NATIONAL INSTITUTE OF OCEANOGRAPHY
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Computer Approximations for Matthews Areas

Corrections at Depths greater than 200 metres

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N.I.O. Internal Report No. N. 22

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INTRODUCTION

The measurement of depth on board R.R.S. Discovery is made by means of a precision echo sounder. A standard sounding velocity of 800 fms/sec is used. The time taken for a pulse to reach the ocean bed and return is measured, and the depths which are recorded on a continuous chart are in fathoms. As the velocity is a function of temperature, salinity and depth, corrections have to be applied to these nominal depths.

These corrections are made using "velocity of sound in pure water and sea water" tables by Matthews (1939), the correct values being written in the log book by hand.

Matthews compiled his tables using soundings taken by a number of research ships all over the world. He divided the oceans into 52 areas of which 1-20 (excluding 15 which is outside the Straits of Gibraltar and considered suspect) and 47-50, lie in the Atlantic and Mediterranean Areas and are considered here.

Since the tables were published more accurate calculations of velocity have been made due to new techniques in calculating temperature and salinity. However, at present, these tables are in general use and accurate to within 5 metres.

None of the measurements is made at depths less than 200 metres.

Computing Methods

In 1969, when an 1800 IBM computer was installed in R.R.S. Discovery it was decided to store the depths (uncorrected fathoms) on the computer, in the form of a data file on disc, and subsequently to correct the depths on the computer and output the results to a typewriter as required. For these purposes two programs were written in Fortran 4, the first to sort the stored depths file into chronological order, and the second to correct the depths stored to fathoms and metres.

It must be remembered that the division Matthews makes of the oceans is a purely artificial boundary and that no physical discontinuities occur. The corrections applied had to be in a form which could be easily stored on disc, and accessed by the programs. The method used was to take the Matthews correction figures and to use a polynomial fitting program to see if the corrections could be used in the form of curves of a reasonably low order. Obviously, the higher the degree fitted the more meaningless the curves become. Taking into account the boundaries and the accuracy of the sounding, an attempt was made to get the curves fitted to have a maximum difference at any point of three metres. On some curves odd points on the original data were found to be in disagreement with the rest and it would appear reasonable to assume that these points were in fact in error, though they made little difference to the final results.

The equations were calculated without setting a surface value as a restriction and the errors occurring at the surface are from 1-5 metres. However, in areas that do have depths less than 200 metres the results are within an error of 3 metres.

Results

The first areas to be tried were the Mediterranean areas (47, 48, 49, 50). Area 47 is in the Straits of Gibraltar. Area 48 the Western Basin. Area 49 the Adriatic and Tyrrhenian Seas and area 50 the Eastern and Aegean Basins. These areas all fitted second order curves, with errors of up to 1.6 metres from Matthews corrections. Areas 48, 49, 50 are adjacent areas of similar composition and the equations fitted agreed closely with each other (see Table 2). Area 47, which is inside the Straits of Gibraltar where the North Atlantic and Mediterranean Water mixes, also agreed closely with Area 48 though only went to a depth of 1600 metres.

Areas 1-4 fall north and east of the British Isles. Area 1 was a third order equation to a depth of 4,000 metres. Area 2 and 3 both to a depth of 3,000 metres were 2nd order equations and area 4 is a third order. It should be noted that area 4 also occurs off the Canadian Coast.

Areas 5-13 occur in the main part of the Atlantic. Areas 5, 6, 7, 8, 9, 12 and 13 converge sharply in the Gulf Stream, and it would appear difficult to use the tables accurately here. Area 11 occurs at approximately 35-40°N and also 18-25°N. Area 12 goes down to 9,000 metres and one curve would not fit the total range. However, on the Eastern side of the Atlantic the greatest depth found is 5,000m. One curve fitted this depth, and if greater depths are required a second curve must be calculated for the bottom 4,000 metres. In area 13 the Matthews Area does not extend to the greatest depths. Area 14 which is near the Gulf Stream, and a rather isolated area, fitted a 5th order curve, and was the highest order curve fitted.

