

**Technical Documents  
for Human Whole Body Phantom with  
Reference Samples of Radionuclides  
Potassium-40, Cobalt-60  
and Caesium-137  
Set UPh-08T**

**Designed by  
Research Institute  
for Industrial and  
Sea Hygiene**

**Produced by  
Scientific and  
Technical Centre  
“Protection Ltd”**

**Saint-Petersburg, Russia  
1996**

**SCIENTIFIC-RESEARCH INSTITUTE FOR INDUSTRIAL AND SEA MEDICINE**

**CERTIFICATE**  
**for reference samples of activity**  
**of incorporated radionuclides,**  
**type "Set UPh-08T"**

1. Purpose: reference samples (RS) are intended for graduation of whole body counters.

2. Metrological parameters

2.1. The certified value of a reference sample: the activity of basic radionuclide, whose actual values are presented in Table 1:

Table 1

Designation of reference sample	Basic radionuclide	Actual value of activity of RS basic radionuclide, Bq
P <sub>1</sub>	Co-60	11900
P <sub>2</sub>		23900
P <sub>3</sub>		49700
P <sub>4</sub>		69600
P <sub>5</sub>		89500
P <sub>6</sub>		109000
P <sub>1</sub>	Cs-137	5800
P <sub>2</sub>		11600
P <sub>3</sub>		24200
P <sub>4</sub>		33900
P <sub>5</sub>		43600
P <sub>6</sub>		53200
P <sub>1</sub>	K-40	970
P <sub>2</sub>		1940
P <sub>3</sub>		4040
P <sub>4</sub>		5660
P <sub>5</sub>		7270
P <sub>6</sub>		8890

2.2. The error of the certified value of RS: the relative error is within the confidence interval  $\pm 5\%$  for the confidence probability 0.95.

The values of metrological parameters of radionuclide sources included as compounds of the RS are presented in Appendix 1.

### 3. Additional information:

1) The set UPh-08T is a collection of blocks of polyethylene (scatterers) and of rod radionuclide sources assembled according to the instructions in whole body phantoms - reference samples of activity of incorporated radionuclides; the general view of the RS for the variants of assembling "standing" (lying), "sitting", and "sitting bending" is shown in Figs. 1 to 3; the general view of the scatterers and rod radionuclide sources is shown in Figs. 4 to 6; the instruction for assembling the phantoms is given in Appendix 2;

2) the flux of photons from the radionuclide source in the solid angle  $4\pi(\text{st})$  is determined as the product of the activity of the basic radionuclide in the source by the absolute number of photons of energy E emitted in decay of a nucleus of the basic radionuclide (Table 2):

Table 2

Basic radionuclide	Half-life period	Photon energy E, keV	Number of photons in nucleus decay
Co-60	1925.3 days	1173	0.999
	5.2712 years	1332	1.000
Cs-137	11019 days	662	0.846
	30.169 years		
K-40	$1.28 \cdot 10^9$ years	1461	0.107

3) the ratio of the total photonic flux of admixed radionuclides to the total photon flux of the basic radionuclide in the source for the interval of photon energies from 50 to 3000 keV is not greater than 0.1 % for radionuclides Co-60 and Cs-137, and not greater than 3.0 % for K-40;

4) the ratio of photon flux recorded by the detector from the module of the set UPh-08T with rod sources to the photon flux recorded by the detector from the volume homogeneous source of the same shape, material, and dimensions (the index of homogeneity\* ), and containing the basic radionuclide of the same activity is presented in Table 3:

\* the index of homogeneity has been determined by the Monte-Carlo method in comparison of energy spectra in five energy intervals, which correspond to Compton scattering of photons in the ranges of angles from  $0^\circ$  to  $30^\circ$ , from  $30^\circ$  to  $60^\circ$ , from  $60^\circ$  to  $90^\circ$ , from  $90^\circ$  to  $180^\circ$ , and multiple scattering, respectively, for a conventional detector with the entrance window with diameter 40 mm at the distance of 10 cm and more from the surface of a volume source.

Table 3

Basic radionuclide	Index of homogeneity
Co-60	0.95...1.10
Cs-137	0.95...1.10
K-40	0.95...1.10

5) the ratio of activity of the basic radionuclide in a separate source to the average value of activity of radionuclide sources of the set UPh-08T (the index of uniformity) is within the interval from 0.97 to 1.03, with the confidence probability 0.95.

