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Technical Report No. 18

SACLANT ASW
RESEARCH CENTER

COMPARATIVE CALIBRATION PROGRAMME WITHIN NATO COUNTRIES

by

H. A. J. RINJA

1 November 1963

NATO
VIALE SAN BARTOLOMEO, 92
LA SPEZIA, ITALY

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TECHNICAL REPORT 18

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Viale San Bartolomeo 92
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APPROVED FOR DISTRIBUTION

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Director

COMPARATIVE CALIBRATION PROGRAMME WITHIN NATO COUNTRIES

PHASE I

Summary

A NATO inter-laboratory programme of comparative hydrophone calibration is described including a description of the calibration facilities and methods of the participants. Hydrophones Type H29, F31, and F36 from the U. S. Navy Underwater Sound Reference Laboratory are described and some comparative calibration results for the first type are presented.

1. INTRODUCTION

Representatives from nine NATO nations, meeting in La Spezia in July 1961 for a conference on underwater sound propagation research,[1] recommended that the SACLANT ASW Research Centre (SACLANTCEN) arrange to circulate an underwater acoustic transducer to various national laboratories for comparative calibration. Uniform calibration standards are of fundamental importance; consequently, the results of such a programme could be given wide distribution and would provide a basis to determine the validity of

[1] Waterman, H. Minutes of the Underwater Acoustic Propagation Meeting Held at the SACLANT ASW Research Centre, La Spezia, Italy, 10th-14th July 1961, SACLANTCEN T.R. No. 9, NATO CONFIDENTIAL.

underwater sound data gathered by one laboratory as compared with that gathered by another.

2. HISTORY OF PHASE I

A questionnaire was prepared and sent to the members of the Scientific Advisory Council, who, at that time, represented the nine NATO nations participating in the SACLANTCEN programme. A copy of the questionnaire is appended as Annex I. Each member of the Council recommended the laboratories and institutions within his own country to which questionnaires should be sent. The information gathered from the questionnaire is presented in tabular form in Annex II.

The second step of the project came with the permission from the U. S. Navy Underwater Sound Reference Laboratory, (USRL), Orlando, Florida, to use two of its Type H29 hydrophones, Serials 008 and 009, which were, at that time, at the Admiralty Underwater Weapons Establishment, (AUWE), Portland, England, for calibration. The characteristics of these hydrophones will be presented in Section 4. The third step in the project occurred when the hydrophones were calibrated at the AUWE, on which a technical note[1] was written, and they were shipped to the Laboratoire de Détection Sous-Marine, Var, France (Le Brusc).

---

[1] C.L. Duck, AUWE T.N. 75/62, April 1962.

Unfortunately, the hydrophones were damaged en route to Le Brusc; serial 009 had lost some oil from the crystal capsule and had to be returned to USRL. Serial 008 suffered only the loss of its protecting cage, so it was calibrated, reported[1], and sent to the SACLANTCEN for similar calibration and report[2]. The results of the AUWE, Le Brusc, and SACLANTCEN calibrations are presented in Section 5.

In the meantime, it was decided that the Type H 29 hydrophone is too delicate for a comparative calibration cycle; consequently, USRL was asked to provide a sturdier type, and, as a result, one hydrophone of each Type F31 and F36 were made available. The characteristics of these hydrophones are presented in Section 6. The calibration cycle with the new hydrophones will be resumed in the near future.

3. RESULTS OF QUESTIONNAIRE

3.1 Activities Participating

The following activities indicated their willingness to participate in the calibration program.

AUWE	Admiralty Underwater Weapons Establishment Portland, Dorset, England

---

[1] ICCAN Gerrebout, Le Brusc Report No. 10175, 20 November 1962

[2] H. Rynja, SACLANTCEN T.M. No. 71

DSM	Laboratoire de Détection Sous-Marine Le Brusc, Var, France
EDO	EDO Limited Cornwall, Ontario, Canada
NRE	Naval Research Establishment Dartmouth, Nova Scotia, Canada
PTB	Physikalisch-Technische Bundesanstalt Braunschweig-Võlkenrode Federal Republic of Germany
RVO	Physical Laboratory of National Defense Research Council, RVO-TNO The Hague, Holland
SACLANTCEN	SACLANT ASW Research Centre La Spezia, Italy
USEA	Ufficio Studi Elettro-Acustici San Terenzo, La Spezia, Italy

A similar calibration programme is conducted* between laboratories in the United States; consequently, no U.S. activity chose to participate. However, the USRL agreed to furnish the hydrophones.

3.2 Calibration Facilities

The hydrophone calibration facilities and methods of the participating activities are described in Tables 1 and 2 of Annex II.

---

*W. James Trott: Calibration Round Robin USRL Report No. 33, 25 March 1955.

