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EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

A NEW CORRELATION FOR ROUND DUCT AND UNIFORM HEATING-COMPARISON WITH WORLD DATA

by

L. BIASI**, G.C. CLERICI**, S. GARRIBA***, R. SALA* and A. TOZZI**

* ARS, SpA
** ARS, SpA and University of Milan
*** CESNEF

1967

EURATOM/US Agreement for Cooperation

EURAEC Report No. 1874 prepared by ARS, SpA
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SUMMARY

A new correlation, having a large range of validity and applicable to circular ducts with uniform heat flux distribution, shall be presented. This correlation is compared with most burnout data with negative inlet quality ($X_{in} < O$) existing in the world. The mean quadratic error σ. over 4551 experimental data coming from various laboratories, is 7.26 %, and the 85.5 % of these data has an error less than 10 %. At last 576 data, which are external to the validity range, are examined and some corrective factors are suggested in order to extend the validity range of the correlation.

KEYWORDS

BURNOUT
TUBES
STATISTICS
ERRORS
HEATING
NUMERICALS
HEAT TRANSFER

Correlation function

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Prof.M.Silvestri gave his time generously to discuss the program during the course of the investigation. Prof.S.Albertoni provided encouragement and suggestion in the writing of this report.

INTRODUCTION

In some previous works [1,2,3,4] the most important burnout correlations - for circular ducts, uniform heat flux distribution and positive outlet quality - have been examined. In these works it has been pointed out that nearly all the correlations may be reduced, by means of suitable transformations, to a common analytic form which consists of one or two straight-lines in the plane ϕ_o, X_o. The study of the correlations thus transformed gave us the idea of predicting the burnout data by means of the following experiments:

$$\phi_o = \frac{1.883 \cdot 10^{3}}{G^{1/6}\, D^{\alpha}} \left(\frac{9.68 \cdot 10^{-4} H_{eg}}{G^{1/6}} - X_o \right) \quad \text{for low quality}$$

$$(1)$$

$$\phi_o = \frac{0.135 \cdot H_{eg}^{1.4517}}{G^{0.544} \cdot D^{0.5} \cdot \left(\frac{D \cdot G}{0.056 \cdot H_{eg}} \right)^{\gamma}} \left(1 - X_o\right) \quad \text{for high quality}$$

$$\alpha \begin{cases} 0.4 & \text{for } D \geqslant 1 \\ 0.6 & \text{for } D < 1 \end{cases} \qquad \gamma \begin{cases} 0 & \text{for } D \geqslant 1 \\ 0.2 & \text{for } D < 1 \end{cases}$$

As predicted value of the critical heat flux the higher value of the two, obtained by intersecting eq. (1) with the heat balance equation, was chosen. This correlation has been compared with 2000 experimental burnout data in the range: 30 ata $\leqslant P \leqslant$ 100 ata, 0.35 cm $\leqslant D \leqslant$ 3 cm, 20 gr/cm^2 sec. $\leqslant G \leqslant$ 560 gr/cm^2 sec., 20 cm $\leqslant L \leqslant$ 500 cm, $X_{in} < 0$, $X_o > 0$

Manuscript received on July 12, 1967.

The main aims that we want to attain in the present work are the following:

i) To simplify the form of eq. (1)

ii) To increase the parameters validity range.

iii) To increase the number of the experimental burnout data for the comparisons.

iiii) To improve the accuracy of predictions.

2. CRITICAL HEAT FLUX CORRELATION

The empirical correlation proposed is the following:

$$\Phi_o = \frac{1.883 \cdot 10^3}{D^\alpha \, G^{1/6}} \left[\frac{y(P)}{G^{1/6}} - X_o \right] \quad \text{for low quality}$$

$$(2)$$

$$\Phi_o = \frac{3.78\,10^3\, h(P)}{D^\alpha \, G^{0.6}} \left[1 - X_o \right] \quad \text{for high quality}$$

with α = 0.4 for $D \geq 1$; 0.6 for $D < 1$

Eq. (2) consists of two straight-lines, whose intersection point does not take place at constant outlet quality, but depends on pressure P and mass flowrate G:

$$X_o = \left(\frac{y(P)}{G^{1/6}} - \frac{2.01 \cdot h(P)}{G^{13/30}} \right) \Big/ \left(1 - \frac{2.01 \cdot h(P)}{G^{13/30}} \right) \qquad (3)$$

As "a priori" it is not possible to divide the validity range of these two straight-lines, we have thought of taking, as the predicted burnout point, the higher of the two values obtained by means of the intersection of eq.(2) with the heat balance equation:

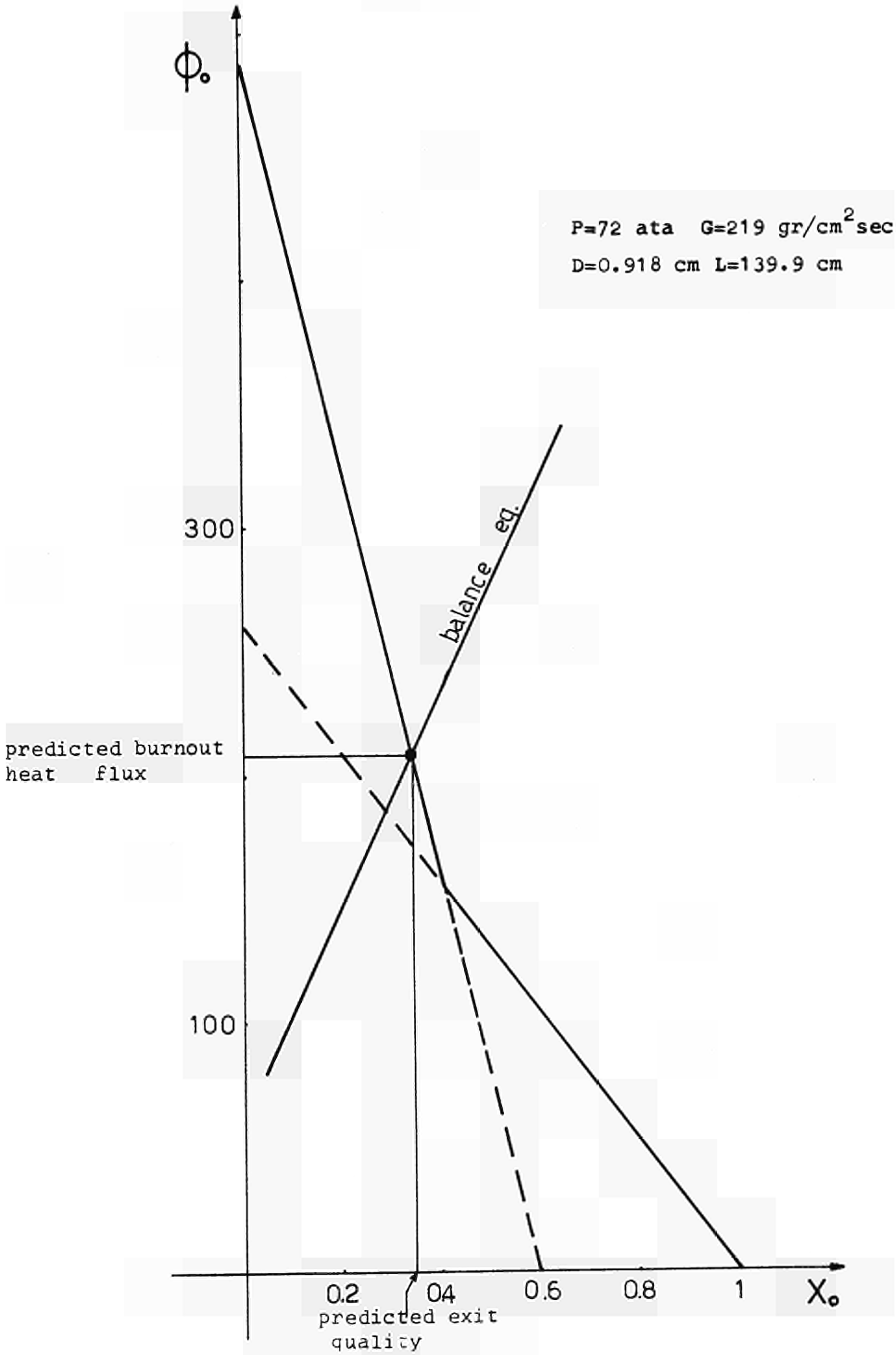
$$\Phi_o = \frac{G \cdot D \cdot H_{eq}}{4 \cdot L} \left(X_o - X_{in} \right) \qquad (4)$$

In fig. 1 the trend of the correlation, for a typical group of values of the parameters is showed. In the same diagram the heat balance equation and burnout points, defined by means of the previous rule, are also reported.
With regards to eq. (1), the new correlation shows a different dependence on the pressure and a more simple form of the trend at high quality. The two functions y(P) and h(P), whose trend in the range 2 ata $\leq P \leq$ 140 ata is showed in figs. 2-3, are defined by means of the following equations:

$$y(P) = 0.7249 + 0.099\, p\, e^{-0.032\, p} \qquad (5)$$

$$h(P) = -1.159 + 0.149 \cdot p\, e^{-0.019\, p} + \frac{8.99 \cdot P}{10 + P^2} \qquad (6)$$

In order to extend the validity range of the pressure, we have been obliged to give up the dependence on the pressure as H_{1g}, previously used. In fact whilst in the range 30 ata $\leq P \leq$ 100 ata the burnout critical heat flux is well represented by means of a monotonously decreasing function of the pressure as H_{1g}, extending the validity range at pressures lower than 30 ata, an inversion of the dependence on the pressure appears. For this reason we have given up the representation by means of a quantity having a physical meaning, adopting two analytic functions of the pressure. The high quality correlation has heen modified with regards to the dependence on G and D in order to simplify its use and have an analytic form of eqs. (2) as simple as possible.



Φo
P=72 ata G=219 gr/cm2sec
D=0.918 cm L=139.9 cm
300
balance eq.
predicted burnout
heat flux
100
0.2
04
0.6
0.8
1
Xo
predicted exit
quality

fig. 1

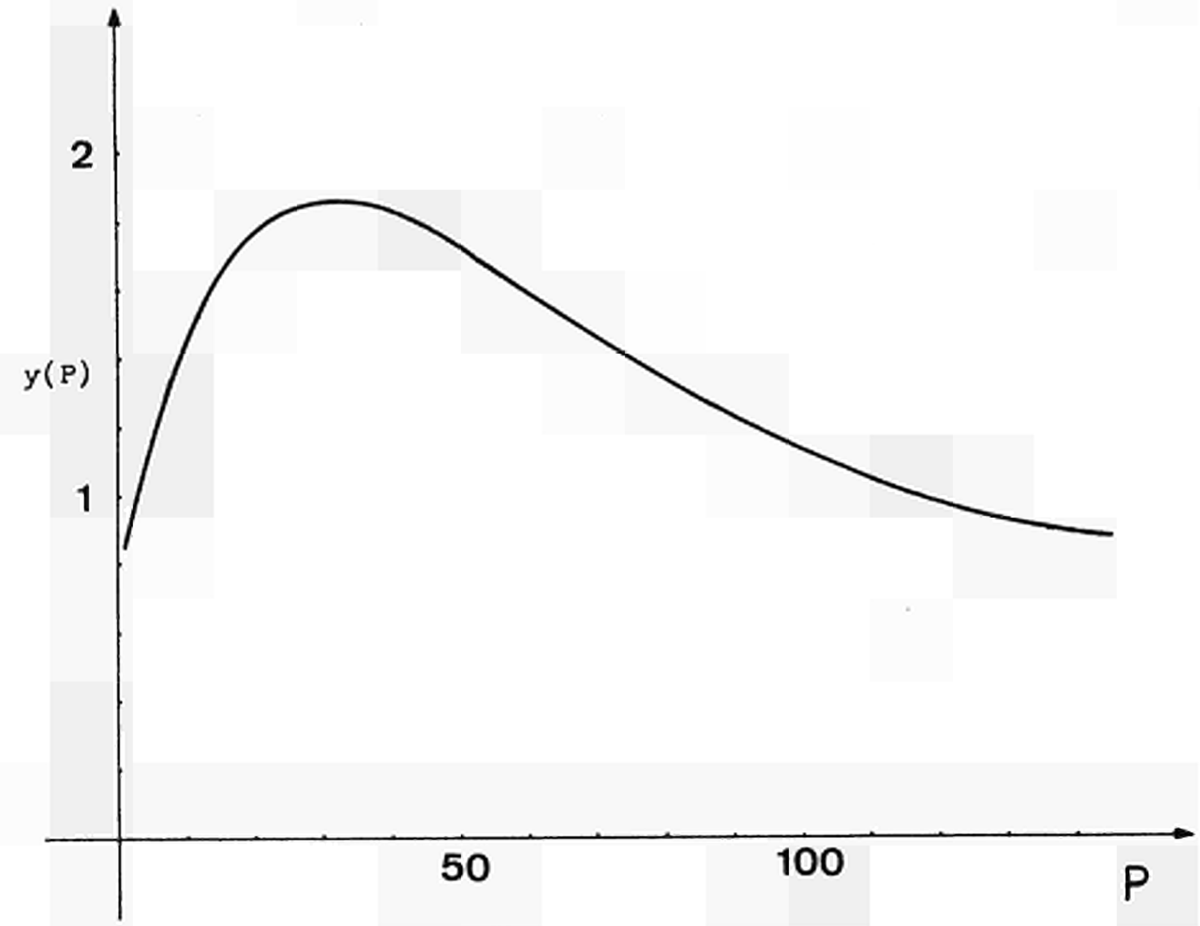


fig. 2

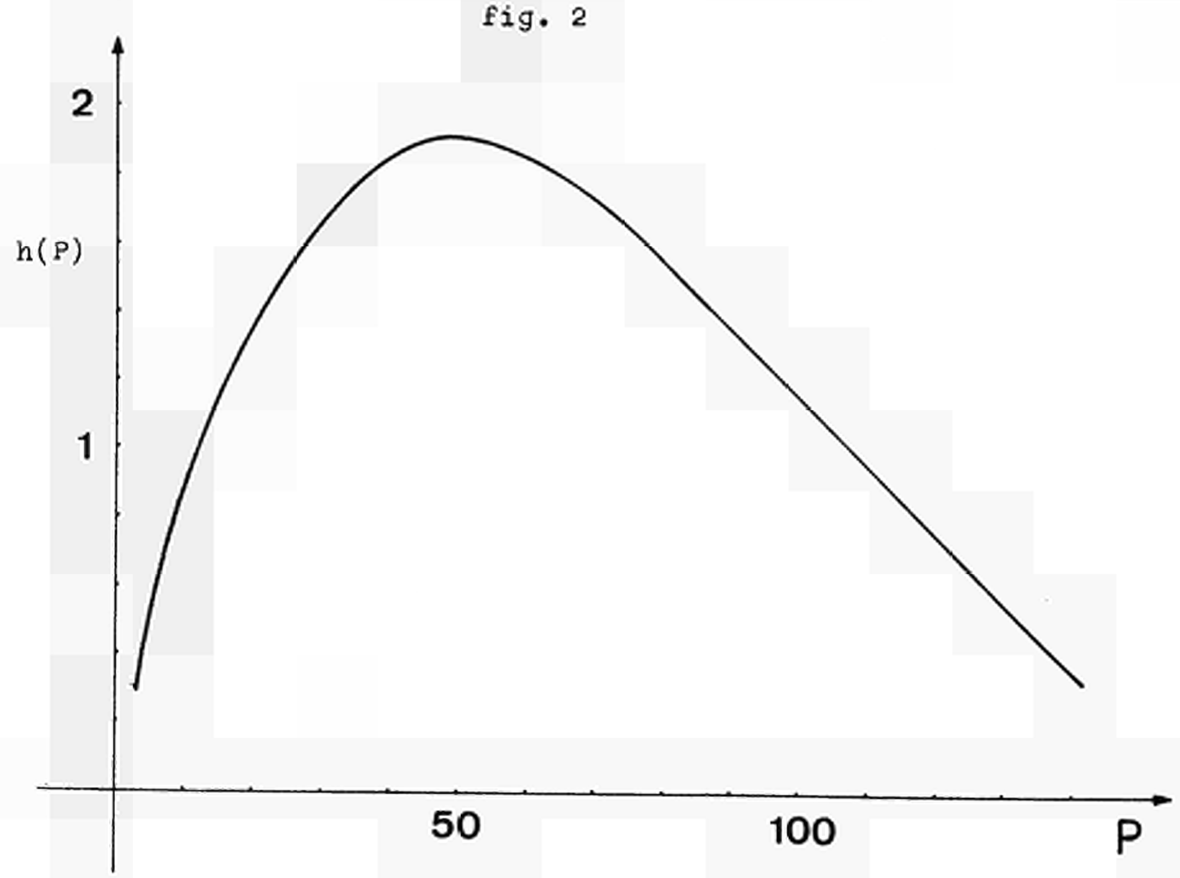


fig.3

The main aims that we want to attain in the extension of the correlation are the following:

a) To obtain an expression valid in a large range of variability.
b) To arrive at a simple analytic form, which allows us a quick prediction.

In order to obtain this simplicity we have preferred to give up the accuracy, avoiding the introduction of more corrective factors or more correlations which are valid only in a restricted range, even it they have an higher accuracy. The use of some corrective factors has been adopted only for the interpretation of burnout data external to the validity range: most probably these data are referred to a different motion path.

3. RANGE OF VALIDITY

The correlation (2) is applicable in the following range of validity:

$$0.3\ \text{cm} \leq D \leq 3.75\ \text{cm}$$
$$20\ \text{cm} \leq L \leq 600\ \text{cm}$$
$$2.7\ \text{ata} \leq P \leq 140\ \text{ata}$$
$$10\ \text{gr/cm}^2\ \text{sec.} \leq G \leq 600\ \text{gr/cm}^2\ \text{sec.}$$
$$X_{in} < 0$$
$$\frac{1}{1+\rho_l/\rho_g} < X_o < 1$$

The restriction $X_{in} \leq 0$ has been laid in order to avoid the dependence on L and on the inlet conditions which is a characteristic of many data with $X_{in} > 0$. The upper restrictions of D, L, P, are not effective restrictions as they have been introduced only for the lack of comparisons with the experimental data in this range. The restiction on X_o is equivalent to exclude the data with $X_v \leq 0.5$: this restriction has been introduced as for little X_v a different type of motion appears. Nevertheless, as we will show afterwords, the correlation gives good predictions also at $X_o \sim 0$ for nearly all the experimental data found in the literature. The lower restrictions of P, L, D, and the restrictions of G, on the contrary, are effective restrictions of the correlation. We must also observe that for $G < 30$ gr/cm^2 sec. it is necessary to use only the second eq. (2), as the first one may give an outlet quality greater than 1.

