, resulting from damage or accidental flooding of ballast No.4 port. For this condition, the final heel of the convoy would be 24o.

g) The effects of the flooding of the closed spaces above the main deck. (Passage tunnel and cargo space).

h) Dynamic Effects and their contributions that lead to flooding of closed spaces above the main deck: an abrupt manoeuvre (swerve) , wind, waves and dynamic sinkage. This topic quantifies the dynamic effects that could have taken the convoy to an angle of inclination that would make possible the flooding of the corridor and the cargo compartment

### **Abrupt Manoeuvre (Swerve)**

As the pusher tug is fitted with two rudders of the flap rudder type of high performance, which can be activated simultaneously by two steering engines, an evaluation was made of the angle of inclination of the convoy when carrying out an abrupt manoeuvre at a speed 10.0 knots. For this was extrapolated data of the tests carried out in the testing tank of MARIN, in Wageningen, Holland, in view of the simulated speed in the tests 12 knots the GM also was extrapolated from 0.95m to 0.618m

The result obtained was of an inclination of up to approximately an angle of 12.0°.

### **MODEL/TEST IN “MARIN”**



Despite the test with reduced models having indicated a pronounced heeling of the convoy, when carrying out zigzag manoeuvres, no technical document given to the owner emphasized this type of behaviour of the vessels.

### **Influence of the Wind**

The convoy was also tested as to the influence of the wind on its surface. In this case the tests were carried out in the laboratories of FORCE Technology, Lyngby, Denmark. The calculations presented inform that the inclination of the convoy would be of up to 1°, in the gusts, that could present a higher value of up to 30% of the wind speed, which was around 20.0 knots on the occasion.

On the occasion of the accident the winds were blowing from the Northeast with a speed of up to 30.0 knots in the gusts, according to the Bulletin of Environmental Information, dated 29 April 2008, issued by the Hydrographic Centre of the Navy (CHM).

### **Influence of the Waves**

The report presents an estimate of the reply of movements of the convoy in a situation of the sea similar to that presented itself on the day of the accident, when the waves in the order of 1.5 m up to 2.0 m.

The “Relative Movement of the Bow” varied from 1.60 m to 6.0 m and the “Rolling” 0.7° to 3.5° for a significant height of waves 2.0 m, hence it would be reasonable to estimate the heeling of the convoy at 3° for these effects.

These results also were obtained based on the tests carried out in MARIN.

### **Dynamic Sinking (sinkage)**

Also based on the tests carried out in MARIN the sinkage of the convoy was calculated when sailing in deep waters at 10 knots.

In that condition it was observed that the ship was down by the head at 0.12 m.

The stability of the convoy, when all the dynamic effects described in the present report are added together, presents an inclination of 16.0°, which would be sufficient to reach the door of the corridor, but would not compromise the stability of the convoy.

What was concluded is that the dynamic effects analyzed would be incapable to take the craft to inclinations that offered any risk to them, except when they were added and there was some other factor that made possible the flooding.

i) Flooding of the closed spaces above the main deck up to the condition necessary for the movement of of the cargo.

An estimate of the time of flooding the corridor and of the volume of water that embarks on the barge by the access door to this compartment is presented in this subject, its values are 1 to 2 minutes, with the volume of water between 157 to 314 cubic metres per minute. These estimates are based on the position of the door and on the speed of the convoy. The resulting flooding takes the convoy to an angle of incline of 27.0°, which would be sufficient to reach the the access door to the cargo compartment.

j) Combination of the flooding of the closed spaces above the main deck and the movement of the cargo.

In this subject, is presented that the occurrence of a progressive flooding of the corridor and of the cargo compartment makes possible the existence of a moment of capsizing capable of heeling the craft to the angle of 27.0°. Around this angle, the coils begin their sliding/falling inside the compartment creating moment of capsizing that exceeds the restorer moment, compromising the stability of the whole convoy, causing its capsizing

Finalizing, the document under discussion was analyzed by the experts and the situations presented therein may be considered as accordant with reality.

