SCIENTIFIC RESEARCH INSTITUTE FOR PRECISION INSTRUMENTS
A FEDERAL STATE UNITARY ENTERPRISE

APPROVED by:
(signed)
V.Shargorodsky,
General Designer
April 21, 2004

GOCE-LRR Laser Retro Reflector

Technical Description

К01-Э147-00-00 ТО

Moscow
2004

1. INTRODUCTION

1.1. This Technical Description and Operating Manual for GOCE-LRR Laser Retro Reflector contains information required for study and proper operations with the GOCE-LRR Laser Retro Reflector.

1.2. Chapter Two hereof presents description and operating principle of the reviewed equipment.

1.3. Chapter Three includes operating instructions.

1.4. The following notifications used in the Technical Description and Operating Manual:

- GOCE-LRR К01-Э147-00-00 – decimal number of LRR array;
- RMS - root-mean-square value;
- LRR - laser retro reflector;
- SC - spacecraft;
- RPF - reflection pattern facility.

2. TECHNICAL DESCRIPTION

2.1. PURPOSE

2.1.1. This GOCE-LRR Laser Retro Reflector is designed to find the range between ground laser stations and the GOCE satellite as required to determine satellite orbit with high accuracy.

2.2. SPECIFICATIONS

2.2.1. The GOCE-LRR Laser Retro Reflector enables range finding at the wavelength of 532 nm.

2.2.2. The GOCE-LRR Laser Retro Reflector supports laser range finding at 20+ deg. angle of position above horizon for all possible bearings.

2.2.3. The RMS value of location error for GOCE-LRR array does not exceed 1 mm.

2.2.4. The range-determination systematic correction relative to GOCE-LRR mounting surface on the spacecraft varies from 21.4 to 13.7 mm, depending on elevation angle (see Table 1). The systematic correction shall be added to the measured range.

Table 1.

Elevation angle, deg	20	30	40	50	60	70	80	90
Systematic correction, mm	20.7	21.4	20.6	18.3	13.7	17.9	20.5	21.4

2.2.5. Sizing error for the position of equivalent reflective plane of the GOCE-LRR Laser Retro Reflector with respect to the centre of mating plane is less than 0.8 mm.

2.2.6. The GOCE-LRR Laser Retro Reflector maintains its designed parameters in open space environment.

2.2.7. The GOCE-LRR Laser Retro Reflector shall remain operational after exposure to mechanical impacts during spacecraft orbital insertion.

2.2.8. The GOCE-LRR Laser Retro Reflector shall maintain its designed parameters in compliance with the climatic and thermal requirements as specified in CS-RS-DOR-LR-0001.

2.2.9. The mass of GOCE-LRR Laser Retro Reflector array is 0.375 ± 0.011 kg.

2.2.10. Overall dimensions of the GOCE-LRR Laser Retro Reflector array are Ø 121 x 56.3 mm.

2.2.11. Total guaranteed lifetime of the GOCE-LRR Laser Retro Reflector array is 5.5 years.

2.3. COMPLETE DELIVERY SET

2.3.1. The complete delivery set of the described equipment includes:

- GOCE-LRR Laser Retro Reflector - 1 set;
- Technical Description and Operating Manual К01-Э147-00-00 ТО - 1 copy;
- Passport-certificate - 1 copy;
- Dimensional Drawing - 1 copy;
- Stowing Container - 1 set.

2.4. GOCE-LRR LASER RETRO REFLECTOR DESIGN AND OPERATION

2.4.1. This GOCE-LRR Laser Retro Reflector includes seven panel-mounted Laser Reflectors. See Fig. 1 below for the general view and dimensions of the GOCE-LRR Laser Retro Reflector.

The panel is made as a flattened cone with a flange provided in the cone base. The material of the panel and

the optical assemblies of the Laser Reflectors is non-magnetic aluminium alloy. Cone flange includes six openings of diameter $5.5^{+0.009}$ mm designed for attaching the GOCE-LRR Laser Retro Reflector to the spacecraft mounting place. There is an arrow indicating flight direction, placed at the bottom of the panel.

Two openings of diameter 1.2 mm drilled on the panel for ventilation and air evacuation.

One Laser Reflector assembly is mounted on the top of the flattened cone; the lateral surface of the cone accommodates six Laser Reflector assemblies fixed by special nuts.

To avoid unwanted unscrewing, the fixing nuts are mastic-locked.

To minimize thermal distortion of Laser Reflector directivity pattern caused by differing temperature expansion coefficients specific to the Laser Reflector material and the rim material, each of the seven Laser Reflector assemblies incorporates a mechanism designed to normalise the mechanical impacts applied to the Laser Reflector.

Laser Reflectors are made of fused quartz with aluminium-coated reflecting prism faces. The distance between the input face plane and the prism vertex equals 19.1 mm. To provide RMS error less than 1 mm, each Laser Reflector is equipped with baffle of 7 mm height, measured from input face plane, and input optical aperture of 28 mm.

The stability of temperature conditions for the GOCE-LRR Laser Retro Reflector during exposure to open space environment is achieved by applying special thermoregulating white paint AK-512 to all (non-optical) outside surfaces.

Red-colour protective caps with ФС-01 flags cover all Laser Reflector assemblies.

2.5. GOCE-LRR LASER RETRO REFLECTOR INTEGRATION

2.5.1. Make sure the requirements of Item 3.3 of the GOCE-LRR Laser Retro Reflector Operating Manual are strictly followed during equipment integration onboard of SC.

2.6. MARKING, CONTAINER SEALING AND PACKING

2.6.1. GOCE-LRR Laser Retro Reflector designation and Serial No. is inscribed on equipment housing.

On completion of testing, the equipment placed inside a protective cover is stowed in the Container. The inscriptions "*Glass*" and "*Not to be tipped*" are made on the outside of the packing.

Attention!

Wear white cotton gloves during all operations with GOCE-LRR Laser Retro Reflector.

Make sure all red-colour protective caps with ФС-01 flags are removed after mounting onboard the spacecraft.

3. OPERATION MANUAL

3.1. INTRODUCTORY

3.1.1. This Operating Manual is designed to ensure correct operation of the GOCE-LRR Laser Retro Reflector. The Manual includes information related to GOCE-LRR Laser Retro Reflector transportation, storage, maintenance and operational readiness.

Use additional guidance of the GOCE-LRR Laser Retro Reflector Technical Description during equipment operation.

3.2. GENERAL INSTRUCTIONS

3.2.1. The Manufacturer supplies this GOCE-LRR Laser Retro Reflector in the Container designed for equipment transportation and storing.

3.2.2. Personnel shall not be authorized to perform integration and/or operate the Reflector small-size satellite unless properly briefed on this Technical Description and Operating Manual К01-Э147-00-00 ТО.

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3.3. INTEGRATION PROCEDURE

3.3.1. User shall inspect the equipment before commencing any operations on the GOCE-LRR Laser Retro Reflector.

Any premises intended for visual inspection of the GOCE-LRR Laser Retro Reflector shall protect the equipment against atmospheric effects and shall provide for max. 80 percent relative humidity at +15^{o}C through +35^{o}C.

3.3.2. Make sure to wear cotton gloves at all times while handling this GOCE-LRR Laser Retro Reflector. To inspect this GOCE-LRR Laser Retro Reflector visually, remove the equipment from the Container, release it from hood and remove the red-colour protective caps from the Laser Reflectors.

3.3.3. Wear cotton gloves to remove tightly mounted process caps carrying ФС-01 flags with care; hold the GOCE-LRR Laser Retro Reflector with hands at the base of the housing to which the Laser Reflector assemblies are attached.

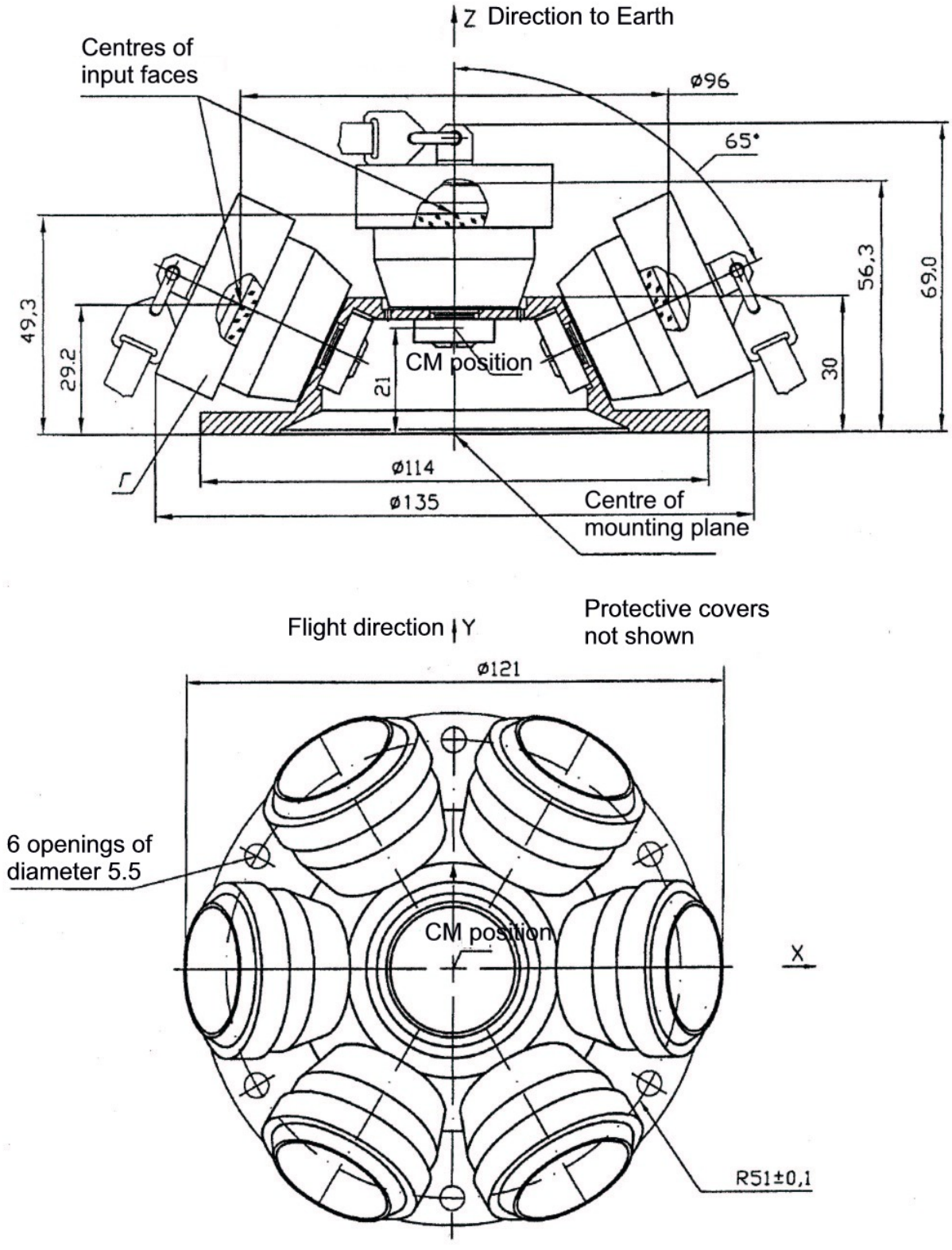

Z Direction to Earth
Centres of
input faces
ø96
65°
56,3
69,0
49,3
29.2
21
CM position
30
ø114
ø135
Centre of
mounting plane
Flight direction Y
Protective covers
not shown
ø121
6 openings of
diameter 5.5
CM position
X
R51±0,1

Fig 1

3.3.4. Inspect the GOCE-LRR Laser Retro Reflector visually; make sure to check the equipment for:

1) optical component chipping;
2) mechanical damage;
3) mudding.