Areas 16-18 are also on the Western Atlantic with 19, 20 in the South all fitted 4th order curves with errors of 5 metres at the surface.

Area 15 outside the Straits of Gibraltar is an isolated area in the middle of area 13 and considered suspect. The area 13 equation is used here.

In Table 2 the equations were originally calculated to 8 decimal places. Cutting these down to three decimal places makes a difference in the depth correction of the order of 1/10 metre, which is well within the error (up to 5 metres) of the final corrected depths.

While the corrections were being done online on the computer, log books were also kept and continuous checking of the two sets of results was done to ensure the accuracy. In fact the two sets of results usually agreed to within 2 metres.

The uncorrected depths are in fathoms and when corrected to metres a conversion factor of 1.828798 was applied.

It should be noted in the following equations that the curves are not very smooth (as seen from the high order coefficients) therefore these equations should not be used at depths of less than 200 metres or greater than the maximum specified in Table 1.

Table 1

Maximum Area	Degree Fitted	Maximum Residual (metres)	Depth of max. residual (metres)	Mean Square	Depth of eqtn. used to (metres)
1	3	1.0	1600	0.34	4000
2	2	-0.9	2000	0.19	3000
3	2	-1.5	1800	0.58	3000
4	3	-2.0	4200	0.50	5000
5	4	-2.7	4200	1.12	5000
6	4	-0.8	2800	0.25	4000
7	4	-0.9	3400	0.27	4200
8	4	1.3	3200	0.63	5000
9	4	0.9	2600	0.31	5000
10	4	2.0	4000	0.92	5000
11	4	1.8	4000	0.28	5600
12 (to 5000m)	3	-0.2	200	1.32	5000
13	3	-1.0	2600	0.30	5000
14	5	1.5	3000	0.91	6000
16	4	2.3	400	0.78	3600
17	4	-1.0	4800	0.35	5000
18	4	-2.5	200	1.16	6000
19	4	-2.2	2000	1.60	5000
20	4	-1.3	200	0.52	5000
47	2	-0.7	800	0.28	1600
48	2	0.9	1000	0.31	3000
49	2	1.5	2800	0.63	4000
50	2	-1.5	1800	0.49	4000

Table 2

Matthews Area	X^5 x 10^{-17}	X^4 x 10^{-13}	X^3 x 10^{-9}	X^2 x 10^{-6}	X x 10^{-2}	constant
1	0.0	0.0	0.212	4.483	-0.981	-1.668
2	0.0	0.0	0.0	5.070	-1.093	2.470
3	0.0	0.0	0.0	3.424	-0.329	3.352
4	0.0	0.0	-0.221	7.140	-0.385	1.644
5	0.0	0.127	-0.317	7.298	-0.443	5.089
6	0.0	-0.179	0.626	2.485	0.459	0.844
7	0.0	-1.419	1.599	-0.544	0.978	1.051
8	0.0	-0.902	1.348	-1.093	1.368	2.333
9	0.0	-2.062	2.838	-7.352	2.400	2.876
10	0.0	-1.812	2.768	-8.840	3.119	-2.149
11	0.0	-1.952	2.790	-8.395	3.017	0.247
12 (25 pts)	0.0	0.0	0.934	-2.872	2.510	5.316
13	0.0	0.0	0.823	-2.867	2.894	1.659
14	6.329	-11.723	8.429	-23.618	5.004	-0.128
16	0.0	-7.238	6.423	-13.460	2.459	3.584
17	0.0	-2.835	3.336	-7.322	2.302	5.342
18	0.0	-1.830	2.669	-6.776	2.584	6.550
19	0.0	-1.861	2.533	-5.957	2.064	5.516
20	0.0	-1.168	1.625	-2.159	1.495	5.393
47	0.0	0.0	0.0	7.440	2.375	0.036
48	0.0	0.0	0.0	6.690	2.555	0.789
49	0.0	0.0	0.0	6.518	2.688	1.096
50	0.0	0.0	0.0	6.573	2.747	1.788

The following 5 figures show the shapes of the curves on the correction figures as found in Matthews Tables.

