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FIELD INTERCALIBRATIONS OF ECHO INTEGRATOR SYSTEMS

by

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ABSTRACT

The paper reviews intercalibrations of echo integrators carried out in 1975 - 1977 where Norwegian research vessels have participated. Analog and digital integrator performance is compared, and methods to make integrator outputs from different vessels comparable are discussed.

INTRODUCTION

Echo abundance surveys of fish species with wide distribution areas may be biased due to migration and fishing and natural mortality in the period it takes to complete the survey. It is therefore important to make the survey in a short time interval as possible, and it is often advisable to carry out

the survey with two or more vessels, each covering a part of the distribution area.

In such a multi-ship echo survey there will be problems in comparing the results from each vessel directly, due to different types of echo sounder and integrator equipment. Trying to intercalibrate the results from different vessels teoretically, i.e. taking into account different source level, voltage response, beam angle etc. has not yielded satisfactory results. The most common form for intercalibration has been to let different vessels record the same fish concentrations and then compare the results. This has been done several times during the international O-group surveys in the Barents Sea (DRAGESUND, MIDTTUN and OLSEN 1970). Intercalibration on blue whiting recordings between hull mounted and towed body transducer has also been carried out (PAWSON et.al 1976). This paper will review intercalibrations carried out in 1975 - 1977 where Norwegian research vessels have participated.

## MATERIAL

Details on dates, locations etc. of the incalibrations which will be discussed in this paper are given in Table 1. The instrument settings of echo sounder equipment are given in Table 2. The measured instrument parameters source level (SL) and receiving voltage response ( $V_R$ ) for "G.O. Sars" and "Johan Hjort" are given in Table 3.

"G.O. Sars" and "Odissey" are equipped with analog echo integrators (NAKKEN og VESTNES 1970), "Johan Hjort" and "Johan Ruud" are equipped with a digital echo integrator system (EIDE, HELLE og KNUTSEN 1975).

## METHODS

The best condition for an intercalibration is, as for echo

integrator technique generally, when the echo recordings occur as a continuous scattering layer of varying density in midwater. In the Norwegian Sea/Barents Sea area this type of recording usually occurs at night-time, and as a consequence most of the intercalibrations have been carried out then (Table 1). Experience has shown that it is useless to carry out an intercalibration if schools are encountered. Due to the distance between the vessels, they will record different schools and completely different integrator outputs can then be noted for the same nautical mile.

Before intercalibration one vessel is a little astern of the other. The vessel astern increases its speed, and the intercalibration starts when the ships are athwart each other. The distance between the vessels during the intercalibrations has been 0.1 - 0.2 nautical miles, with one vessel somewhat astern and to the side of the other. The vessel astern must avoid the wake of the other vessel, care for this must specially be taken during change of course. If the vessels are running too close to one another, general noise from one vessel (propeller etc.) may cause unwanted noise signals on the echo sounder of the other. Also, if the echo sounders on the two vessels are operating on the same (or near) frequency, the transmission pulse from one vessel will be recorded by the other. Intergration of this type of recording can sometimes be avoided by an appropriate setting of integrator channels. Finally, navigational security also demands a certain distance between the vessels. The intercalibration is terminated in a similar manner as it started, with the vessel astern coming up athwart of the other. This ensures that both ships have sailed the exact same distance. Course lines have largely been chosen on the basis of the wind and the sea, the aim being a minimum of rolling and pitching by the vessels. Favourable weather conditions are imperative, scattering of sound energy by air bubbles (due to rough seas) must be avoided.

At this time it should be pointed out the two vessels do not record the exact same density during the intercalibration, and a perfect correlation of the integrator outputs can not be expected. Teoretically, it should be possible to obtain a certain overlapping if the recordings are located in deep water (due to the widening of the sound cone by depth). However, sea and weather conditions have to be perfect if one utilizes scattering layers in deeper water for an intercalibration. Due to the time varied gain ( $20 \log R$ , Table 2), noise at the transducer will, in addition to the received signals, also be amplified and this may cause inaccurate integrator outputs.

## RESULTS

The integrator outputs from the intercalibrations listed in Table 1 are shown in Figs. 1-8. The units on the ordinate are in mm deflection per. n.mile (for a certain integrator gain). This unit originates from the analog integrator where the recorder unit was equipped with a stylus pen writing on paper with millimeter scale. When the digital integrator was introduced, the output numbers were adjusted to give values of the same magnitude. The absussa gives the values from the distance logs of the vessels in question (1 unit = 1 nautical mile). The total sailed distance during the intercalibration for both vessels will be the same. However, the log readings from the vessels do not show the exact same sailed distance, the difference is in the order of 10% during some of the intercalibrations.

Fig. 9. compares the echograms from the Norwegian research vessel "G.O. Sars" and the Soviet research vessel "Odyssey".

## DISCUSSION

### Comparison of analog and digital integrators

Figs. 1-6 show the integrator output from the intercalibrations between an analog integrator ("G.O. Sars") and a digital integrator ("Johan Hjort"). For integrator values below 100 there seems to be no systematic difference between the two vessels. However, at high fish densities the integrator output are higher on the "Johan Hjort" compared with the "G.O. Sars". This occurs in every intercalibration during the period 1975-1977 (perhaps with the exception of the intercalibration of 30.9-1977, Fig. 6). Since this has occurred over such a large period of time, one can exclude the possibility of "Johan Hjort" actually recording a higher fish density.

The cause of the difference in integrator output at high fish density may be due to

- A. Operator error
- B. Differences in the signal processing of the two integrator systems.

The permanent instruments settings are shown in Table 2, but the settings which to some degree have to be changed due to varying recordings of fish and bottom, are the discriminator function of the echo sounder and the amplitude threshold of the integrator. In addition, the gain function of the analog integrator may be the cause of operator error.

The discriminator is used to avoid integration of bottom signals. The settings must sometimes be changed when dense fish schools are encountered, this can be controlled when the echo sounder is operating with the white line (WL) function. However, no such dense recordings have been encountered during the intercalibrations described here. AGLEN (1978) has shown that the threshold effect is not of vital importance with the type of recordings (organisms approx. 10 cm, individual target

strength  $> -50$  dB), and the high signal to noise ratio on "G.O. Sars" and "Johan Hjort". The Simrad MK II analog integrator on "G.O. Sars" has a warning light which indicates equipment saturation. It tells the operator to switch to a lesser gain setting. This warning light has been watched closely during the intercalibrations, and this type of saturation is excluded as a cause of the larger "Johan Hjort" readings. Altogether it is concluded that operator error is not the cause of the differences in the integrator readings of the analog and digital systems. Table 2 shows that the echo sounders of "G.O. Sars" and "Johan Hjort" operate on 38 kHz and 50 kHz respectively, but this should not influence the integrator output in such manner.

