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EXPERIMENTAL CONTROL ROD STUDIES FOR SUPER-PHENIX  
PERFORMED IN MASURCA DURING THE PRE-RACINE PROGRAMME

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- INTRODUCTION -

A specific experimental programme is devoted to the study of the SUPER-PHENIX control-rods on the critical facility MASURCA. The aim of this programme is twofold :

1°/ to provide the bias factors -and their uncertainties- for the design calculations taking into account the characteristics of these rods : size and composition.

This step takes place during the PRE-RACINE programme between May and December 1978 ;

2°/ to analyze the control-rod interactions on critical configurations sufficiently large ( $R_c \approx 1.20$  to  $1.40$  cm) to give significant results as far as interaction factors are concerned.

This study must improve the calculational methods used for the power distribution prediction and for the fuel management.

The corresponding experiments could be performed during the years 1979-1980 within the framework of the CEA-CNEN-KFK cooperation.

In this paper, one presents the results obtained for the diluent rods (Na follower - diluant subassembly for the start-up core), which have been used in the SUPER-PHENIX critical enrichment definition.

I - EXPERIMENTAL PROGRAMME -

I-1/ Rods under study :

After the control-rod experiments which have been performed to study the PHENIX control-rods /1/, complementary informations are necessary for the SUPER-PHENIX rods on the following points :

- Na\_follower -

- Size effect : one has to investigate if the SUPER-PHENIX rod size (280 cm<sup>2</sup>) much larger than the PHENIX one (140 cm<sup>2</sup>) gives rise to different calculation to experiment deviations.
- Composition effect : the SUPER-PHENIX followers will include a low content of stainless steel ( $\approx 9\%$  v/o) whereas the PHENIX ones includes a higher content ( $\approx 15\%$  v/o). A preliminary study performed on MASURCA indicated that the calculation to experiment deviation was sensitive to this effect.

- Diluent\_subassembly -

The calculation to experiment deviations have to be determined for various Na and S.S. contents in a SUPER-PHENIX subassembly according to the conclusions drawn from the first studies performed on MASURCA after the PHENIX start-up. It was shown at this time that a linear interpolation between the  $\frac{E-C}{C}$  values obtained for a pure S.S. rod and a pure Na rod is insufficient to get the bias factor corresponding to the diluent subassembly composition.

- Absorber\_rod -

The SUPER-PHENIX control-rod will included 90% enriched B4C whereas the first PHENIX rods contain only 47% enriched B4C. Moreover no systematic studies of the enriched B4C have been performed on MASURCA.

Therefore the following aspects will be analyzed during the control-rod programme now in progress :

- sensitivity of the calculation to experiment deviation to the B4C enrichment, and the rod size for a given enrichment ;
- check and improvement of the present calculational method used for the rod cross-section definition : presently the rods are considered as homogeneous media where B4C and Na are mixed. Such an approximation leads to an overestimation of 10% of the rod antireactivity with respect to a more refined calculation : this point has to be checked experimentally.

$$R_i = \dots$$

I-2/ Experimental programme :

The parameters under study are :

- the antireactivity of each rod ;
- the power distribution perturbation due to the SUPER-PHENIX type rods ;
- the  $\gamma$  heating in the S.S. subassembly or in the enriched B4C rod ;
- the Na void effect at the vicinity of the absorber rod.

According to the approach used at CEA, the reactivity effects are studied parametrically versus :

- the rod size (112 cm<sup>2</sup> and 280 cm<sup>2</sup>) in order to be able to analyze the results obtained for the largest size in the light of previous results /1/ ;
- the rod composition : the following tables give the diluent rod and the absorber rod compositions built in MASURCA :

DILUENT	% v/o Na	93	88	66	45	24	0
	% v/o SS	7	12	34	55	76	100
		≈SUPER-PHENIX follower	≈ PHENIX follower		SUPER-PHENIX diluent subassembly	PHENIX diluant subassembly	

ABSORBER successively nat. B4C, 50% enriched B4C, 90% enriched B4C.

### I-3/ Core configuration :

The PRE-RACINE core built in the critical facility MASURCA is a two-zoned core : Figure 1.

- a central Plutonium zone with an enrichment of  $\approx 18.2\%$  in equivalent Plutonium which has a radius of 44.5 cm.
- a external Uranium zone with an enrichment  $\frac{U5}{U5 + U8} = 22.3\%$

The critical radius is about 55 cm. The fissile core has a height of 91.44 cm. The axial blanket is made of  $UO_2Na$  and the radial one of depleted  $UO_2$ .

All the rods studied are fully inserted at the core center overall the total reactor height (core+axial blankets).