6) the ratio of the value of the linear factor of gamma radiation attenuation in the material of the reference samples to the values of the linear factor of gamma radiation attenuation in soft biological tissues of human body (the index of tissue equivalence) is presented in Table 4:

Table 4

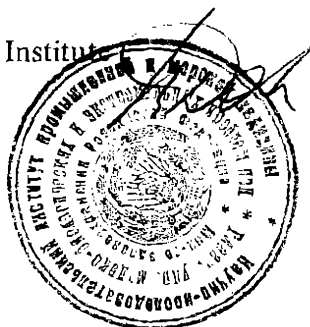
Energy of gamma radiation, MeV	Index of tissue equivalence	Energy of gamma radiation, MeV	Index of tissue equivalence
0.05	0.80	0.66	0.98
0.10	0.93	0.80	0.99
0.20	0.95	1.50	0.99
0.40	0.97	3.00	0.99

4. The document determining the order and conditions of application of the reference samples: the Operating instructions for the RS (Appendix 2).

5. The application time of the RS: 1 year.

6. The date of production of the RS: 01 August 1996.

Director of the Scientific Research Institute  
for Industrial and Sea Medicine



V.V.Dovgusha

**Results of certification  
of rod radionuclide sources  
RS type "Set UPh-08T"**

Metrological parameters

Basic radionuclide	Source number	Actual value of activity of basic radionuclide in source as of 1 August 1996, Bq	Value of relative error for $P = 0.95$ , %
Co-60	10.001...10.180	497	5.0
	10.181...10.260	249	
Cs-137	30.001...30.180	242	5.0
	30.181...30.260	121	
K-40	04.001...04.180	40.4	5.0
	04.181...04.260	20.0	

The date of production: 01 August 1996 (the date of certification)

The results of certification are valid till 01 August 1997

Leading research worker

Engineer of the 1st category



A.N. Kovtun




S.M. Prokofyev



**REFERENCE SAMPLES FOR ACTIVITY  
OF INCORPORATED RADIONUCLIDES  
TYPE "SET UPh-08T"**

**Operating instructions**

**Head of the project**  
  
**A.N.Kovtun**  
**01 August 1996**

## 1. INTRODUCTION

The operating instructions determine the purpose, composition, and the order of assembling of the reference samples, and gives general instructions on their application.

The reference samples of activity of incorporated radionuclides of the type "Set UPh-08T" are intended for graduation of whole body counters.

Additionally, the reference samples provide opportunity to perform comparison of indications of whole body counters which use different geometry of measurements of types: "sitting", "lying (standing)", and "sitting bending".

## 2. GENERAL INSTRUCTIONS

2.1. The "Set UPh-08T" is supplied to the user as a collection of components assembled at the place of operation in reference samples (RS) of activity of incorporated radionuclides - whole-body phantoms.

The composition of the set includes: the collection of blocks of polyethylene (the collection of scatterers) with installation tools and the collection of rod radionuclide sources.

The reference collection of scatterers with the installation tools includes:

- scatterer (one-piece), 90;
- scatterer (half-piece), 40;
- connector, 250;
- fixing arm, 20;
- stand, 1;
- assembling spade, 2;
- pusher, 1;
- case for sources.

The reference set of rod radionuclide sources includes:

- rod radionuclide source (one-piece), 180;
- rod radionuclide source (half-piece), 80;

2.2. Service conditions:

- temperature of ambient air from 10 to 35°C,
- relative humidity of air up to 75 % at 30°C,
- atmospheric pressure from 84 to 106.7 kPa.

**Warning:** to avoid destruction of rod radionuclide sources and loss of their metrological parameters, no mechanical damage or action of acids and alkali to them is allowed.

### 2.3. Safety requirements:

- to avoid turning the article over and inflicting traumas to personnel, assembling the phantoms of types P<sub>3</sub>...P<sub>6</sub> in the geometry "standing" should be performed using the stand;
- total activity of the material of rod radionuclide sources of the set UPh-08T is less than 3.7·10<sup>6</sup> Bq and does not belong to dangerous radioactive substances. ("Safety guide for transportation of radioactive substances" (ИБТФБ-73), п.1.1.7.).

## 3. PURPOSE OF COMPONENTS OF THE ARTICLE

3.1. The scatterers of two standard sizes: 165x110x55 mm and 165x110x25 mm with the mass of 0.88 and 0.40 kg, respectively, serve as simulators of soft biological tissues.