3.3.5. Where dust, mud or fatty spots are identified on the input faces of the optical components, make sure to clean the optics by using guidance of the Appendix hereto.

3.3.6. Re-install red-colour process caps with ΦС-01 flags on Laser Reflector assemblies on completion of the GOCE-LRR Laser Retro Reflector handling operations.

Attention!

Remove all protective covers with red flags ΦС-01 after mounting GOCE-LRR Laser Retro Reflector. Caps, mounted tightly, remove with care, wearing cotton gloves and holding the unit for the panel base.

3.3.7. Observe the following rules:

- don't shock the unit,
- don't touch its optical surfaces,
- don't contaminate it, especially optical surfaces.

3.4. STORING REQUIREMENTS

3.4.1. Store this GOCE-LRR Laser Retro Reflector at storage facilities in Manufacturer-supplied Stowing Container at +5^{o}C through +35^{o}C, 80 percent relative humidity. No vapour of acids, alkali or any different aggressive agent shall be tolerated in the storing environment.

3.5. RULES OF TRANSPORTATION

3.5.1. Make sure this GOCE-LRR Laser Retro Reflector is transported inside Manufacturer-supplied Stowing Container specially designed to properly protect the equipment against outside mechanical impacts, penetration of moist and/or dust.

This equipment can be hauled by any means of transport, at any distance or speed specified for the carrying means, at ambient temperature between minus 50^{o}C through +50^{o}C.

Attention!

During loading, hauling and downloading, don’t drop, tilt or shock the unit when packed in storage container.

Annex A
(recommended)

OPTICS CLEANING INSTRUCTIONS

Clean outer surfaces of the optical components as required to remove fatty spots, traces of moist, dust or any different mudding of the optical surfaces.

Make sure to wash hands with soap and wipe hands dry before doing the cleaning.

Wear cotton gloves to perform the following sequence:

1) use squirrel fur brush or dry air to remove dust or any different easily removable mudding;

2) use cambric napkin or purified cotton tampon wrapped around the opposite tip of the squirrel fur brush to clean fatty contamination. Wrap cotton as follows: dip the opposite tip of the brush in alcohol, insert tip in cotton and rotate brush. To avoid scratching the optical surfaces, make sure the tip is properly wrapped in cotton. Finally, soak cotton in alcohol before cleaning;

3) clean optical surfaces in circular motion, from centre to edge, by pressing slightly to exclude damage. Change tampons from time to time, making sure not to use mudded tampons;

4) use rectified ethyl alcohol of premium quality to clean the optics. Never apply hydrolytic alcohol for danger of oily stains on optical surfaces.

IPIE

PASSPORT – CERTIFICATE

for the flight model of GOCE-LRR-01 array

serial No. 08284145

КО1-Э147-00-00 ПС

I. Delivery set

Table 1

№	Contents	Number	Notation	Note
1	The flight model of LRR array – GOCE-LRR-01	1 p.	КО1 – Э147-00-00	
2	Dimension drawing	1 c.	КО1-Э147-00-00 ГЧ	
3	Technical description and operating instruction	1 c.	КО1-Э147-00-00 ТО	
4	Passport - certificate	1 c.	КО1-Э147-00-00 ПС	
5	Package	1 p.		

II. Technical data

Table 2

N	Parameter	Unit	Value
1	Number of retroreflectors	p.	7
2	GOCE LRR-01 array cross-section	$m^2 \cdot 10^6$	≥0,7
3	RMS target error	mm	<1
4	Working elevation angle	deg.	>20
5	GOCE LRR-01 array field of view	deg.	>130
6	GOCE LRR-01 array phase center position accuracy relative to the reference point (contact area center)	mm	<0,8
7	GOCE LRR-01 array dimensions	mm	Ø121x56,3
8	GOCE LRR-01 array mass	kg	0,3822
9	Operating wavelength	nm	532

Table 3

N	Tests	Specification	Test results	Notes
1	Random vibration Frequency band, Hz: 20– 100; 100 – 200; 200 – 400; 400 - 500; 500 - 1000; 1000 – 2000 Spectral density of acceleration, g^2/Hz: 0,02; 0,02 – 0,07; 0,07; 0,07 – 0,05; 0,05 – 0,04; 0,04 – 0,02 Test duration 3 min in each of the three orthogonal directions	GO-RQ-AI-0017, p.3.4	Corresponds to the requirements	Test protocol N102/35
2	Sine vibration Frequency band, Hz: 5 – 20; 20 – 50; 50 – 600; 600 – 2000 Acceleration, g: 1 – 1.7; 1.7 – 3; 3 – 10; 10 – 12 Scan duration 4 min in each of the three orthogonal directions. Before and after sine vibration tests, scanning has been made with sine vibration from 5 to 2000 Hz, with 2g and scanning speed 2 octaves per minute, duration 3 minutes.	L1-4719 CS-RS-DOR-LR-0001	Corresponds to the requirements	Test protocol N102/35
3	Random vibration Frequency band, Hz: 20 – 100; 100 – 400; 400 - 2000 perpendicular: 6dB/octave; $0,17g^2$/Hz; -6dB/octave lateral: 6dB/octave; $0,17g^2$/Hz; -6dB/octave Test duration: 2 min in each of the three orthogonal directions	L1-5841	Corresponds to the requirements	Test protocol N102/35
4	Peak shock acceleration ±200 g, duration 0.5 ms in each direction	L1-4718	Corresponds to the requirements	Test protocol N102/35

Note: Other test results are corresponding to the requirements in p.p.3.4, 3.5, 3.6 of GO-RQ-AI-0017, and are presented in protocols N 102/35 and N102/37

Technical inspection representative

"24" 04 2004

3. COMPLIANCE CERTIFICATE AND GUARANTEE

The COCE-LRR-01 array, serial No. 08284145, is in accordance with the Chief Designer's documentation, the Specification Requirements (CS-RS-DOR-LR-0001, GO-RQ-AI-0017), and is suitable for operation in space conditions. The guaranteed lifetime is 5.5 years, including 3.5 years in orbit, if the user acts in accordance with the regulations for storage, transportation, and operation (Document KO1-Э147-00-00 ТО).

The guaranteed lifetime start date is 21.04. 2004

Head of the Technical Inspection Department

Signature O. Golubovsky

General Designer

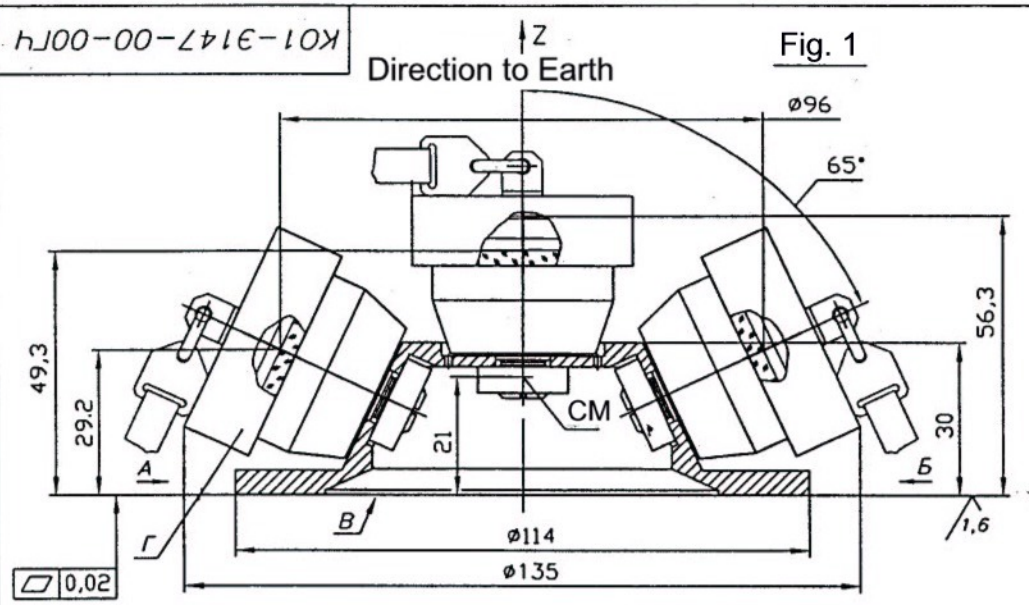
Signature V. Shargorodsky

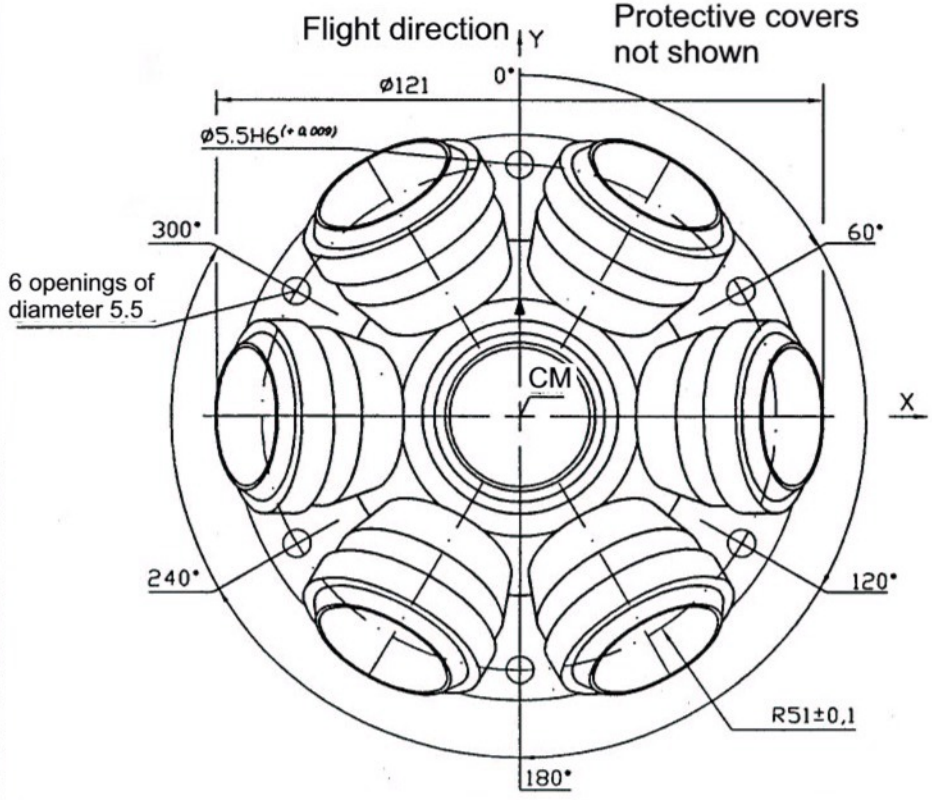
КО1-3147-00-00ГЧ

Перв. примен. КО1-3147-00-00

Справ. N

Fig. 1





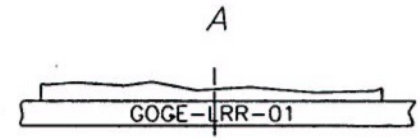
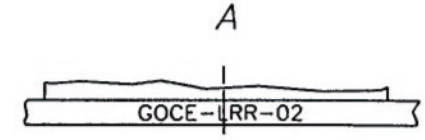


Fig. 2

For the rest see Fig. 1



1. Don't touch the unit and its optical surfaces during intergration and testing.
2. Don't shade the unit's field of view.
3. To provide thermal contact with mounting place, surface B not painted.
4. Contact surface of the mounting shall be machined to match surface B of the unit.
5. Remove red-flagged protective caps ФС-01 prior to encapsulation.
6. Moments of inertia:
   Ix = 0.000377 kg*sqm,
   Iy = 0.000377 kg*sqm,
   Iz = 0.00061 kg*sqm.
7. Mass, CM position and moments of inertia specified without protective caps Г.