Digital integrators are more accurate than analog integrators as it is more accurate to square and integrate echo voltages by computer than by analog squaring and integration circuits. It will be beyond the scope of this paper to analyse the magnitude of an eventual error from squaring and integrating a signal by analog circuits. But the results from the intercalibrations seem to indicate a saturation of one type or another in the analog integrator systems. Fig.8 shows a intercalibration of two vessels which are both equipped with digital echo integrators. Although this single intercalibration is too little to draw firm conclusions from, the results here seem to indicate the same systematic difference both at low and high density, in contrast to the analog-digital intercalibrations.

#### Inter-equipment conversion factor

A conversion factor can, in principle, be calculated by tabulating the integrator output from the two vessels for corresponding miles and then carry out a regression of the two sets of data. First, however, the echograms of both vessels have

to be scrutinized in order to exclude any miles where one vessel, and not the other, have recorded schools. Examples of this are given in Fig. 4 ("G.O. Sars" log 347) and Fig. 7 ("G.O. Sars" log 394).

In 1975, a conversion factor between "G.O. Sars" and "Johan Hjort" was calculated on basis of the intercalibration on 4.10-1975 (calibration no. 2, Table 1). For the same distance, "G.O. Sars" logged 42.0 nautical miles and "Johan Hjort" logged 42.5. If the integrator outputs were plotted mile for mile, the regression line would have the following formula:

$$M_{GOS} = 0.39 M_{JH} + 101 \quad (r= 0.7)$$

where  $M_{GOS}$  is the integrator output of "G.O. Sars" and  $M_{JH}$  is the integrator output for "Johan Hjort". However, after a close examination of the echograms at both vessels, it was discovered that a interval with high fish density had been recorded at the end of mile 423 on the "G.O. Sars", while it was recorded at the beginning of the next mile on the "Johan Hjort". There were also some minor discrepancies of the echograms earlier during the intercalibration. It was therefore decided to calculate running means (over 5 n.miles) for the integrator values. These data were plotted (Fig. 10) and a regression of these two sets of data gave the values:

$$M_{GOS} = 0.54 M_{JH} + 18.1 \quad (r= 0.93)$$

It was decided to use this conversion factor for 1975 (DOMMASNES, NAKKEN og RØTTINGEN 1976). By similar approach the conversion factor for 1976 and 1977 have been:

$$M_{GOS} = 0.45 M_{JH} + 14$$

(DOMMASNES og RØTTINGEN 1977, MØNSTAD og RØTTINGEN 1977). A third method of approach is to use the log of one of the

vessels as a reference log. The corresponding integrator output data from the other vessel is then found by extending the line from the reference log to where it cuts the line representing the integrator output from the other vessel.

Additional difficulties arises if the distance log (and resetting of the integrators) of the vessels show significantly different numbers of n.miles for the same distance sailed. This was the case during the "Johan Hjort" - "Johan Ruud" intercalibration (Table 1, no. 8). Here the distance log of "Johan Ruud" showed 10 % over the log of "Johan Hjort". Therefore, the integrator outputs could not be compared mile for mile. For the same distance, the log of "Johan Ruud" showed 11 n.miles and the log of "Johan Hjort" 10 n.miles (Fig. 8), and it was decided to average the output over 11 n.miles for "Johan Ruud" and over 10 n.miles for "Johan Hjort". This of course reduces the number of values which can be used to make a regression, so the intercalibration run has to be carried out for quite a number of miles. The conversion factor obtained was:

$$M_{JR} = 0.38 M_{JH} + 3.6 \quad (r= 0.95)$$

The setting of the integrator can be done at the same moment if the integrator vessels is reset at the same time. This was done during the "G.O. Sars" - "Odissey" intercalibrations (Table 2, Figs. 7 and 9). Here the integrator of the "Odissey" was reset manually when the "G.O. Sars" integrator was reset by the ships log, the time for resetting was transmitted by radio communication. Here each mile could be compared (with the exception of a few schools recorded by "G.O. Sars"). The values obtained were:

$$M_{GOS} = 1.95 M_{Odissey} + 4.1 \quad (r= 0.93)$$



By calculating the time lag due to the distance between the vessels (see difference in capelin recording and bottom countours in Fig. 9), and taking this into account when the integrator is manually reset, a further improvement could be made.

The regression coefficients have been calculated by the method of least squares. For the intercalibrations of the analog and digital integrators, however, the relationship between the integrator outputs seem to be linear only up to a certain output value. Regressions on the different parts of the distribution may be calculated, or a functional relationship (RICKER 1973) may be applied.

Decision on type of regression and on eventual averagging of integrator output values should therefore be made after taking into account the following factors.

- A. Type of echo recordings.
- B. Discrepancies in distance log readings of the vessels taking part in the intercalibration.
- C. Number of compareable n.miles.

#### ACKNOWLEDGEMENT

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Table 1. Date, position, time (GMT) and type of echo recordings during the inter-calibration runs.

No.	Vessels	Date	Time (GMT)	Position	Species composition of echo recordings
1	"G.O. Sars"- "Johan Hjort"	17.9.-1975	16.01-18.55	N77°30'E57°00'	Capelin
2	" "	4.10.-1975	15.50-19.57	N78°55'E32°00'	Capelin
3	" "	11.9.-1976	19.12-21.18	N71°11'E23°30'	0-group redfish
4	" "	27.9.-1976	18.47-20.30	N77°25'E28°00'	Capelin
5	" "	17.9.-1977	04.45-06.40	N71°30'E27°00'	Div.species of 0-group
6	" "	30.9.-1.10.-1977	20.02-01.05	N76°15'E33°00'	Capelin, mixed with some polar cod
7	"G.O. Sars"- "Odissey"	4.10.-1977	17.15-23.15	N76°45'E33°00'	Capelin, mixed with some polar cod
8	"Johan Hjort"- "Johan Ruud"	9.11.-1977	11.15-20.30	Sognefj., W. Norway	0-group herring and sprat

Table 2. Instrument settings for "G.O. Sars", "Johan Hjort",  
"Odissey" and "Johan Ruud".

"G.O. Sars"	1975	1976	1977
Type	Simrad EK	Simrad EK	Simrad EK
Freq.	38 kHz	38 kHz	38 kHz
Range	0-250	0-250	0-250
Transducer	5,5 <sup>0</sup> x5 <sup>0</sup> stab	5,5 <sup>0</sup> x5 <sup>0</sup> stab	stab 3 (5x5,5 <sup>0</sup> )
Power Outp.	ext	ext	ext
Bandw & Pulsl.	36 Hz 0.6 ms	36 Hz 0.6 ms	3 kHz 0.6 ms
TVG & Gain	20 logR-20 dB	20 logR-20 dB	20 logR-20 dB
Recorder Gain	7	7	7

"Johan Hjort"			
Type	Simrad EK	Simrad EK	Simrad EK
Freq.	50 kHz	50 kHz	50 kHz
Range	0-250	0-250	0-250
Transducer	1	1	1
Power-Outp.	1/1	1/1	1/1
Bandw & Pulsl.	Narrow 2	11 Hz 0.2 ms	Narrow 0.6 ms
TVG & Gain	20 logR 0 dB	20 logR 0 dB	20 logR 0 dB
Recorder Gain	9	6	6

"Odissey"	
Type	Simrad EK
Freq.	38 kHz
Range	0-250
Transducer	1
Power-Outp.	External trans.
Bandw & Pulsl.	1 kHz 0.6 ms
TVG & Gain	20 logR 0 dB
Recorder Gain	6

"Johan Ruud"	
Type	Simrad EK
Freq.	38 kHz
Range	0-250
Transducer	Ceramic (30x30)
Power-Outp.	ext
Bandw & Pulsl.	W 2
TVG & Gain	20 logR-20 dB
Recorder Gain	9

Table 3. Source level (dB//1 Bar ref 1 m) and receiving voltage response (dB// 1 volt per Bar) for R/V "G.O. Sars" and R/V "Johan Hjort".