4. COMPARISON WITH THE EXPERIMENTAL DATA

a) Source of data.

The correlation has been compared with as great a number as possible of experimental data ($\sim$ 5000) of which 4500 are internal to the validity range. Most of them have been derived from Macbeth[5], with the exclusion of the data having $X_o < 0$, $P \sim 1$ ata and advised as inconsistent. Besides we have also considered the data assembled by Becker, coming from Aktiebolagt, Columbia, Winfrith and Harwell laboratories, in references 6÷8, and the data of laboratories of Sorin[9] and M.A.N.[10]

From these data we have removed 10 data which do not satisfy the heat balance equation-probably for an error of transcription, and 9 data which give an outlet quality greater than 1, even if satisfy the heat balance equation. All the data coming from reference 5 have been quoted as Macbeth data, whilst we have kept the name of the laboratory which they come from, for the other ones.

For reason of clarity the groups of data have been arranged as in table 1. For every group the validity range of the most important parameters has been quoted also. The number of the data examined is lower than the total number contained in the various references, as some data of reference 6÷10 were still present in reference 5. Notwithstanding our attention to excluding these double data, some data have been certainly considered twice.

b) Examination of the error.

Once the inlet conditions (P, G, X_{in}) and the channel geometry (L, d) are fixed, the values of Φ_o and X_o are predicted by means of eq. 2, in the way previously described.

SOURCE	PRESSURE RANGE	RANGE OF DIAMETERS	RANGE OF LENGTHS	RANGE OF MASS VELOCITY	No. OF EXPTS ORIGINAL	No. OF EXPTS ACTUAL	
Macbeth-Thom. table 2-3-4-5	7-53	0.11-1.08	7.6-173	1.3-1043	315	232	1
table 6	70	0.46-3.75	21.6-366	2.8-1337	603	102	2
table 7-8-9	90-126	0.46-1.98	22.9-152.4	2.8-412	198	148	3
table 10	140	0.46-1.11	23.9-183	3.8-747	396	194	4
table 15	4.5-38	0.39	103.9-311.9	50-191	162	162	5
table 15	3.7-41.5	0.78	103.9-311.9	22-141.5	247	247	6
table 15	2.4-40	0.99	59.9-311.9	14.4-241	539	516	7
table 15	6.4-36.5	1.	100-250	10-251	628	627	8
Bennett	71	0.92-1.26	172.7-556.3	65-584	174	174	9

TABLE 1

SOURCE	PRESSURE RANGE	RANGE OF DIAMETERS	RANGE OF LENGTHS	RANGE OF MASS VELOCITY	No. OF EXPTS. ORIGINAL	No. OF EXPTS. ACTUAL	
Winfrith	70	0.95-1.18	84.1-366	199-411.5	136	132	10
Winfrith	70	0.56-1.15	21.6-200.7	40.5-440	303	284	11
Columbia	52.7-70	0.62-3.75	61-197.2	64-558.6	196	167	12
Becker	28-96	0.39-2.49	40-350	14.4-500	928	917	13
Becker	2.7-22.7	0.6-1.31	40-300	10.2-264	312	311	14
Becker	70	1.	500	72.5-305	10	10	15
MAN	32.5-141.5	0.7-1.50	28-98	93.8-361.5	261	230	16
SORIN	80.7-145	1.02-1.71	78.5-131.7	48-314	153	98	17
total					5561	4551	

TABLE 1 (CONT.)

The error percent is determined with the following equation:
$\sigma_i = \frac{\Phi_m - \Phi_o}{\Phi_m} \cdot 100$ where Φ_m is the experimental value of the critical burnout heat flux, whilst Φ_o is the calculated one. The mean error $\bar{\varepsilon}$ and the mean quadratic error $\bar{\sigma}$ have been calculated as $\bar{\varepsilon} = \frac{\sum_i \sigma_i}{n}$ $\bar{\sigma} = \sqrt{\frac{\sum_i \sigma_i^2}{n}}$

In table 2 there is the total number of data, the number of data having an error less than 1%, the number of data having an error between 1% and 2% and so on. The results are sommarized in table 3, and in fig. 4 are compared with the normal distribution of Gauss.
Out of 4551 experimental data we have a mean error $\bar{\varepsilon} = -0.124$, a mean quadratic error $\bar{\sigma} = 7.26\%$ and the 85.5% of the data exhibits an error less than 10%.

c) The error distribution versus the various parameters.

For the sake of semplicity, the dependence of the errors on the various parameters has been examined only for a restricted range of the data. The error distribution versus D, G, L, X_{in}, for P = 70 ata and $0.2 < X_o < 0.3$ is given in figs. 5 ÷ 12. Examining the diagrams in which the data of all the laboratories are reported, it appears that the systematic error is negligible, whilst the data of a single laboratory exhibits (figs. 9÷12) a separation of the errors: for instance at P = 70 ata, $0.2 < X_o < 0.3$ Becker's data are overestimated whilst Man's data are underestimated. For this reason it is possible to improve the error of a single laboratory appreciably, but it is very difficult to improve the accuracy of the predictions on the whole, if we give the same weight to the various laboratories. For example a group of 132 data of Winfrith, which has at present a mean quadratic error equal to 7.75%, gave an error $\bar{\sigma}$ equal to 6% with a correlation previously checked.

Fig. 13 gives the error distribution versus P, P $<$ 70 ata and 0.2 $< X_0 <$ 0.3, figs 14÷15 give the error distribution versus P, P $<$ 70 ata and 0.7 $< X_0 <$ 0.8. Fig. 16 gives the error distribution versus P, P $>$ 70 ata and 0.2 $< X_0 <$ 0.3. Fig. 17 gives the error distribution versus G, at P = 140 ata and 0.2 $< X_0 <$ 0.3. Obviously it is questionable to consider only the data with 0.2 $< X_0 <$ 0.3 as this can point out systematic errors which are not present out of the all of data in general when the critical heat flux is not a linear function of X_0 and, on the contrary, hides some errors which are present. The only justification for this way of proceeding, is the difficulty in handling a great number of data and the lack of clearness in a diagram which contains many points.

The form of representation adopted makes the comparisons amongst the various groups of data easier.

d) Examination of the errors in the single groups of data.

In table 4 we have reported the mean error $\bar{\varepsilon}$, the mean quadratic error $\bar{\sigma}$ for every group of data, following the subdivision of table 1. Figs. 18÷31 give the values of the fluxes calculated versus the experimental ones in a bilogarithmic scale. In table 4 one can see that few groups have a mean quadratic error higher than 10%. Sometimes this error is so high in owing to the presence of few data having a strong shifting from the predictions. For instance 94 data over 98 on the whole of the Sorin laboratory are predicted with a mean quadratic error σ equal to 8.7%, whilst the remaining ones exhibit errors equal to 25%, 27%, 47%, 51%.

TABLE 2

$0 < \varepsilon < 1$	304	6.68%	$-1 < \varepsilon < 0$	295	6.48%
$1 < \varepsilon < 2$	282	6.20%	$-2 < \varepsilon < -1$	286	6.28%
$2 < \varepsilon < 3$	249	5.47%	$-3 < \varepsilon < -2$	288	6.33%
$3 < \varepsilon < 4$	229	5.03%	$-4 < \varepsilon < -3$	289	6.35%
$4 < \varepsilon < 5$	204	4.48%	$-5 < \varepsilon < -4$	252	5.54%
$5 < \varepsilon < 6$	167	3.67%	$-6 < \varepsilon < -5$	191	4.20%
$6 < \varepsilon < 7$	133	2.92%	$-7 < \varepsilon < -6$	145	3.19%
$7 < \varepsilon < 8$	96	2.11%	$-8 < \varepsilon < -7$	133	2.92%
$8 < \varepsilon < 9$	90	1.98%	$-9 < \varepsilon < -8$	100	2.20%
$9 < \varepsilon < 10$	94	2.07%	$-10 < \varepsilon < -9$	66	1.45%
$10 < \varepsilon < 11$	79	1.74%	$-11 < \varepsilon < -10$	57	1.25%
$11 < \varepsilon < 12$	68	1.49%	$-12 < \varepsilon < -11$	51	1.12%
$12 < \varepsilon < 13$	67	1.47%	$-13 < \varepsilon < -12$	39	0.86%
$13 < \varepsilon < 14$	22	0.48%	$-14 < \varepsilon < -13$	27	0.59%
$14 < \varepsilon < 15$	22	0.48%	$-15 < \varepsilon < -14$	10	0.22%
$15 < \varepsilon < 16$	24	0.53%	$-16 < \varepsilon < -15$	18	0.40%
$16 < \varepsilon < 17$	20	0.44%	$-17 < \varepsilon < -16$	13	0.29%
$17 < \varepsilon < 18$	10	0.22%	$-18 < \varepsilon < -17$	8	0.18%
$18 < \varepsilon < 19$	13	0.29%	$-19 < \varepsilon < -18$	12	0.26%
$19 < \varepsilon < 20$	8	0.18%	$-20 < \varepsilon < -19$	9	0.20%
$20 < \varepsilon < 21$	7	0.15%	$-21 < \varepsilon < -20$	6	0.13%
$21 < \varepsilon < 22$	9	0.20%	$-22 < \varepsilon < -21$	4	0.09%
$22 < \varepsilon < 23$	6	0.13	$-23 < \varepsilon < -22$	5	0.11%
$23 < \varepsilon < 24$	3	0.07%	$-24 < \varepsilon < -23$	8	0.18%
$24 < \varepsilon < 25$	1	0.02%	$-25 < \varepsilon < -24$	4	0.09%

TABLE 3

RANGE OF ε ERROR	No. OF EXPTS. PREDICTED	PERC. OF TOTAL EXPTS. DATA
$-5 < \varepsilon < 5$	2678	58.84%
$-10 < \varepsilon < 10$	3893	85.54%
$-15 < \varepsilon < 15$	4335	92.25%
$-20 < \varepsilon < 20$	4470	98.22%
$-25 < \varepsilon < 25$	4523	99.38%

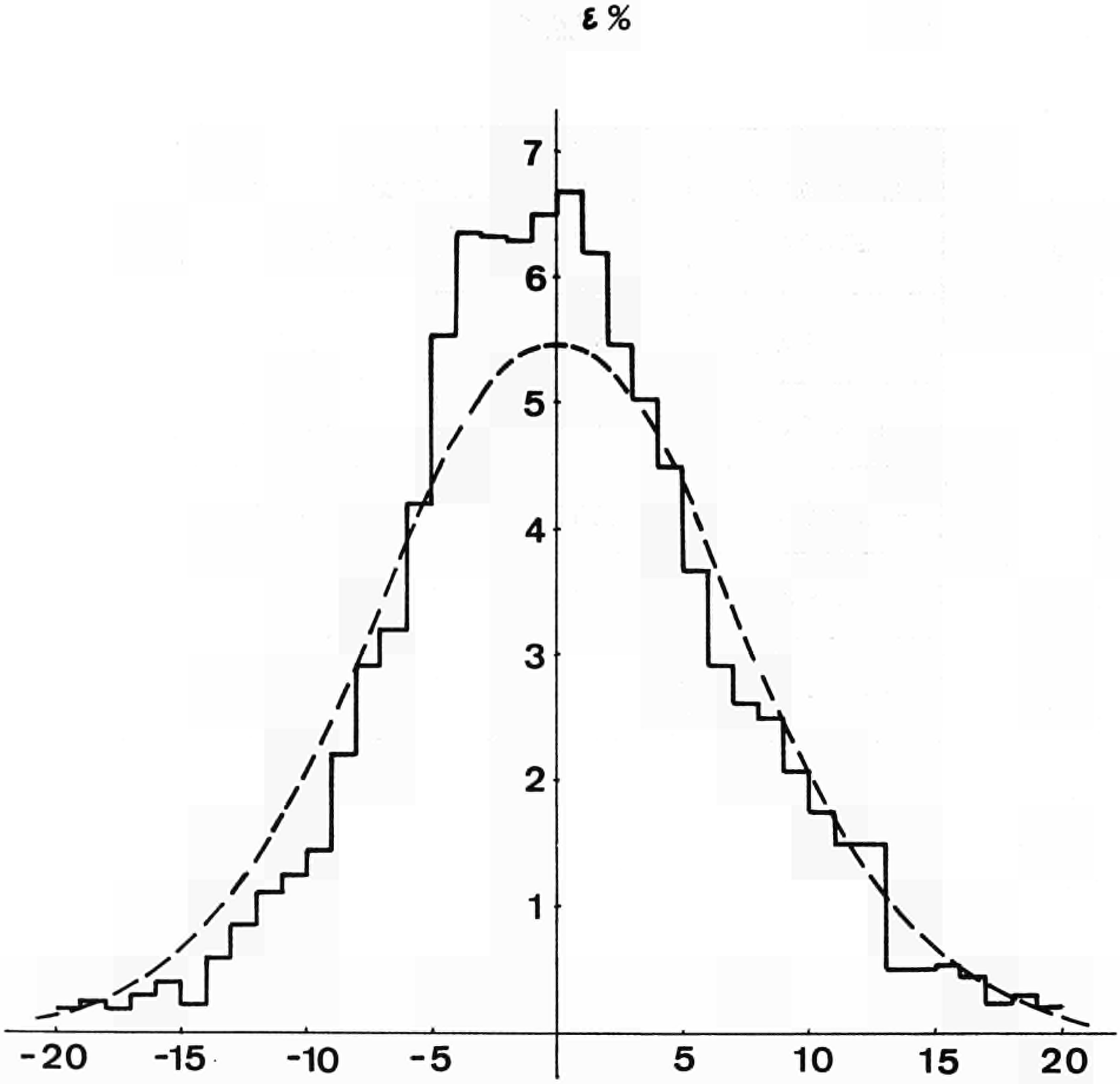


fig. 4

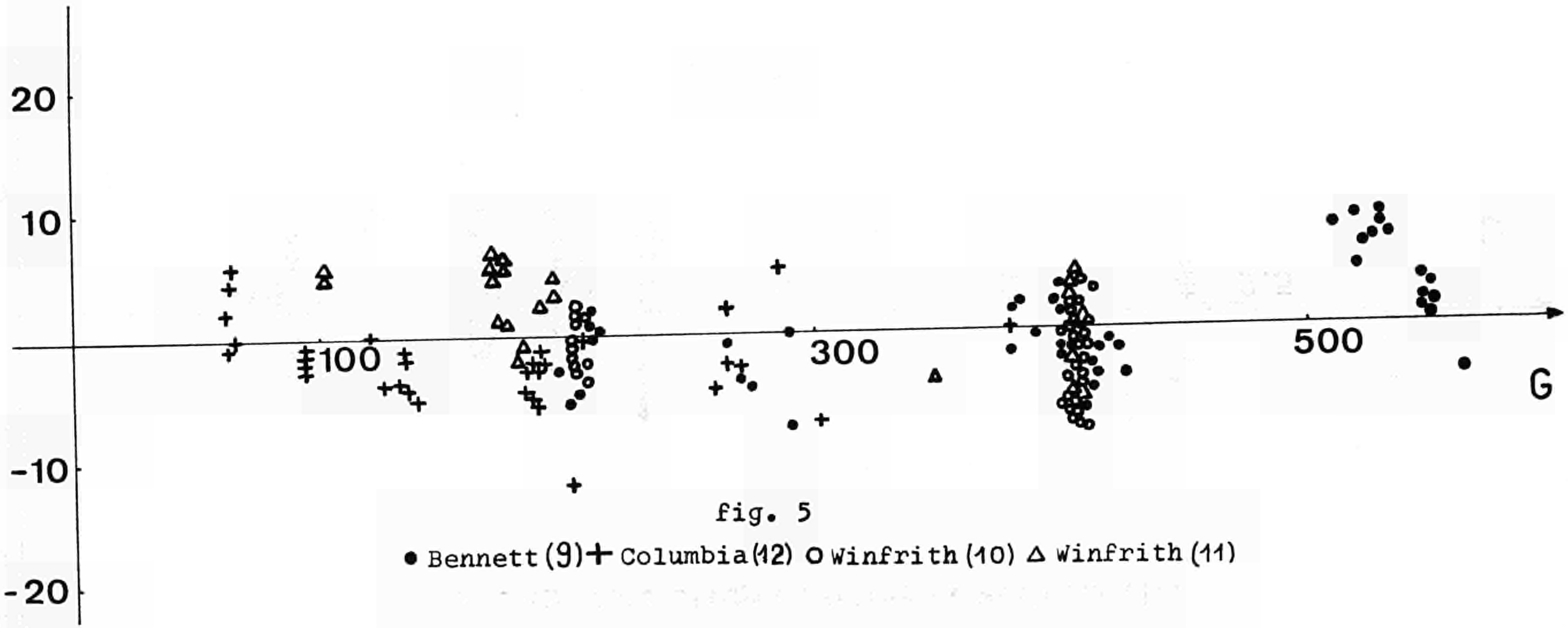


fig. 5

● Bennett (9) + Columbia (12) o Winfrith (10) △ Winfrith (11)