Изм.	Лист	N докум.	Подп.	Дата	КО1-Э147-00-00ГЧ		
Разроб.		Арешкина		15.03.04	GOCE-LRR	Лит.	Mass / Масштаб
Пров.		Илларионов		15.03.04	Dimensional drawing		375 ± 11 g / 1:1
Т. контр.						Лист	Листов 1
Н. контр.							
Утв.		Шаргородский		15.03.04			

Копировал

Формат А3

Подп. и дата | Инв. N дубл. | Взам. инв. N | Подп. и дата | Инв. N подл.

AGREED with
(signed)
O.Golubovsky
Deputy Designer General
for QA&PA
March 16, 2004

APPROVED by:
(signed)
V.Shargorodsky
Designer General

March 16, 2004

TEST REPORT

March 16, 2004 № 102/35

1. **TEST ARTICLE:** Laser Retro Reflector array GOCE-LRR-01 №08284145 К01-Э147-00-00.
2. **TEST OBJECTIVE**: Check compliance with technical specifications in para 3.4 and 3.6 GO-RQ-AI-0017 and L1-4719, L1-5841, L1-4718 CS-RS-DOR-LR-0001.

3. TEST PROGRAM

3.1. Test program defined in Table 3.4-1 of GO-RQ-AI-0017.

3.1.1. Random vibration levels

Frequency band, Hz	Acceleration spectral density, g^2/Hz
20 - 100	0.02 - 0.02
100 - 200	0.02 - 0.07
200 - 400	0.07 - 0.07
400 - 500	0.07 - 0.05
500 - 1000	0.05 - 0.04
1000 - 2000	0.04 - 0.02

3 axes, 3 minutes along each axis.

3.1.2. Shock loads: 3 shocks ±40 g during 4 ms along each of 3 axes.

3.2. Test conditions and sequence were defined in para 5.2.2.3, 5.2.24 and 5.2.25 of CS-RA-DOR-LR-0001.

3.2.1. Prior to and after each test (shock, sine and random vibrations), sine resonance search was performed in a frequency range from 5 to 2000 Hz at level 2 g.

3.2.2. Shock loads of ± 200 g were applied during 0.5 ms along each of 3 axes.

3.2.3. Sine vibration levels

Frequency band, Hz	Acceleration level, g
5 - 20	1 - 1.7
20 - 50	1.7 - 3
50 - 600	3 - 10
600 - 2000	10 - 12

3 axes, 4 minutes along each axis.

4. TEST EQUIPMENT AND INSTRUMENTATION

4.1. Vibroshaker VP 600.

4.2. Shock bench CTT – 400/500.

4.3. Supporting frame № 485619.

4.4. Reflectance diagram measuring bench.

5. TEST RESULTS

5.1. Test article GOCE-LRR-01 №08284145 successfully passed through all tests.

5.2. The following spices were revealed during full-level vibration tests according 3.2.3:

- X axis - at 850 and 1900-2200 Hz,
- Y axis - at 800 and 950 Hz;
- Z axis – at 1200 Hz.

All spices did not exceed doubled amplitude of the input sensor. No changes of sine resonance curves revealed.

Visual inspection was performed prior to and after of each mechanical test. No changes revealed. Hold-down pressure of cube corners were within tolerance after mechanical tests.

Vibration records are given in Annex B.

6. OPTICAL (FUNCTIONAL) TESTS

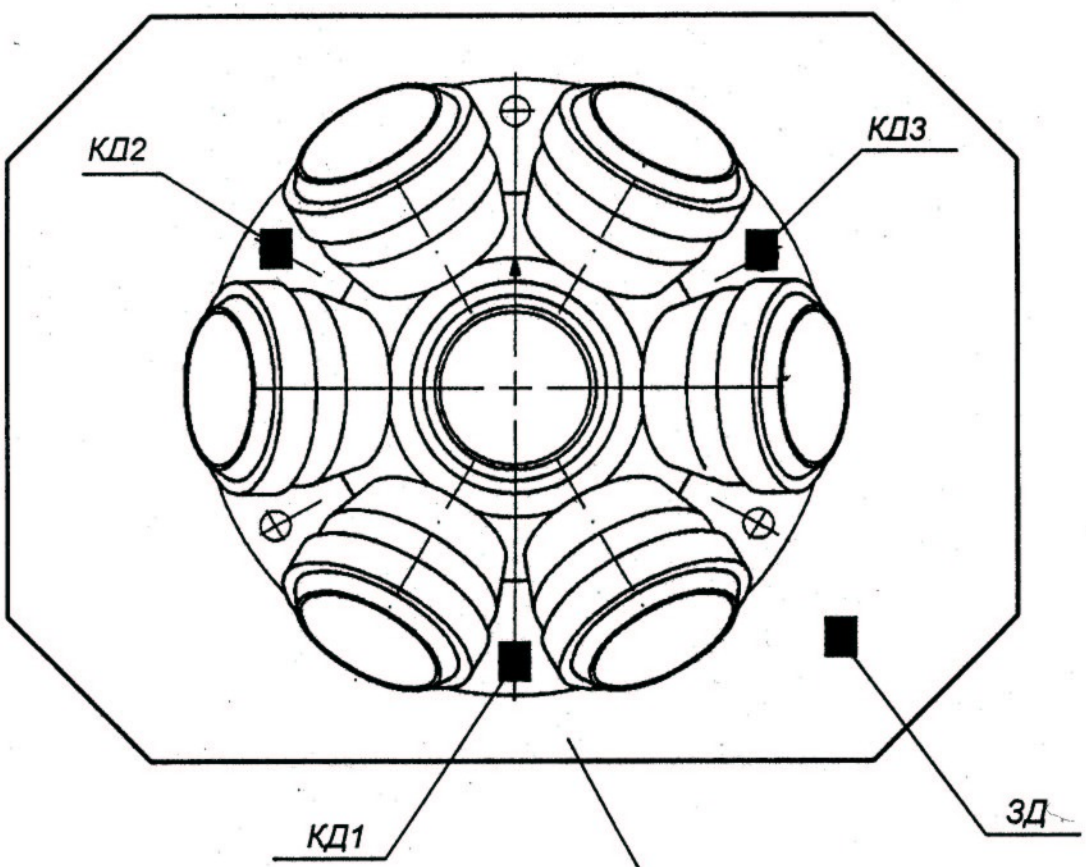
Reflectance diagrams of each cube corner were measured before and after all mechanical tests. No changes in reflectance diagrams revealed. The diagrams are given in Annex C.

7. CONCLUSION

Laser Retro Reflector array GOCE-LRR-01 is fully compliant with technical requirements.

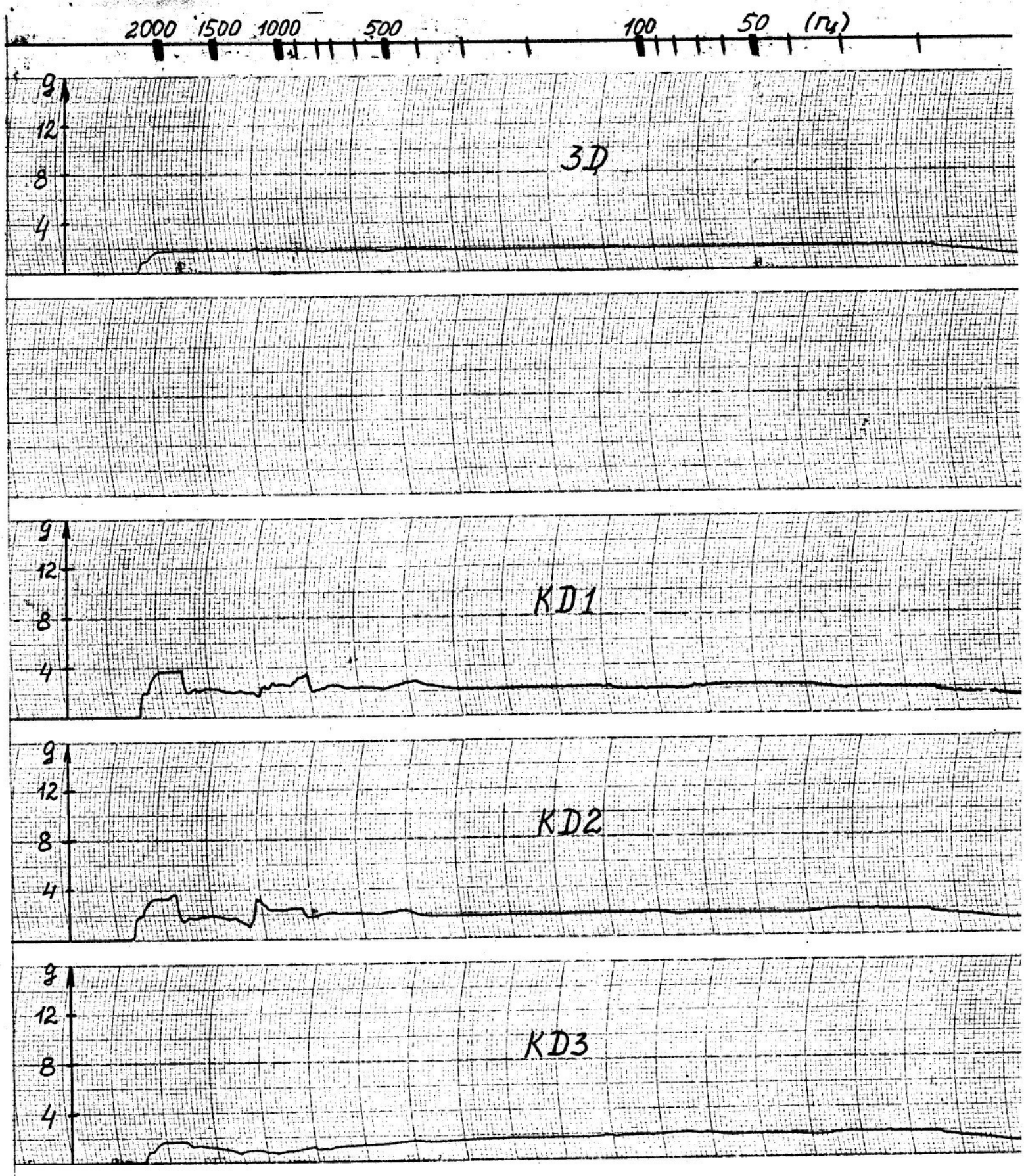
Head of Test Division	*signed*	I.V.VASSILETZ
Test operators	*signed*	V.A.FEDOROVA
	signed	L.E.BIRYUKOVA
	signed	Ye.A.NIKOLAYEV
	signed	T.I.KHOROSHEVA