Vessel	Date	Source level	Receiving voltage response
"G.O. Sars"	31.7.1975	131.6	+ 6.8
	20.8.1977	136.2	+ 7.0
	4.1.1978	136.0	+ 10.2
"Johan Hjort"	23.10.1975	119.0	+ 8.6
	25.10.1976	119.8	+ 0.8
	1. 8.1977	115.8	+ 1.5
	5. 1.1978	121.9	+ 2.5

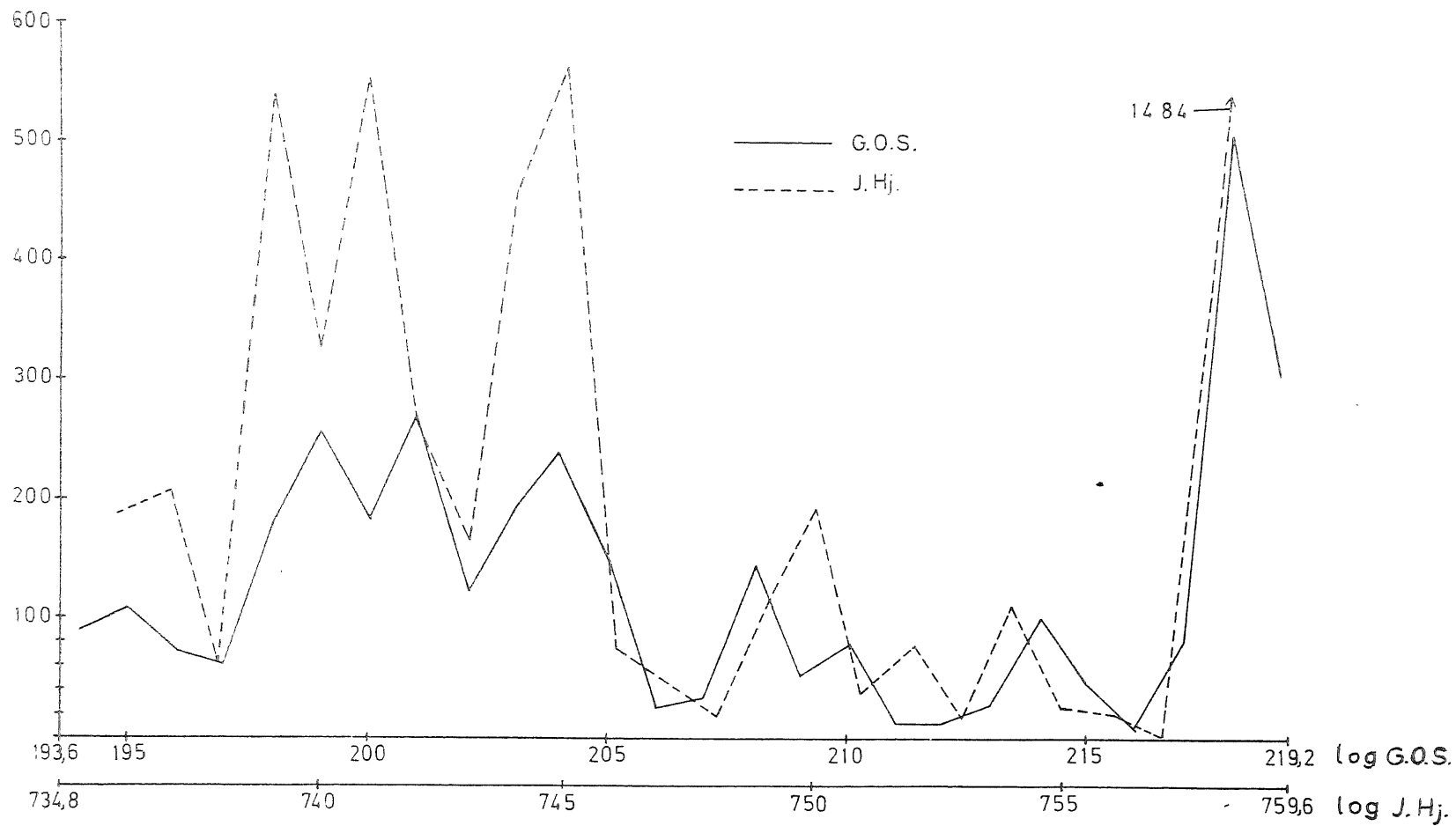


Fig. 1. Intercalibration "G.O. Sars" - "Johan Hjort"  
 17.9-1975. Abscissa shows readings from the  
 distance log of the vessels, the ordinate gives  
 integrator output.