4. DESCRIPTION OF TYPE H29 HYDROPHONE

The USRL hydrophone Type H29 consists of a crystal head and an associated preamplifier assembled into a single unit. Four lithium sulfate crystals are mounted in a clamped-drive arrangement with a tungsten backing and surrounded by castor oil in a metal-lined vinyl boot. The preamplifier is a cathode-follower type with an output impedance of 600 ohms. A precision 10-ohm calibrating resistor is provided to permit measurement of the hydrophone voltage coupling loss. For the least loss in the preamplifier, the hydrophone output should be terminated by a load greater than 10,000 ohms. The output is unbalanced. The temperature stability of the free-field voltage sensitivity is better than 1.0 dB between 10^{o} and 25^{o}C. The sensitivity is unaffected by hydrostatic pressure from 0 to 700 m depths.

The overall length of the hydrophone is 7-7/8 in., the overall diameter is 1-5/8 in., and it weighs 8.2 lb with a 40 ft cable.

The active element is essentially a piston which is 1 in. in diameter. The measured directivity patterns correspond with those of a piston of 25-30 mm diameter.

5. CALIBRATION RESULTS

The calibration results for the Type H29 hydrophone are presented graphically in Annex III. Figures 1, 2, and 3 are for the calibrations made at AUWE, Le Brusc, and SACLANTCEN respectively with the USRL calibration curve

drawn for comparison. Figure 1, for AUWE shows curves for both serial 008 and 009 hydrophones.

The calibration curves from AUWE and Le Brusc (Figs. 1 and 2) agree with the USRL curves within 1 dB below 18 kc and above 50 kc. The Le Brusc curve shows a sensitivity above 60 kc which is too high, but this may be due to errors in instrumentation or acoustic field conditions.

Figure 4 plots a comparison between the AUWE, Le Brusc, and SACLANTCEN calibrations for Type H29 hydrophone serial 008, which indicates that the results from the three laboratories are within $\pm$ 1 dB for all frequencies below 60 kc. The disagreement between 18 and 50 kc for the curves of the 3 European laboratories compared with the one from USRL would appear to indicate an error in the USRL calibration method or a change in the hydrophone itself.

6. DESCRIPTION OF TYPES F31 AND F36 HYDROPHONES

6.1 Type F31

The active element is a stack of 3 PZT-5 disks, each 1-1/2 in. in diameter and 1/4 in. thick, mounted on a brass block and operating as a piston drive. The container is filled with castor oil and has a gum rubber window. The hydrophone directivity is that of a 1-1/2 in. piston, and the capacitance, with 40 feet of microphone cable, is 9000 pf. Figure 5, Annex III, shows the response characteristics with a curve which is reported to show no change:

with time over 3 months
with temperature between 3^{o} and $26^{o}C$
with hydrostatic pressure between 0 and 700 m depths.

6.2 Type F36

A framework of 1/8 in. steel rods supports 7 ceramic cylinders with glass end-caps placed end-to-end in a line. Each cylinder has a 3/4 in. outside diameter, a 5/8 in. inside diameter, and is 3/4 in. long. The total length of the line is 7-1/2 inches and the cylinders are attached to the steel rods with natural rubber supports. The butyl rubber boot is filled with castor oil. The directivity is that of a 7-1/2 in. line, and the capacitance, with 100 ft of microphone cable, is 60,000 pf. The response characteristics are plotted in Fig. 6, Annex III, with a curve which is reported to show no change:

with time over 4 months
with temperature between 3^{o} and $26^{o}C$
with hydrostatic pressure between 0 and 140 m depths.

ANNEX I

UNDERWATER ACOUSTIC CALIBRATION FACILITIES QUESTIONNAIRE

UNDERWATER ACOUSTIC CALIBRATION

FACILITIES QUESTIONNAIRE

Explanatory Note

A Conference on Underwater Sound Propagation Research was held at SACLANT ASW Research Center in July 1961. Representatives of working groups in each of the nine NATO nations participating joined in recommending that the Center arrange for the circulation of an underwater acoustic transducer or transducers for calibration by the various national laboratories. The results of such a programme, made available to all, would provide a better basis for determining the validity of comparing underwater sound data gathered by one laboratory with that gathered by another. The uniformity of calibration standards in use is of fundamental importance.

This questionnaire is a first step in implementing the recommendation of the Conference. When completed and returned to the SACLANT ASW Research Center it will permit the drafting of a schedule for the programme of measurements and the specification of certain common conditions under which they should be made in order to facilitate the comparison of results.

Each organisation having the ability to carry out any kind of calibration of underwater transducers is requested to complete this questionnaire even if participation in the programme of measurements is not desired.

UNDERWATER ACOUSTIC CALIBRATION

FACILITIES QUESTIONNAIRE

To this cover sheet, please attach one completed form for each type of facility available.

Name of Laboratory or Organisation submitting information:

....

Address of Laboratory or Organisation:

....

....

....

....

Location of Calibration Facility (if address is different from above):

....

....

....

....

Name of person completing this questionnaire:

....

Is participation in the Calibration Programme desired? (Yes or No):

....

Date:.........................

CHARACTERISTICS OF UNDERWATER ACOUSTIC

CALIBRATION FACILITY

Type of Facility (use separate forms for each type) i.e. open-water system, open tank, pressure tank, etc.