3.2. The radionuclide sources in the form of rod capsules serve as standards for activity of incorporated radionuclides and are produced with two values of activity with the ratio of one (a half-piece source) to two (a one-piece source).

3.3. The scatterers with the rod radionuclide sources inserted in the through holes form a unified module (one-piece and half-piece) with two values of activity of the radionuclide in it (Figs. 5 and 6). The unified module is the minimal representative sample of the reference sample, to which the values of metrological parameters given in the certificate belong.

3.4. The connectors are inserted in blind holes on the surface of the scatterers to join the modules during assembling the phantoms.

3.5. The stand is applied for assembling phantoms simulating the body of man with the mass of 50 kg and more in the geometry "standing". The fixing arms are used if the assembly needs strengthening.

3.6. The assembling spade and the pusher are used for disassembling the phantoms.

## 4. PLACEMENT AND ASSEMBLING OF REFERENCE SAMPLES

4.1. The assembling of phantoms should be performed on smooth and rigid surface directly on the measuring bed of the calibrated device.

4.2. The stability and preservation of the assembled phantom is provided by joining the modules to one another by not less than two connectors for each joined module. If a slot



between modules is formed, fixing arms should be mounted outside the phantom to tie the blocks.

#### 4.3. Assembling sequence

4.3.1. First, modules should be formed by inserting rod radionuclide sources in scatterers of the corresponding standard sizes.

4.3.2. The modules should be assembled in separate blocks which model parts of the body of man: abdomen, thighs, chest, shins, arms, and head. The number of modules in blocks should correspond to Table 5:

Table 5

Block name	Number of modules in blocks of phantoms											
	P <sub>1</sub>		P <sub>2</sub>		P <sub>3</sub>		P <sub>4</sub>		P <sub>5</sub>		P <sub>6</sub>	
	one	half	one	half	one	half	one	half	one	half	one	half
Head (neck)	2	-	2	2	3	3	4	2	4	2	4	3
Chest	6	-	5	-	12	5	20	-	20	12	28	16
Arms	-	-	4	-	-	8	8	-	8	-	8	-
Abdomen	-	-	3	2	6	3	13	-	14	8	19	8
Thighs	4	-	3	2	9	5	14	-	14	10	17	9
Shins	-	-	4	-	6	4	10	-	12	4	14	4
Total	12	-	21	6	36	28	69	2	72	36	90	40

4.3.3. The phantom should be assembled joining blocks in the sequence indicated in the list of point 4.3.2.

4.3.4. Assembling of phantoms in the geometry "standing (lying)", "sitting", and "sitting bending" should correspond to the schemes presented in Figs. 7 to 12.

4.3.5. Disassembling of a phantom should be performed in the reverse sequence. The difference: the rod radionuclide sources should be removed out of the blocks by means of the pusher before disassembling the blocks.

## 5. TECHNICAL DATA

5.1. The values of metrological parameters of the reference samples are presented in the basic text of the Certificate.

5.2. The values of additional parameters of the reference samples - the phantoms P<sub>1</sub> to P<sub>6</sub> are presented in Table 6:

Table 6

Phantom index*	Values of additional parameters				
	Mass, kg	Height, cm	Height sitting, cm	Average thickness, cm	Density, g/cm <sup>3</sup>
P <sub>1</sub>	10.6	82.5	44.0	8.8	0.95
P <sub>2</sub>	20.9	121.0	66.0	9.4	
P <sub>3</sub>	40.9	160.0	77.0	11.5	
P <sub>4</sub>	61.5	170.5	88.0	13.0	0.95
P <sub>5</sub>	77.8	170.5	88.0	14.3	
P <sub>6</sub>	95.2	170.5	88.0	17.8	

## 6. STORAGE AND TRANSPORTATION

6.1. The conditions of transportation and storage of the article should correspond to the requirements to operation conditions (See 2.2).

6.2. The set UPh-08T should be transported by air and motor transport in heated and sealed sections, in package which excludes possibility of the article damage.

6.3. The set UPh-08T should be stored in the market container. The article does not require attendance during storage.

\* The phantoms P<sub>1</sub>, P<sub>2</sub>, and P<sub>3</sub> simulate the average body build of a child one year of age (mass 12 kg), of a child six years of age (mass 24 kg), and a teenager of fourteen years of age (mass 50 kg), respectively; the phantoms P<sub>4</sub>, P<sub>5</sub>, and P<sub>6</sub> simulate the body build of adult persons with the mass of 70, 90, and 110 kg, respectively.