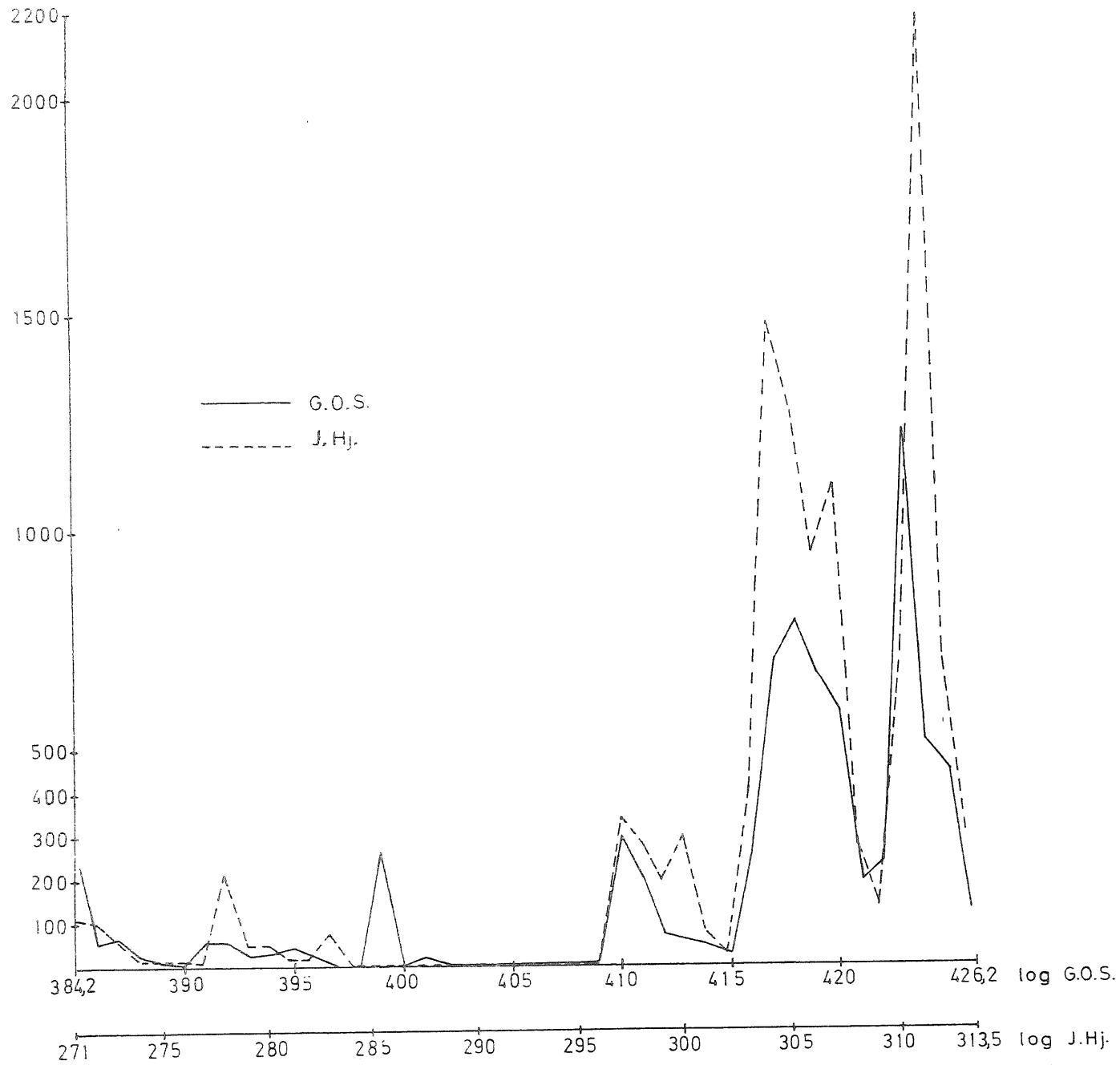


Fig. 2. Intercalibration "G.O. Sars" - "Johan Hjort"  
4.10-1975. Legend as Fig. 1.

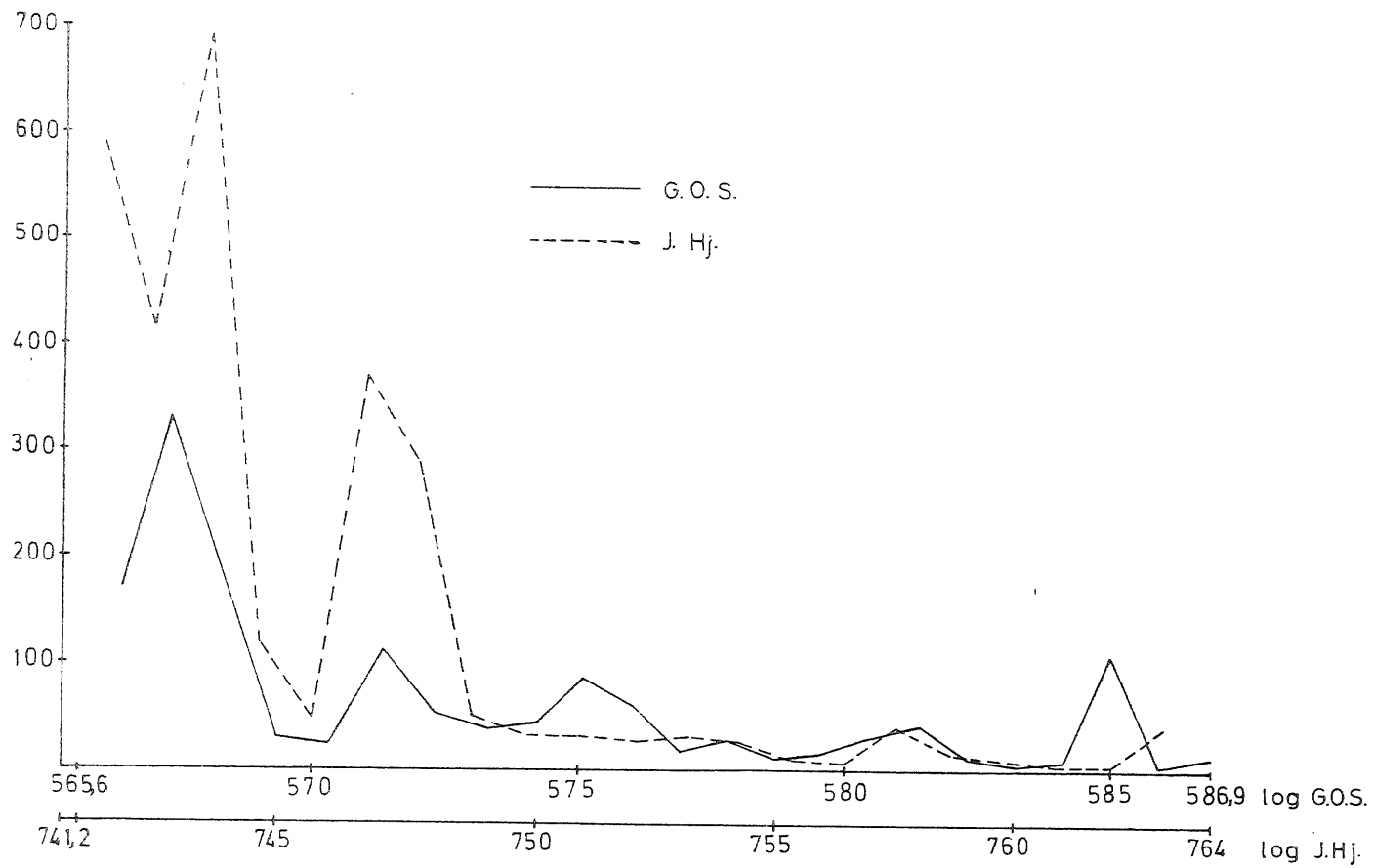


Fig. 3. Intercalibration "G.O. Sars" - "Johan Hjort"  
 11.9-1976. Legend as Fig. 1.