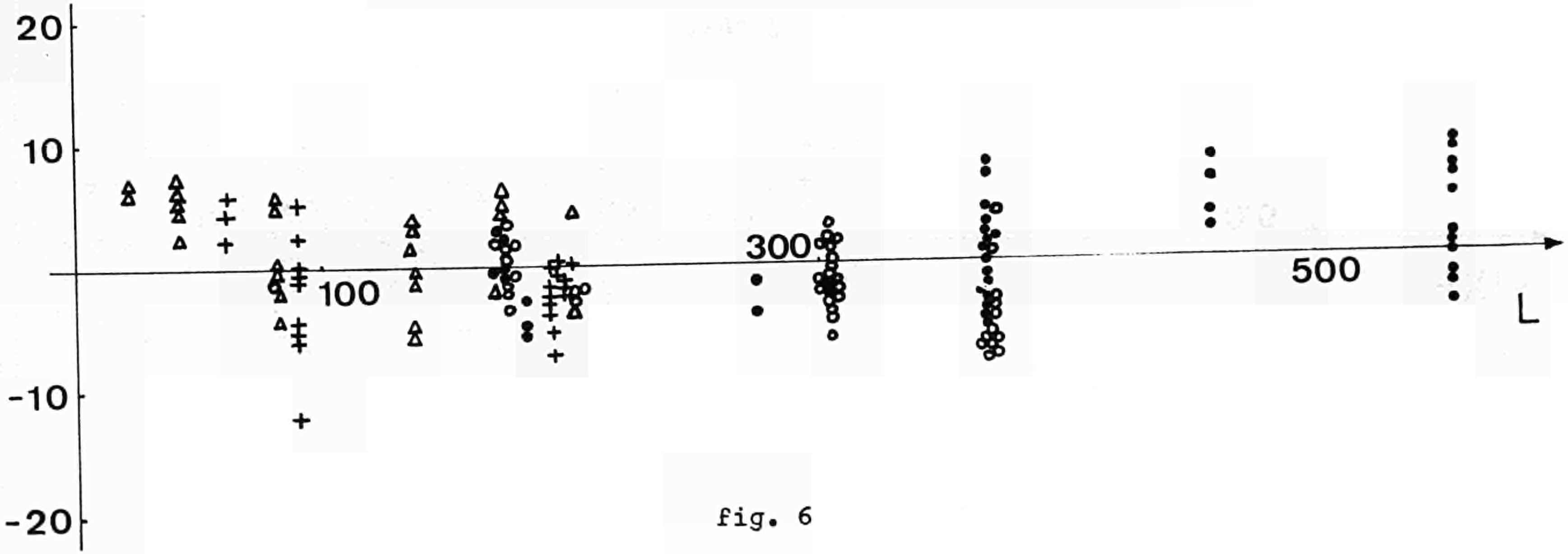


fig. 6

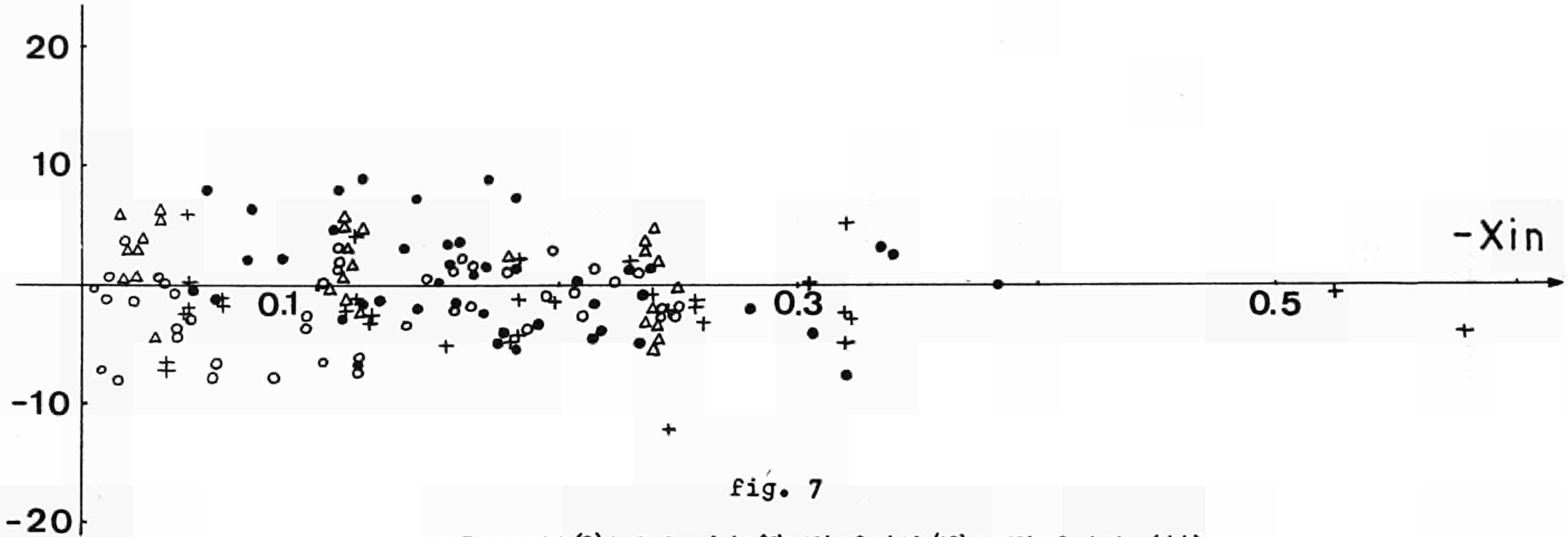


fig. 7

• Bennett (9) + Columbia (12) o Winfrith (10) Δ Winfrith (11)

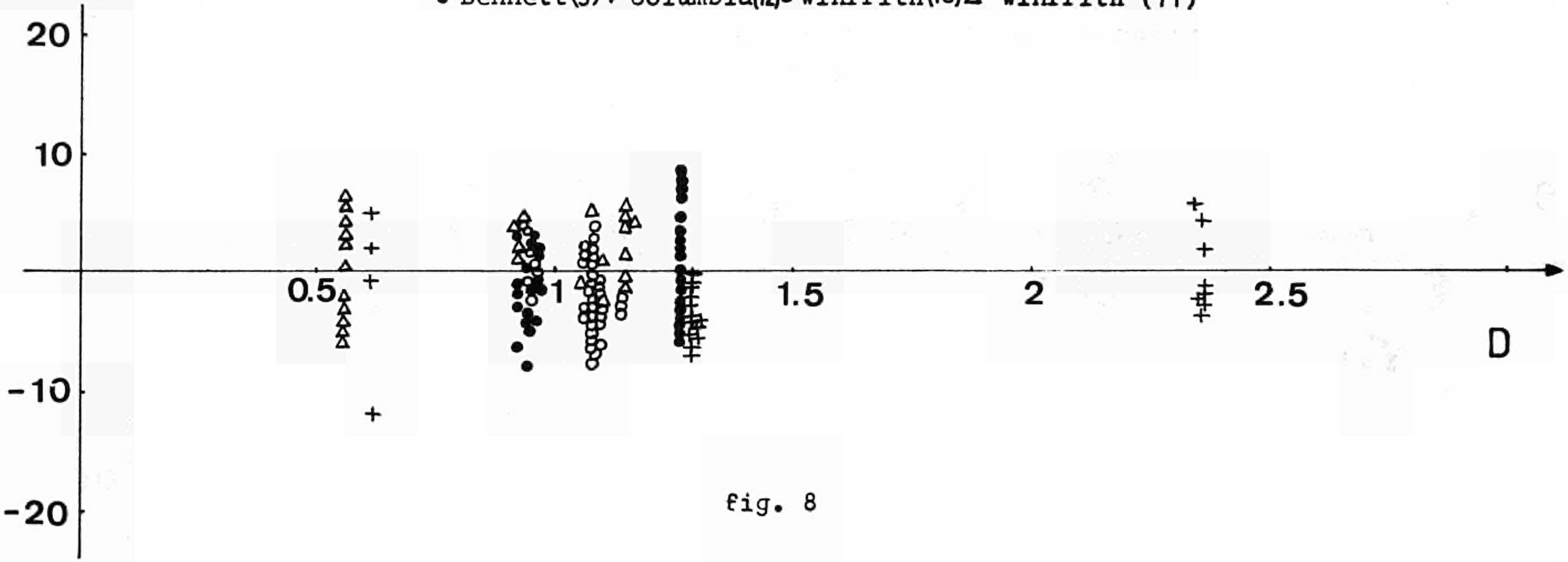


fig. 8

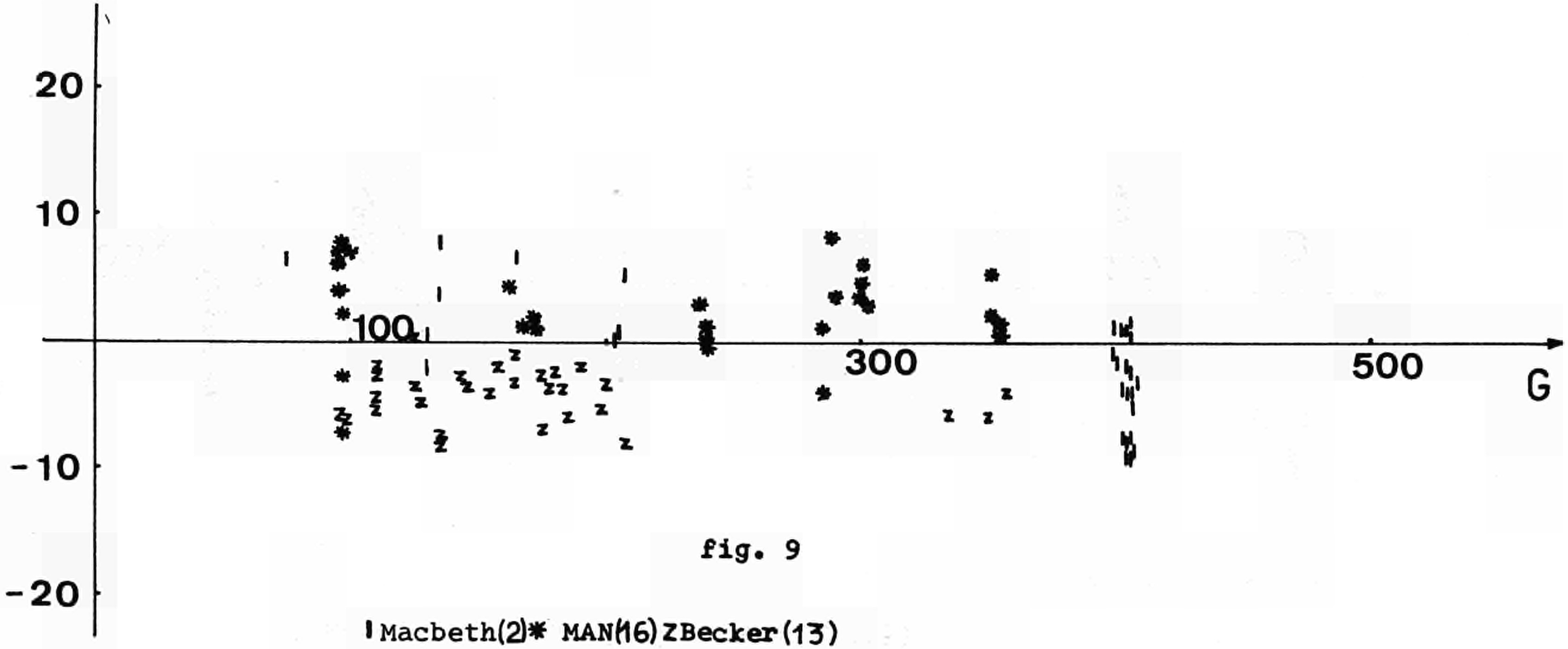


fig. 9

I Macbeth(2) * MAN(16) Z Becker(13)

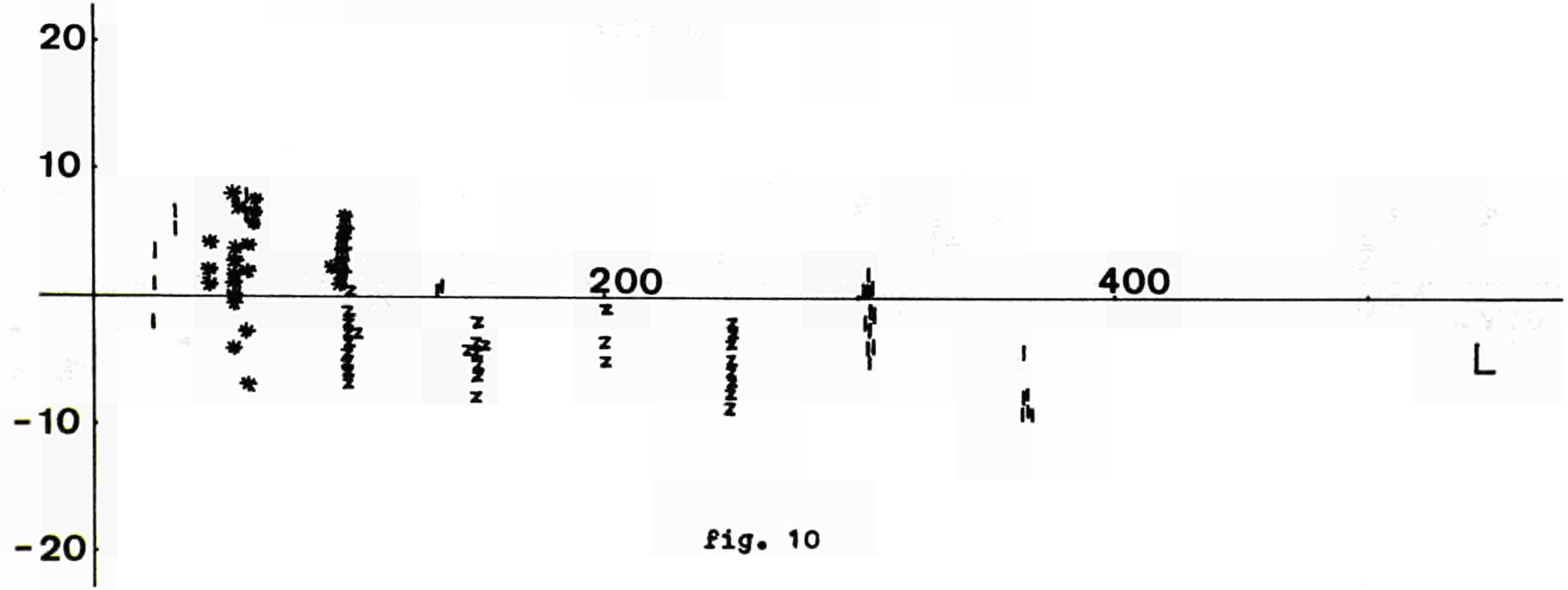


fig. 10

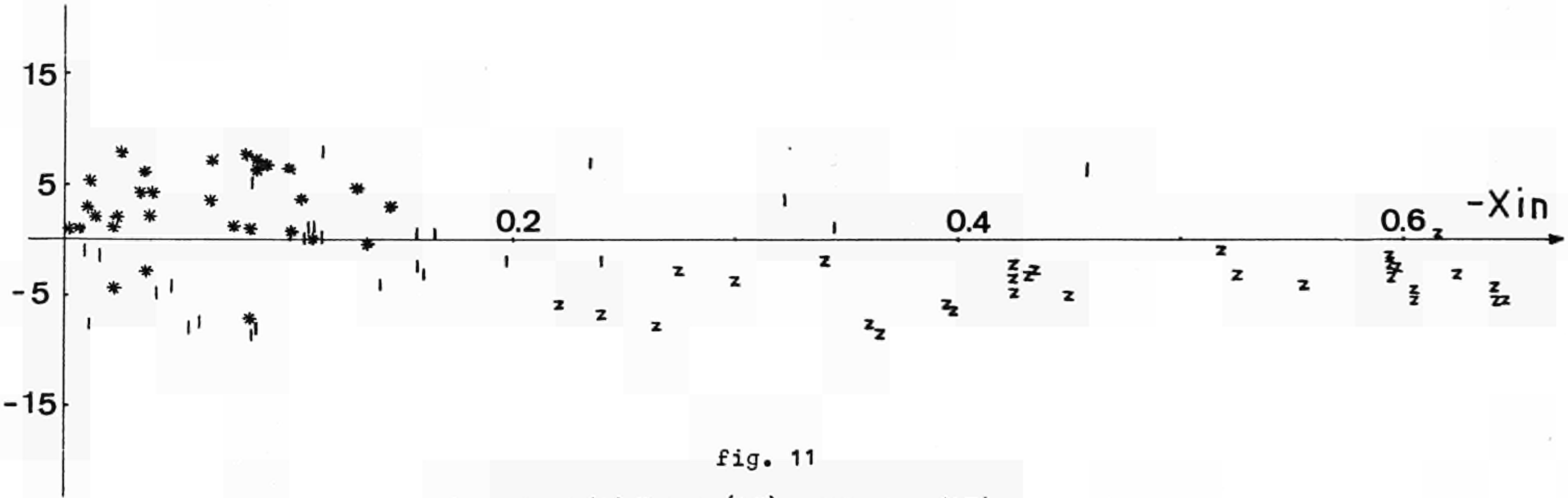


fig. 11

| Macbeth (2) * MAN (16) Z Becker (13)