## **THE CONDITION OF STRUCTURAL STRESSES**

Two Strain conditions were analyzed - the bending moments and the sheering stresses - in keeping with the loading of the barge, the first one being the first condition analyzed in the Condition of Loading No. 16 of the document “Study of loading and discharge-Articulated Connection Integrated Tug-Barge of 1000 tons gross deadweight (Barge0”, No. 1d11-008, where the cargo was 9450 t and the ballast was 167.37 t which is a condition of loading with strain superior to the condition of strains that the barge presented and the second that which was presented in the document “Investigation of the accident with the CONVOY “NORSUL 12” –“NORSUL VITÓRIA”, where also are presented the calculations of these strains.

In both of the conditions of stresses verified, it was observed that, in the respective diagrams of “Shear Stresses” and “Bending Moments”, the barge did not present a condition of extreme structural stress, verifying that the structural stresses at the moment of the accident did not exceed the maximum values permitted for the vessel.

## **INTACT STABILITY**

An analysis was carried out of the intact stability of the vessel “NORSUL 12”, being used for the definition of the Gross Deadweight, the values already used in this report in the items “THE GROSS TONNAGE” and “THE CARGO” and the document “Leaflet of Trim and Stability”, No. 1d10-110 issued by PROJEMAR S.A. For the verification of the position of the centre of gravity of the cargo the document used was “Voyage 008/08s”, presented by NORSUL S.A., contemplating the location and the unitary weight of the coils on the vessel in question. A small divergence was observed between the centre of gravity of the coils obtained and that presented in the document “Investigation of the Accident with the Convoy “NORSUL 12” –“NORSUL VITÓRIA’, but which did not come to invalidate the calculations of stability already carried out.

The positions of the two coils on Level II, informed in the document “Voyage 008/08S, were corrected for their position and the centre of gravity of the cargo also was calculated for this position. As informed by the Owner, these two coils were stowed in Level I.

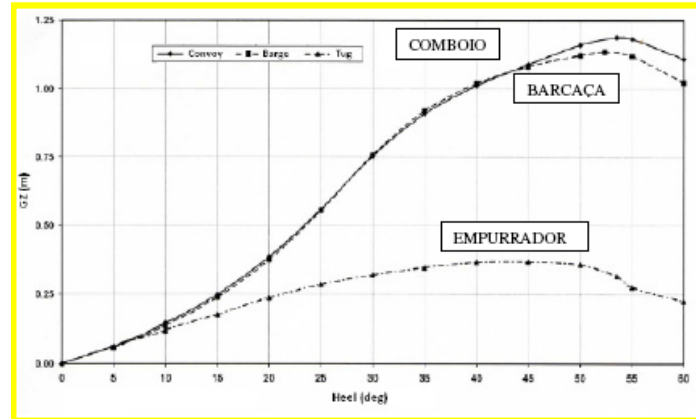
A verification was made of the condition of loading for the vessel “NORSUL 12 on the arrival in São Francisco do Sul with cargo and ballast.

It was observed that, even in traffic in interior waters, and the vessel is located outside the entrance to Babitonga Bay, in an area considered as “Interior 2” as is preconized in the “Norms and Procedures of the Port Captaincy of Santa Catarina, in item 0102 of its Chapter 1. The door with access to the corridor could not be open seeing that, in such condition, the barge did not meet the criteria pertinent to the angle of flooding preconized in the “Norms for the Vessels Employed in Interior Navigation-NORMAM-02/DPC.

It also was observed that there existed various rows with empty spaces between the coils.

The condition verified above did not present any nonconformity with the applicable norms, coming to be in accord with the condition presented in the document issued by PROJEMAR S.A. “Investigation of the Accident with the Convoy “NORSUL 12” - “NORSUL VITÓRIA.

The Curve of Static Stability of the convoy, composed of curves of the pusher tug and the barge are found below. It is observed that the determinant in the stability of the convoy is the barge.