These have been grouped in adjacent areas.

Fig. 1 shows areas 1-4, North of the British Isles.

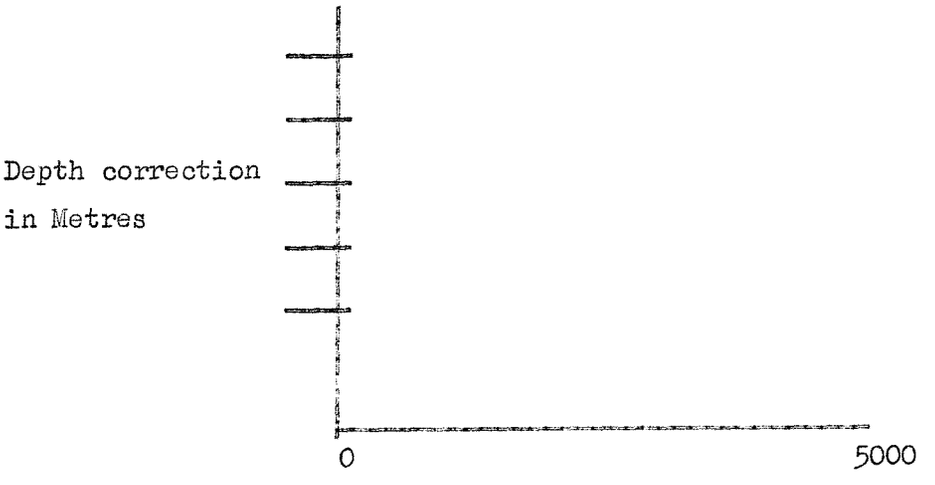
Fig. 2 shows areas 5-10, Mid-Atlantic going from West to East.

Fig. 3 shows areas 11-14 to the South.

Fig. 4 shows areas 16-20 mainly on the West.

Fig. 5 shows areas 47-50 in the Mediterranean.