....

Calibration Methods employed with this type of facility (i.e. comparison or absolute - specify):

....

Frequency range and kind of emission:

CW:	from............kc to............kc
Pulse:	from............kc to............kc
Other (specify):	from............kc to............kc

Method of covering specified frequency range, i.e. point to point frequency sweep, etc.:

CW:	....
Pulse:	....
Other (specify):	....

Power available for each kind of emission and frequency range, where applicable:

CW:	.... watts at frequencies from
	.... kc to................kc
	.... watts at frequencies from
	.... kc to................kc

Pulse: .... watts at frequencies from

.... kc to...............kc

.... watts at frequencies from

.... kc to...............kc

Other (specify): ....:

.... watts at frequencies from

.... kc to...............kc

.... watts at frequencies from

.... kc to...............kc

Depth of water available: .... metres

Nature of boundaries, i.e. soft mud, sound absorbent material, etc.:

....

....

Maximum depth at which transducer can be calibrated (not applicable to systems which allow calibration to be carried out under controlled

pressures): ....metres

Distance at which measurements are carried out:

Maximum .... metres

Minimum .... metres

Ambient temperature in which measurements are made:

Controlled: Maximum.................. ^{o}C

Minimum.................. ^{o}C

Uncontrolled: Maximum.................. ^{o}C

Minimum.................. ^{o}C

Static pressure under which measurements may be made (applicable to closed systems):

Maximum .... Atmospheres

or .... Kgs/sq. cm

Minimum .... Atmospheres

or .... Kgs/sq. cm

Limitations on transducers that can be calibrated:

Maximum weight .... kgs.

Maximum dimensions:

height .... cms

width .... cms

thickness .... cms

Minimum cable length .... metres

Maximum cable diameter (where applicable) .... metres

Other (specify): ....

....

Amplifying Comments:

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

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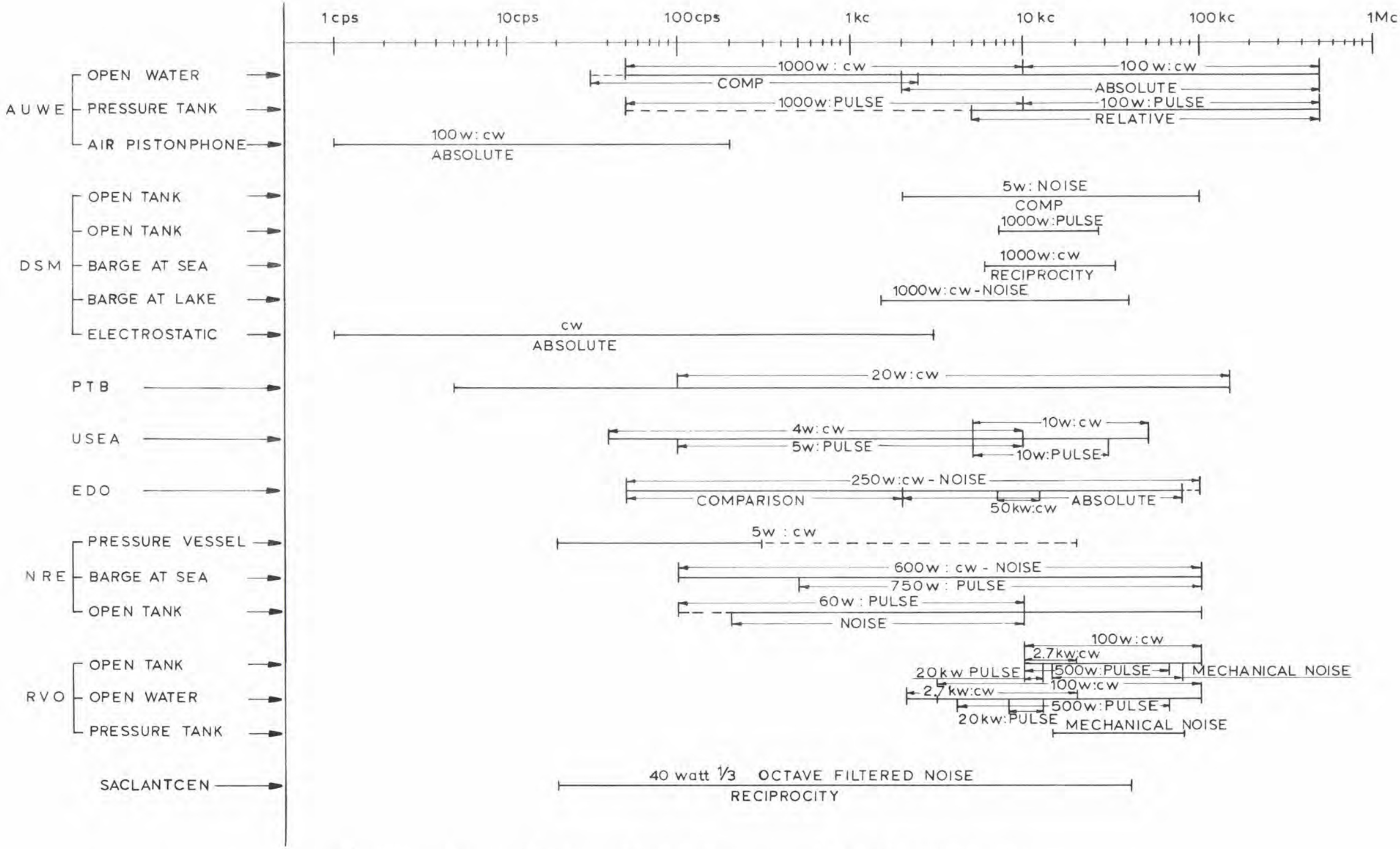
ANNEX II