## **CONSIDERATIONS ON THE SLIDING/FALLING OF THE CARGO**

In virtue of the cargo not being lashed and the maintaining of its position is exclusively by the attrition between the coil and the cradle or by the attrition between coils, in the case of the coils positioned in Level II, an evaluation was made of this situation of the cargo, which is presented in the annex “Evaluation of Falling/Sliding of the cargo”.

## **THE “SQUAT” EFFECT**

The convoy formed by the barge “NORSUL12” and the Pusher tug “NORSUL VITÓRIA”, at the moment of its capsizing, was sailing in a channel of shallow water at a speed of approximately 10 knots and as the SQUAT phenomenon is the tendency of a ship to sink and acquire trim when in movement, in the case of this type of vessel, a trim by the bow, reducing its possible flooding angle if we consider the doors of the cargo compartment and the corridor open.

Being thus, this effect is being quantified in the annex “Evaluation of the SQUAT effect” and its contribution for the decrease of the flooding angle, with the already mentioned doors open. Considering the sinking of the bow 0.60 m, the flooding angle becomes approximately  $12.9^\circ$ , for the access door to the corridor.

## **THE SURVEY OF THE VESSELS**

The first visit of the surveyors to the convoy formed by the barge “NORSUL 12” and the Pusher tug “NORSUL VITÓRIA”, after the accident took place on 14/02/08 at 10.00 hours. On the occasion, the vessels were, connected by the articulation pins of the pusher tug.

Only part of the sides and of the bottoms of the vessels were immersed, with a heeling of approximately 20°, as may be observed in the photos taken on the occasion. The upper part to port of the barge was touching the bed of the banks of the channel and starboard was approximately 3.0 metres from the bottom.

The access to the interior was only being carried out by autonomous divers, contracted by the insurer of the vessels. Thus access to the interior of the craft was not possible for the surveyors.

The pusher tug “NORSUL VITÓRIA” presented its starboard rudder with a small angle to port.

Excepting the dents in the bows of this tug, no damage to its quick works or to the side was observed. The after end was submersed and could not be observed during this survey. The barge “NORSUL 12” also did not present damages on its bottom and on the part of the side which was visible, however a strip located on the bottom, close to the port bilge keel indicated that this vessel had touched the bottom of the bay. The operation for discharging the oil onboard after the accident, was carried out by the Dutch company Smit Salvage BV. The company contracted to carry out the task of righting the convoy was the Dutch company Svitzer Wijsmuller.



On 03/05/08, due to severe meteorological conditions of the region, composed of winds of force 7 to 8, on Beaufort Scale and waves of more than 2m, the hull of the barge separated from the cargo compartment, the so called garage, becoming liberated. On the bottom remained the coils and some cradles at the bottom of the bay, at the initial position of the capsizing

The pusher tug “NORSUL VITÓRIA ” remained in the same position, seeing that its superstructure was in contact with the bottom. The righting was carried out with a manoeuvre of ballast and traction by means of cables, as described in the document “08031 – PROPOSAL FOR THE SALVAGE OF NORSUL VITÓRIA & NORSUL 12”, issued by Svitzer Wijsmuller.

On 13/06/08 after the righting of the barge “NORSUL 12”, carried out on 07/06/08 and afterwards the towage to alongside the raft “SUPERPESA X”, the surveyor went onboard that vessel finding it quite dirty with biological encrustations. On this opportunity, no evidence that could contribute for the clarification of the accident was observed.

The cradles that on the occasion of the capsizing were fixed on the deck of the barge, were stowed on the deck of the raft “SUPERPESA X”.



On this opportunity, it was verified that the two lower locks of the ramp disembarking/embarking were in the normal position of closing the ramp, thus denoting that it was totally closed at the time of capsizing.

The access had the weight of 200 tons and when open without being supported on the quayside, in the condition of loading of the accident, would be capable of heeling the barge to port in angles higher than 7°. One can have a notion of the size of this ramp in relation to the barge by observing the drawing ‘DECK NORSUL 12’. It was also verified that the doors giving access to the Port corridor and to the cargo compartment on the same side were open. Up to the date of the closing of this report, there remained 109 coils and 4 cradles under water.