In the following five figures the units on the graph are as follows:-



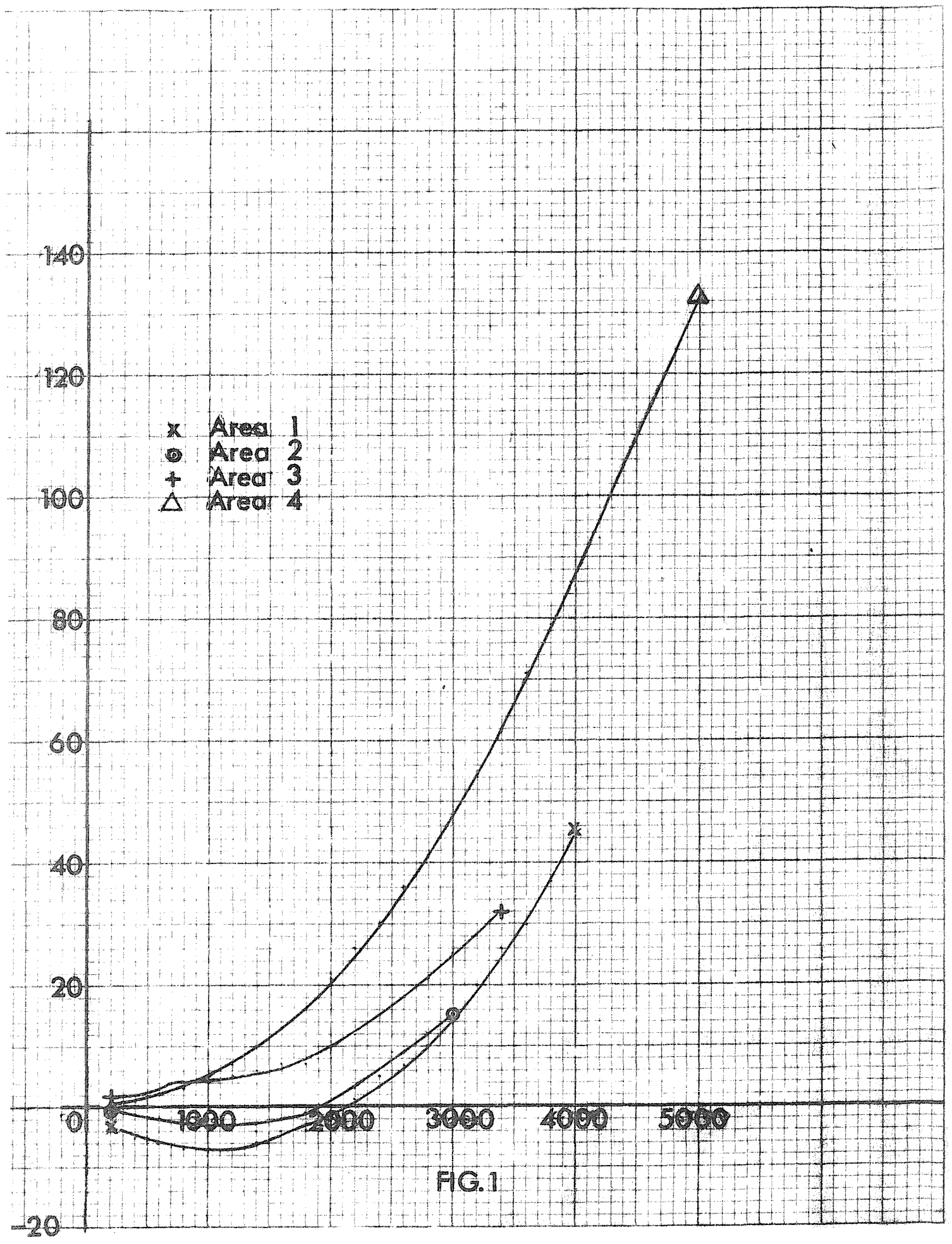

140
120
100
80
60
40
20
0
-20
1000
2000
3000
4000
5000
x Area 1
⊙ Area 2
+ Area 3
△ Area 4