## LIST OF ABBREVIATIONS

IRS	-	Industry Reference Sample
SRIHST	-	Scientific-Research Institute for Hygiene of Sea Transport
PhTh	-	Phantom of Thyroid
SIA ASRIM	-	Scientific-Industrial Amalgamation "All-Union Scientific-Research Institute for Metrology"
ASRIMRS	-	All-Union Scientific-Research Institute for Metrology of Reference Samples
SRIISM	-	Scientific-Research Institute for Industrial and Sea Medicine

Geometry "standing (lying)"

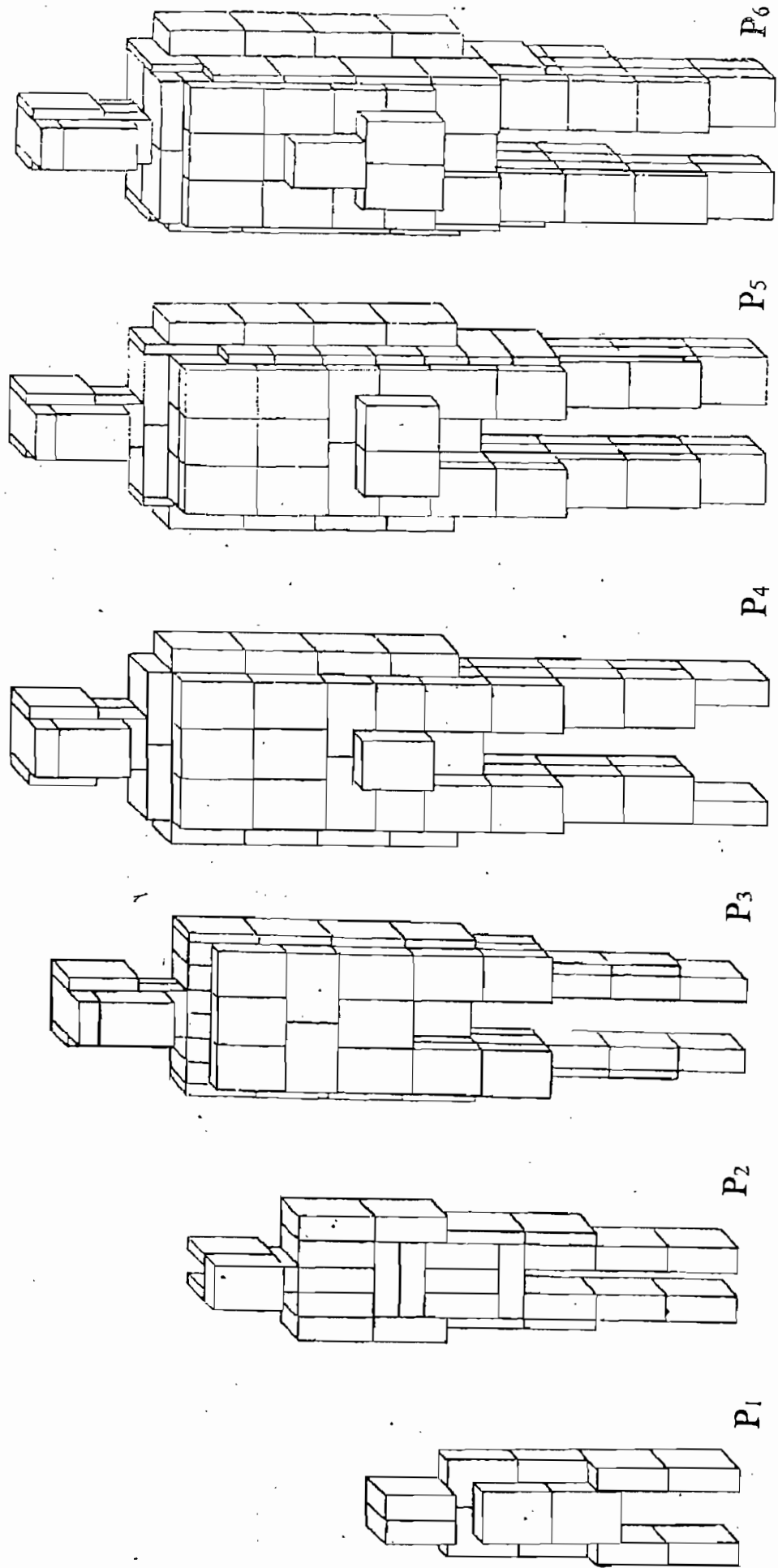


Fig. 1.