CALIBRATION FACILITIES AND METHODS OF PARTICIPANTS

Name of Institute	A.U.W.E.			D.S.M.				P.T.B.	U.S.E.A.	EDO	N.R.E.			R.V.O.			SACLANTCEN
Facility (m^3)	Open water	Pressure tank	Air pistonphone	Open tank	Open tank 3.0 x 2.4 x 2.8	Barge at sea	Barge at lake	Open water air pressure	Open water	Open water	Pressure vessel	Barge at sea 17 x 36	Open tank	Open tank 3.5 x 1 x 1	Open water	Pressure tank	Barge at sea
Method: Comparison	0.03-2.5 kc	Rel.	-	Comp.	Comp.	-	Comp.	Comp.	Comp.	Low freq.	Comp.	Comp.	Comp.	Comp.	Comp	Comp	-
absolute	2-500 kc	-	Abs.	-	Abs.	Reciproc.	Reciproc.	Reciproc.	Reciproc.	high freq.	Abs.	Abs.	Abs.	-	-	-	Reciprocity
Frequency range (kc) CW	0.03-500	-	0.001-0.2	-	-	6-34	1.5-40	0.005-150	0.04-50	2-80	0.02-0.3	0.1-100	-	-	2-100	-	-
pulse	-	5-500	-	-	7-27	-	-	-	0.1 -30	-	-	0.5-100	1-100	10-100	2-100	-	-
noise	-	-	-	2-100	-	-	1.5-40	-	-	0.05-2	-	0.1-10	0.2-10	15-80	-	15-80	0.02-40
Frequency covering CW	P-to-P	-	P-to-P	-	-	P-to-P	P-to-P	P-to-P	P-to-P	Sweep+P-P	P-to-P	P-to-P	-	-	P-to-P	-	-
pulse	-	P-to-P	-	-	P-to-P	-	-	-	P-to-P	-	-	P-to-P	Sweep	P-to-P	P-to-P	-	-
noise	-	-	-	Sweep	-	-	-	-	-	P-to-P	-	P-to-P	P-to-P	P-P or sweep	-	P-to-P	P-to-P
Power (Watts) in frequency range (kc) CW	1000;0.05-10 100;10-500	-	100	-	-	1000	1000	20;0.1-20 20;5-150	4:0.04-10 10;5-50	250;0.05-100 50.000;7-12	5;0.02-20	600	-	100;10-100 2700;10-20	100;3-100 2700;2-20	- -	- -
pulse	-	1000;0.05-10 100;10-500	-	-	1000	-	-	-	5:0.1-10 10:5-30	-	-	750	60;0.1-10	500;10-65 20,000;10-12	500;4-65 20,000;8-12	- -	- -
noise	-	-	-	5	-	-	-	-	-	250;0.05-100	-	600	-	Mechanical	-	Mechanical	40 Watts
Water depth (m)	15	-	-	1.5	2.8	4.5	50-80	20	10-200	30	-	44	3.5	1	17	0.7	10
Boundaries	Mud	Steel	Steel	S.A.M.	S.A.M.	Soft mud and seaweed	Soft mud	Soft mud	Soft mud	Mud sand	- -	Soft mud	insulkrete	Wooden wedges	Soft mud	Steel	Sand
Transducer Depth (m)	5	-	-	1.2	2.4	4	40	10	10	10	-	36	1.7	0.5	7	-	5
Test Distances (m)	2-60	2.5	-	3	3	6.5	23	0.5-1.5	0.5-5	0.1-10	-	1-18	0.3-2.5	3.2	5.6	-	0-2 or 5
Temperature Range (°C)	5-20	5-20	5-20	10-25	10-25	15-25	8-22	9-20	14-26	0-21	16-25	-2 +18	16-24	15-20	4-20	15-20	5-25
Static Pressures (atm)	-	1-30	-	-	-	-	-	-	-	1.2-475	4-1000	-	-	-	-	0.1-100	-
Maximum Weight (kg)	-	-	-	100	150	1000	10.000	15	10	6.000	-	2800	50	500	2500	500	20
Max. Dimensions (cm^3)	-	-	-	30 x 30 x 30	80 x 80 x 80	100 x 300 x 100	200 x 900 x 200	20 x 20 x 20	20 x 15 x 6	300 x 300 x 400	15 x 7 x 7	300 x 450 x 300	100 x 100 x 50	80 x 64 x...	220 x 170 x 300	0.7 x 0.47	100 x 100 x 100
Min. Cable Length (m)	15	15	-	1	3.5	6	7	7	10	2	-	Depth + 10 M	6	-	10	1	8
Max. Cable Diameter (cm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Additional Comments				Also: Small tank 1 x 1 m^2 Electrostatic cal: 1-3000 cps Pressure tank: D 1.5 m, HGT 3 m, 90 kg/cm^2		Pit under barge 30 x 15 m	Lac de Castillon 10 x 2 km	0.1-20 kc J9 projector 5-150 kc crystal proj.	Standard Hydr: 0.4-50 kc Dyna Empire D315 0.4-3 kc Atl. Res. BC 50	White noise filtered in 1 Hz filter	No acoustic soft transducers or cables can be calibrated	Barge 17 x 36 m^2 Well 9 x 18 m^2 Salt water 600 m from shore		Noise measurement with octave filters or with recorder-driven selective amplifier	Floating pier on lake with test station 50 m from shore		