### **UNDERWATER FILMING CARRIED OUT**

On 18/02/08 underwater filming was carried out by divers of the 5th Naval District, where was observed the situation of the cargo which was positioned on the roof of the cargo compartment, some cradles fixed on the cargo deck and the nonexistence of damages on this deck.

On 02/05/08, another filming made by the divers of the 5th Naval District and of the Admiral Castro e Silva Naval Base (BACS), where were observed the damages to the ramp, to electric switchboards, on the exposed bottom of the barge and of the pusher and other details, including that in this filming it was ascertained that the Ballast Control Centre was closed with a padlock.

In both underwater filming sessions, the transparency of the water was not good, many times not permitting to have a better notion of the visualized detail.

## **II) PERSONAL DATA:**

### **(a) QUALIFICATION OF THE CREW**

The crew of the pusher tug was made up of 11 (eleven) crewmembers. Considering the importance of the qualification of the crewmembers below will be confronted the Safe Manning Card, issued by the Delegacy in São Francisco do Sul, on 09/11/2007, with the qualification certificates of the crew embarked. The Safety Manning Card (SMC) refers only to the pusher tug “NORSUL VITORIA”. The barge “NORSUL 12” was not manned

### **THE SAFETY MANNING CARD (SMC)**

Grade/Capacity	Certificate (STCW Regulation)	Number of persons		
		Category	Level	Quantity
Master	II/2	CPI	9	01

Chief Officer	II/III/31V/2	1ON	8	01
Deck Officer	II/III/31V/2	2ON	7	01
Radio Officer	IV/2	20R	7	01 <sup>1)</sup>
Boatswain	-	-	-	-
Chief Engineer	III/2	10M	8	01
Second Engineer	III/1	20M	7	01
Engineer Officer	-	-	-	-
Petty Officer Engineer	-	-	-	-
Electrician	III/4	ELT	5	01
Male Nurse	-	ASA	3	01 <sup>2)</sup>
Cook	-	-	-	-
Steward	-	-	-	-
Oiler	-	-	-	-
Able Seaman	-	-	-	-
Ordinary Seaman	II/4	MOC	3	01 <sup>3)</sup>
Wiper	III/4	MOM	3	02
TOTAL NUMBER				11

The SMC of the pusher tug has the following additional exigencies:

- 1) The function of Radio Officer will be performed by a Deck Officer who fills the requirements of Chapter IV of the STCW78/95 Convention;
- 2) The function of ASA may be performed by a crewmember that possesses the First Aid Course recognized by the Directorate of Ports and Coasts (DPC); and
- 3) The Ordinary Seaman may be substituted by a cook (CZA).

After analysis of the documentation referring to the qualification of the maritime personnel embarked, it was verified and considered in conformity with the “International Convention on Standards of Training, Certification and Watchkeeping” (Convention STCW 78/95). However, it was observed, through the document “Request for Clearance”, that one crewmember had been cleared as Able Seaman and however he did not possess that qualification

### **III) DATA OF THE LOCALITY OF THE ACCIDENT**

#### **(a) IDENTIFICATION OF THE LOCALITY**

The capsizing of the convoy formed by the barge “NORSUL 12” and the pusher tug “NORSUL VITÓRIA”, occurred in the access channel of Babitonga Bay, and the vessels remained at the position Lat 26° 09.8 S and LONG 48° 31.0 W. The depth at that place is approximately 8.0 m .

The distance to the coast was 0).7 kilometres and to São Francisco do Sul 15 kilometres.

This data was taken from Chart no. 1840 “Access Channel to the Port of São Francisco do Sul”, of the Directorate of Hydrography and Navigation of the Navy (DHN).