Geometry "sitting"

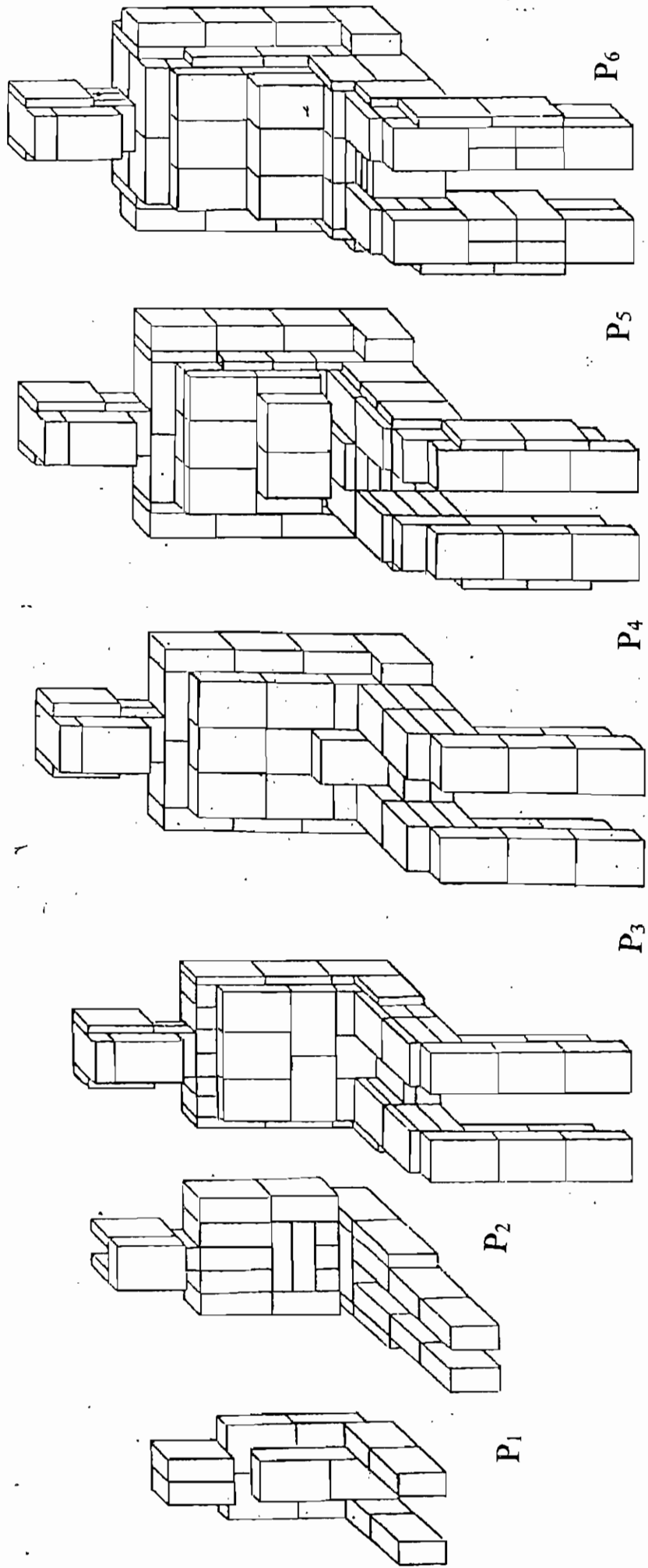


Fig. 2.