### I-4/ Experimental techniques :

All the reactivity measurements are made using the critical balance technique. Additional fuel elements at the outer core blanket boundary are used to compensate the worth of the control rod. Moreover, the modified source multiplication technique has been used with corrections for spatial effects, the corresponding results are now under analysis.

Macroscopic relative power distributions are measured either in the clean core or in the core with the rod by standard fission chambers scan and various foils distributions to go close the rod and within the rod.

## II - DILUENT ROD RESULTS -

### II-1/ Calculational method :

The reference method used to analyze the rod effect involves 2D (R,Z) diffusion calculations using the 25 groups CARNAVAL IV cross-sections.

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The basic design calculational method for SUPER-PHENIX uses 2D (R,Z) calculations with 6 groups condensed cross-sections. The condensation effect on the reactivity values is negligible /1/ 1D cylindrical calculations have been performed for the MASURCA experiment analysis in order to check the values given for the PHENIX start-up prediction..

II-2/ Results :

The main results obtained are given in the following table which presents the calculation to experiment deviations corresponding to 2D (R,Z) and 1D (R) calculations :

Rod composition	Rod size cm <sup>2</sup>	$\frac{E - C}{C} \% (2D)$	$\frac{E - C}{C} (1D)$
93 v/o Na 7 v/o SS	112	- 7 ± 2	- 19 ± 2
88 v/o Na 12 v/o SS	112 280	- 5.5 ± 1.5 - 3.5 ± 1	- 16 ± 1.5 - 14 ± 1
66 v/o Na 34 v/o SS	112 280	- 1.7 ± 1.5 - 1 ± 1	- 7.7 ± 1.5 - 7.6 ± 1
45 v/o Na 55 v/o SS	112 280	- 1 ± 1.5 - 1.6 ± 1	- 4.5 ± 1.5 - 4.5 ± 1
24 v/o Na 76 v/o SS	112 280	+ 0.1 ± 1.5 - 0.7 ± 1	- 1.3 ± 1.5 - 1.9 ± 1
100 v/o SS	112 280	+ 0.5 ± 1.5 + 0.3 ± 1	- 0.2 ± 1.5 + 0.5 ± 1

One has to note that the influence of the rod size on the  $\frac{E-C}{C}$  deviations is quite small.

The results corresponding to the PHENIX Sodium follower or S.S. subassembly obtained during the previous programme R,Z /2/, and the PRE-RACINE programme core compared in the table hereafter :

$\frac{E - C}{C} (2D R, Z)$	PRE-RACINE (ZONA 1)	R, Z		
		Z1	R1	R3
Sodium follower	-5.5 ± 1.5	-8.3 ± 2	-5.2 ± 1	-17 ± 2
S.S. subassembly	-0.5 ± 1.5	+3 ± 2	-8 ± 1	0 ± 5

The  $\frac{E-C}{C}$  deviations observed for the Sodium follower depend upon the length of the rod under study :

- the rod is inserted on the core height for Z1 and R1 ;
- the rod is inserted on the core + axial blankets height for ZONA 1 and R3 ;

and upon the composition of the axial blankets :

- $UO_2$ -Na for ZONA 1, Z1 ;
- depleted U for R3, R1.

1D(R) calculations give  $\frac{E-C}{C}$  deviations which are independent of the axial blanket composition.

As an example, the  $\frac{2D - 1D}{1D}$  deviations are given hereafter for the "long" and "short" Na follower inserted in the R3 core reflected successively by depleted U or  $UO_2$ -Na axial blankets :

$\frac{2D - 1D}{1D}$	Depleted U axial blanket	$UO_2$ -Na axial blanket
"long" rod	- 11 %	- 25 %
"short" rod	- 27 %	- 28 %

These results are used to improve the analysis performed with 2D(R,Z) calculations.

The  $\frac{E-C}{C}$  deviations obtained for various S.S. contents in the PRE-RACINE programme are presented on Figure 2 for 2D and 1D calculations. These deviations can be compared to the previous ones issued from the R,Z programme (R3 core, see /2/). One has to note that the PRE-RACINE enrichment corresponds to the external SUPER-PHENIX core zone and R3 enrichment is equivalent to the inner SUPER-PHENIX core zone.

If the 2D(R,Z) results are not directly comparable due to the axial blanket composition differences between PRE-RACINE and R3, one observes on the 1D results that there is a systematic variation of  $\approx 7\%$  between the bias factors corresponding to the inner zone of SUPER-PHENIX (R3), and the bias factors relative to the outer zone (ZONA 1).

- CONCLUSION -

The control rod experiments performed during the PRE-RACINE programme in order to improve the bias factors associated the SUPER-PHENIX design calculations, have usefully completed the previous results obtained on MASURCA.