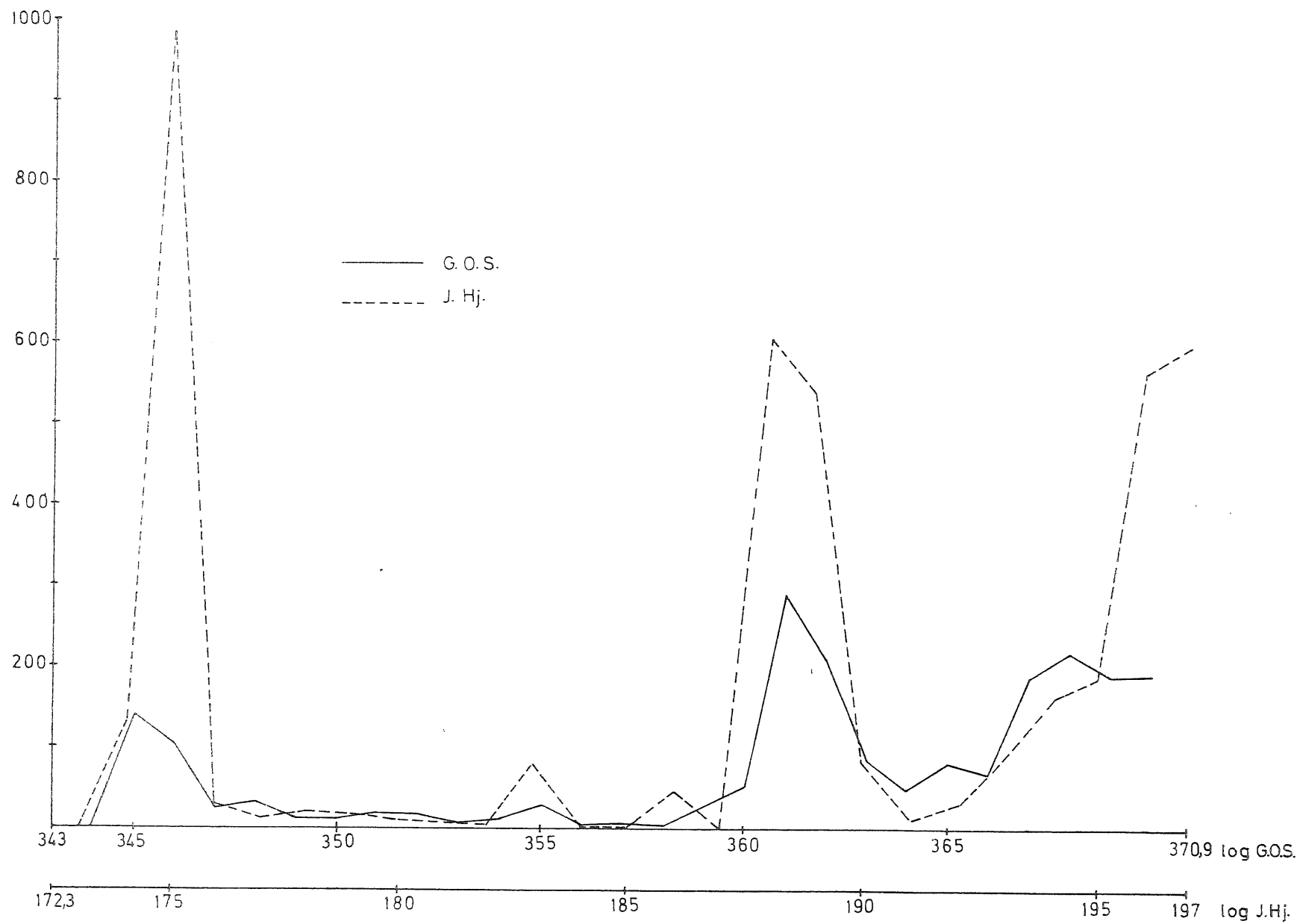


Fig. 4. Intercalibration "G.O. Sars" - "Johan Hjort"  
 27.9-1976. Legend as Fig. 1.

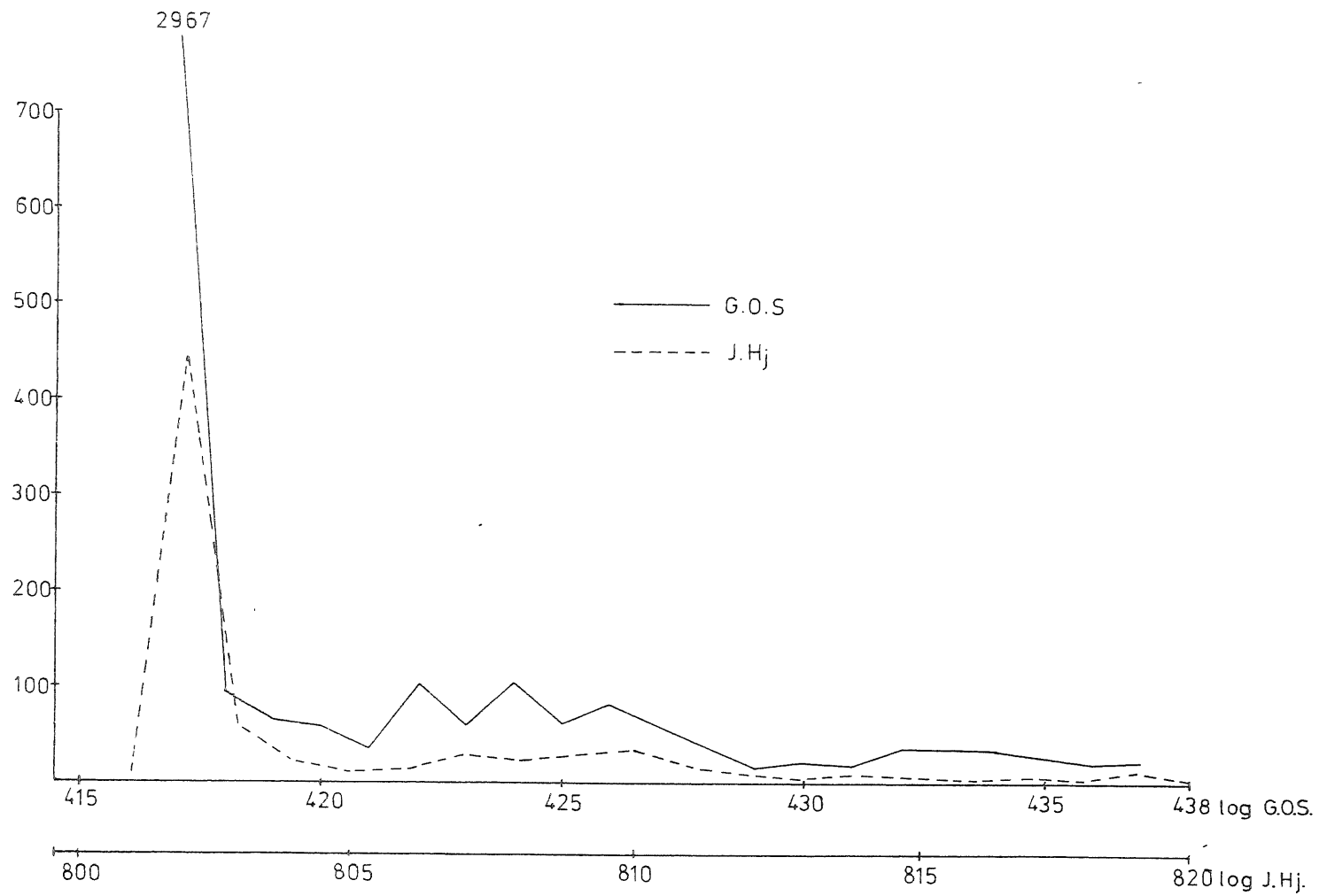


Fig. 5. Intercalibration "G.O. Sars" - "Johan Hjort"  
 17.9-1977. Legend as Fig. 1.