Calibration Facilities



Frequency Ranges, Maximum Electric Powers, and Methods of Calibration of the Different Participating Laboratories

ANNEX III

CALIBRATION CURVES

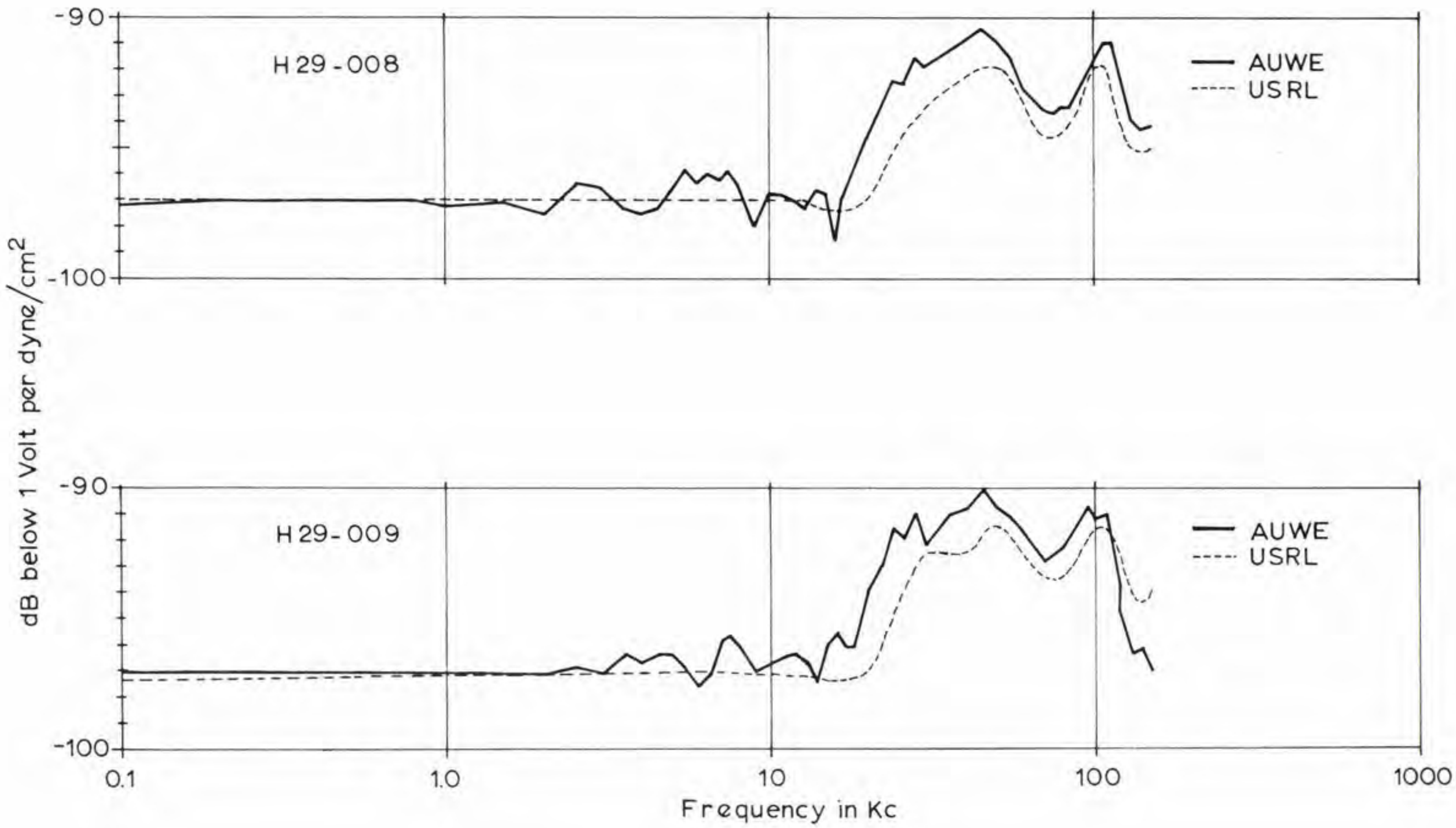


Fig. 1 Calibrations of A.U.W.E. Portland

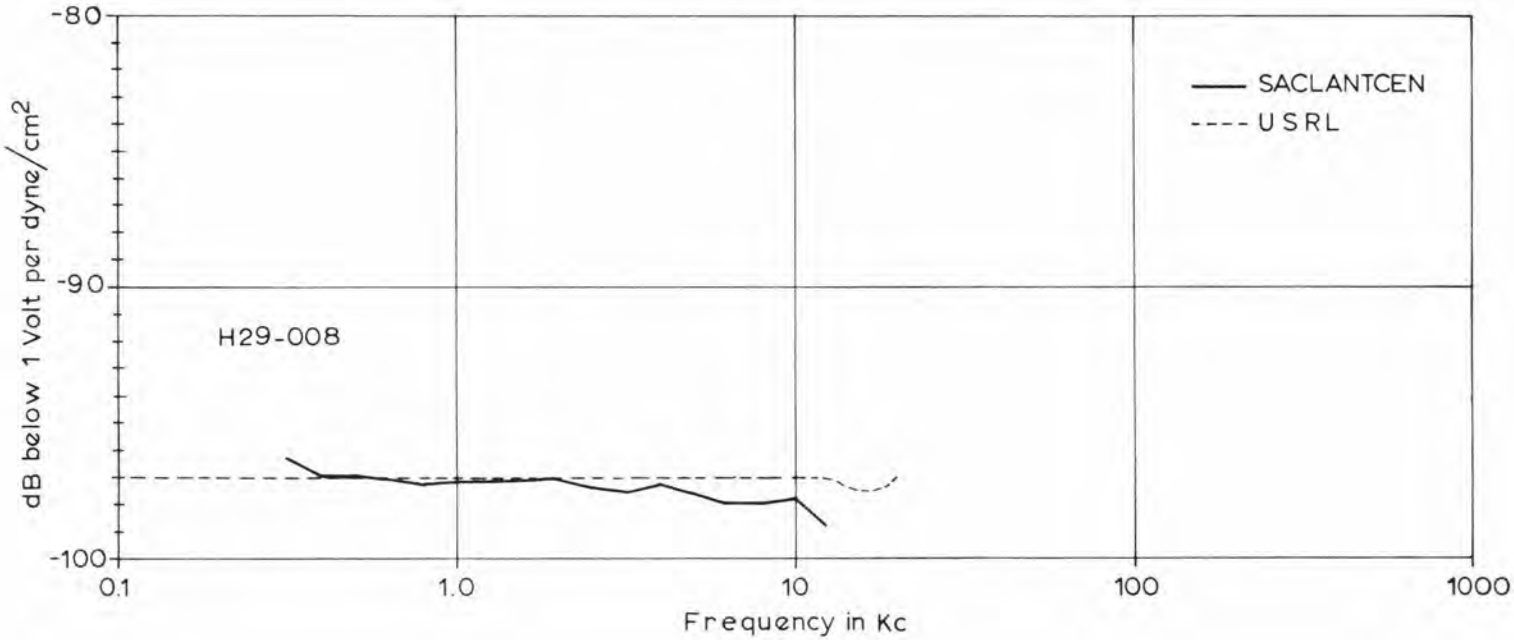


Fig. 3 Calibration of SACLANTCEN