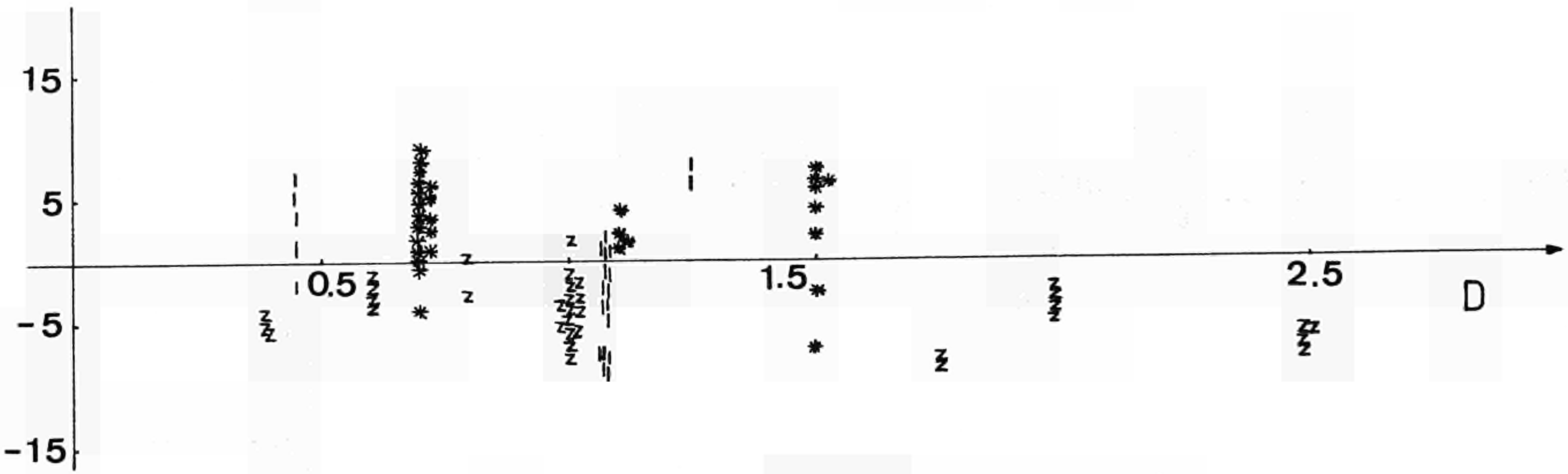
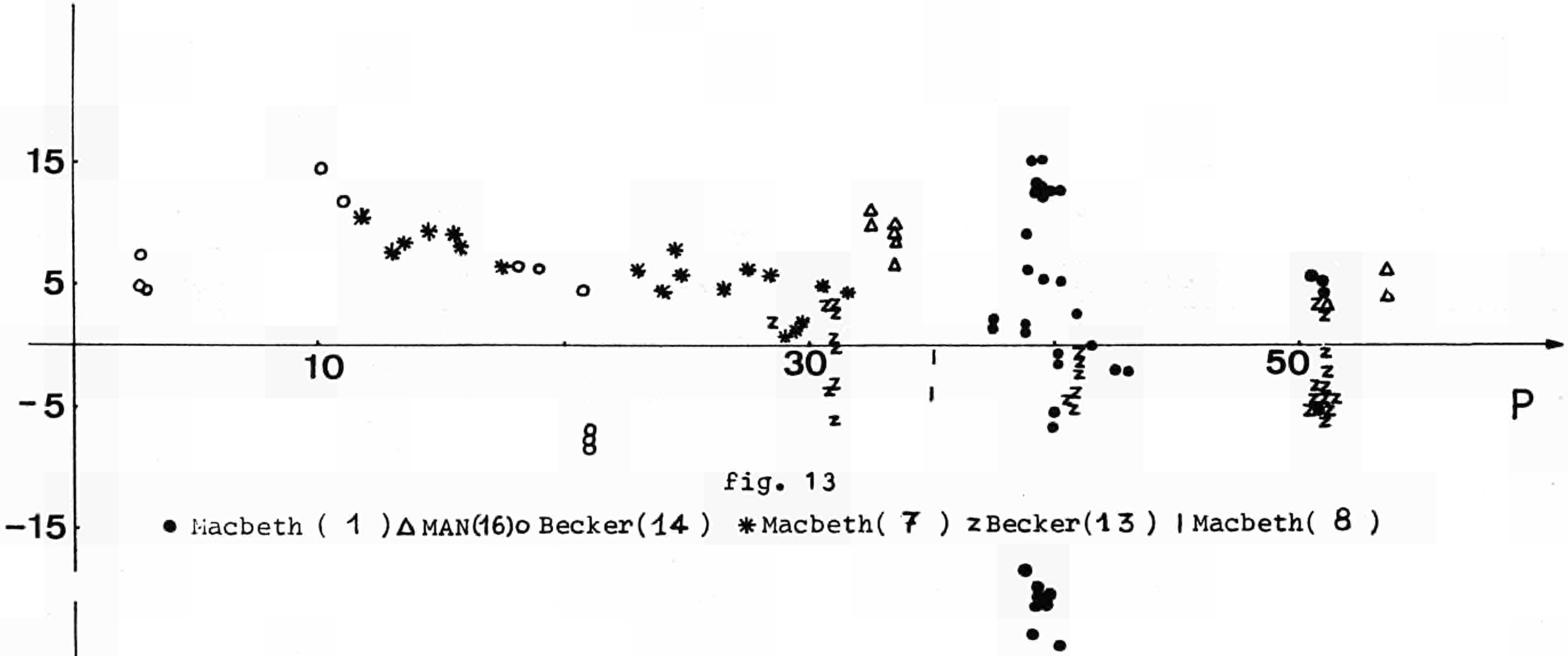


fig. 12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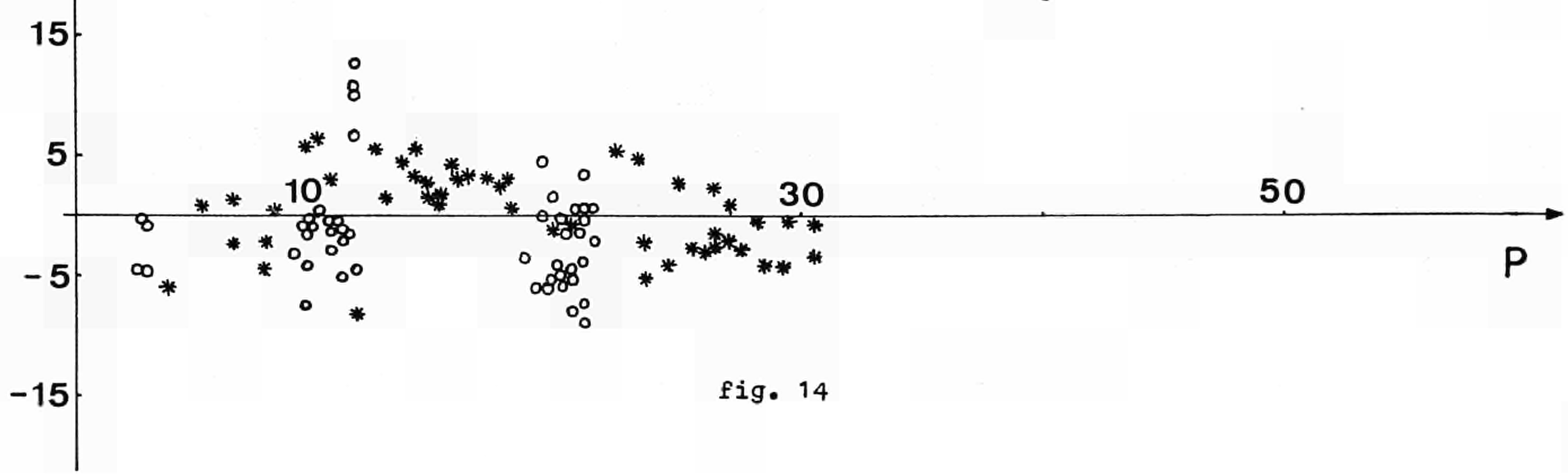
● Macbeth (1) Δ MAN(16) o Becker(14) * Macbeth(7) z Becker(13) | Macbeth(8)
fig. 13


15
5
-5
-15
10
30
50
P
fig. 14

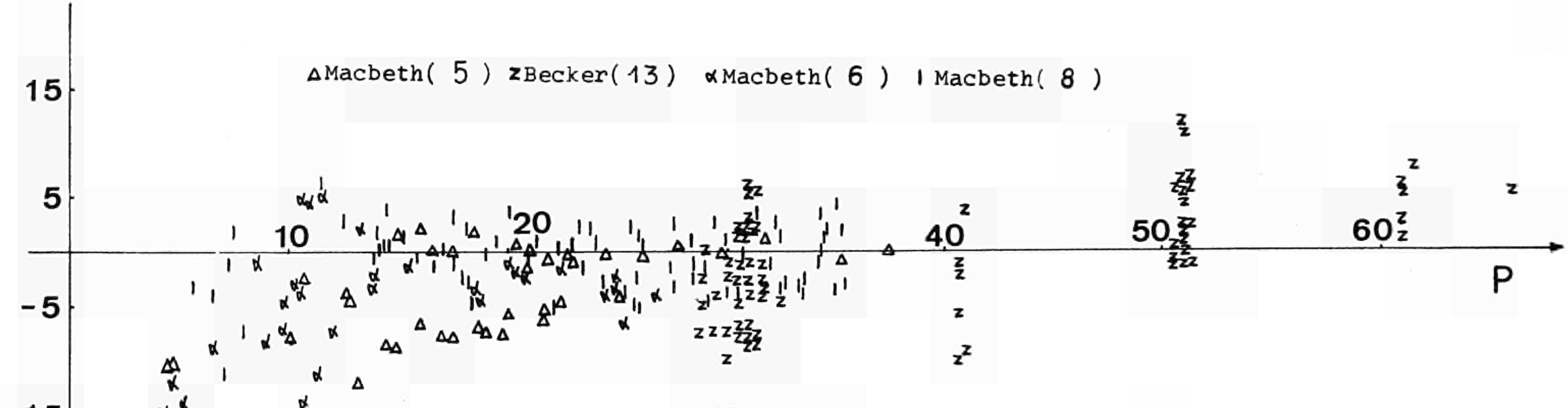

ΔMacbeth(5) zBecker(13) αMacbeth(6) ǀ Macbeth(8)
15
5
-5
-15
10
20
40
50
60
P

fig. 15

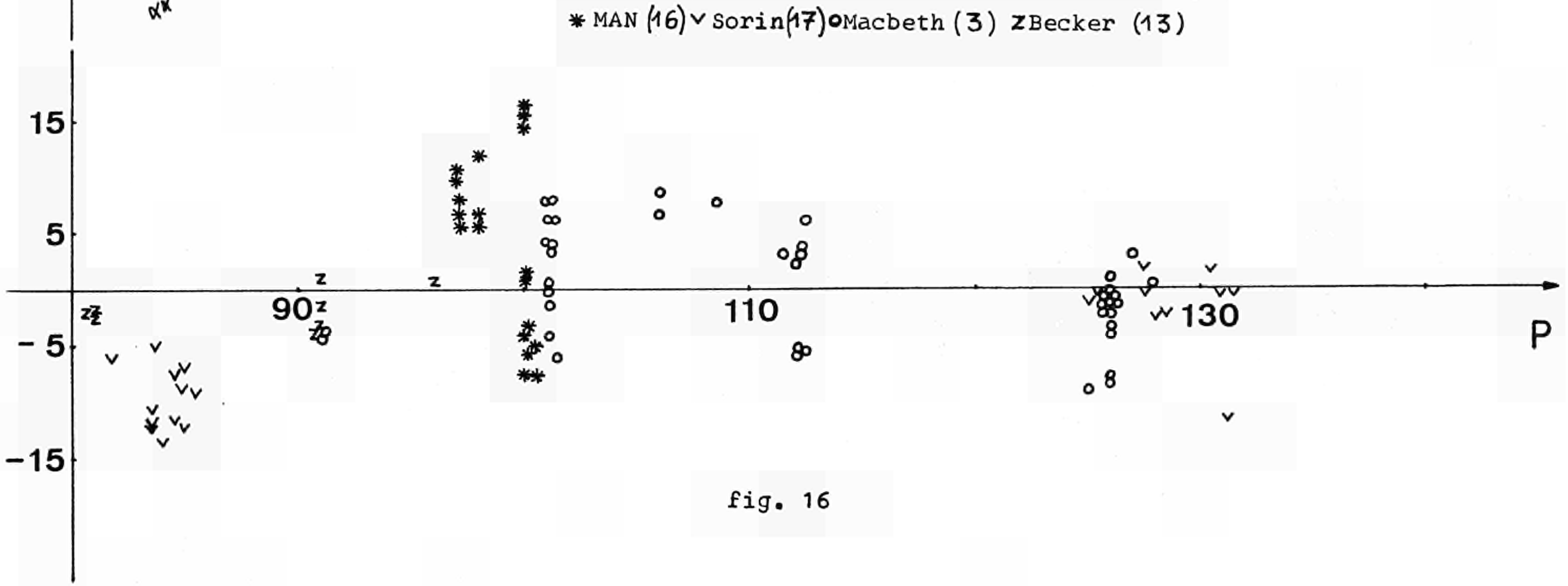

* MAN (16) v Sorin(17) o Macbeth (3) z Becker (13)
15
5
-5
-15
90
110
130
P

fig. 16

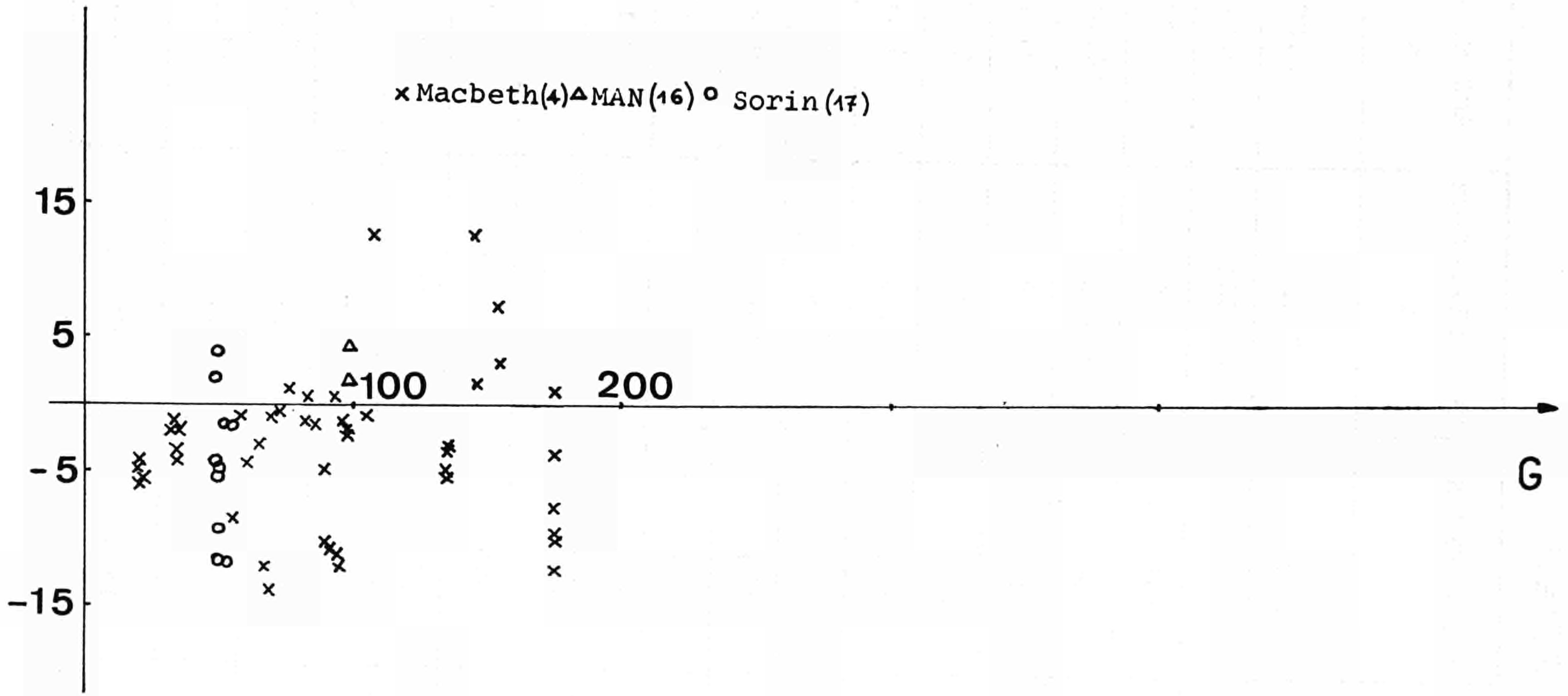


fig. 17

TABLE 4

REF.ACCORDING TABLE 1	No.OF EXPTS.	MEAN DEVIATION %	RMS ERROR %
1	232	7.82	12.07
2	102	-0.884	8.51
3	148	0.443	5.79
4	194	-0.932	10.08
5	162	-3.68	6.82
6	247	-5.24	10.49
7	516	3.72	6.76
8	627	-2.32	4.72
9	174	-2.49	6.52
10	132	-4.45	7.75
11	284	4.76	9.16
12	167	-2.04	6.25
13	917	-0.692	4.54
14	311	-0.168	5.98
15	10	-7.2	8.44
16	230	3.197	7.24
17	98	-7.32	11.76
TOTAL	4551	-0.125	7.26