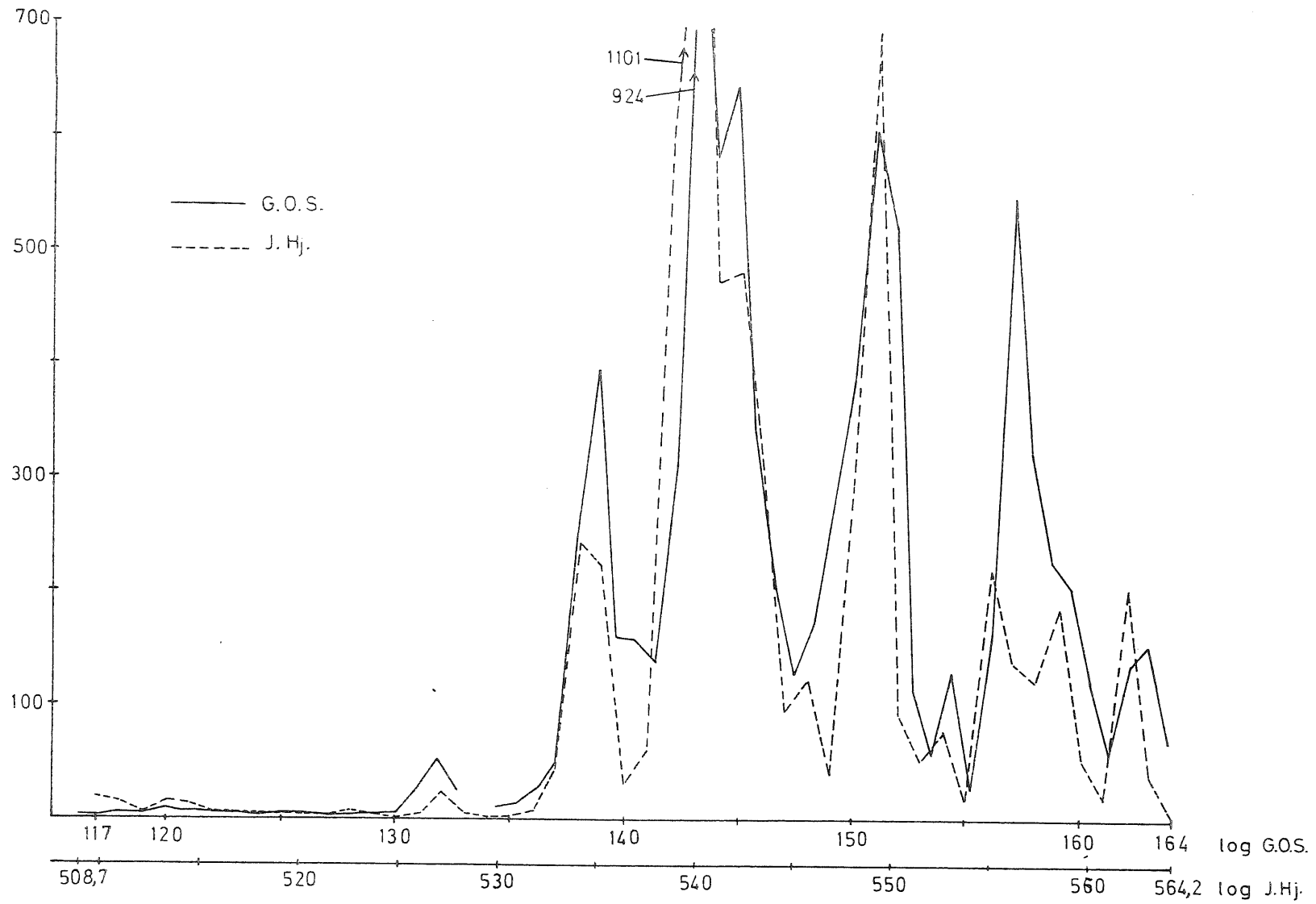


Fig. 6. Intercalibration "G.O. Sars" - "JOhan Hjort"  
 30.9 - 1.10-1977. Legend as Fig. 1.