Below is a reproduced part of the above mentioned chart with the position of the vessels:



## **b) ENVIRONMENTAL CONDITIONS**

### **THE TIDE**

At the time of the accident, the tide foreseen was ebbing, with the high tide at 20:43 on 30/01/08, height of 1.0 m and low tide at 00.06 on 31/01/08, with a height 0.6 m, according to the publication “Tide tables for 2008” for the Port of São Francisco do Sul.

### **THE CLIMATIC CONDITIONS**

As presented in the Bulletin of Environmental Information, dated 29 April 2008, issued by the Hydrographic Centre of the Navy (CHM), the meteorological occurrences, on 30 and 31 /01/08 were:

#### **30/01/08**

Sky nearly overcast, with drizzle/light rain, wind from NE/SE occasionally SW with velocity of 02 to 13 knots; visibility good (greater than 10 km), passing to moderate (4 to 10 km) air temperature between 21.0°C and 25.0°C and temperature of seawater 25.5°C.

#### **31/01/08**

Sky nearly overcast with moderate/strong rain and thunder; winds from SW/SE with speed of 02 to 18 knots with gusts of between 18 and 30 knots; moderate visibility (4 to 10 km) occasionally restricted (1 to 2 km); air temperature between 19.0°C and 23.0°C and sea water temperature 24.5°C.

It is observed that the meteorological conditions did not present any restriction for the vessels and did not influence incisively for the occurrence of the accident.

According to information, obtained from sites available on the internet, during the voyage Vitória – São Francisco do Sul, the convoy faced more severe sea conditions than those found in the entrance to Babitonga Bay.

**THE “AIS” SYSTEM OF THE WATCH TOWER OF THE PILOTAGE OF SÃO FRANCISCO DO SUL**

The Watch Tower of the PILOTAGE OF SÃO FRANCISCO DO SUL, located close to the beach of Ubatuba, close to the position LAT 26° 11.2 S and LONG 048° 31.8 W, possesses an Automatic Identification System (AIS) of vessels, that made it possible to observe the dynamics of the events, from the moment when the convoy arrived at São Francisco do Sul up to its capsizing.

The register provides the time, the date the latitude, the longitude, the course and the speed of the convoy, besides various segments obtain from the DVD of recording the movement of the vessels and commence at 22:34:58, on 30/0108 and end at 23:33:23 the same day.

On 07/05/08 a visit was made to this watch tower by the investigators when were crossed the data of the recordings existing there, with the printed records.

Below are some events observed in the recordings of the watch tower and entered on the records of the convoy:

<b>EVENT</b>	<b>TIME</b>	<b>LAT</b>	<b>LONG</b>	<b>COURSE</b>	<b>SPEED (knots)</b>
Arrival in range of the AIS	22.34.58	26 10 53.4S	048 27 52.2W	231.0	12.4
Pilot on Bridge	22:52:12	26 11 03.3S	048 30 10.7W	335	7.5
Swerve to STBD	22:56:47	26 10 21.0S	048 30 25.2W	334.1	10.2
Entrance to channel	22:57:47	26 10 12.6S	048 30 31.8 W	314.0	11.3
Stopped at distance 2.55 miles from Buoy 2	23:01:02	26 09 54.6S	048 31 02.4W	285.00	11.1
Call for support of the launch and heeling	23:11:17	26 09 54.0 S	048 31 02.4W	270	0.3
Start to capsize	23:14:17	26 09 54.0S	048 31 02.4W	308.5	1.0
Capsized	23:20:51	26 09 54.0S	048 31 02.4W	295	0.3
Launch in locality	23:25:21	26 09 54.6S	048 31 02.4W	211.3	0.5
End of the AIS transmissions	23:33:23	26 09 54.8S	048 31 04.3W	211.3	0.5

It should be emphasized that the times shown may diverge slightly with the times of the actual events.