As far as diluent rods are concerned (Sodium follower, diluent subassembly), the first conclusions drawn concerning the antireactivity effects are :

- that the size effect ( $140 \rightarrow 280 \text{ cm}^2$ ) does not modify significantly the  $\frac{E-C}{C}$  deviations ;
- that a complete analysis of the programme can provide the bias factors for both core zones of SUPER-PHENIX. These results have effectively been used for the SUPER-PHENIX critical enrichment definition.;
- some discrepancies observed between the diluent bias factors issued from the R,Z programme and the PHENIX measurements /2/ can be now fully analyzed in the light of the PRE-RACINE programme.

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- REFERENCES -

/1/ - Y.H. BOUGET -

"Etude des barres de commande pour les réacteurs de la  
filrière à neutrons rapides"

THESE de 3° cycle - ORSAY le 19 Décembre 1974

/2/ - Ph. HAMMER et al. -

"Control rod studies in the CEA fast reactor programme"

A.N.S. Conférence on Advanced Reactors : Physics, Design  
and Economy - ATLANTA (Septembre 1974)

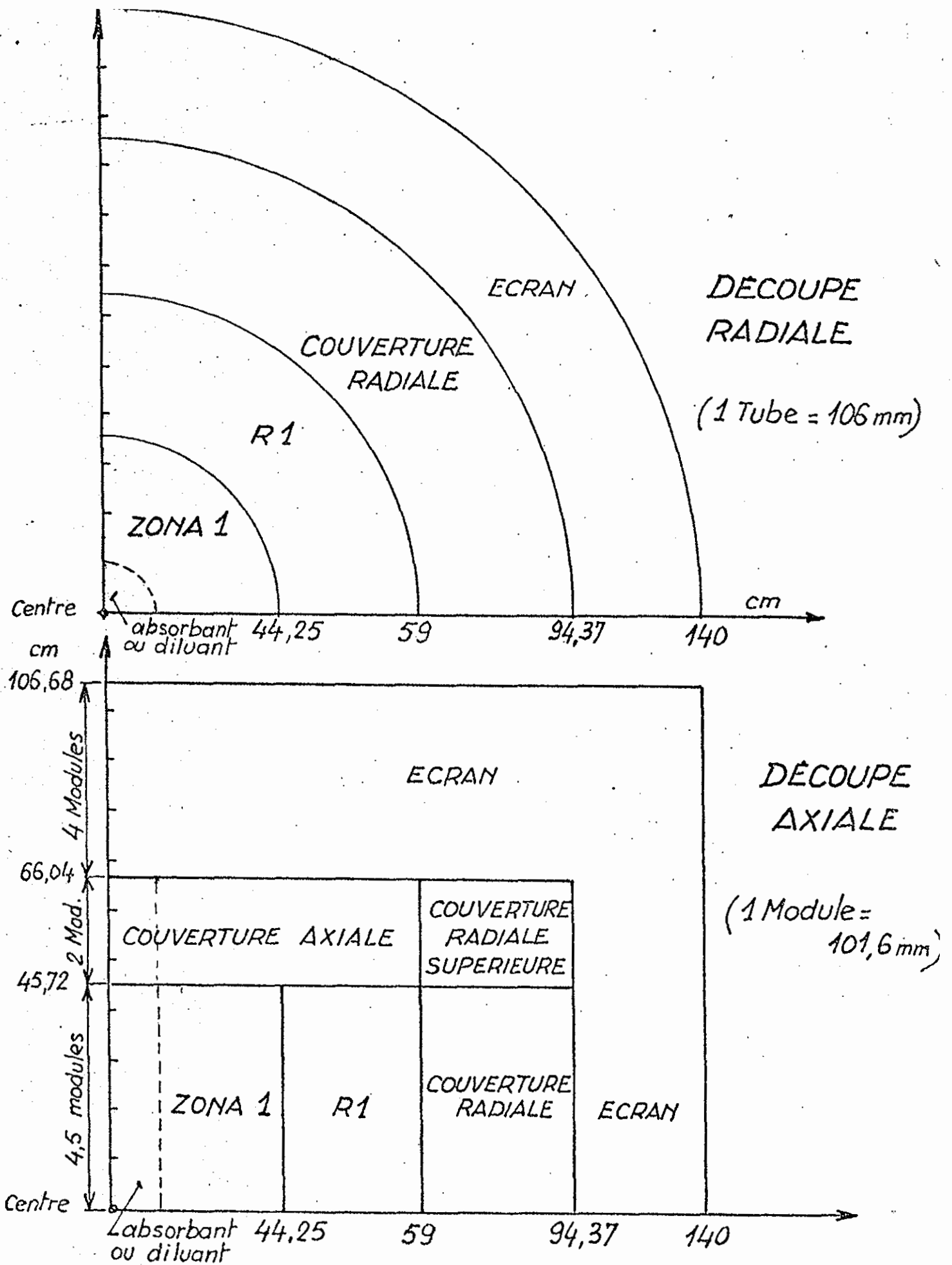
/3/ - J. BOUCHARD, J.Y. BARRE et al. -

"Physique des réacteurs au CEA : Etudes des isotopes  
supérieurs du Plutonium"