ANNEX B
To the Test Report N 102/35
dated March 16, 2004
13 pages

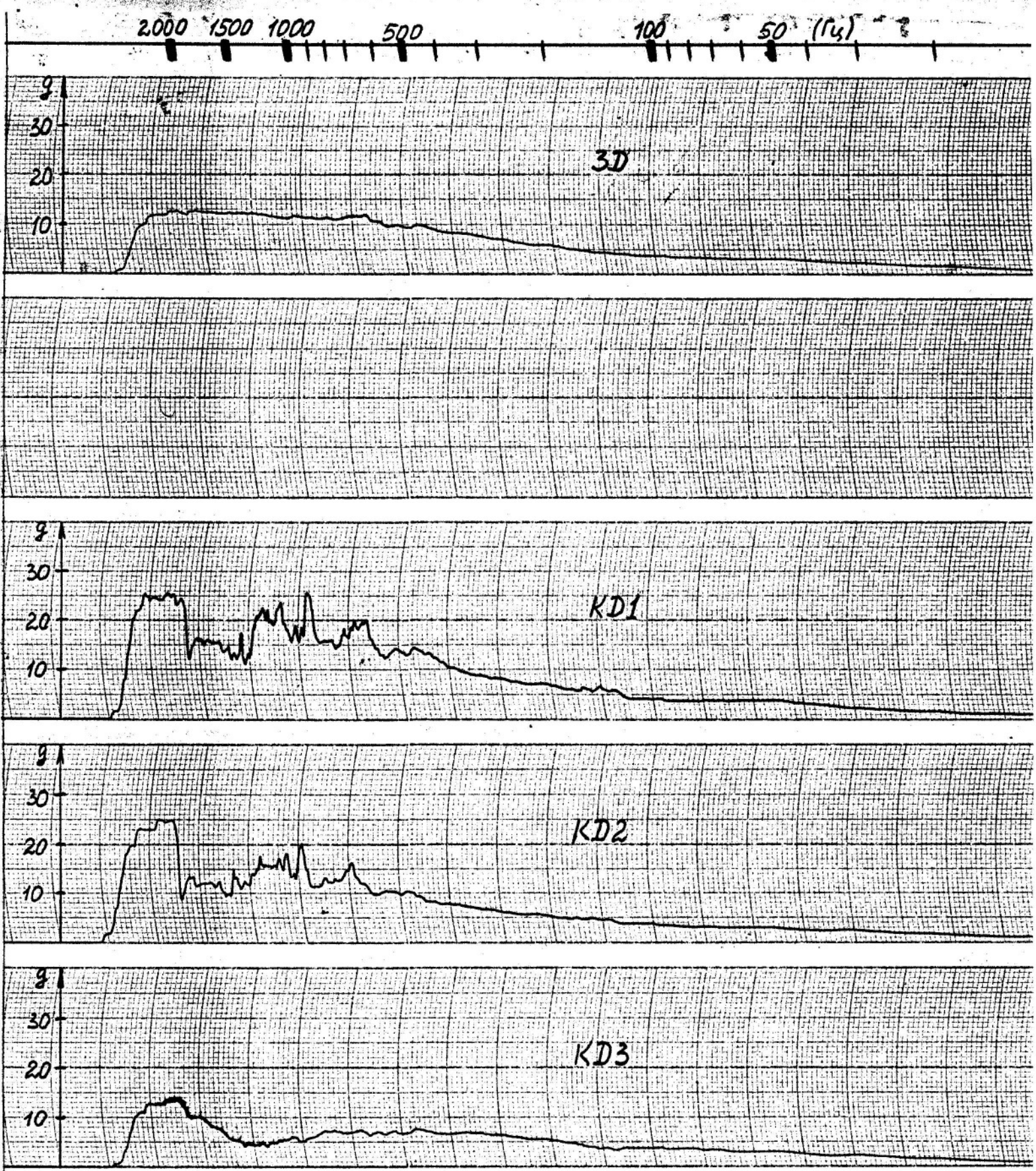


ЗД - input accelerometer
КД - measuring accelerometer

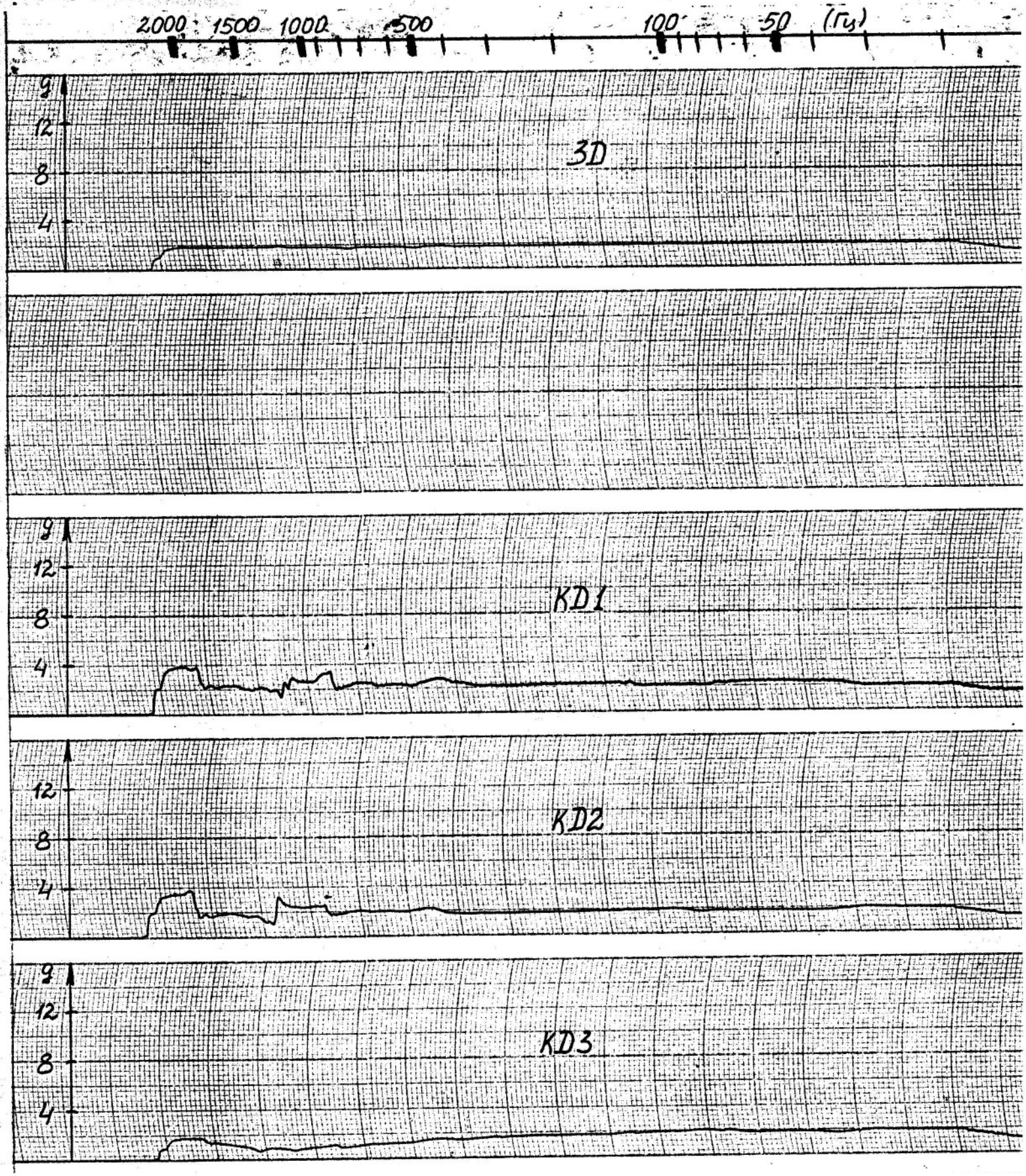
Supporting frame
№ 485619



