CHAPTER TWO HUNDRED TWELVE

A New Nuclear Density Gauge to Measure Directly High Turbidities in Muddy Areas

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Foreword

A better knowledge of the characteristics of muddy areas, in access fairways and port basins, and of the behaviour of ships during their crossing, presents the double interest of enhancing the navigation possibilities, through a more precise adjustment of the ship draught to the status of the bottoms, and permiting a more rational organization of the maintenance dredging campaigns. Considerable savings will be obtained through the development of such knowledges for harbours management.

These improvements imply the use of measuring equipments which must be handy, sturdy, reliable and which give accurate measurements.

The JTD3 gauge presented by the Radioisotopes Applications Service of the French Atomic Energy Commission is an important step in the development of such measuring equipments. It is now in running order, and commercially available, after thorough test campaigns, undertaken during many months in different french harbours.

New developments are already engaged, namely through the design of a turbidity gauge able to make dynamic measurements.

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I - Introduction

The depth necessary for sailing includes the free space between the keel and the bed of the channel, called keelclearance (Fig. 1a). However in muddy areas, it is quite possible for ships to sail through non consolidated silt (Fig. 1b) without reducing the safety.

The usual method to determine the water depth is based on the traditional hydrographic survey. But the upper trace recorded by echosounder appears as the bottom of the channel. In these conditions it is very difficult to say exactly where the nautical depth is, and the maintenance dredging takes two aspects:

- when, where to dredge and to which depth ?
- how to control dredging works cost ?

In assessing the nautical as well as the dredging aspects, an important factor is the density of the silt/water mixture. For this purpose, a nuclear scattering gauge, called SAPRA JTD3, has been developed to measure directly in the mud layer, vertical density (or concentration) profiles versus depth.

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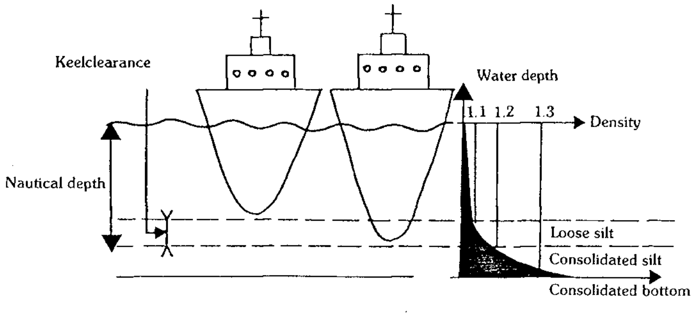

Fig. 1 - Scheme of keelclearance showing the consolidated bottom, the consolidated silt layer, and the loose silt layer.

II - Principle and Description of the Scattering Gauge

II.1 - Principle

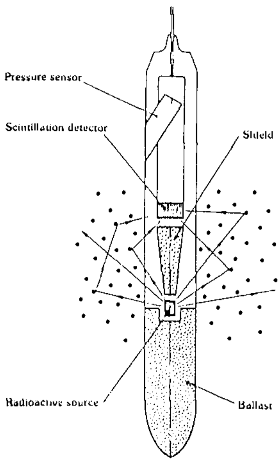

Fig. 2 - Scheme of the SAPRA JTD3 probe.

Gamma rays emitted in all directions by a very small cesium 137 sealed source (500 μCi or 18.5 MBq - Energy 661 keV - half life 30.18 years), are scattered through the sediment (Fig. 2).

The detector is shielded from direct gamma rays emitted by the source by the mean of a conical shaped tungsten plug set between the detector and the source housing (Fig. 3). The source to detector spacing is nominally 5 cm.

Gamma rays emitted by the source interact with the electrons of matter through two main ways: Compton effect and photoelectric absorption. Figure 4 shows the relative importance of those interactions versus gamma energy and atomic number Z.