#### **IV) SEQUENCE OF THE EVENTS**

On 30/01/08 the convoy formed by the barge “NORSUL 12” and the pusher tug “NORSUL VITÓRIA”, arrived at 22:34 on that day, at the entrance of the port of São Francisco do Sul, in the position 26 10 53.4 S and 048 27 52.2 W, with a draft of 6.124 m excepting the SQUAT. In the proximities of this position, the electrician went to the recess of the berthing winches to STBD opening the watertight doors of access to the cargo compartment and to the port corridor.

According to testimonies, excepting the watertight door of the corridor to starboard, all the forward watertight doors were open on the occasion of the approach to the port of São Francisco do Sul.

This convoy sailed from Vitória (ES) on 28/01/08 at 18.15 hours, with a cargo of steel coils weighing 9014.315 t. During the voyage, the convoy faced environmental conditions more severe than those encountered at the entrance to São Francisco do Sul and, despite the routine inspections of the cargo compartment, no abnormality was reported.

In the proximities of No.2 buoy, at 22.45, the pilot embarked on the side of the barge “NORSUL 12”, going to the pusher tug “NORSUL VITÓRIA”, arriving on the bridge of this vessel at 22.52.

After, he went to the flying bridge, since that was the only place on the pusher tug that “permits visibility of the channel and of the buoys”. When making a course correction to starboard, in order to make for buoys nos. 03 and 08, he observed that the change of course was not obeyed, developing full helm to starboard.

The actions of the sea, of the wind and the swerving maneuver, made the convoy heel more than 16°.

As the watertight doors of access to the corridor and the cargo compartment, existing in the recess of the Pt berthing winches, were open and the angle of flooding, considering the SQUAT effect reaches 12.9°, the flooding of those compartments commenced.

As the flow of embarked water, was between 157 and 314 cubic metres per minute, it filled the corridor in approximately 2.0 minutes, starting to flood the cargo compartment.

Upon reaching an angle of approximately 27°, the coils that were on Level II, to starboard, started to slide/fall to port increasing the heeling, followed by other coils stowed to starboard that started to slide untidily to port.

So the speed of the vessels was reduced and also an attempt was made to break the swerve, however without success. From thereon measures taken were for the safety of the crew that were on the barge and a maneuver carried out to avoid an accident in the access channel to the port, which could obstruct it. For this was actuated the bow thruster and the convoy, already heeled, went slowly to the side of the access channel. The heeling continues until all the quickworks were exposed with the convoy totally capsized, remaining with a slight inclination to port.

The crew was picked up from the sea, by the Launch “PILOT 4” and efforts were made to save the Chief Engineer, who caught in the interior of the pusher tug waved from a porthole of that vessel.

## **V) CONSEQUENCES OF THE ACCIDENT**

### **(a) PERSONAL ACCIDENTS**

The capsizing of the vessels did not cause any deaths amongst their crewmembers and their other occupants. However, some of these crewmembers suffered slight injuries and were immediately attended in a hospital of the region, being promptly liberated, not requiring internment.

### **(b) MATERIAL DAMAGES**

Both the barge “NORSUL 12” and the pusher tug “NORSUL VITÓRIA” were righted, with the barge being prepared for towing, in Babitonga Bay (SC), near the city of Itapoá (SC), and the tug was taken to the port of São Francisco do Sul (SC). Afterwards, they were towed to Rio de Janeiro (RJ) to be recuperated in the shipyard NAVE SHIP S.A. All the upper works of the vessels were damaged, as well as the equipment on board.

All the cargo, made up of steel coils, also could not be re-utilized, being sent for scrapping.

### **(c) POLLUTION**

The information about the damages referring to water pollution caused by the capsizing of the convoy formed by the barge “NORSUL 12” and the pusher tug “NORSUL VITÓRIA” were taken from the document “Technical Environmental Report 022/2008”, issued by the Management of Environment of the Directorate of Ports and Coasts. This document informs that, right after the accident it was possible to notice presence of oil in the water around the vessels and, that after 12 hours, the oil stain had an extension of approximately 1500 m length by 300 m width

### **BY THE FUEL OIL/DIESEL OIL/ LUBRICANT OILS**

The convoy carried approximately 90,000 litres of heavy oil (density between 0.9665 and 0.9697), 13,800 litres of diesel oil (density between 0.82 and 0.88), 13,350 litres of lubricating oils and others (density between 0.89 and 0.916), besides 7,000 litres of oily mixture. Of this total volume of the above quantities, 116,500 litres were spilt due to the accident, whilst approximately 7,900 litres were collected.