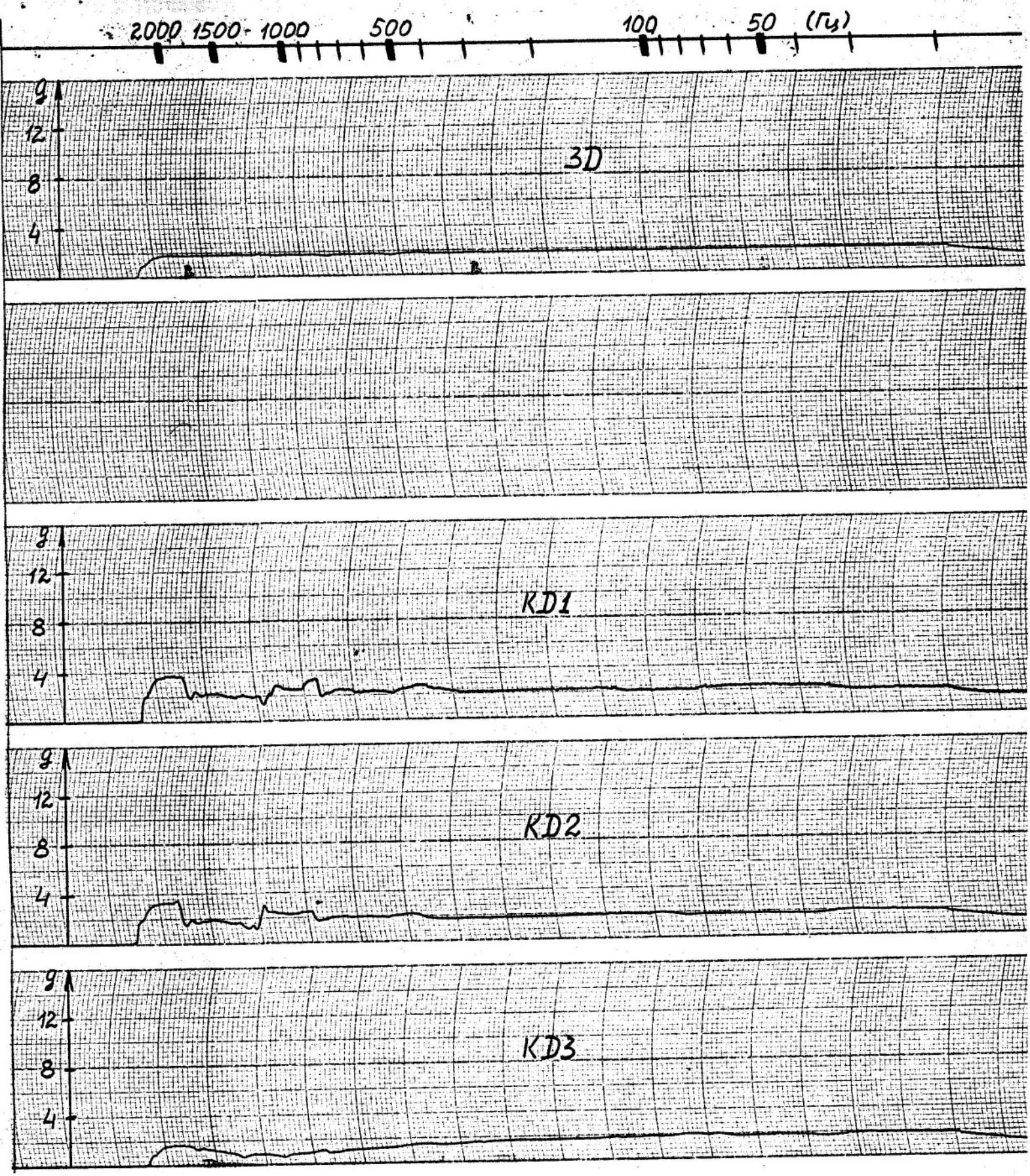
X axis
Initial sine resonance curves



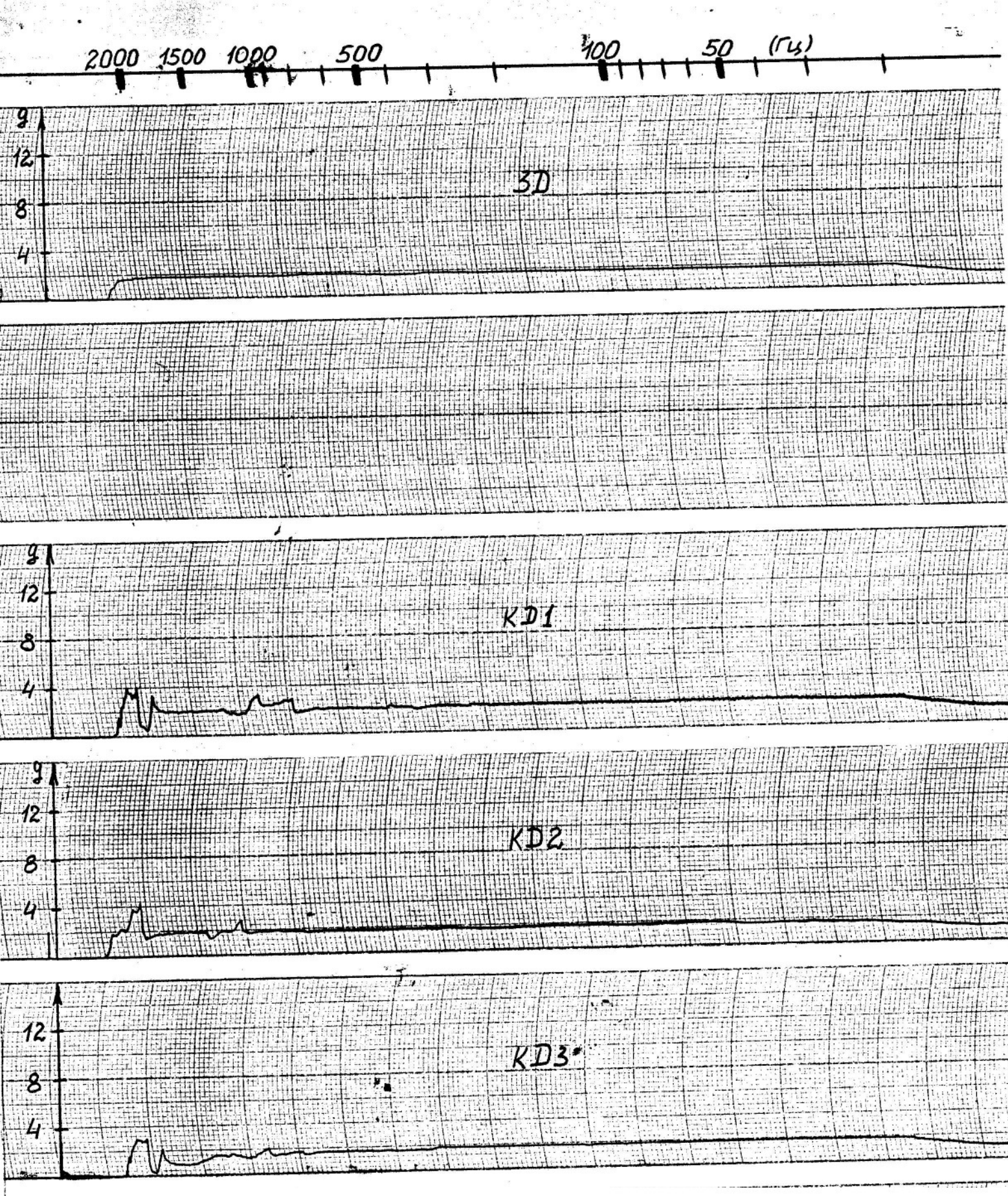
X axis
Full-level sine vibration



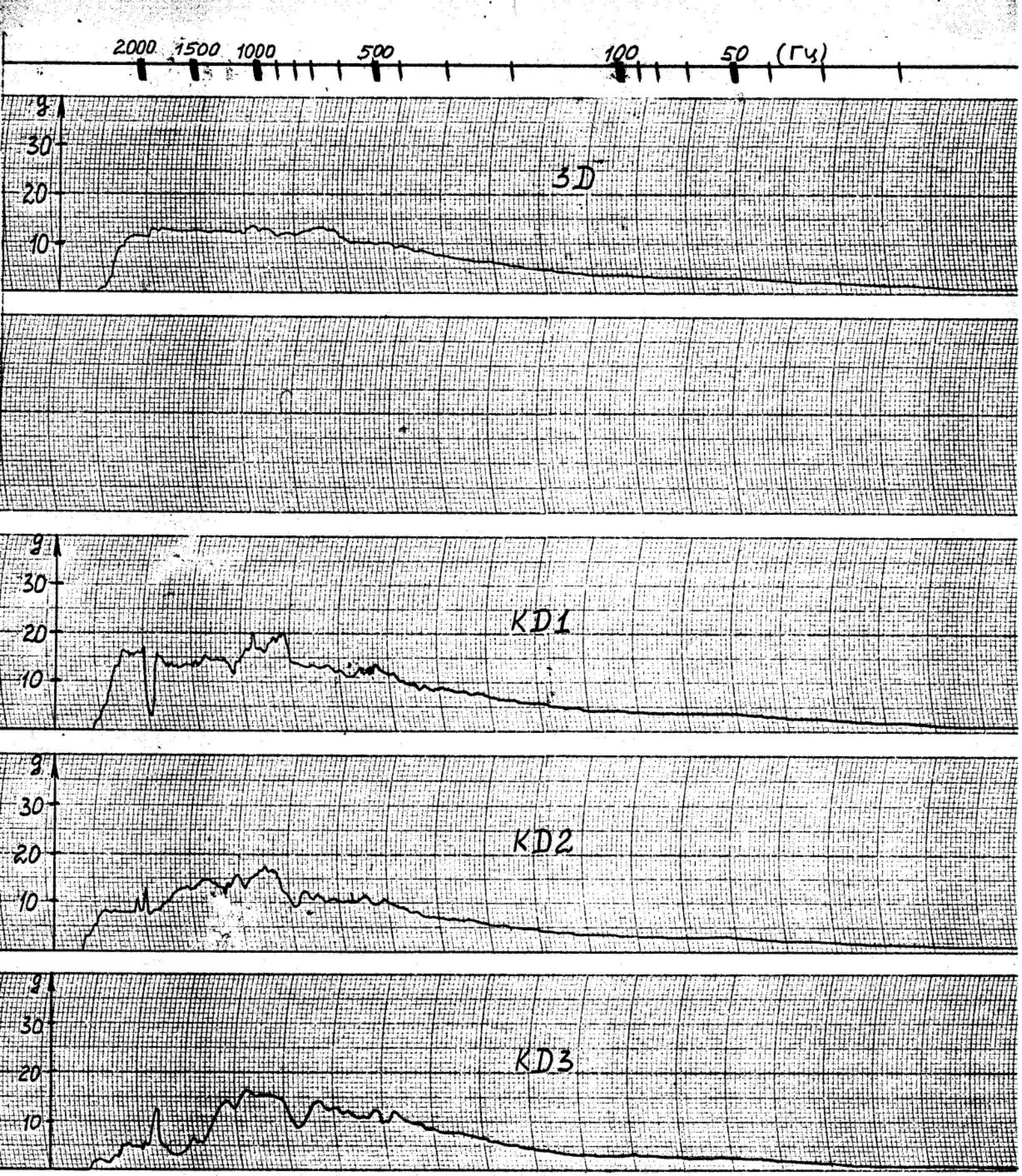
X axis
Sine resonance curves after full-level sine vibration