FIG. 1

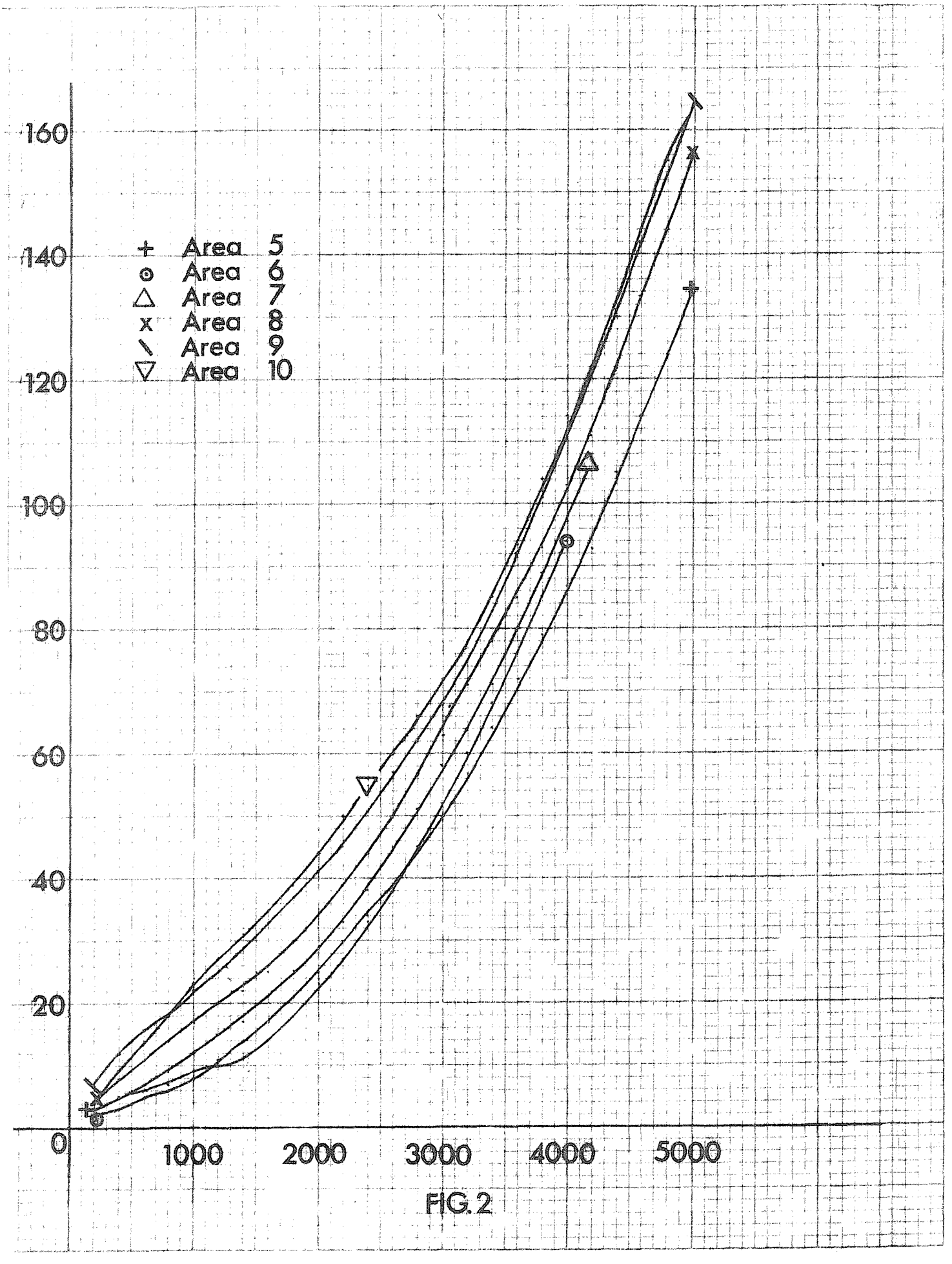

160
140
120
100
80
60
40
20
0
1000
2000
3000
4000
5000
+ Area 5
⊙ Area 6
△ Area 7
x Area 8
\ Area 9
▽ Area 10