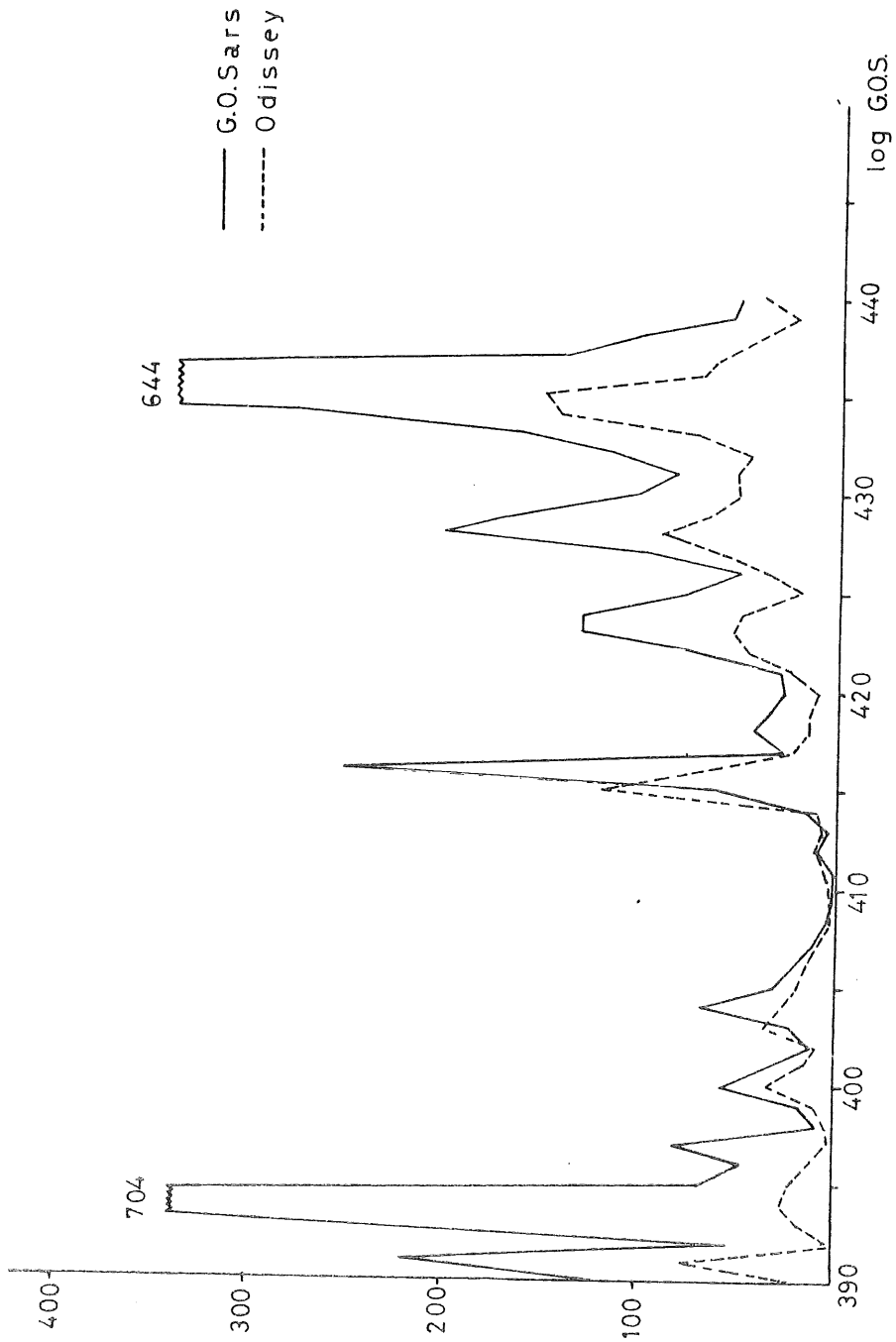


Fig. 7. Intercalibration "G.O. Sars" - "Odyssey"  
4.10-1977.

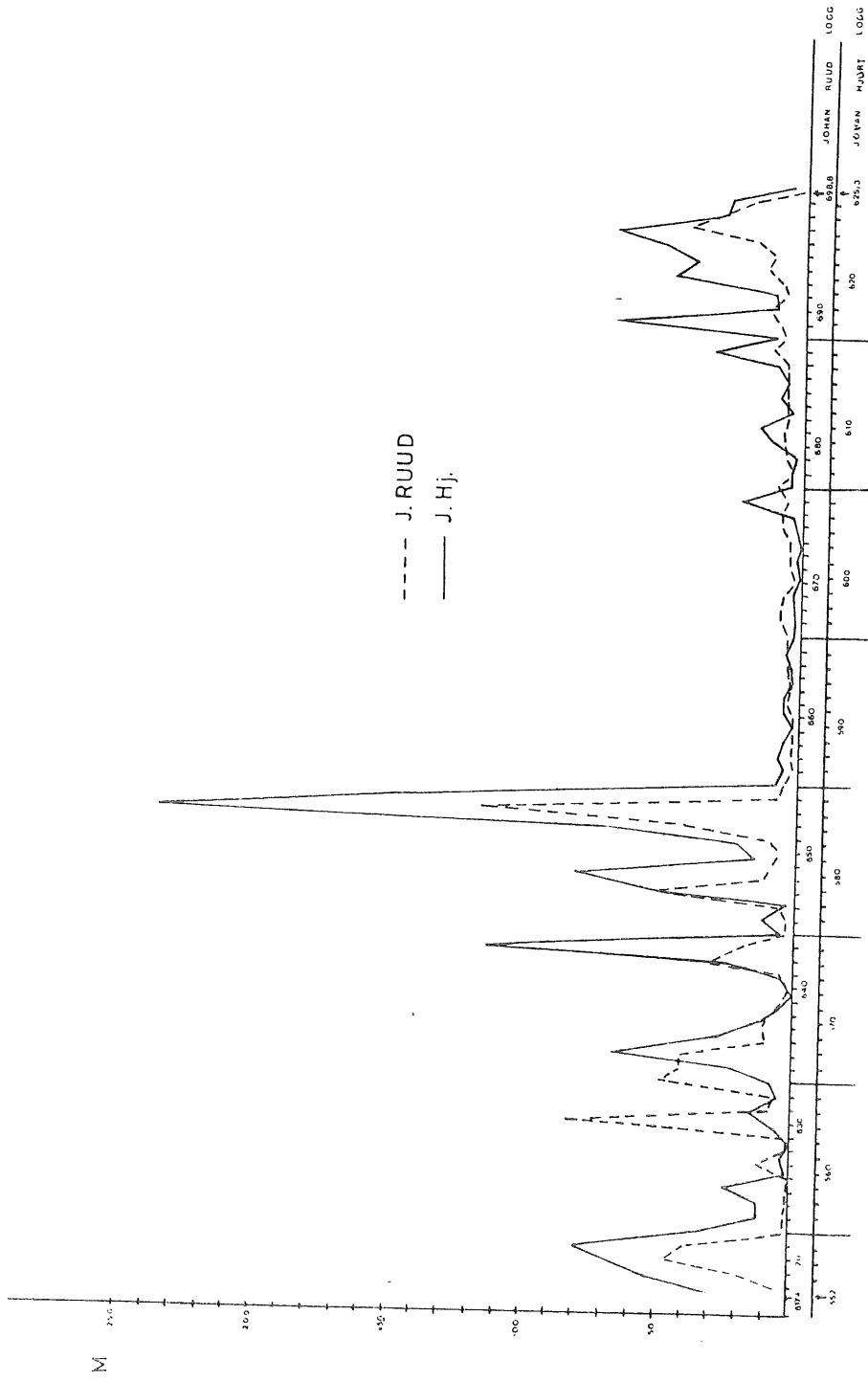


Fig. 8. Intercalibration "Johan Hjort" - "Johan Ruud"  
 9.11-1977.