X axis
Sine resonance curves after random vibration tests

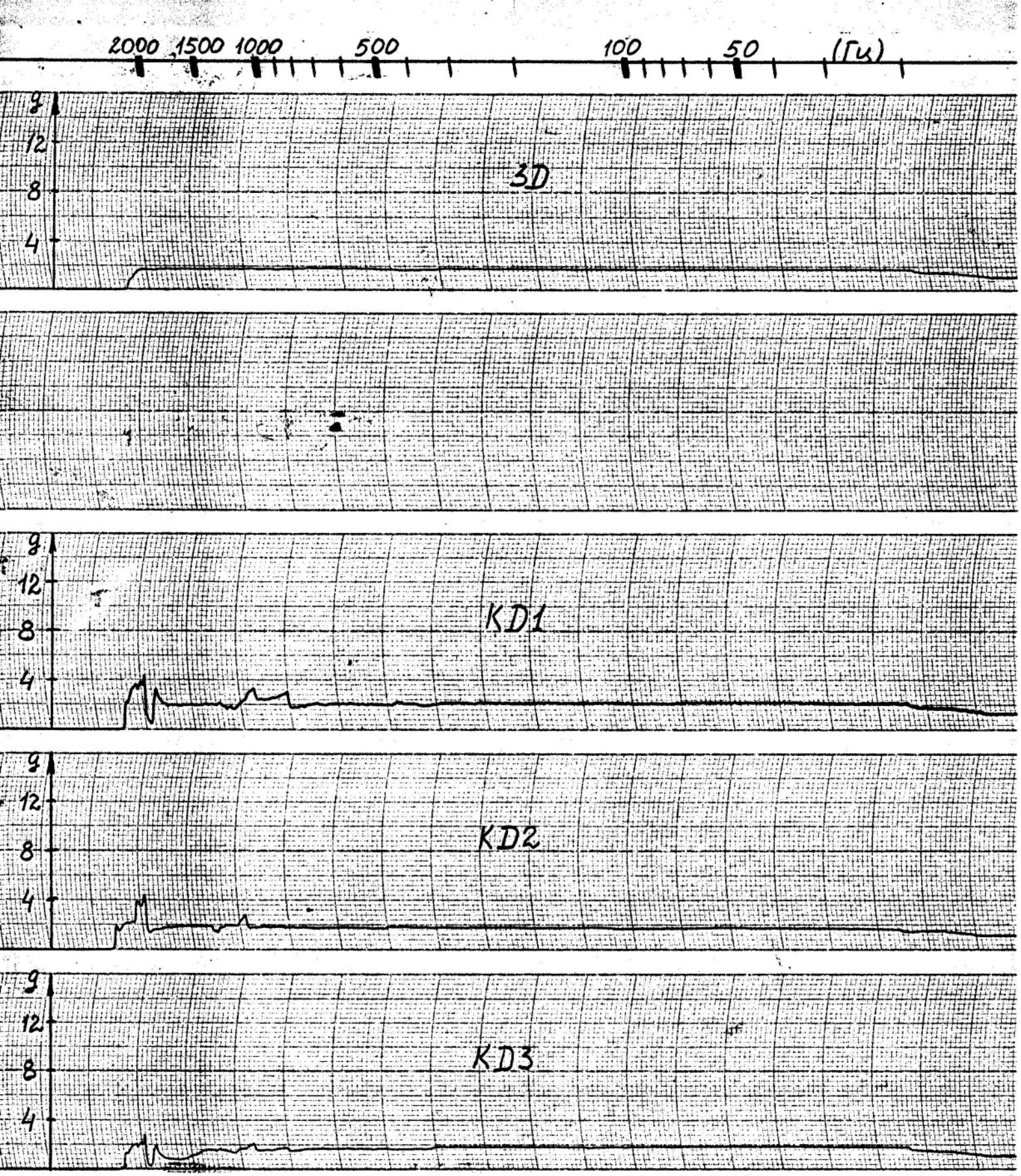


Y axis
Initial sine resonance curves



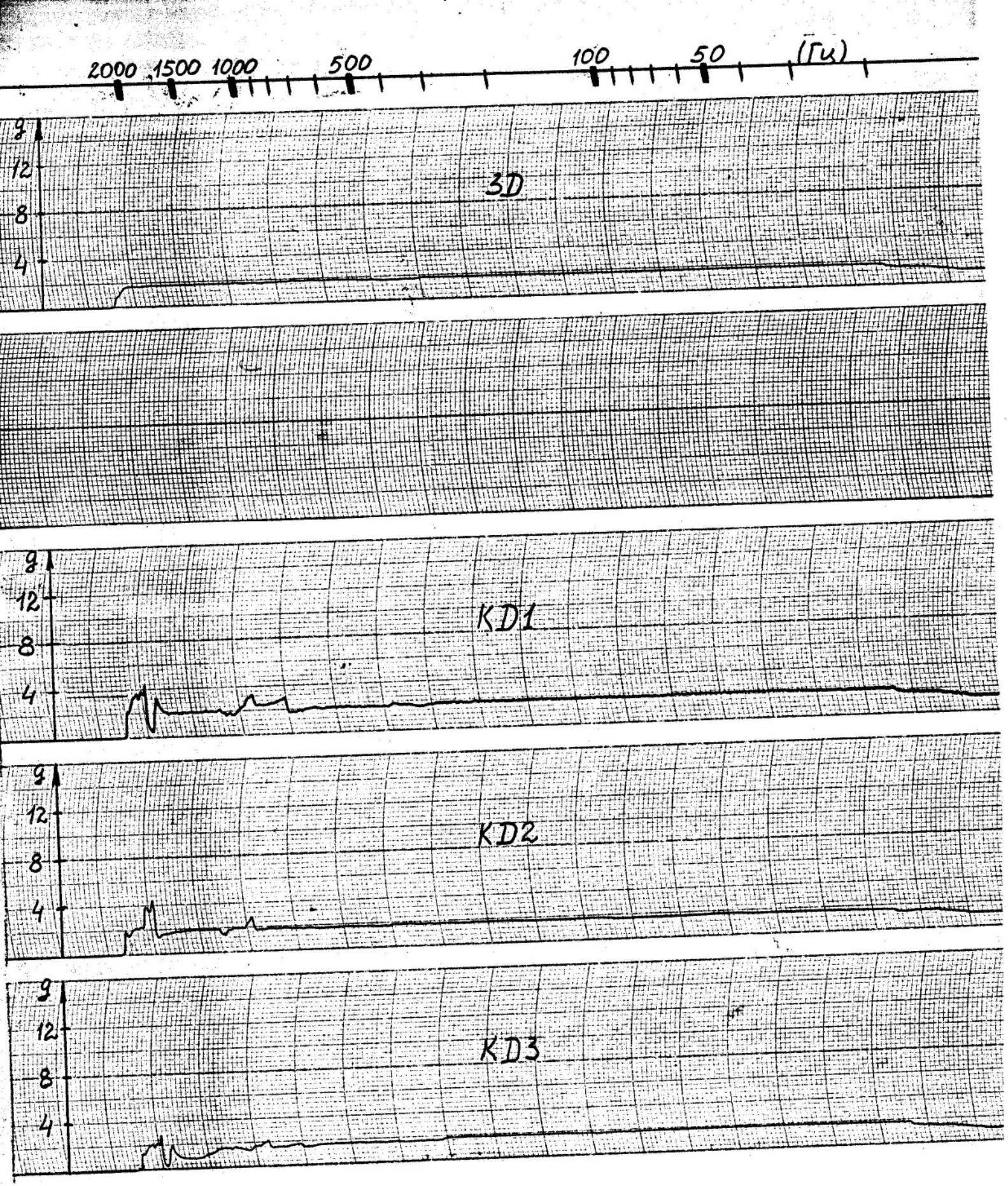
Y axis

Full-level sine vibration



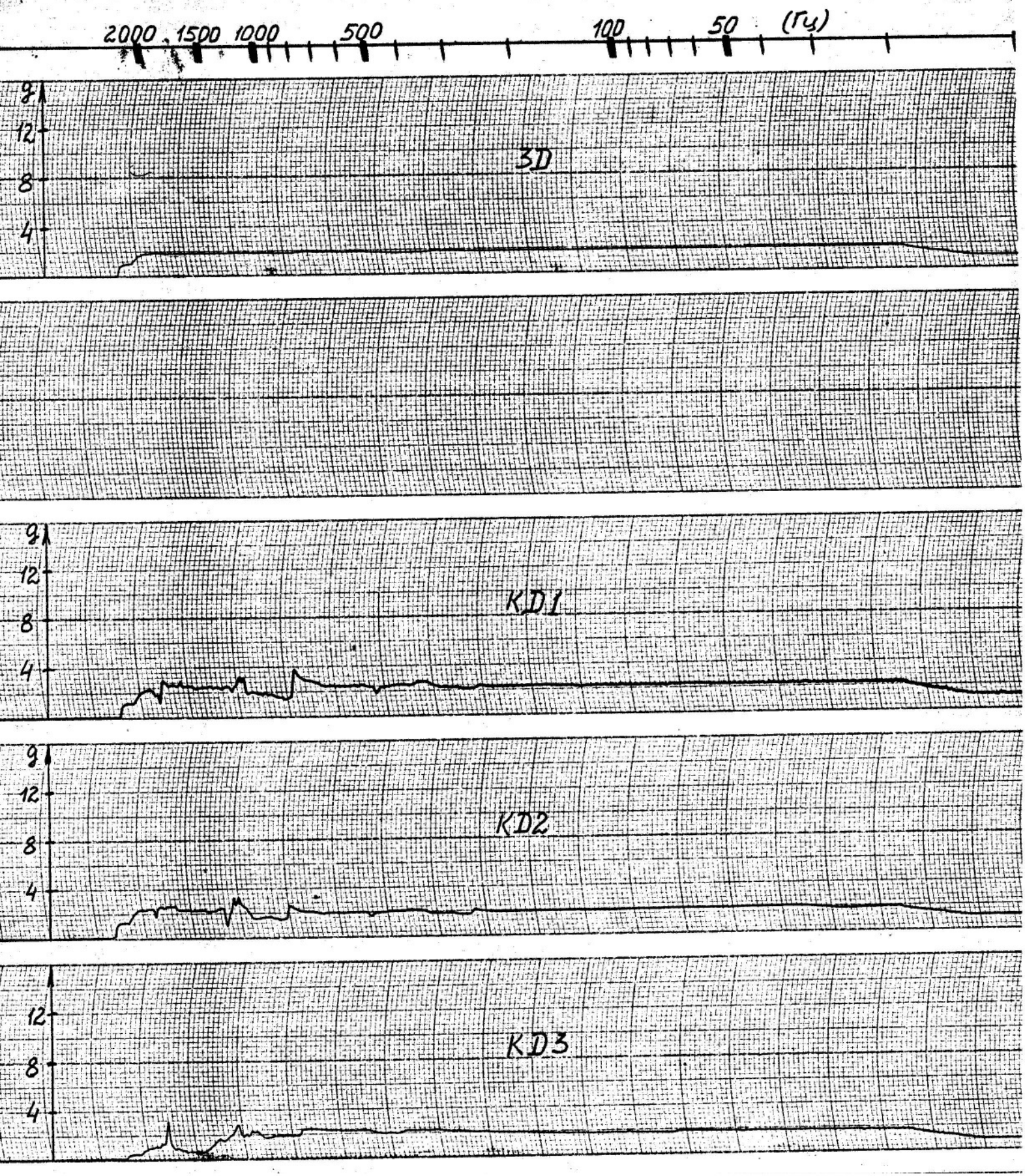
Y axis

Sine resonance curves after full-level sine vibration



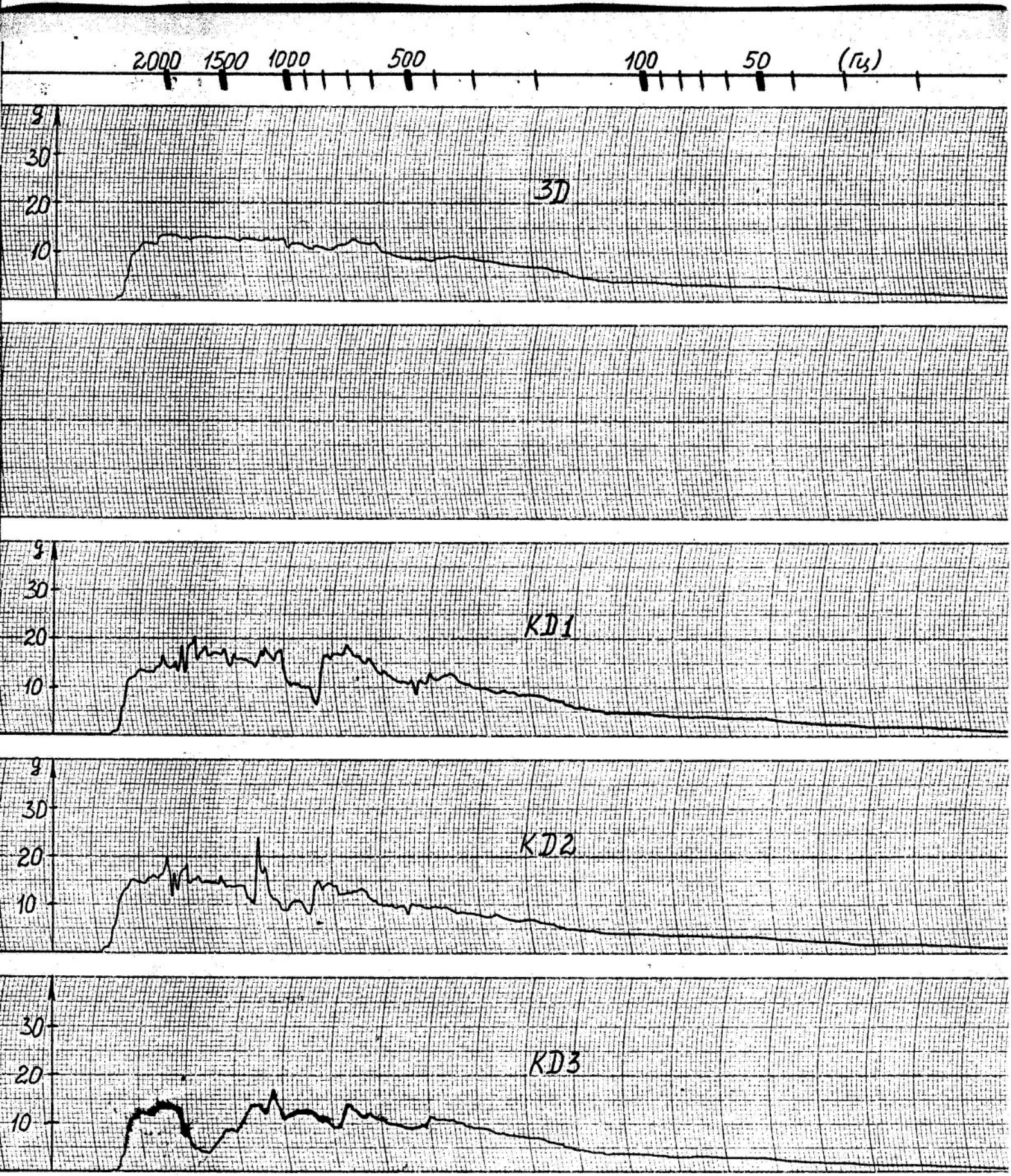
Y axis

Sine resonance curves after random vibration test



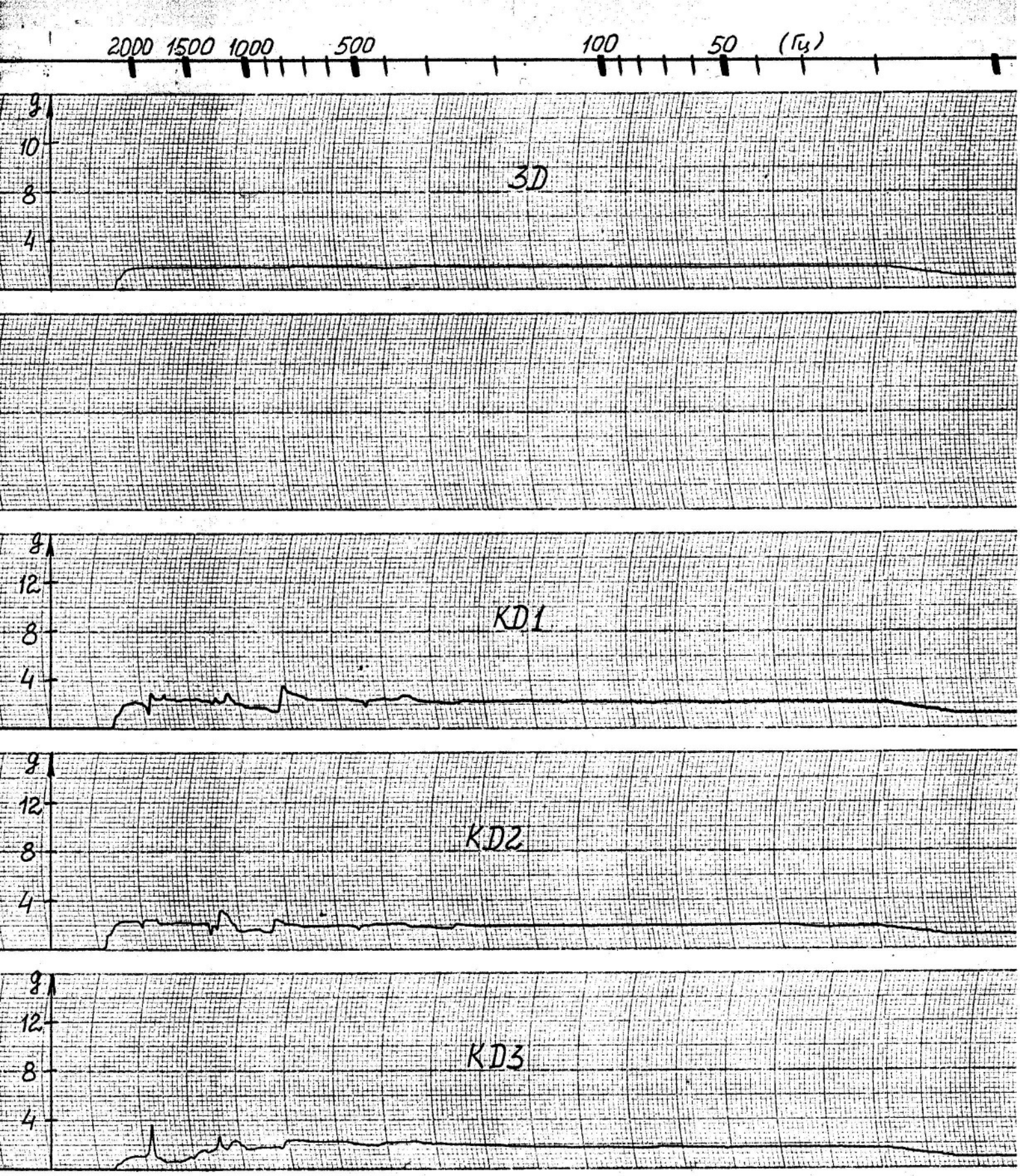
Z axis

Initial sine resonance curves