FIG. 2

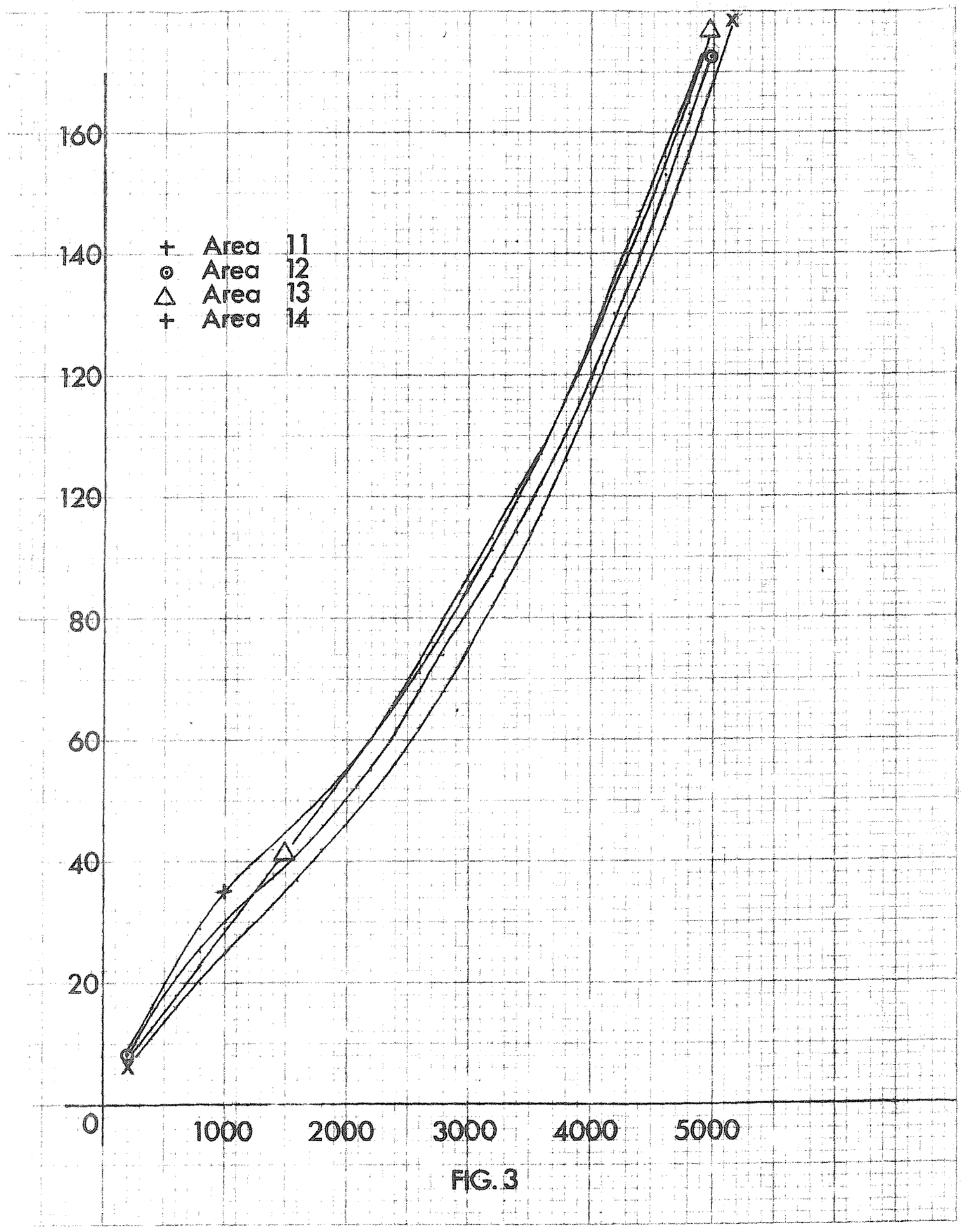

160
140
120
120
80
60
40
20
0
1000
2000
3000
4000
5000
+ Area 11
⊙ Area 12
△ Area 13
+ Area 14