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ASSEMBLAGE CRITIQUE PRÉ-RACINE

Découpe 1/4 cœur

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Fig. 1

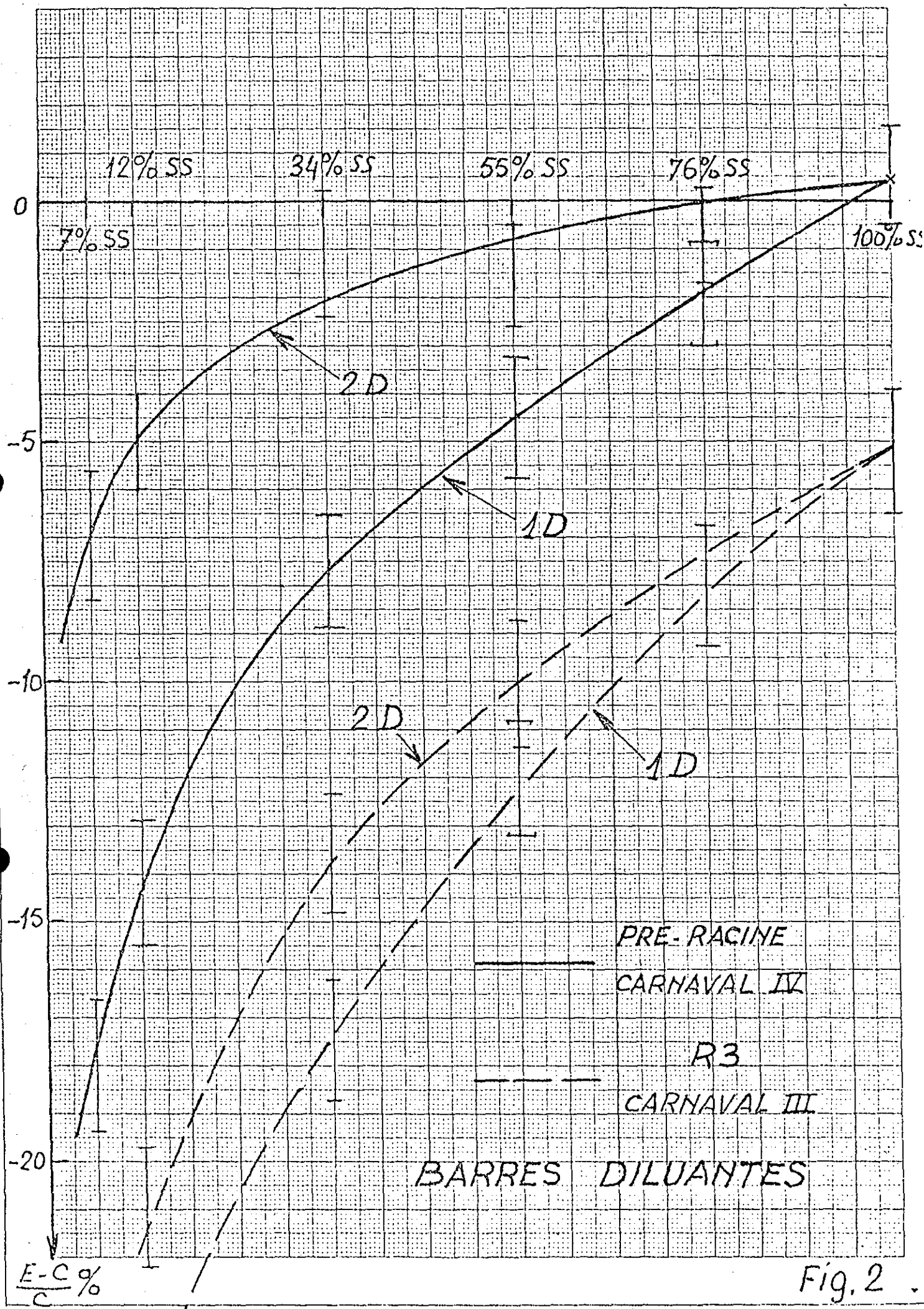


Fig. 2