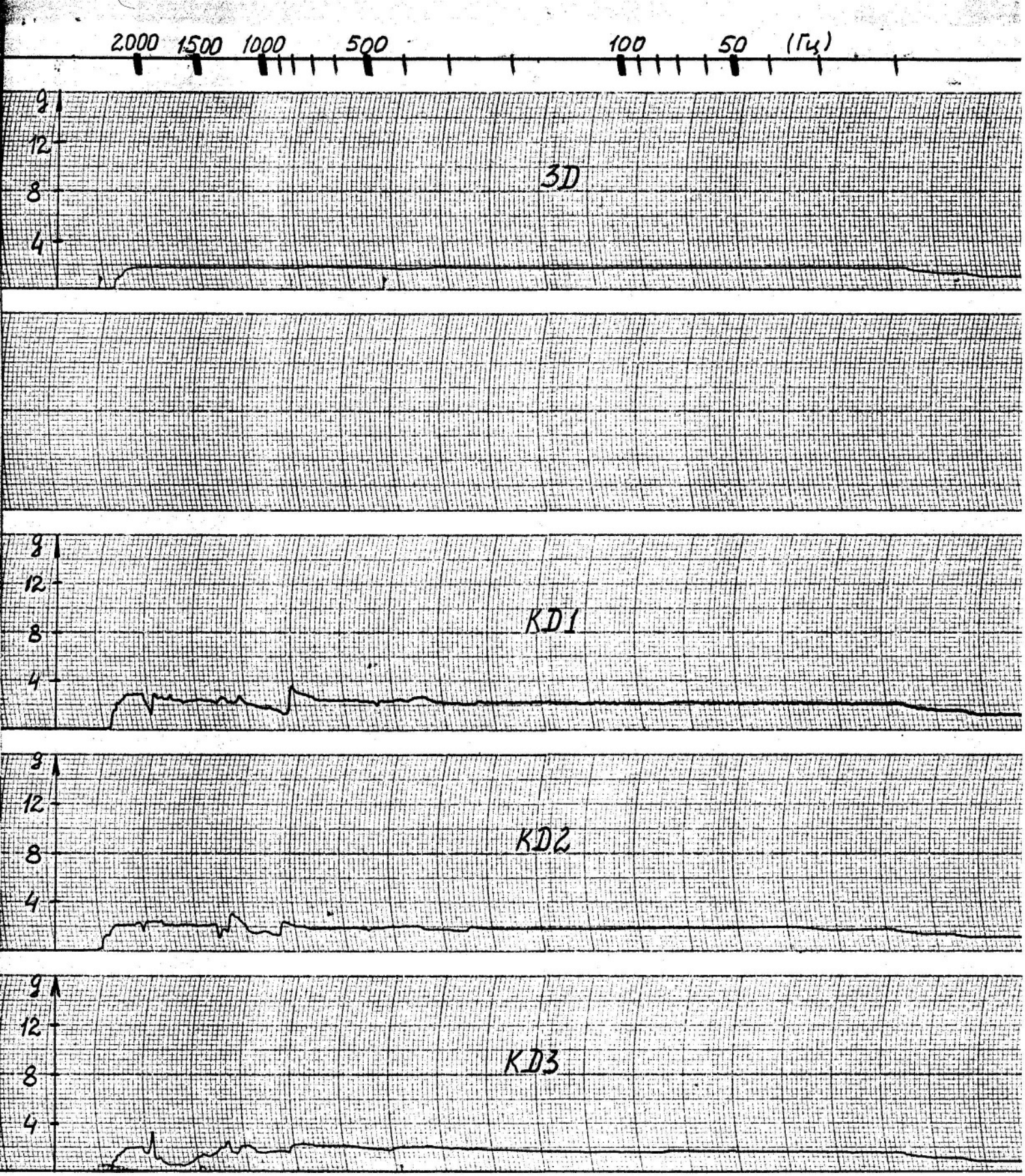
Z axis

Full-level sine vibration



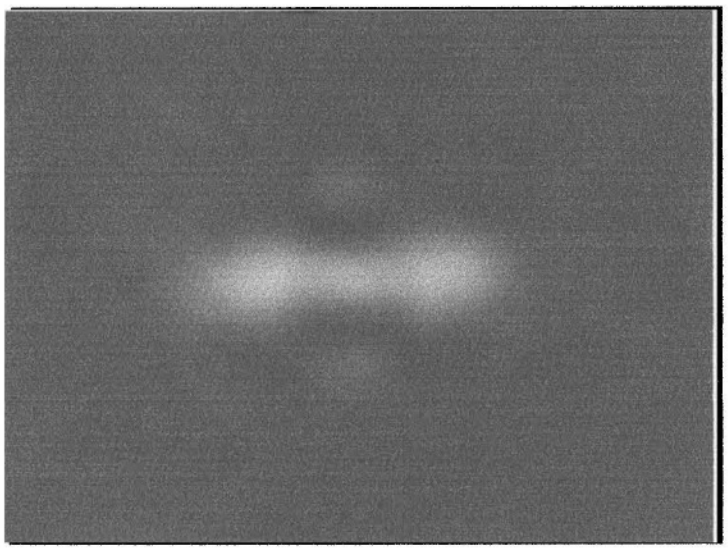
Z axis

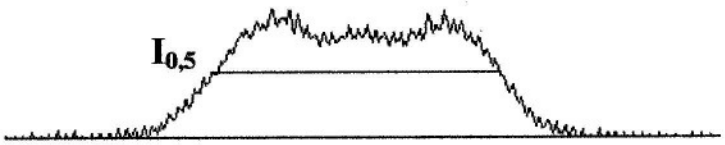
Sine resonance curves after full-level sine vibration



Z axis

Sine resonance curves after random vibration





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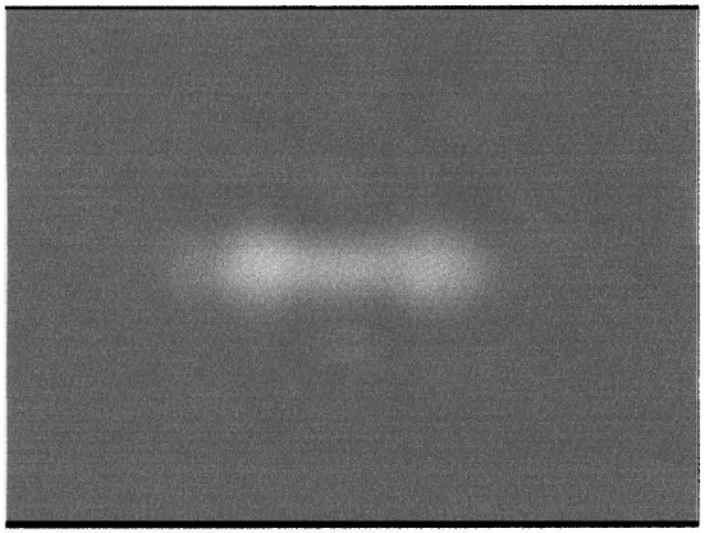

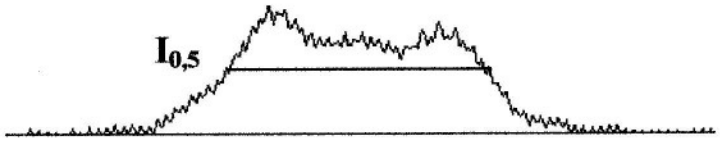

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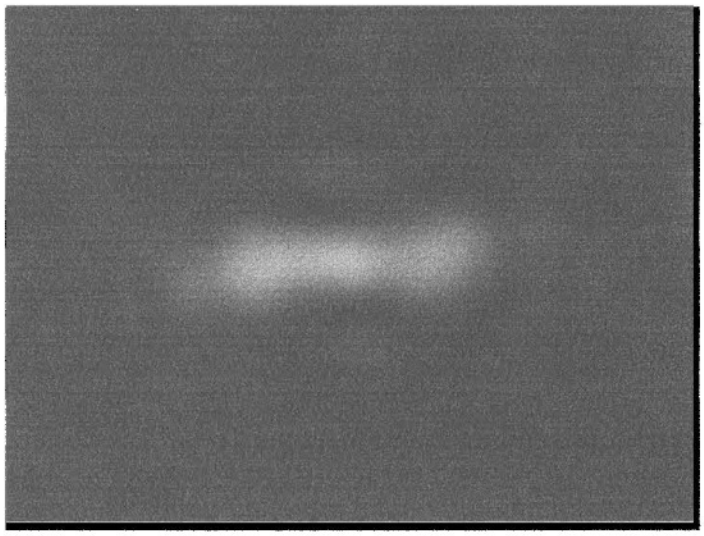