FIG. 3

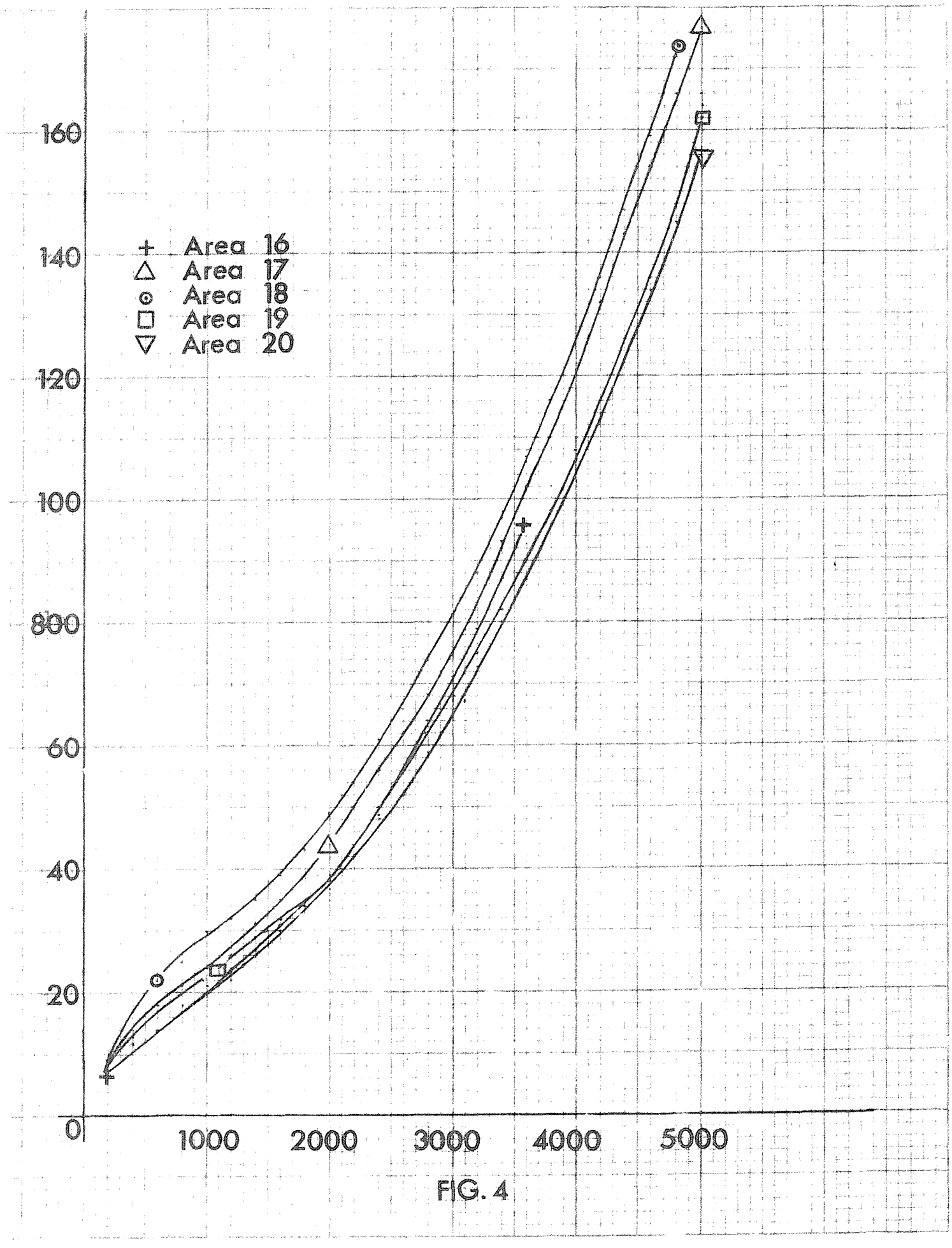

160
140
120
100
800
60
40
20
0
1000
2000
3000
4000
5000
Area 16
Area 17
Area 18
Area 19
Area 20