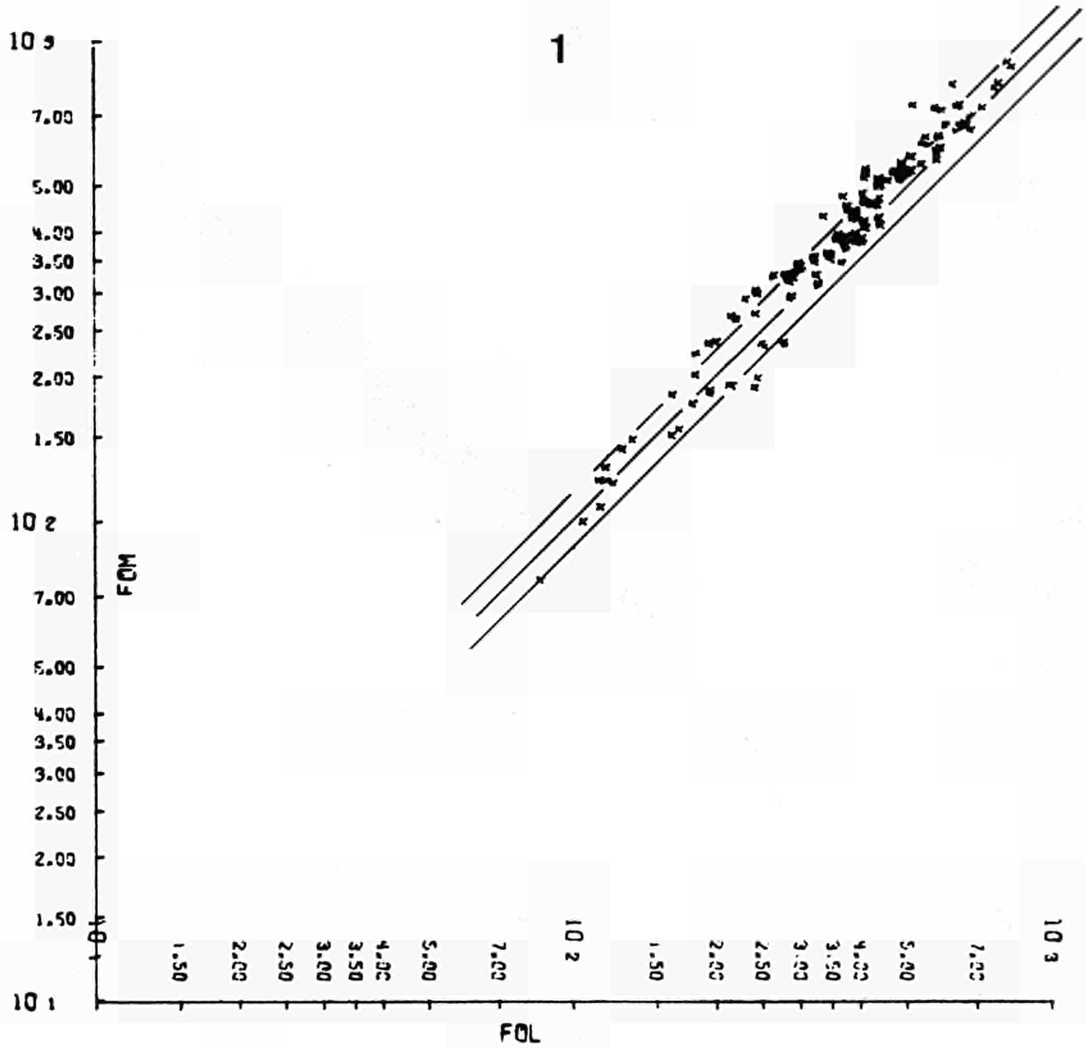
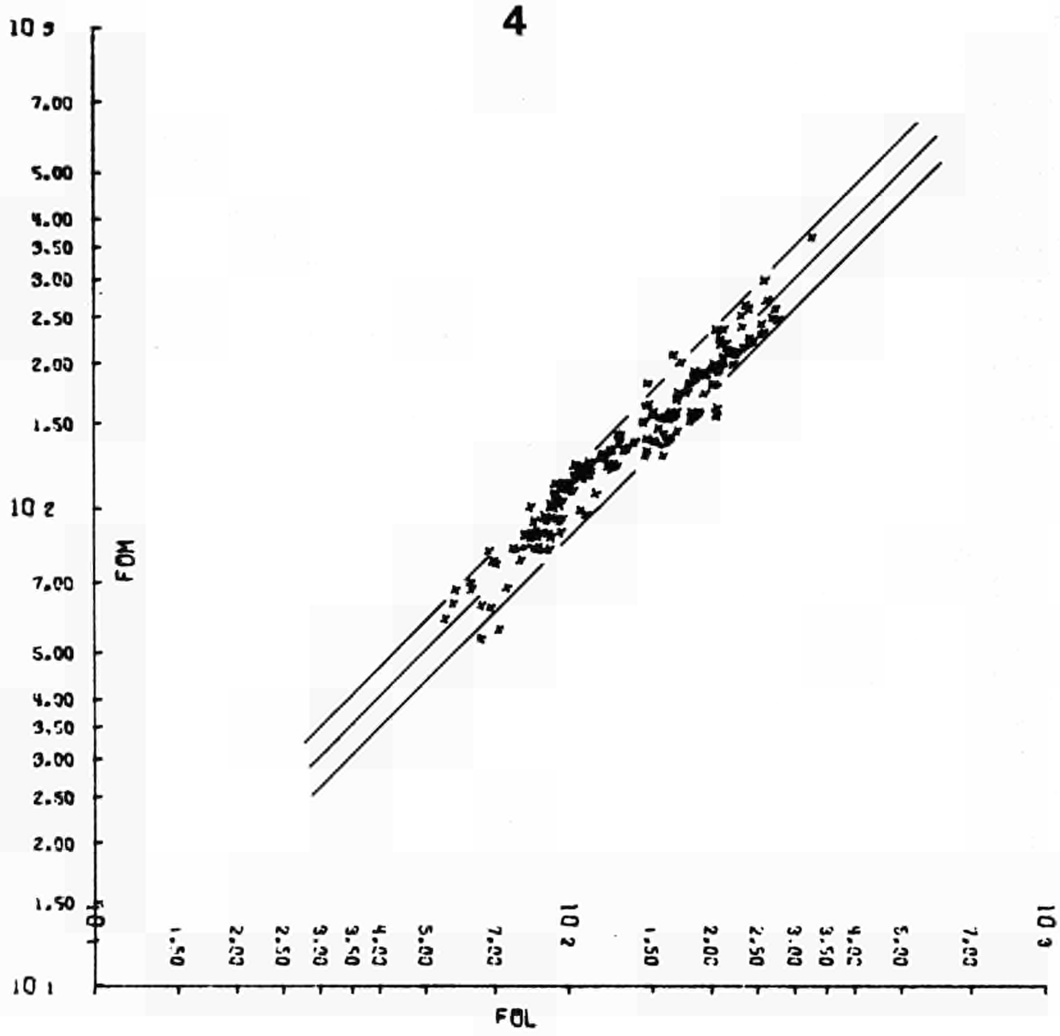


fig. 18

4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2.00
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10 2
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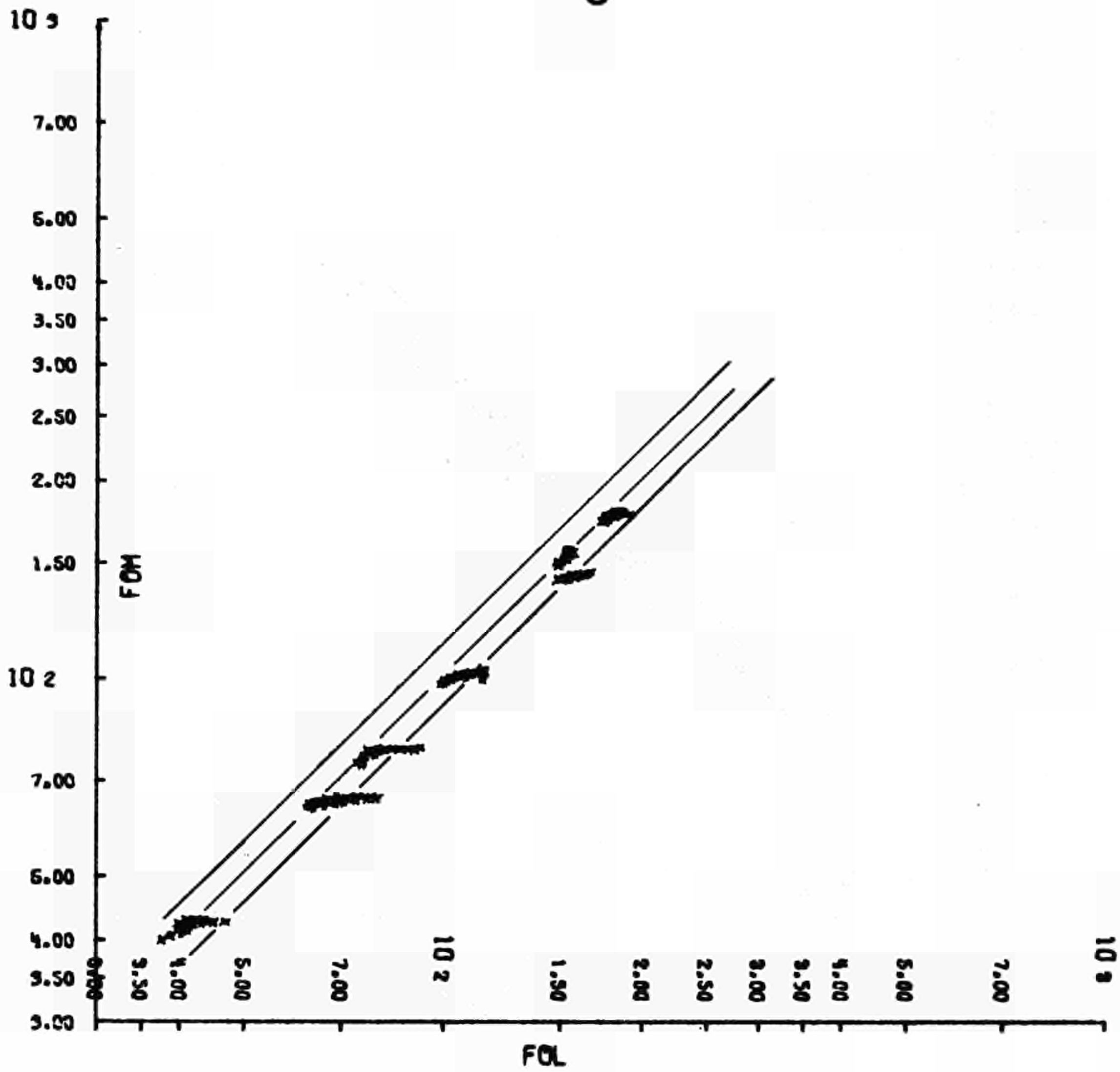
2.50
2.00
1.50
10 1
FOM
FOL

fig.19

5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5.00
7.00
10 2
1.50
2.00
2.50
3.00
3.50
4.00
5.00
7.00
10 3
FOL

fig. 20

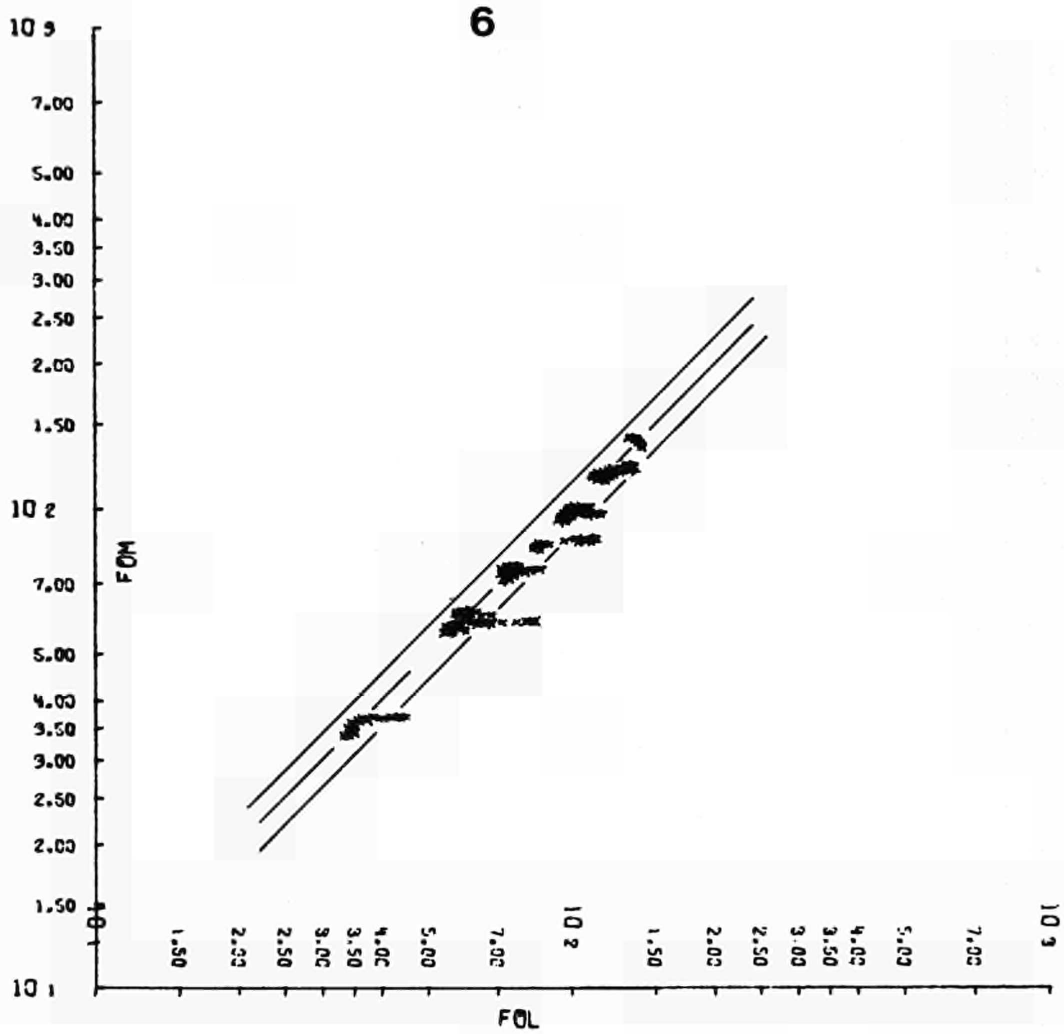
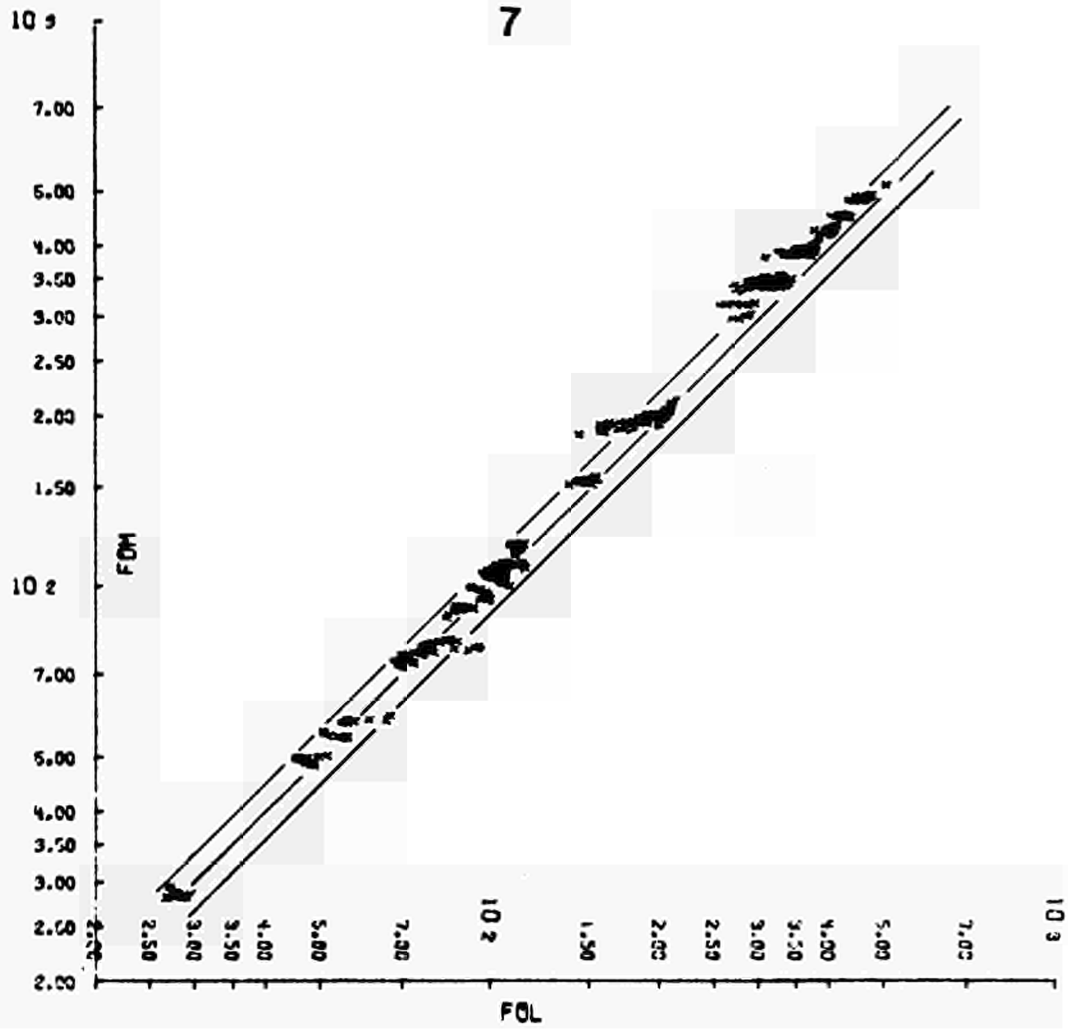


fig.21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10 3
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fig.22