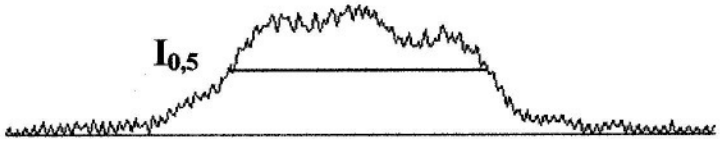

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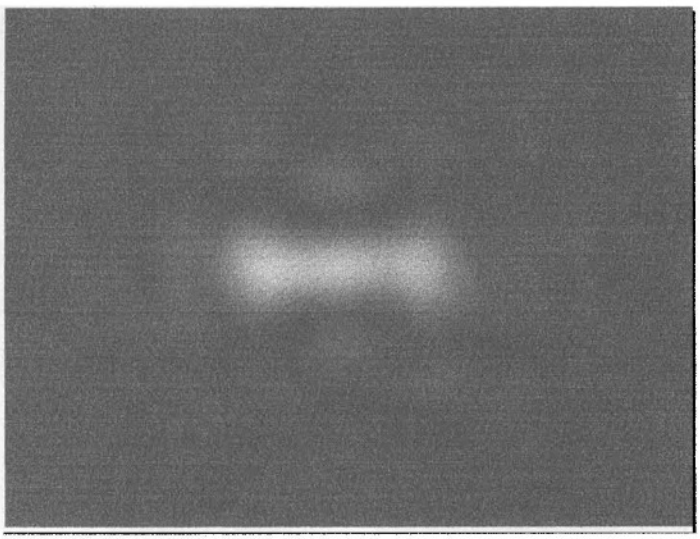
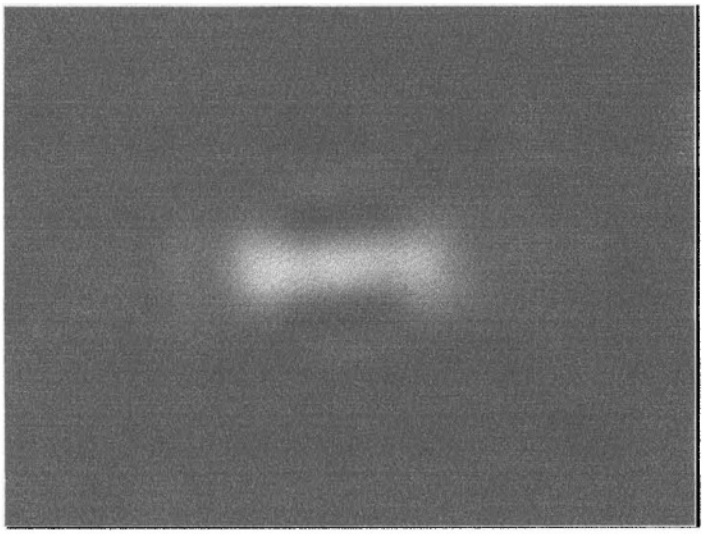


№ 4, 13,8 сек



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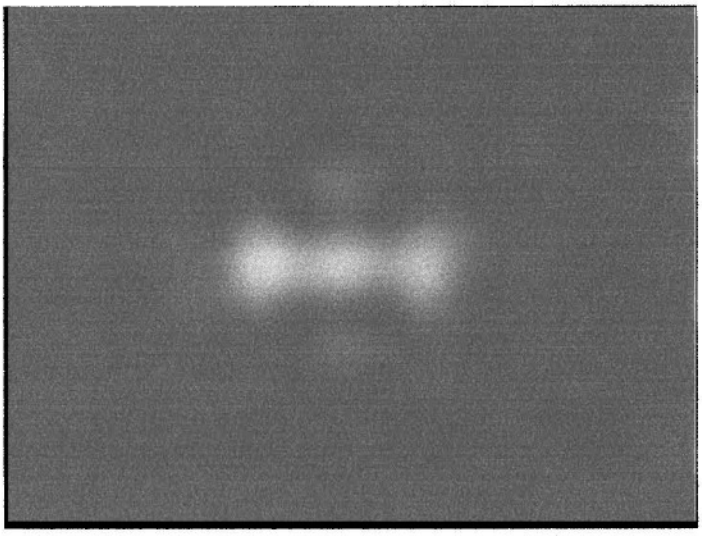
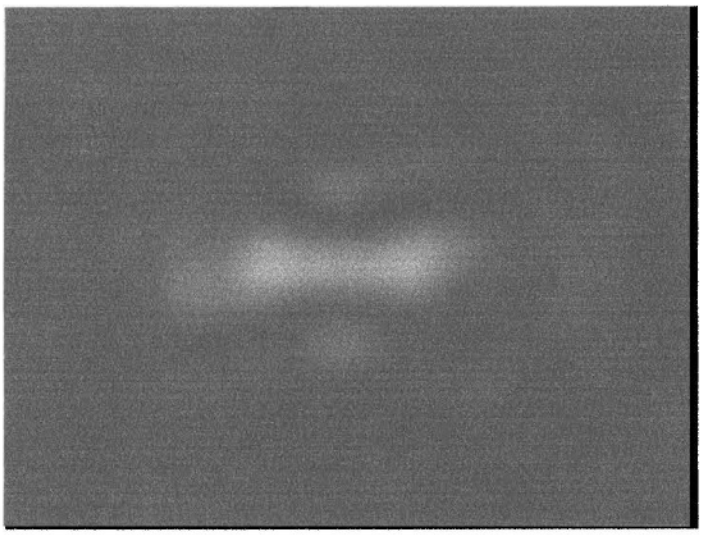
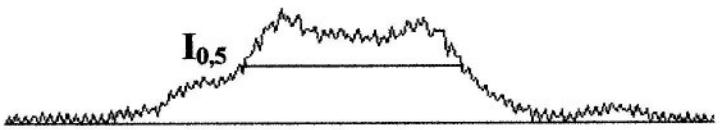


№ 6, 13,8 сек





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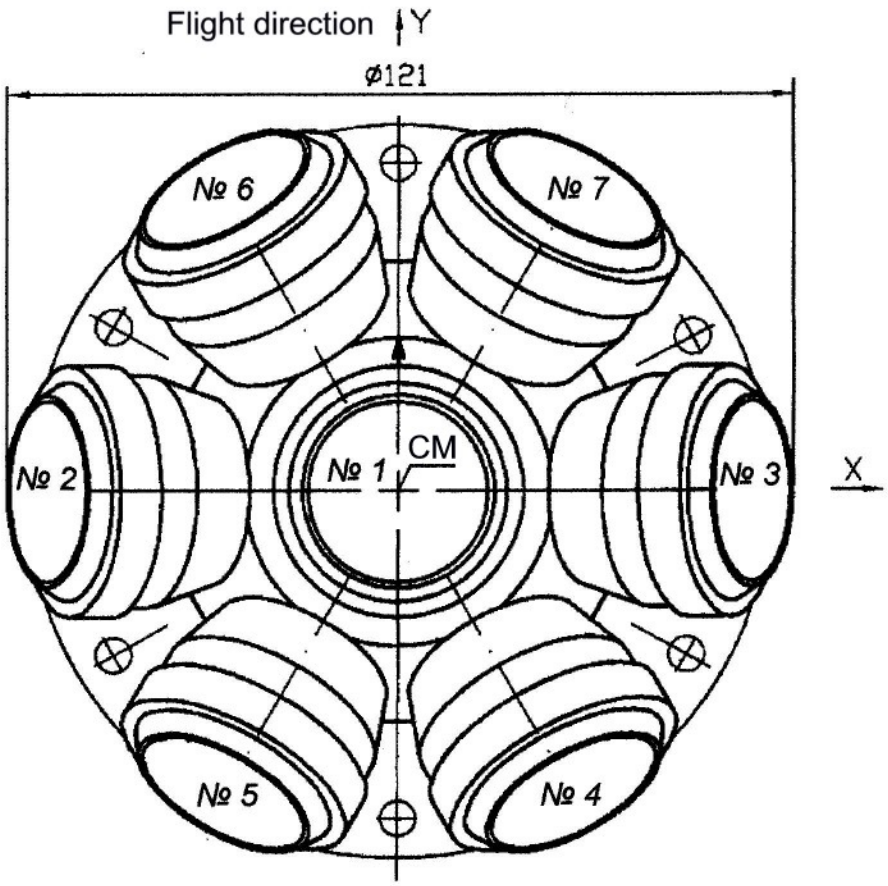

Comment

No changes of individual reflectance diagrams
was revealed within measument accuracy

AGREED with
(signed)
O.Golubovsky
Deputy Designer General
for QA&PA
April 2, 2004

APPROVED by:
(signed)
V.Shargorodsky
Designer General

April 2, 2004

TEST REPORT

April 2, 2004 № 102/37

1. **TEST ARTICLES:** Laser Retro Reflector arrays GOCE-LRR-01 №08284145 К01-Э147-00-00 and GOCE-LRR-02 №08284146 К01-Э147-00-00.
2. **TEST OBJECTIVE**: Thermocycling in accordance to technical specifications para 3.5 GO-RQ-AI-0017.

3. TEST PROGRAM

Laser Retro Reflector arrays GOCE-LRR-01 and GOCE-LRR-02 were subjected to thermocycling according to profile given in Annex D. The following checks were performed during thermocycling procedure:

1. Initial measurement of reflectance diagram. Keeping at temperature 20 ± 5 deg C for 1 hour.
2. Cooling down to the temperature minus 20 deg C during 0.5 hour.
3. Cooling down to minus 155 deg C during 13.5 min.
4. Keeping at the lowest temperature for 3 hours.
5. Warming up to minus 20 deg C during 13.5 min.
6. Warming up to 20 deg C during 0.5 hour.
7. Heating up to 125 deg C during 10.5 min.
8. Keeping at maximum temperature for 3 hours.
9. Cooling down to 20 deg C durin 10.5 min.
10. Repeat point 2-9 to 10 cycles.
11. Keep at room temperature not less than 1 hour. Check reflectance diagram.

The temperature history was recorded during phases 3, 5, 7 and 9.

4. TEST EQUIPMENT AND INSTRUMENTATION

4.1. Thermovacuum chamber ТВУ-1000.

4.2. Deep-freezing chamber КГХ.

4.3. Reflectance diagram measuring bench.

5. TEST RESULTS

Test articles GOCE-LRR-01 and GOCE-LRR-02 successfully passed through thermocycling tests. No damages or changes of structure discovered after visual inspection. Temperature profile is given in Annex D.

6. OPTICAL (FUNCTIONAL) TESTS

Reflectance diagrams of each cube corner were measured before and after thermocycling tests. No changes in reflectance diagrams revealed. The diagrams are given in Annex C.

7. CONCLUSION

Laser Retro Reflector arrays GOCE-LRR-01 GOCE-LRR-02 are fully compliant with technical requirements in terms of thermocycling.

Head of Test Division	*signed*	I.V.VASSILETZ
Test operators	*signed*	V.N.GLEBOV
	signed	L.E.BIRYUKOVA
	signed	N.M.SOYUZOVA
	signed	T.I.KHOROSHEVA

Annex D
Thermocycling profile for
GOCE-LRR-01 and GOCE-LRR-02