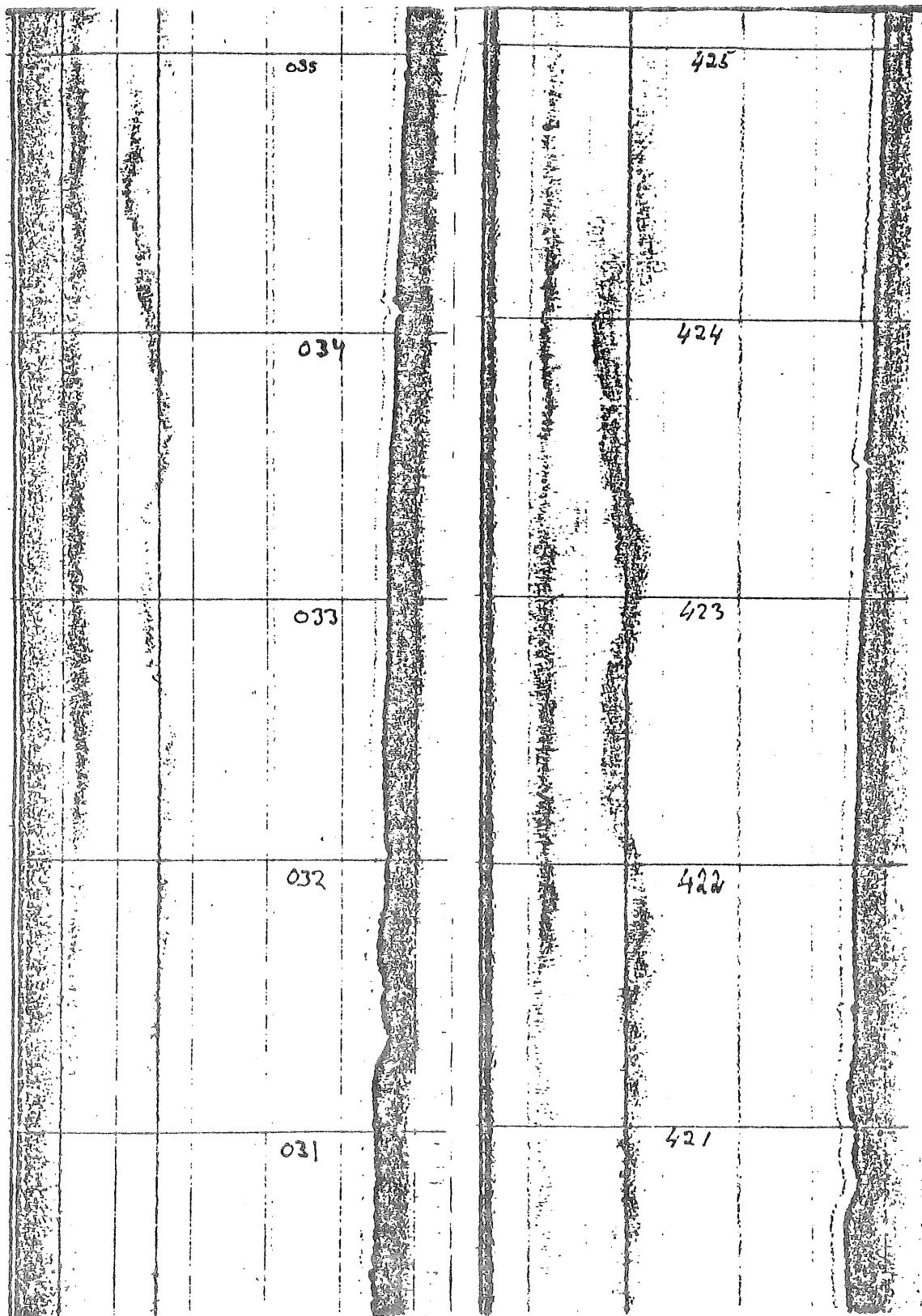


Fig. 9. Echograms of corresponding miles from "Odyssey" (top) and "G.O. Sars" (lower) 4.10-1977.

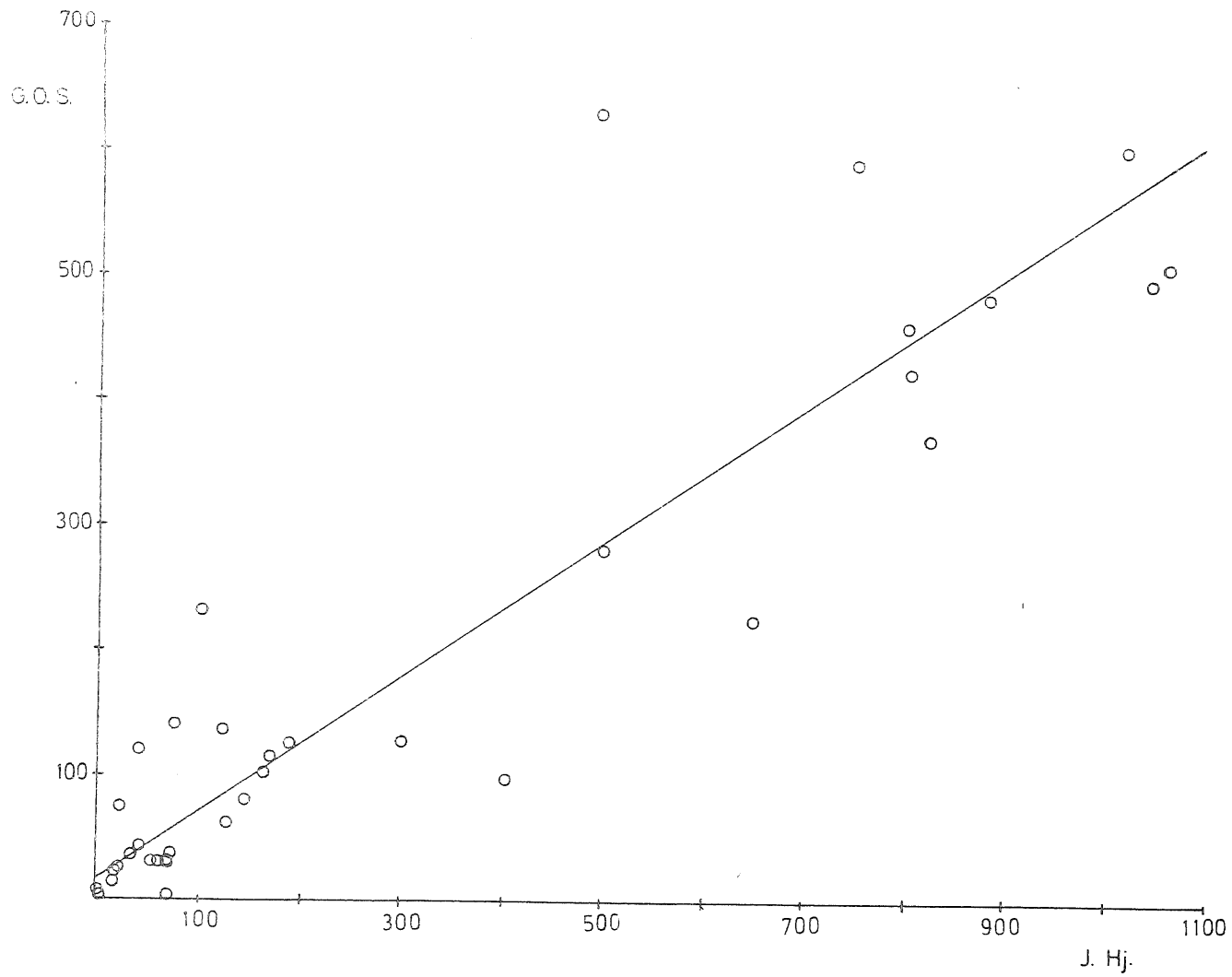


Fig. 10. Relationship between "G.O. Sars" and "Johan Hjort" integrator outputs 4.10-1975. (See text).