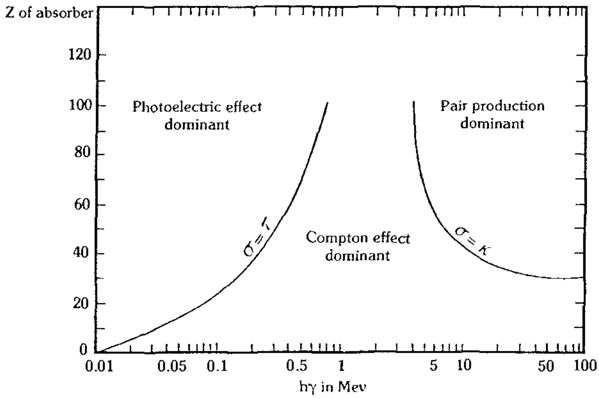

Fig. 4 - Relative importance of the different interaction effects between X or γ rays with matter.

The probability of occurrence of Compton effect is proportional to the ratio Z/A of an atom (A atomic mass of the element). This ratio is nearly the same for all the element, except hydrogen. That means that the diffusion effect is nearly independent of the chemical constitution of the sediment one wants to measure the concentration. But the probability of occurrence of photoelectric effect is proportional to the ratio Z^5/A of an atom. So this absorption effect will increase with the presence of mineral element of higher mean atomic number than classical SiO_2, CaO, Al_2O_3, K_2O... and so on.

As the two effects occur in competition in the same media, one must be careful to calibrate the probe in a media of chemical composition, more precisely mean atomic number not too different from the material which will be measured in situ.

11.2 - Description

The probe device consists in a stainless steel pencil-shaped tube (Fig. 3). Length: 1000 mm, diameter: 55 mm, weight about 20 kg. Due to its shape, this gauge penetrates easily into the mud layer up to a density of 1.3 (about 500 gl^{-1}). lt is connected with an electronic data acquisition system through a four conductors steel cable (diameter 4.6 mm - tensile strength 1200 daN) stored on an electric winch.

This gauge can be connected (Fig. 5) to a small computer (APPLE 11) which controls the winch and calculates the sediment concentration profile.

The submersion depth is determined by a pressure sensor up to a maximum depth of 100 m. Winch and data processing equipment are powered by a gasoline or oil fired generator providing an AC 220 V supply.

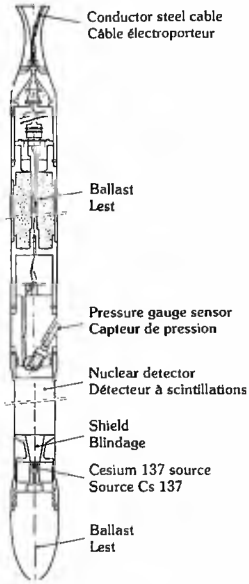

Fig. 5 - Photograph of the SATRA-JTD3 gauge showing the probe, the winch, the computer and the printer.

II.3 - Safety

The radioactive source is certified as "material under special form" ISO GE 65 535 in agreement with international standards.

Maximum dose equivalent rate in contact with the gauge close to the source is less than 10 mrem/h when the probe is out of its transport shielding. In these conditions the handling of the probe requires minimum radiation safety.

III - Measurements in Practice

III.1 - Calibration

The calibration will be done in large barrels (called infinite medium size ones). The probe hanging in medias ranging from water (fresh or salt water) up to mud suspension in the range density from 1 to 1.5.

Reference measurements N_W is taken in water. Table I and Fig. 6 give typical results.

Table I - Calibration of the gauge

Concentrations G in g/l	0	195	262	306	359	413	484	542	629
Densities ρ	1	1,12	1,16	1,18	1,21	1,25	1,29	1,32	1,37
$R = \frac{N_e}{N_W}$	1	1,037	1,040	1,054	1,063	1,074	1,083	1,094	1,113

A least square fit (first order) gives the following calibration relation:

$$\frac{N}{N_W} = 0.700 + (0.301 \pm 0.01)\ \rho$$

Such coefficients must be entered in the computer by the operator.

III.2 - Field Measurements

Operational density measurements using SAPRA JTD3 gauges have been performed in harbours and channels like ZEEBRUGE (Belgium), SINGAPORE, LOIRE esturay, ROGHEFORT (France),...etc.