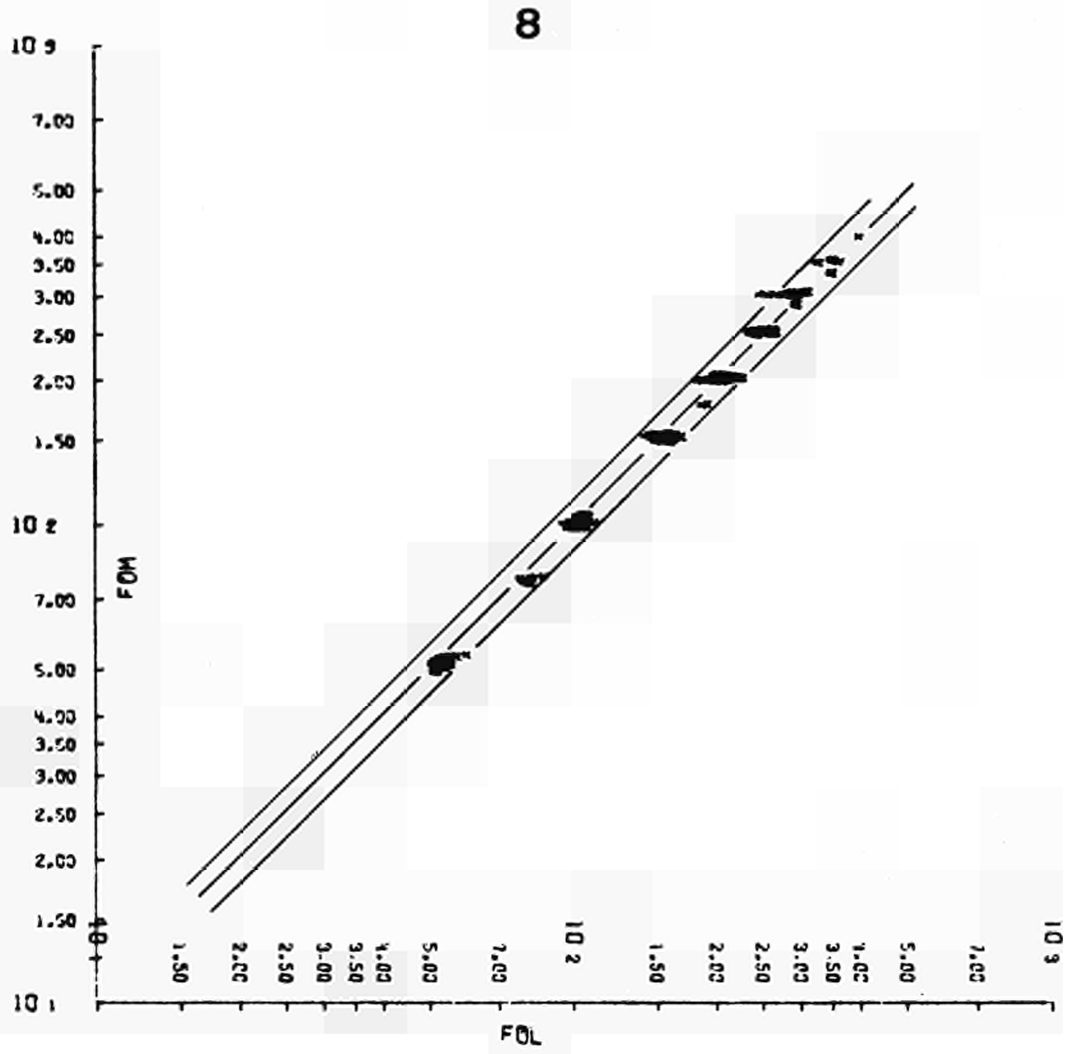
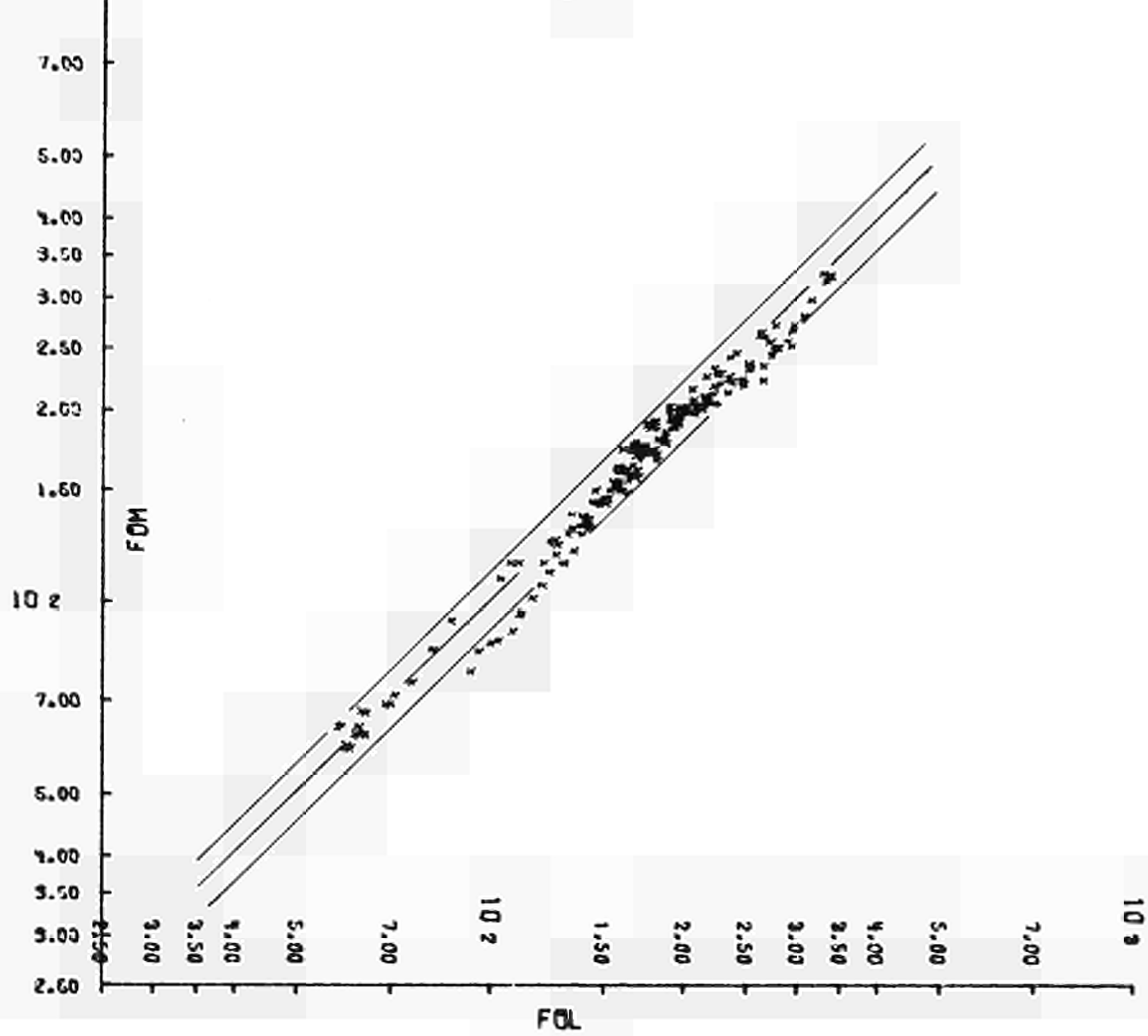


fig. 23

9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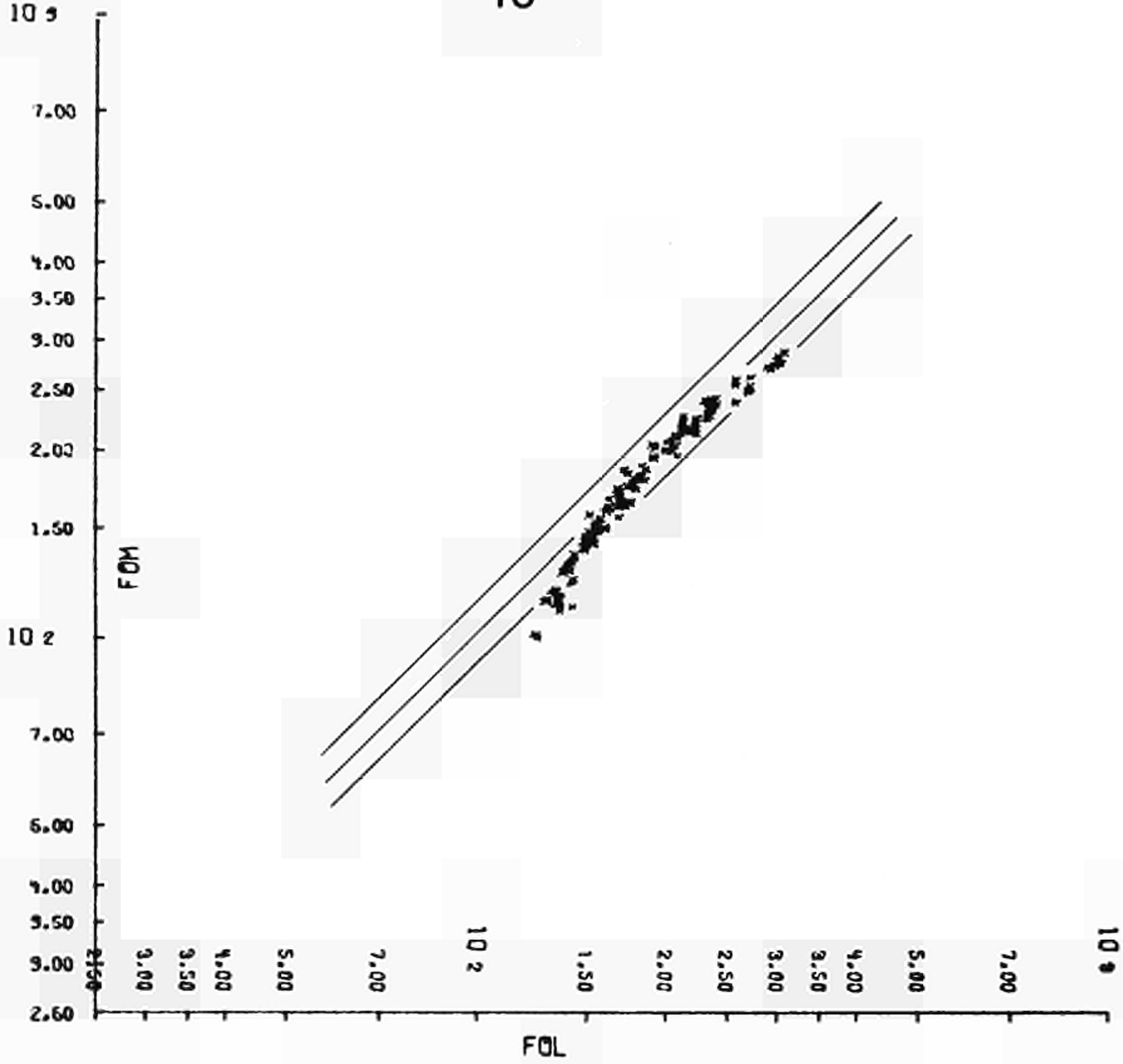
7.00
10 3
FOL

fig.24

10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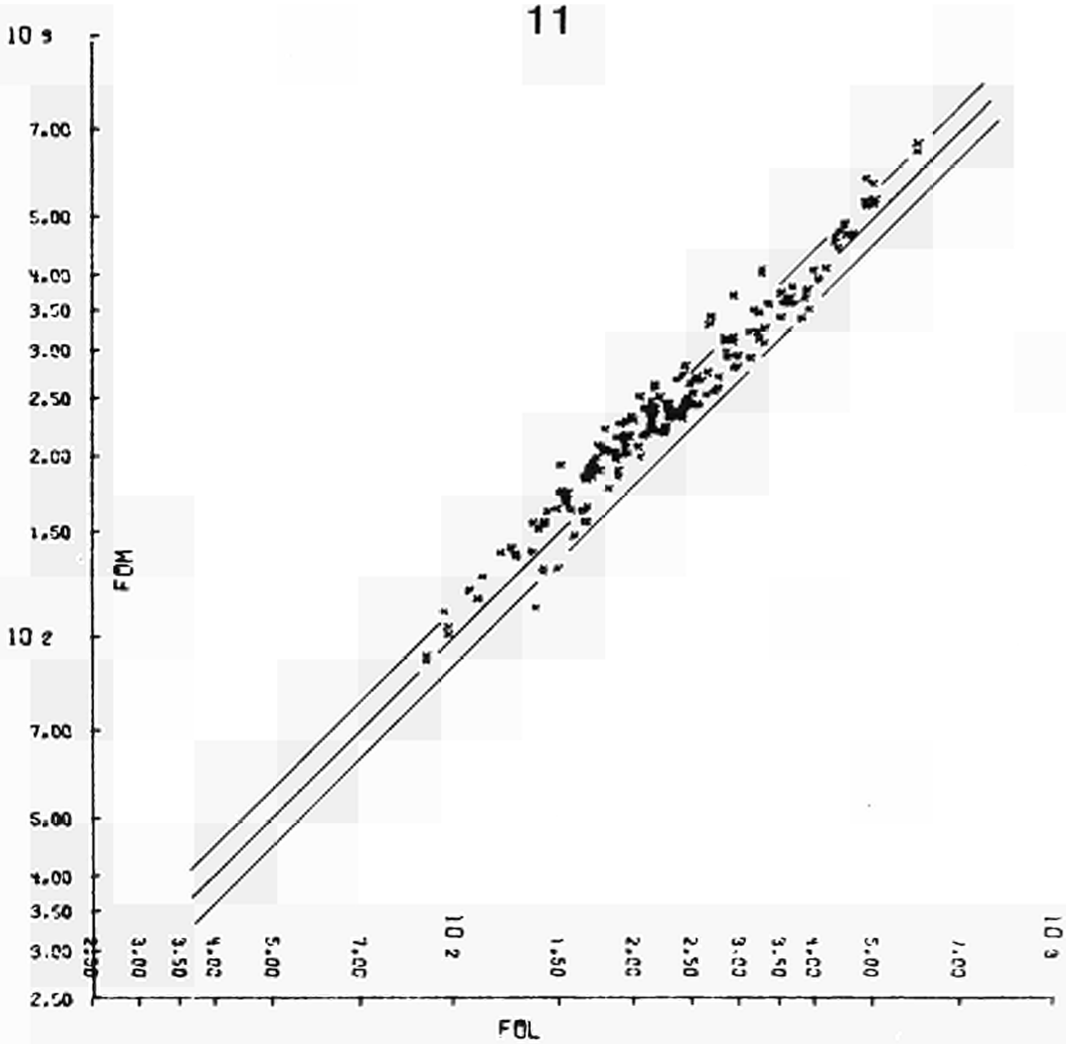
7.00
10 3
FOL

fig. 25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10 3
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fig.26