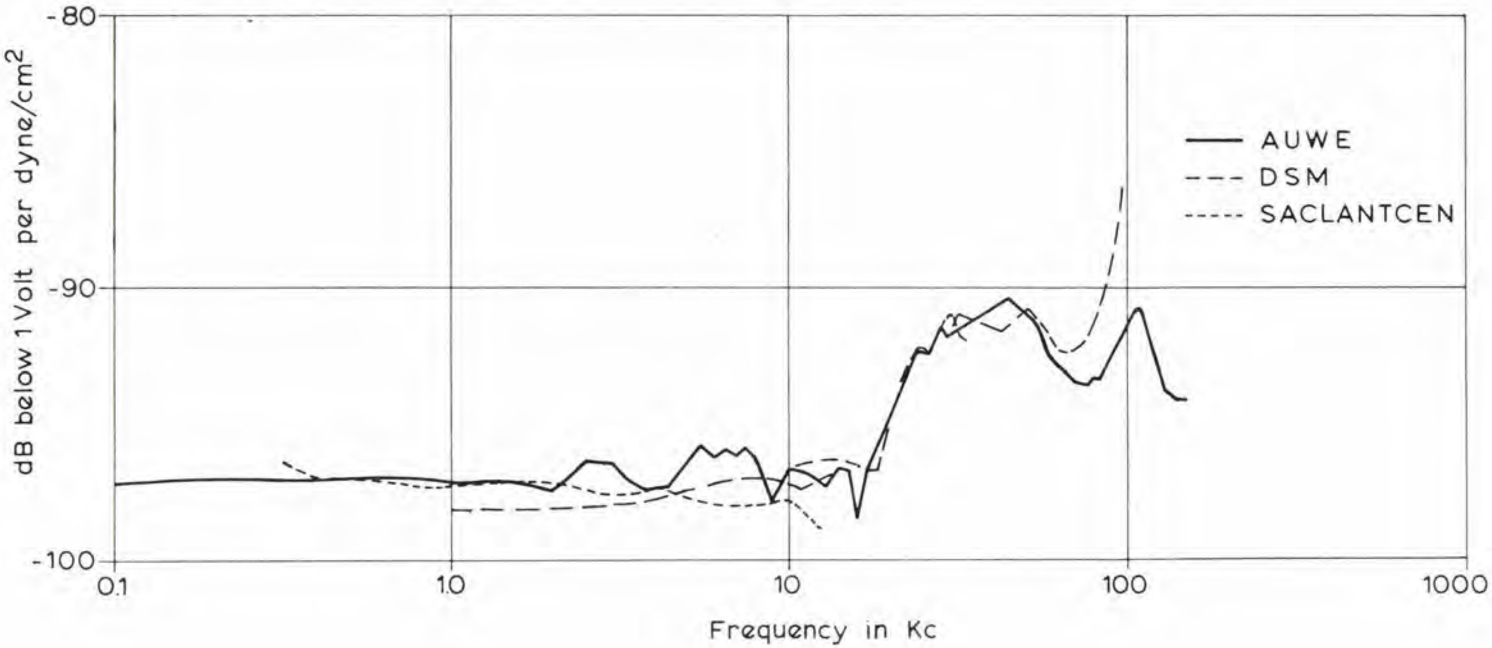


Fig. 4 Comparison between 3 Laboratories

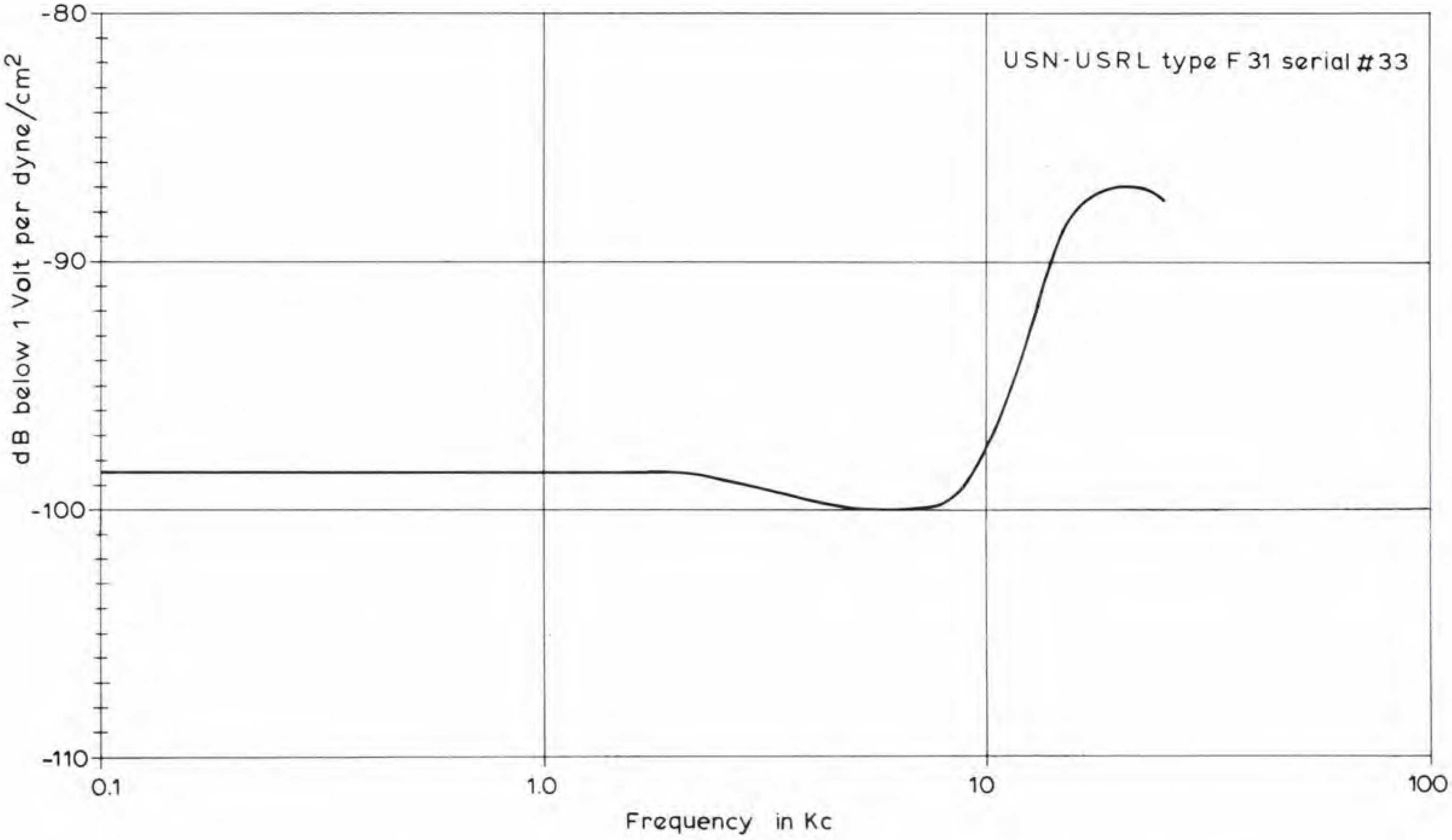


Fig. 5 Calibration Curve of USN-USRL - Type F31 - Serial No. 33