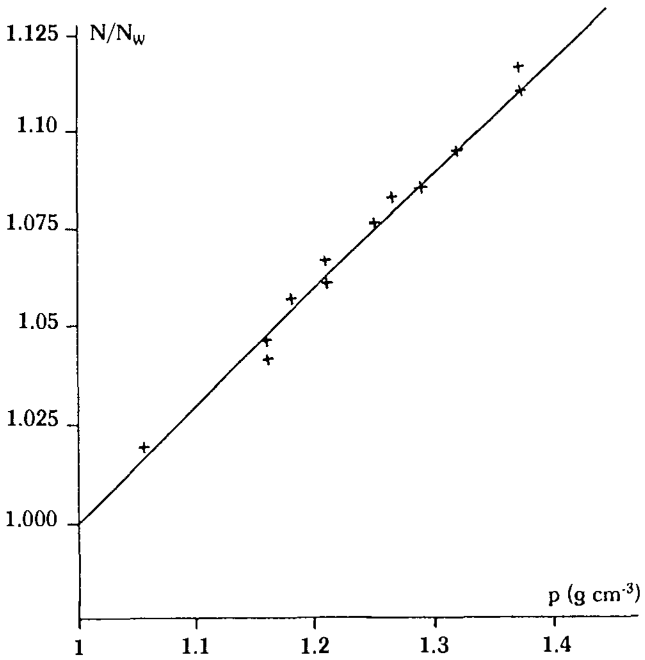

Fig. 6 - Calibration of the gauge.

The motor boat is neither morred nor anchored. The lowering speed of the probe is fixed between 0 to 30 cm/s (the usual lowering speed is 5 to 10 cm/s). Every second a measurement is realised, however the accuracy increases as the counting time increases too (typically this counting time is 5 seconds).

Typical concentration profiles are given on Fig. 7.

III.3 - Performances

The instrument has a measurement range densities of 1.020 to 1.350 (about 30 to 580 g/l).

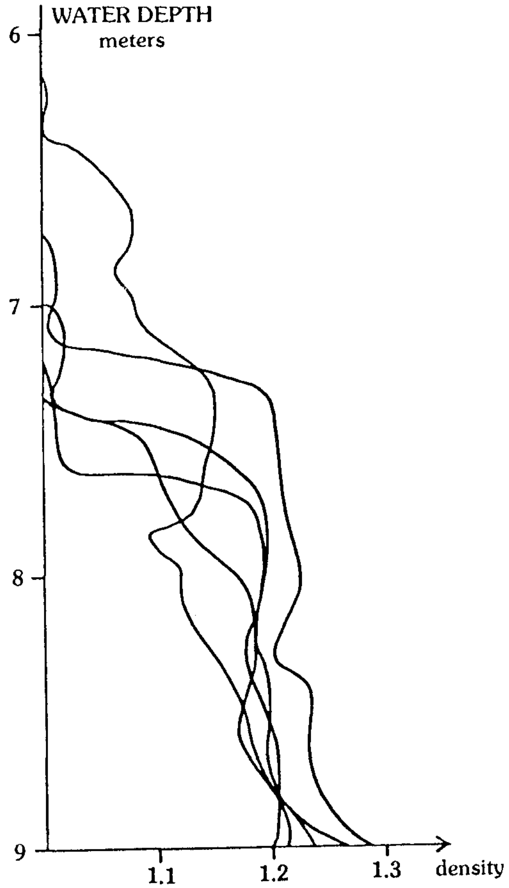

Fig. 7 – Typical density profiles in Rochefort harbour.

The accuracy is about ± 0.010 with a confidence level 95%.

The volume "seen" by the gauge is a horizontal cylinder (diameter: 60 cm – height: 15 cm).

Ten to fifteen vertical profiles per hour are recorded if the water current is lower than 2 m/s.

IV - Conclusion

In muddy areas, such as access channels and harbours, where repeatable in situ measurements of the density in sediment layers are necessary, the SAPRA JTD3 gauge and the echosounder are complementary tools. This nuclear gauge's use permits to get an optimization of the dredging schedules.