12

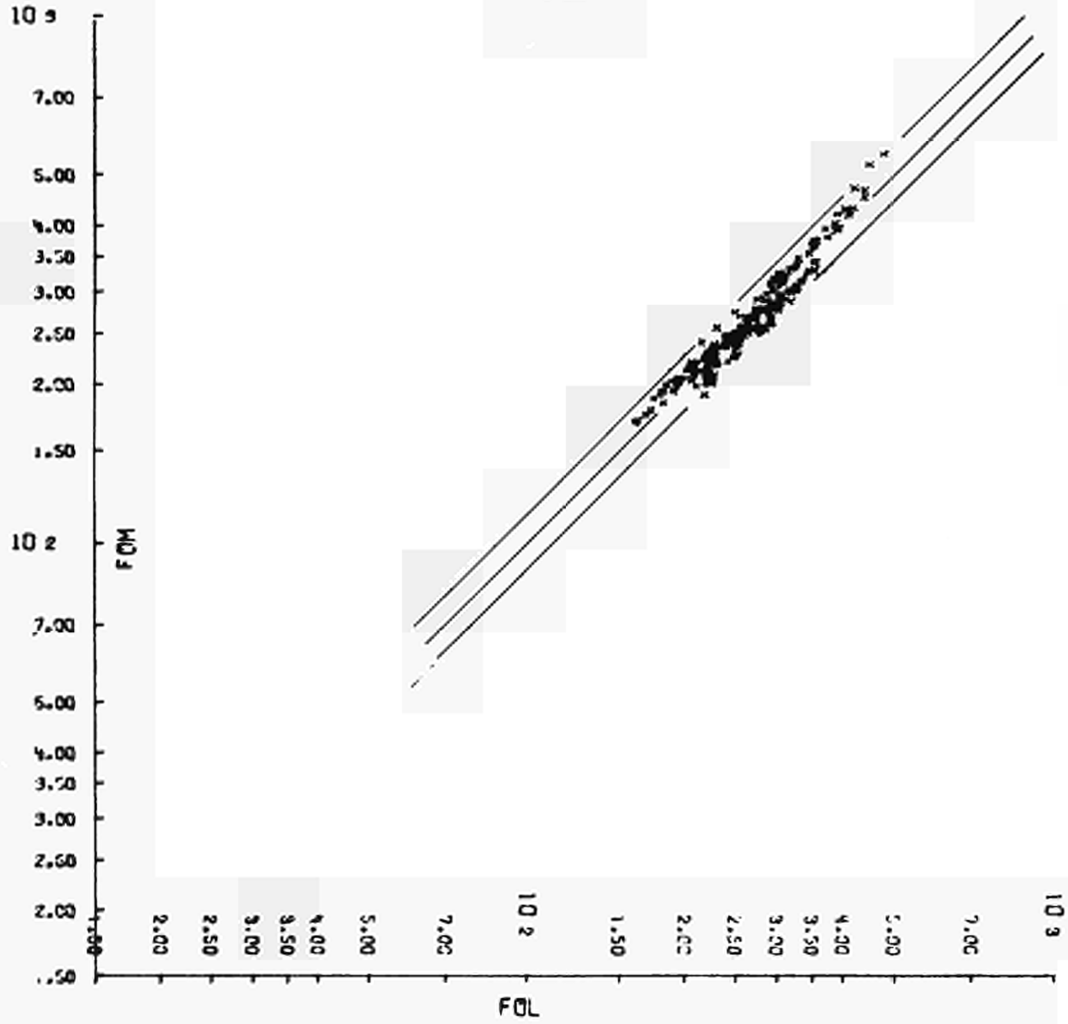


fig.27

13

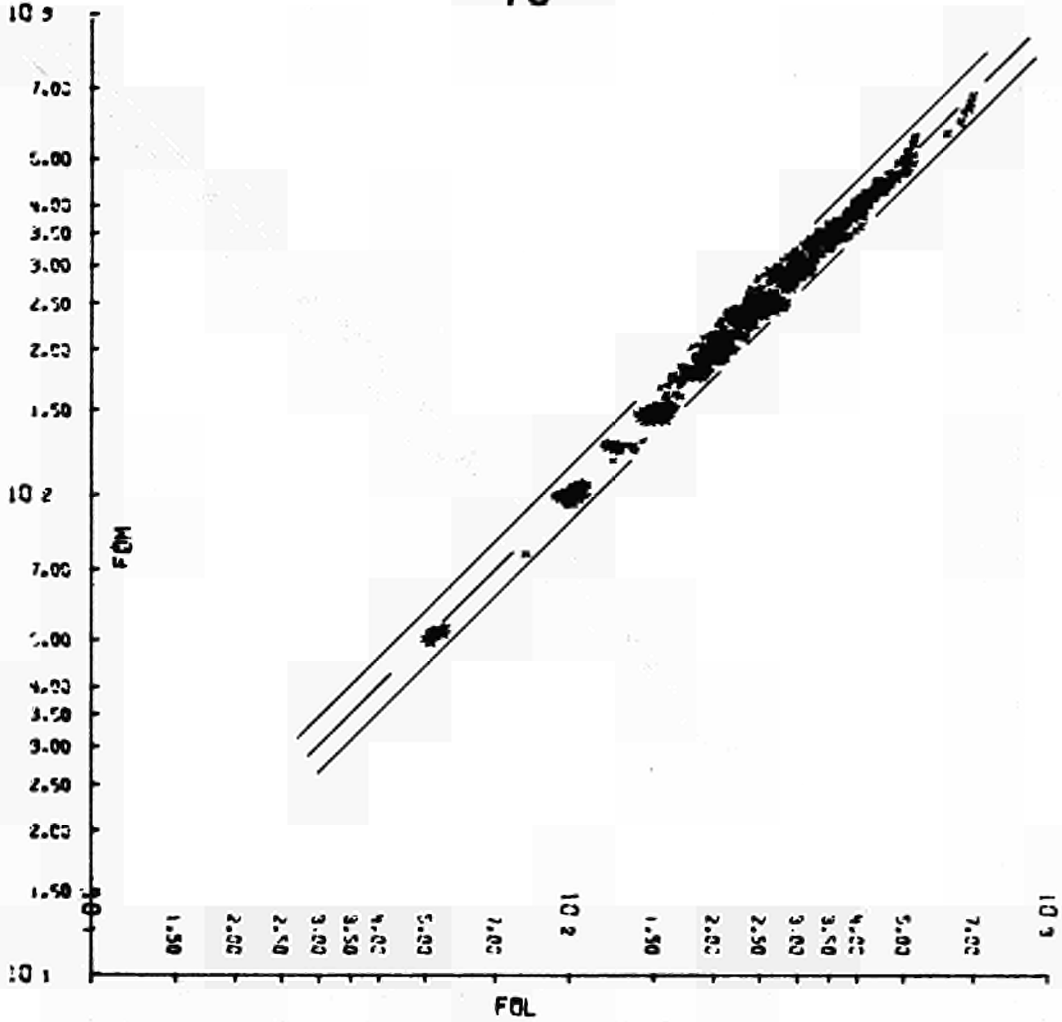
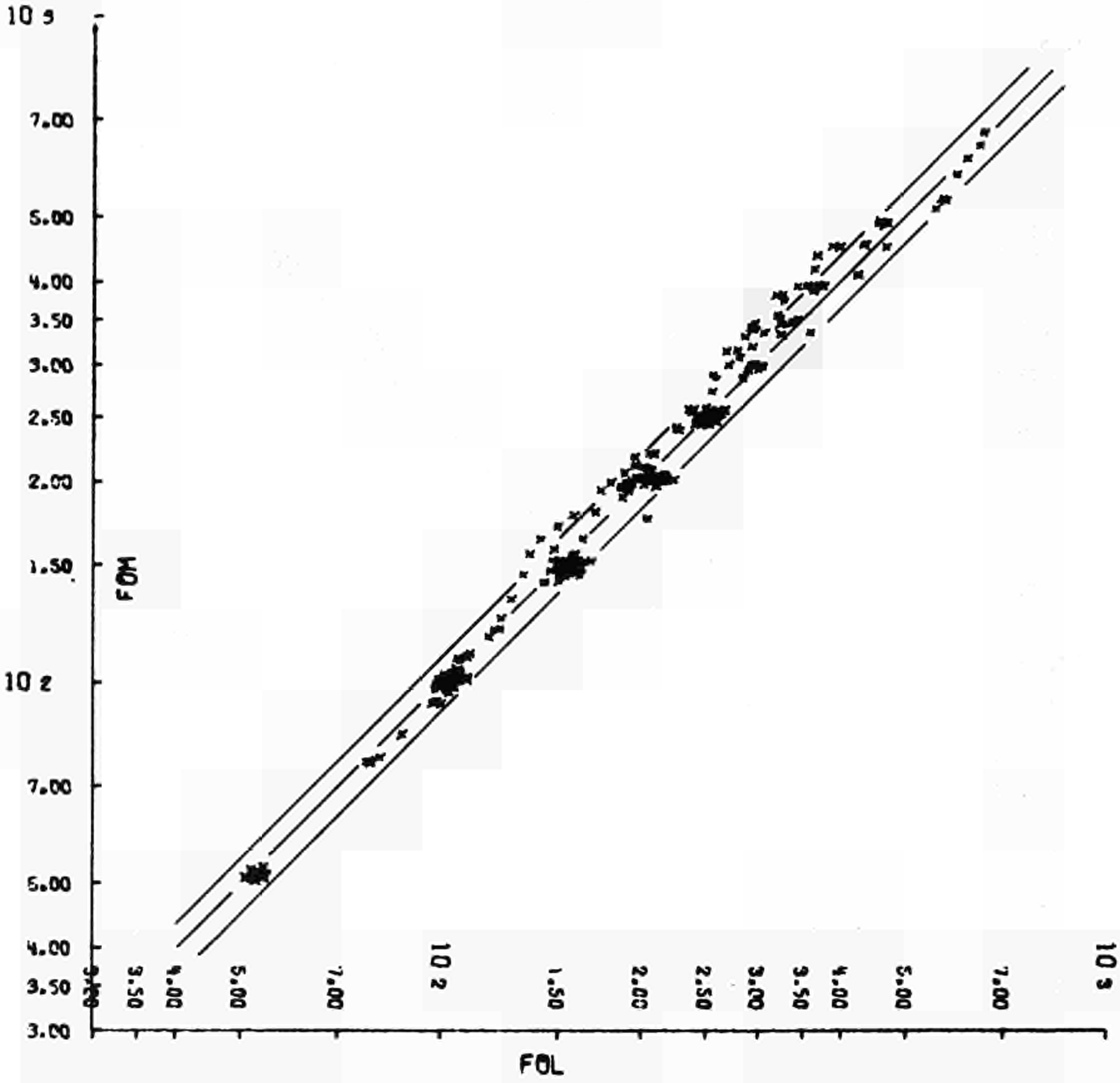


fig.28

14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5.00
7.00
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2.50
3.00
3.50
4.00
5.00
7.00
10 3
FOL

fig.29

16

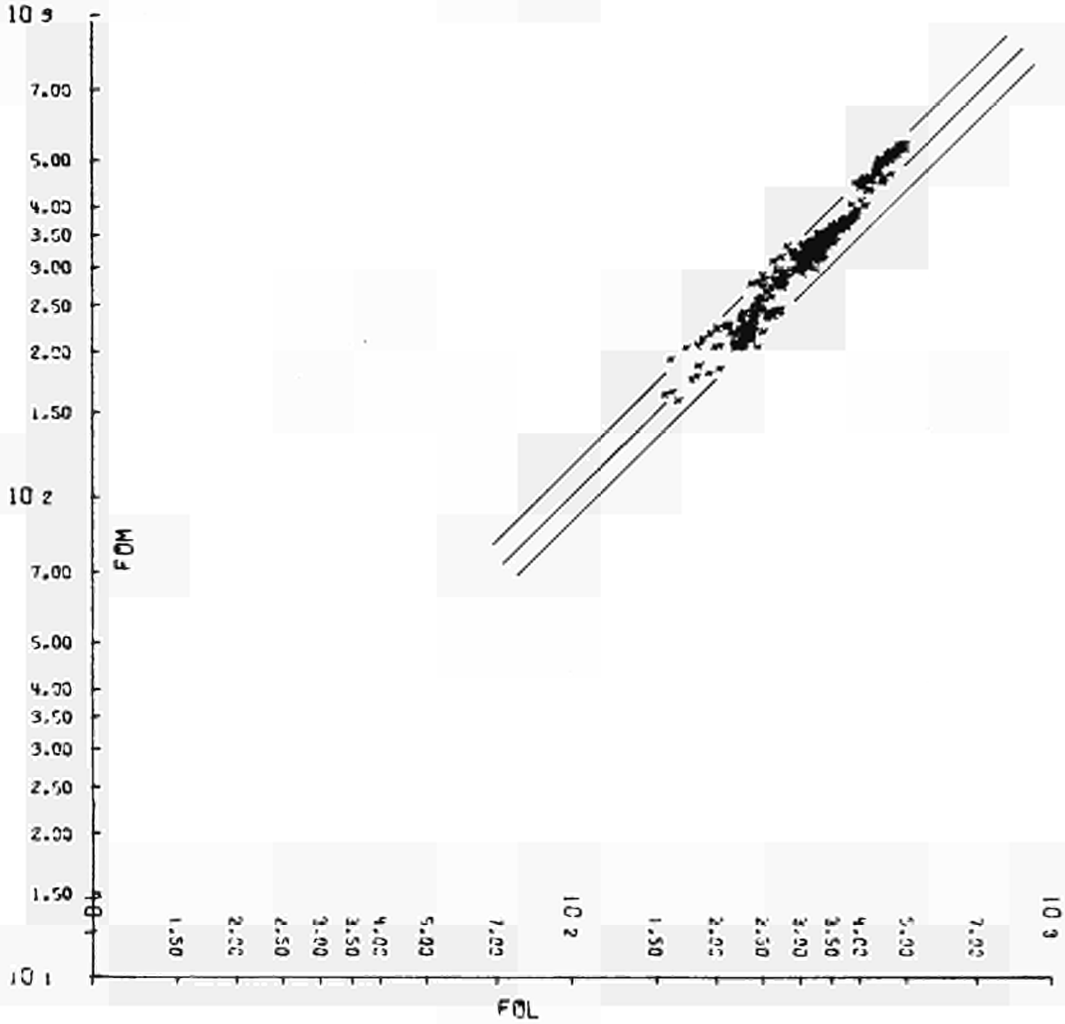

fig.30

17

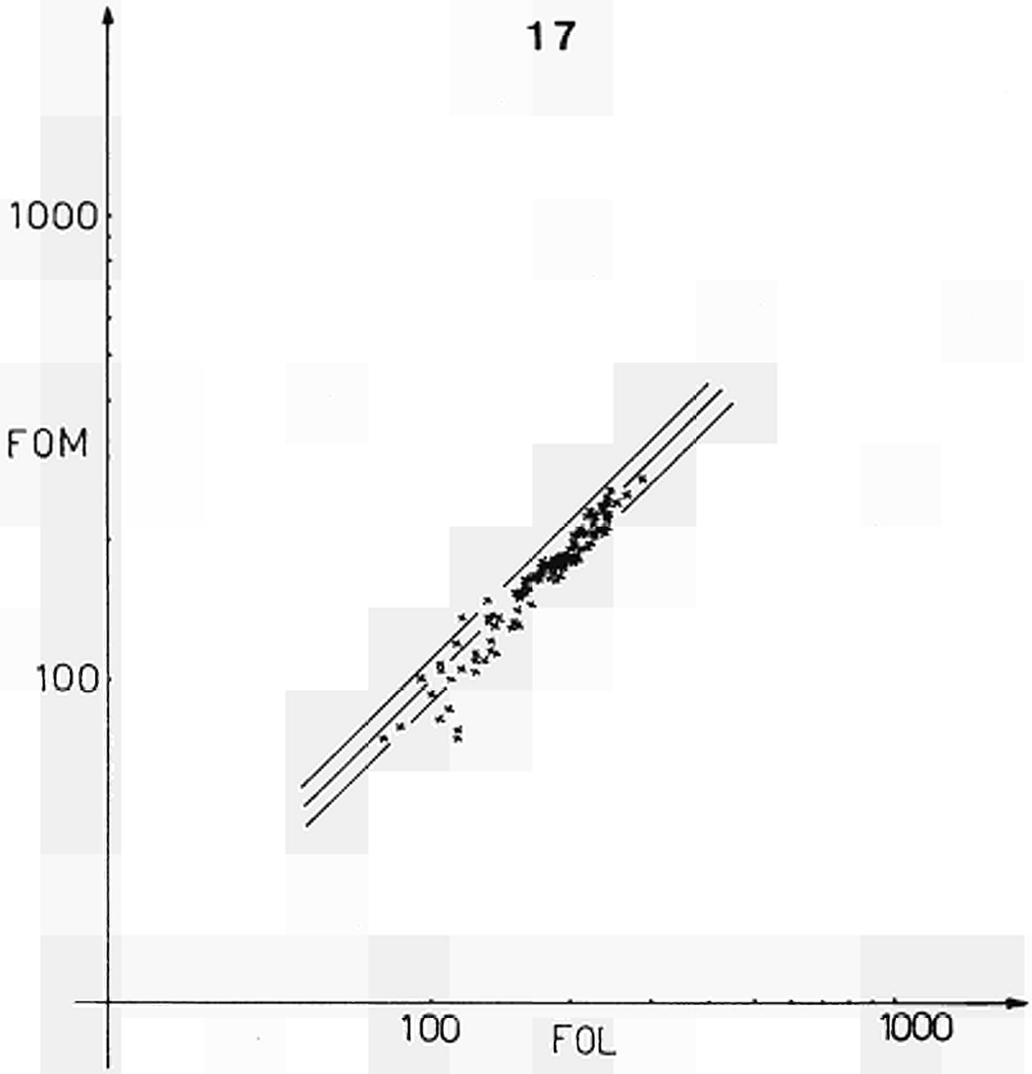

fig.31

5. EXAMINATION OF THE DATA WHICH ARE EXTERNAL TO THE VALIDITY RANGE

There are 576 data excluded from the previous examination, as external to the validity range. These data have been subdivided into four groups according to the pressure. Such subdivision has been introduced in order to point out if there is a coupling amongst the pressure and the parameters used time by time. In the same table we have also reported the results obtained by the examination of these data by means of the correlation

TABLE 5

	Runs	$\bar{\sigma}$
P 70 ata	85	16
P= 70 ata	169	11.27
80ata < P < 130 ata	115	14.35
P=140 ata	216	15.41

In the complex of the data excluded some data are present wich are characterized by very different condition,for instance:

D	L	P	G	Xin	Φom	Xom
0.46	23.9	7	1.4	-0.054	11.9	0.824
0.57	62.5	32.9	1043.3	-0.116	526.7	0.012

where the specific mass flow rate G changes from 1.4 gr/cm^2sec to 1043.3 gr/cm^2sec.

We did not think it possible to predict also these data with our correlation .In fact it is probable that at such extreme conditions a different motion path will raise

and different relation between the critical heat flux and the various parameters will be set up. In any case the 576 data, external to the validity range, have been compared with the predictions of the correlation. The shifting has been examined by collecting the data in accordance with the reasons of the exclusion: $G<10$, $G>600$, $D<0.3$, $L<20$, $X_o<\frac{1}{1+\rho_l/\rho_g}$
As some data are external to the validity range for more than a parameter, we have established an order of precedence first collecting the data excluded for G, and then the data excluded for D, for L and for X_o.

$G>600$

In fig. 32 we have reported the data with $G>600$ (33 data): for values of G so high there are very low outlet qualities, so that many of these data are excluded also for X_o which is less than $1/(1+\rho_l/\rho_g)$. The difference amongst the flux experimentally measured and the flux predicted by the correlation is strongly positive, except for three data.
A very simple correction may be introduced by multiplying the critical heat flux, calculated by means of eq. 2, by the corrective factor 1.15. In such a way the mean quadratic error changes from 19.2% to 12.35%, obviously the great value of the error is owing to the presence of the tree data with strongly negative errors.

$G<10$ gr/cm^2 sec.

The 78 data with $G<10$ gr/cm^2 sec. are reported also in fig. 32. Also in this case the error of the predictions exhibits a constant sign and most of the data is overestimated, indipendent of the pressure. As we have found no dependence of the error on some parameters, we have thought it was sufficient to multiply the predicted values by a constant. Putting $\Phi_o(G<10) = 0.9\,\Phi_{o,calc.}$ the mean quadratic error $\bar{\sigma}$ changes from 14.1% to 7.1%

$L < 20$ cm, $D < 0.3$ cm

The data with $L < 20$ cm have also $D < 0.3$ cm. The errors of these 134 data are given in fig.33 versus X_{in} in order to have a better separation. Some data, indicated with (•) in fig.33 have also $G < 10$. The corrective factor introduced, 0.9 as a multiplying constant, changes the mean quadratic error σ from 14.2% to 6.25%.

$X_o < 1/(1 + \rho_l/\rho_g)$

The greatest number of data external to the validity range consists of the data with $X_o < 1/(1 + \rho_l/\rho_g)$. On the whole there are 437 data for a large range of geometrical parameters and inlet conditions. Fig. 34 gives, versus G, the data at P=70 ata, $0.01 < X_o < 0.03$. In fig.35 always versus G the data at P=140 ata and $0.08 < X_o < 1/(1 + \rho_l/\rho_g)$ are reported. From these two figures it results that the error of the predictions depends on G. The correlation, applied to the data with $X_o < 1/(1+\frac{\rho_l}{\rho_g})$ overestimates the critical heat flux for $G \lesssim 300$ gr/cm^2 sec., and underestimates the critical heat flux for $G \gtrsim 300$ gr/cm^2 sec. Such different dependence on G, for very low outlet quality, has been already considered by us in reference (2), (4). An attempt to correct it has been made multiplying the critical heat flux predicted by correlation by the corrective factor $\eta = 0.425\ G^{0.15}$. In figs. 36 and 37, we have reported the errors for the same points of figs. 34 and 35, after the introduction of the corrective factor. The mean quadratic error changes from 13.85% to 9.9%.

In all the cases considered, when some corrective factors are introduced, it is necessary to calculate the outlet quality again.