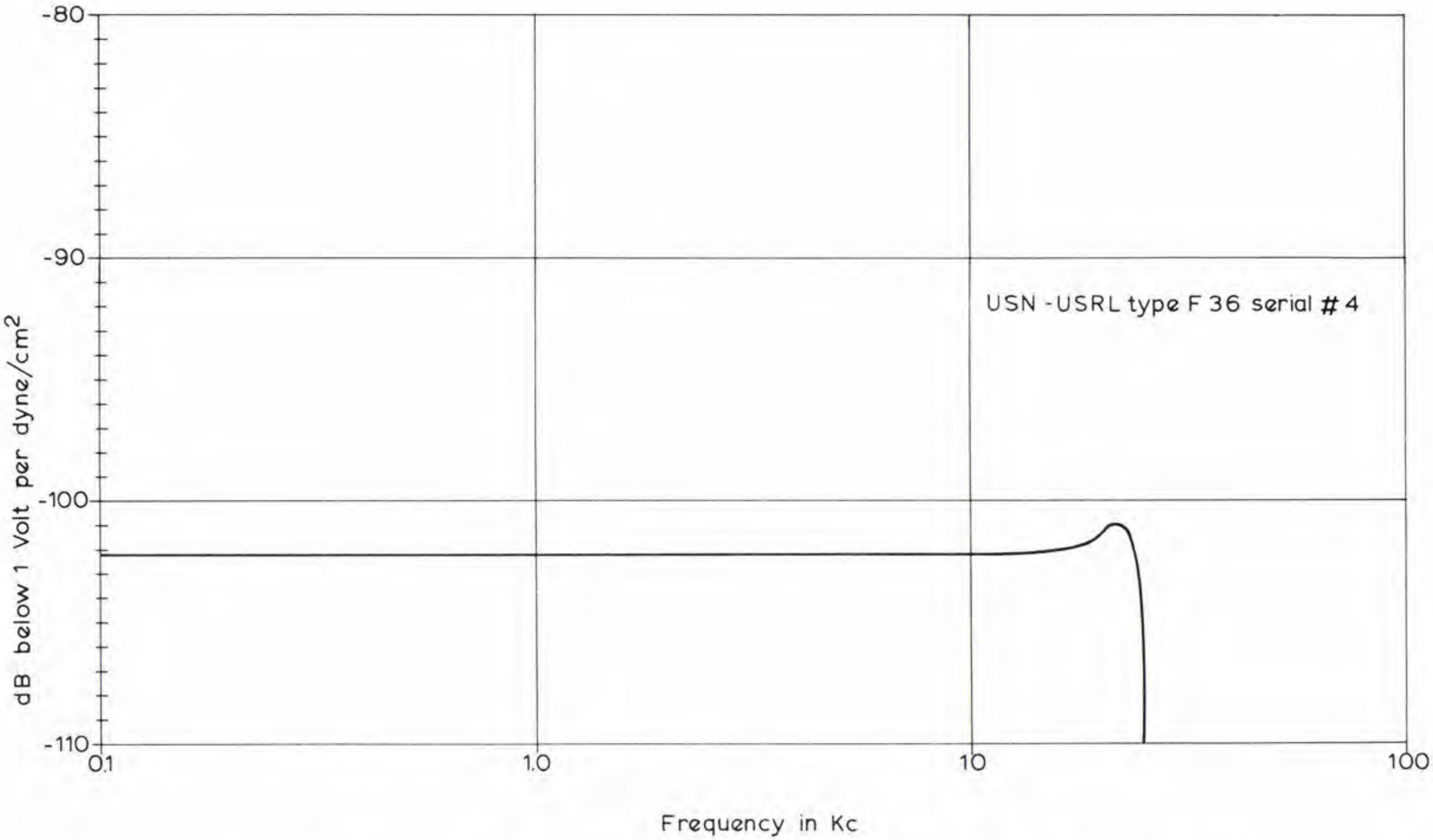


Fig. 6 Calibration Curve of USN-USRL - Type F36 - Serial No. 4

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