FIG. 4

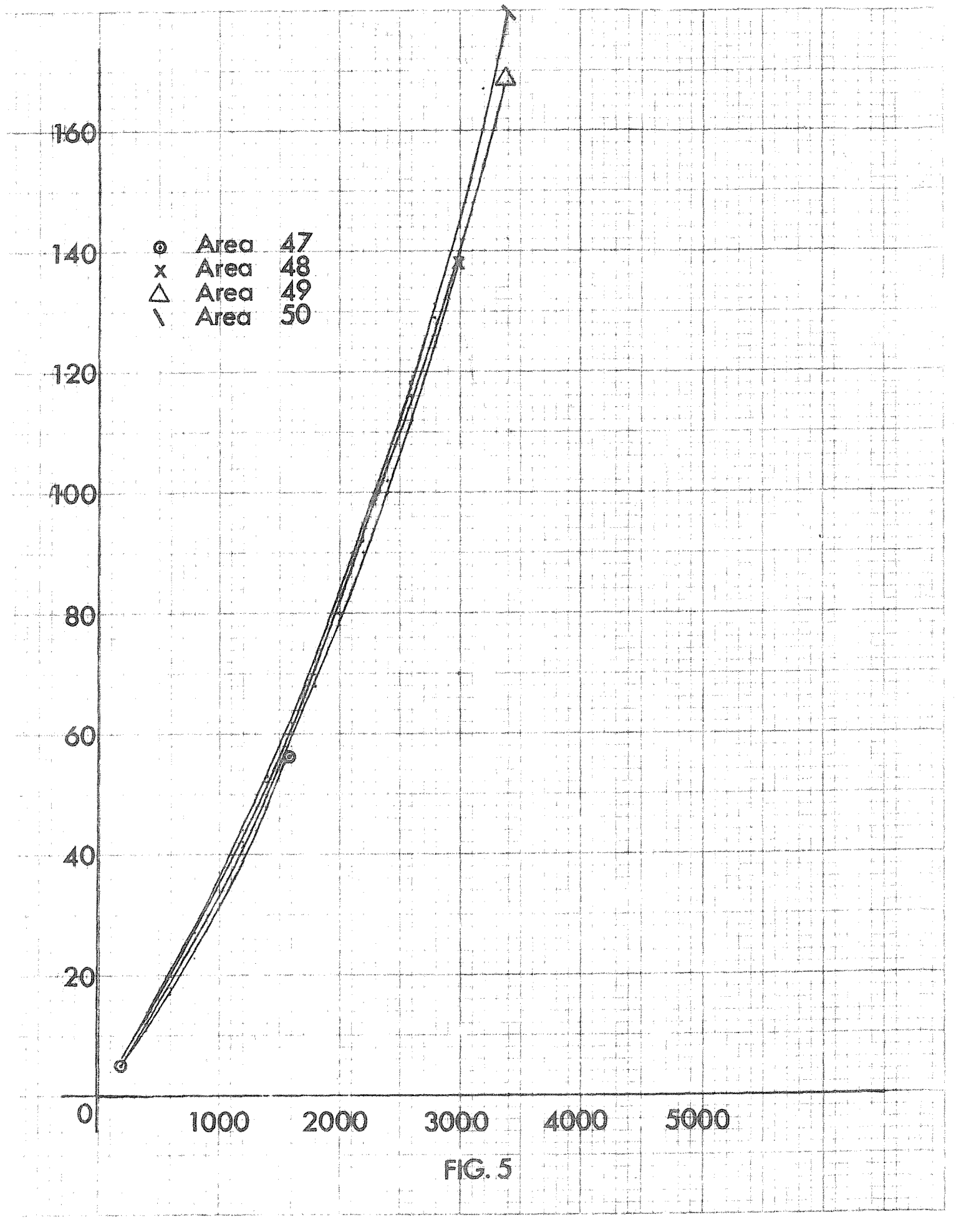

160
140
120
100
80
60
40
20
0
1000
2000
3000
4000
5000
Area 47
Area 48
Area 49
Area 50

FIG. 5

References

Tables of the velocity of sound in Pure Water and Sea Water - D.J. Matthews EIC (1939).

Acknowledgments

I should like to thank the members of the data processing group at N.I.O. for their help, in particular Miss Caroline Spackman who did several of the curve fitting calculations.

Conclusion

As Matthews Areas are widely used in their current form, the method of fitting curves is certainly as accurate as the original tables, and a convenient way of quickly correcting large amounts of data for permanent storage.

The accuracy at less than 200 metres is suspect. However, to date in those areas when depths of less than 200 metres were encountered, the accuracy in these particular areas is well within the limits (2 metres). Very shallow depths where errors of 5 metres might occur are very unlikely as these appear to be in general the deeper areas.