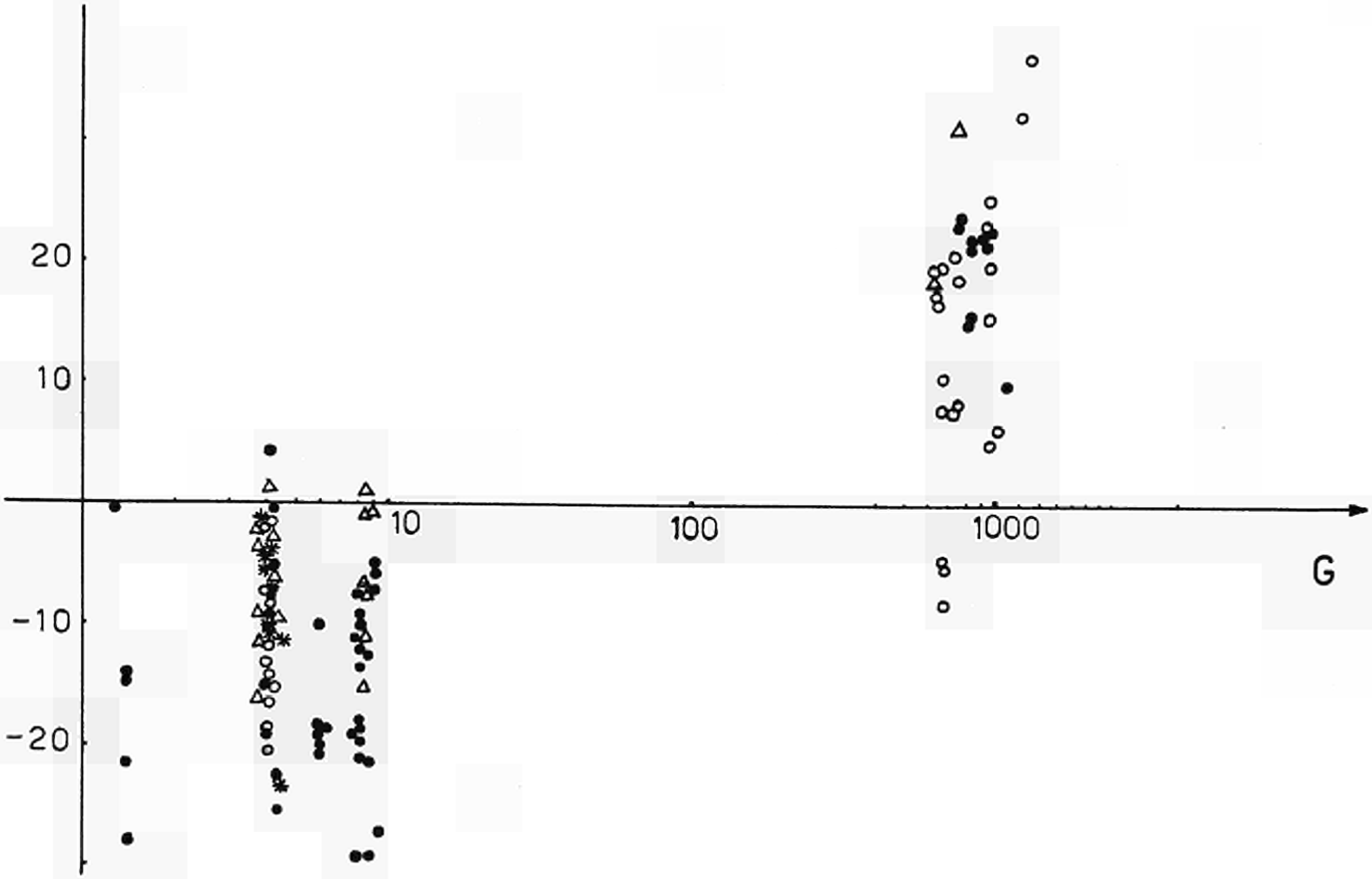

fig. 32

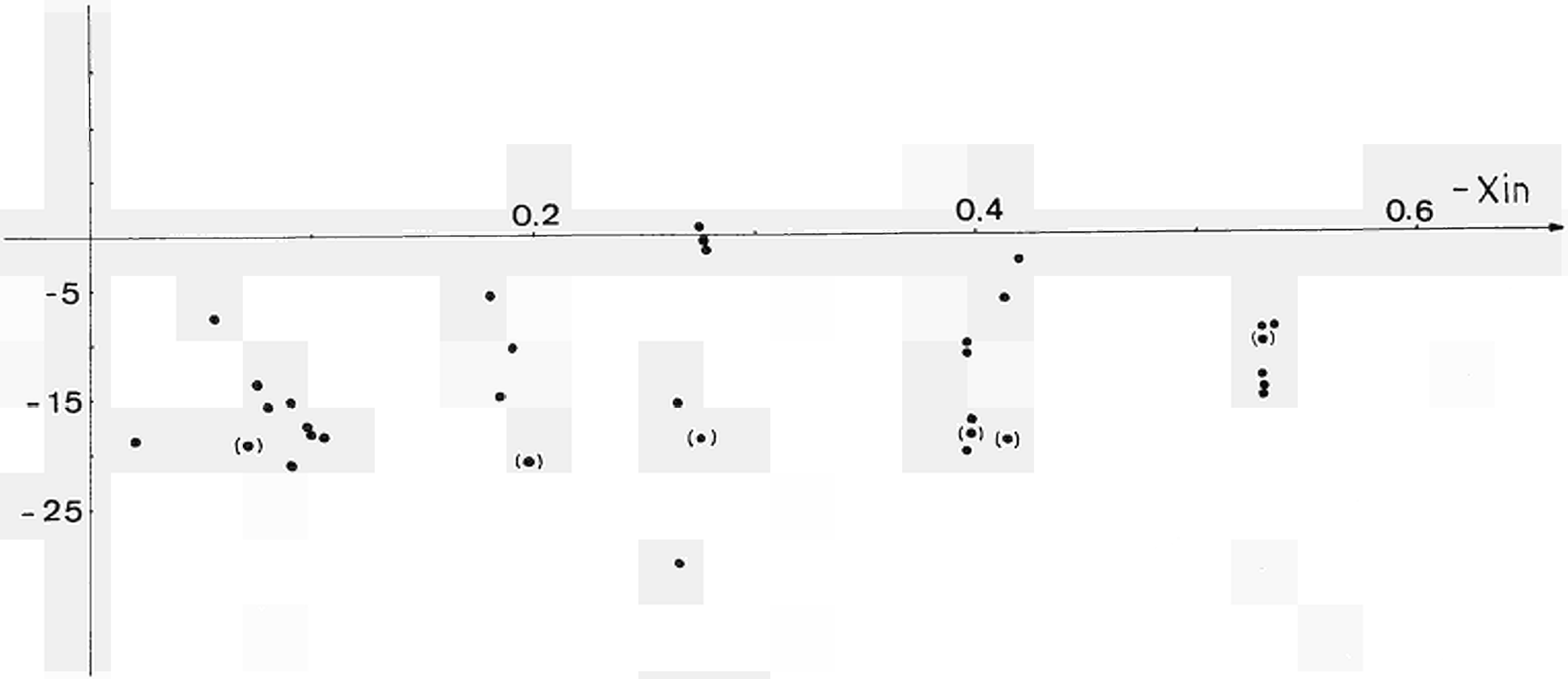

fig. 33

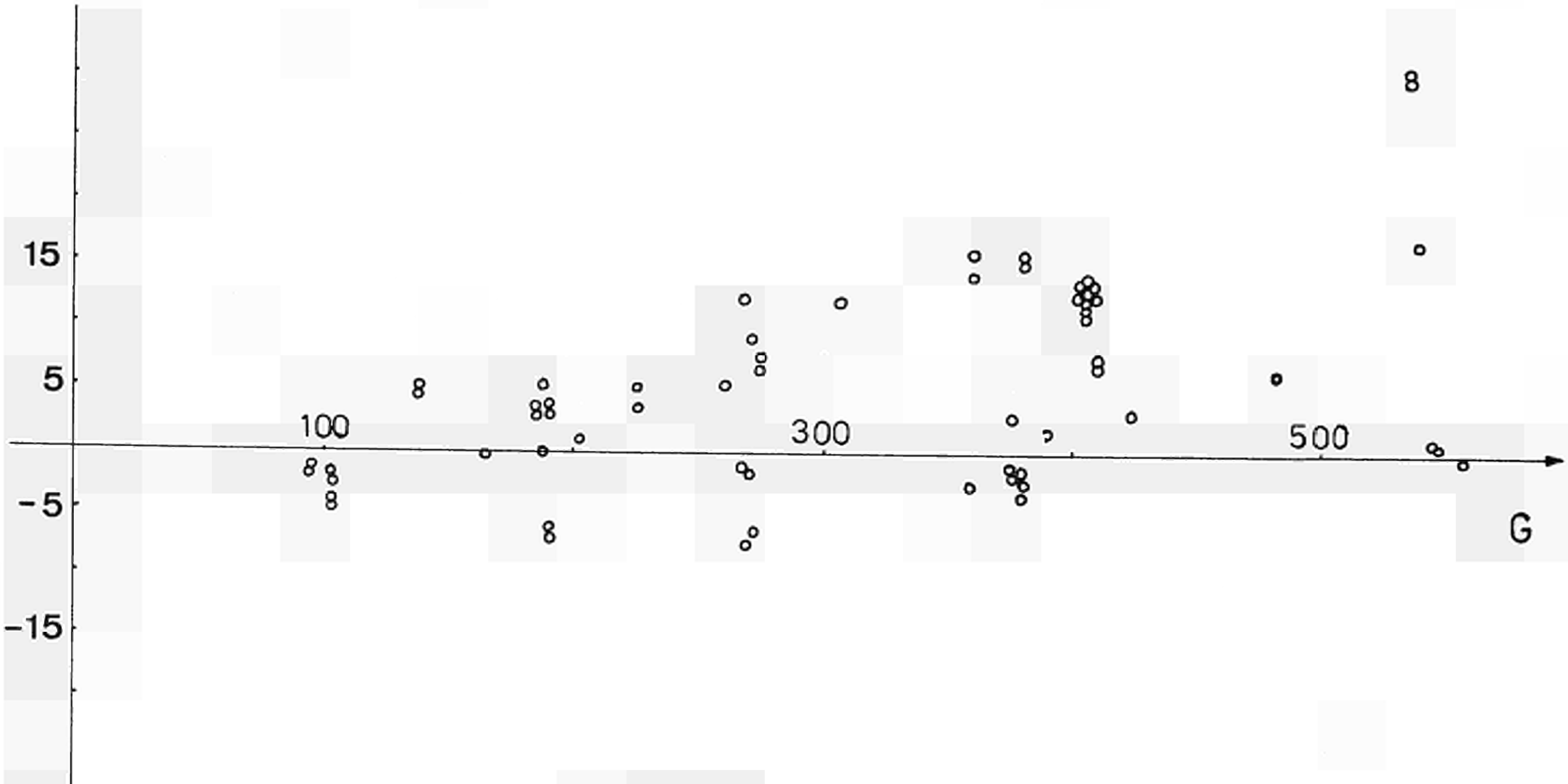

fig. 34

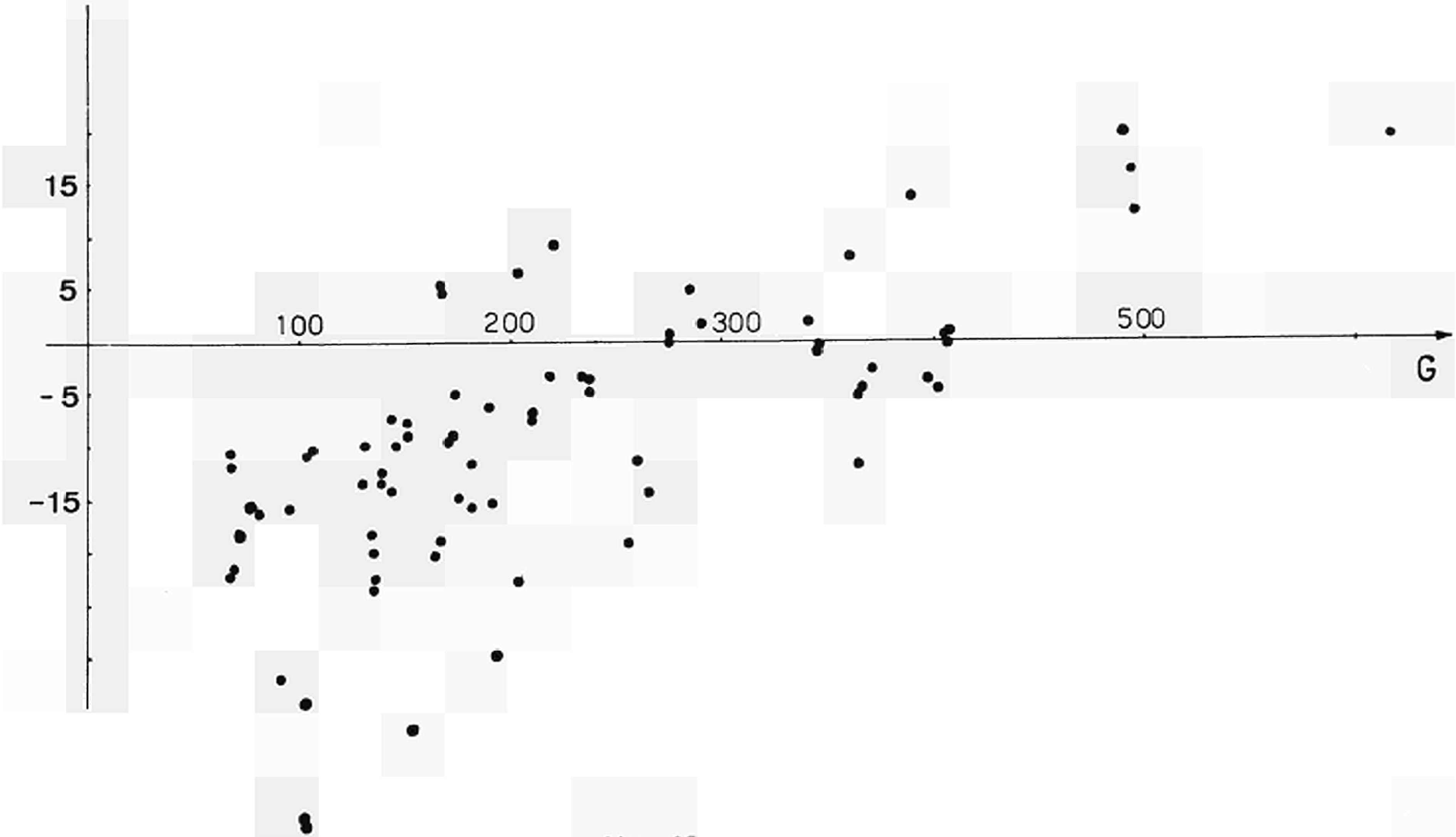

fig. 35

fig. 36

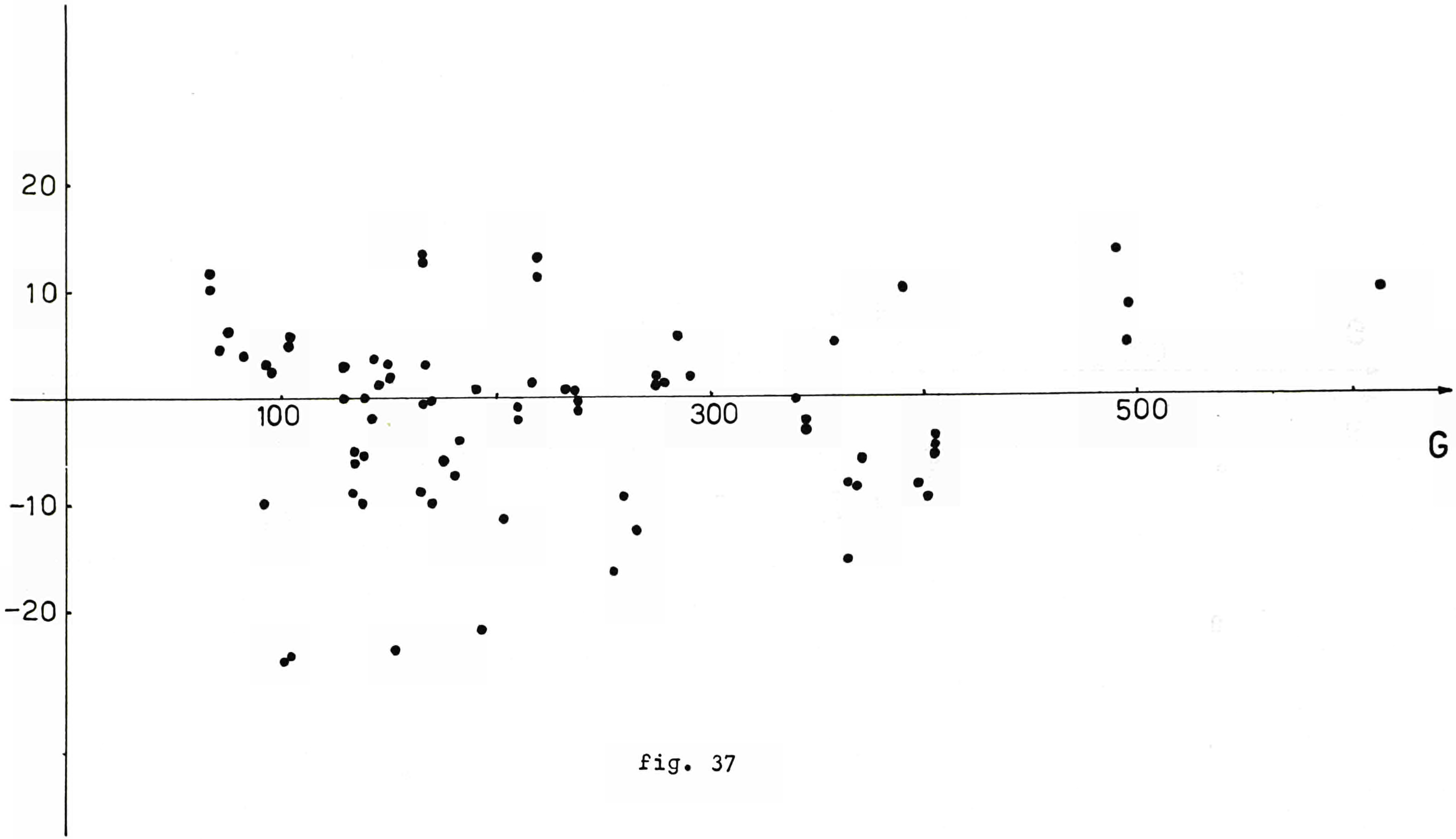

fig. 37

NOMENCLATURE

D	diameter	cm
G	specific mass flowrate	$gr/cm^2 sec$
H_{lg}	latent heat of vaporization	joule/gr
L	heated length	cm
P	pressure	ata
X_{in}	inlet quality	-
X_o	outlet quality	-
X_v	volume flowrate quality	-
ρ	density	gr/cm^3
ϕ_o	critical heat flux	$watt/cm^2$

Subscripts

g	steam
l	liquid

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Alfred Nobel

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