According to the conclusion of the “Technical Environmental Report 022/2008”, in view of the volume of the oil spilt, the reaching of the beaches in the region, the existence of threatened species, the locality itself being considered of great environmental importance, tardy containment actions, the spilt oil being from group IV (persistent) and the socio-economical problems caused, “the incident should be classified as very serious environmental damage”

## **VI) ANALYSIS OF THE DATA OBTAINED**

Based on the information collected and presented throughout this technical report one can have an image of the facts that elapsed and ended with the accident. In the analysis of the possible causes of the capsizing of the convoy formed by the barge “NORSUL 12” and the pusher tug “NORSUL VITÓRIA” the following premises were considered:

- a) The doors of access to the corridor and to the cargo compartment (main deck) to PT were open, as informed by testimonies of the crew;
- b) The access ramp for vehicles was closed and locked, since its principal locks were found in closed position;
- c) The rolling bridge was considered stowed in its position for the voyage and did not move at any moment, for there were no reports of any abnormality in the compartment by the crew, that accessed it regularly;
- d) The convoy sailed with a SQUAT on the bow estimated at 0.69 m, and which came to contribute for the diminution of the angle of flooding of approximately  $2.0^\circ$ , considering as point of flooding the door of access to the corridor;
- e) There was no manoeuvre at all with the ballast of the barge, during the voyage, seeing that the Ballast Control Centre of the barge was closed with a padlock and the crewmembers responsible for this manoeuvre testified that no manoeuvre had been made. Also no abnormality was reported by the pilot, when boarding;
- f) A fault in the “anti-heeling” system of the barge which could transfer the ballast from tank No.4 starboard to tank No.4 port would not be capable of capsizing the convoy;
- g) The convoy, when carrying out manoeuvres of the zigzag type, has inclinations in the order of  $12^\circ$  for either of the sides, which was known to the Master, but was not emphasized in the pamphlet of trim and stability;
- h) The convoy did not touch the bottom before being taken, deliberately, by the crew to outside of the canal, seeing that the depth in the locality was of 10.0 m (Chart 1804) more the draft of the convoy, which was approximately 6.70 forward, if added to the calculated SQUAT effect;
- i) the action of the rudders of the pusher tug, which are the type “flap rudders”, causes heeling and going down by the head of the whole convoy;
- j) The flooding of the corridor and of the cargo compartment happened very rapidly without it being possible for the crewmembers, who were on the barge, take any measures to stop it.
- k) The barge did not suffer any damage or structural fault.: and
- l) the vessels that make up the convoy were in a good state of conservation their project attended the norms in force.

## **Possible causes of the capsizing of the convoy “NORSUL VITÓRIA” and “NORSUL 12”**

The convoy formed by the vessels “NORSUL VITÓRIA” – “NORSUL 12” when executing manoeuvres composed of swerving, at a speed of approximately 10.0 knots, suffers an inclination in the order of  $12^{\circ}$ . These inclinations added to the inclinations caused by winds and waves, totalize  $16^{\circ}$ . Adding all these effects to the sinking of the bow of the barge, when sailing in shallow waters, made it that the water reached the door giving access to the lateral corridor and to the cargo compartment, existing forward, on the main deck, to port, whose angles of flooding, when added to the SQUAT effect, becomes in the order of  $12.9^{\circ}$ .

As these doors were open, there commenced a progressive flooding of the compartments mentioned above, taking the convoy to an inclination of  $27^{\circ}$ , an angle at which the cargo commences to move starboard, causing the capsizing of the convoy.

The form of fixing of the cradles on the main deck did not contribute for the sliding/falling of the cargo. The cradles for stowage of the coils are fixed to the deck by means of accessories for the fixing of containers although some were welded directly to the deck by points of solder, as verified in the first underwater filming. However, the cradles placed transversely to the Centre Line of the barge, quite close to each other and practically they are contained, at the ends of their rows by the bulkheads of the Port and Starboard corridors.

Thus, both the fixing and the layout of the cradles did not contribute for the sliding of the cargo

There was no excess of cargo on the barge “NORSUL12”.

- a) the barge sailed with a draft of 6.123 m inferior to the projected draft which is 6.50 m;
- b) the cargo of coils was of 9014.315 t, also inferior to the various loadings of coils presented in the document “Leaflet of Trim and Stability” no. 1D10-110, issued by PROJEMAR S. A. which are in the order of 9500 t;
- c) the gross deadweight of the barge, at the moment of the accident was 9452.785 t and, at the maximum draft, this gross deadweight is of 10352.074 t; and
- d) The pilot, when embarking, read the draft of 6.20 m on the barge and, in the manner that was made the reading of the draft, at night and in adverse environmental conditions, the value read was coherent with the calculated draft

The cargo of the barge “NORSUL 12” was badly stowed. It may be considered that the cargo was badly stowed seeing that there were coils with a weight superior to 13 t on Level II and spaces for stowage in the transversal direction of the barge between the coils stowed on the main deck. Such arrangements contravene the “Leaflet of Trim and Stability”, No. 1D10-110, issued by PROJEMAR S. A., and other documents presented referring to stability of the vessel.



There was no free surface in tanks that, combined with the state of the sea, could provoke the heeling or capsizing of the convoy. All the studies of stability of the vessels, made by the company PROJEMAR S. A. and approved by the Classification Society American Bureau of Shipping (ABS), always include the evaluation of the free surfaces of the tanks. In no condition of loading, the existing tanks do not compromise the stability of the convoy.

With the forward doors of access to the cargo compartment and to the corridor to PT closed, in the conditions of loading and environment at the moment of the accident, the flooding of these compartments would not have occurred. The flooding would not occur seeing these doors, are fitted with sealing, they are considered watertight doors and, in accordance with the good norm of shipbuilding, must have been tested as to their waterproofing and would have been sufficient to restrain the water that came to flood the recess of the berthing winches existing forward on the main deck. The point of flooding of the barge stipulated for the calculation of intact stability of this vessel is a respirator existing on the ceiling of the cargo compartment and the respective angle of flooding considered is 56°.

A fault in the anti-heeling system could not cause an inadvertent manoeuvre of ballast that with consequence would capsize the convoy. According to calculations made by PROJEMAR S. A. ,presented in its document “Investigation of the Accident with the convoy NORSUL 12 – NORSUL VITÓRIA”, in a static situation, without the actuation of the wind, sea, swerve, and SQUAT, the inadvertent transfer of all the ballast existing in ballast tank no. 4 Stbd to tank no. 4 Pt would cause an inclination of only 2.50° to Pt not putting at risk the integrity of the vessels.

The other ballast tanks are in the central region of the barge and for their manoeuvre a human presence is necessary in the Ballast Control Centre, which was closed with a padlock. Furthermore the transfer of ballast from a tank situated astern to another forward that could increase the SQUAT is not probable.

### **Faults in the operations procedure of the vessels that contributed for the accident**

On the part of the crew, seeing that, when opening the doors of the barge “NORSUL 12”, to carry out the ventilation of the cargo space and of the corridor existing close to the side, the angle of flooding of the barge was reduced, permitting that , upon heeling due to the swerves made for correction of course and other factors, there was flooding of the compartments in question that culminated in the capsizing of the whole convoy.

### **DETERMINANT CAUSE OF THE ACCIDENT**

The determinant cause for the accident was the doors of access to the cargo compartment and to the corridor to port being open, on the occasion of carrying out of swerves, in the environmental conditions prevailing at that time.