Geometry "sitting bending"

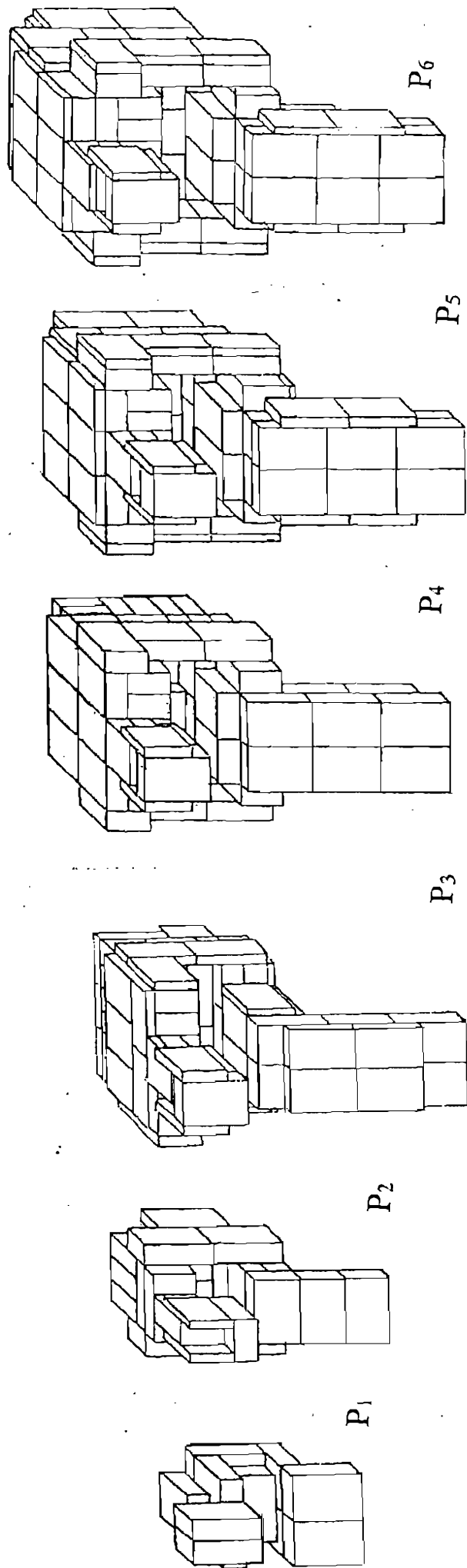
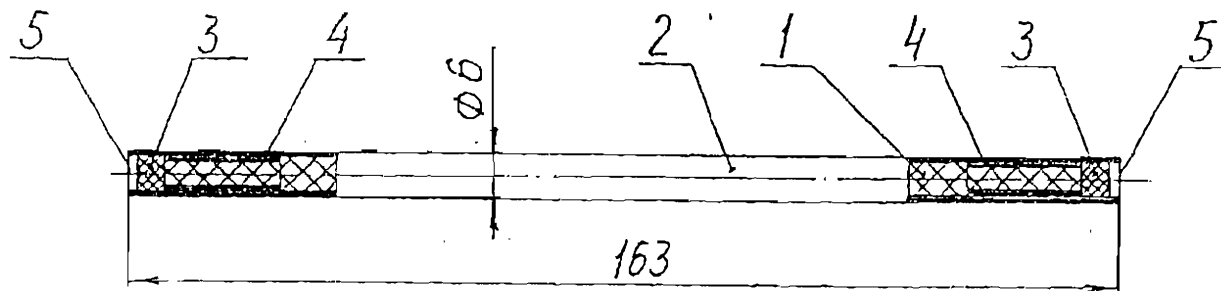


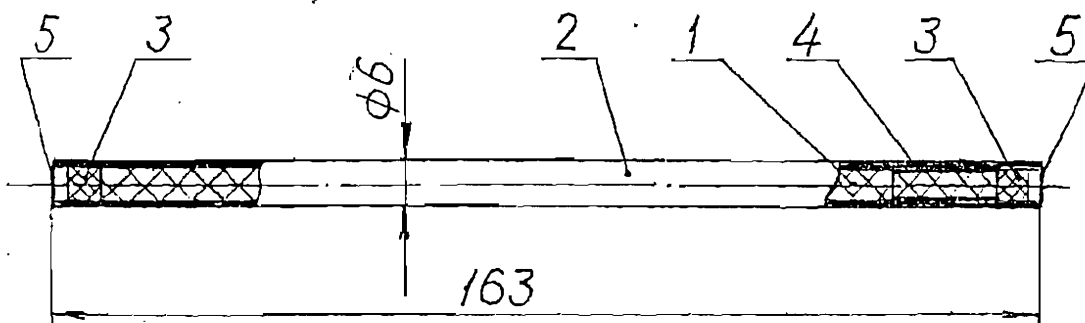
Fig. 3.

# Rod radionuclide source

a)



b)



1 - active part of source

2 - capsule

3 - plug

4 - control label

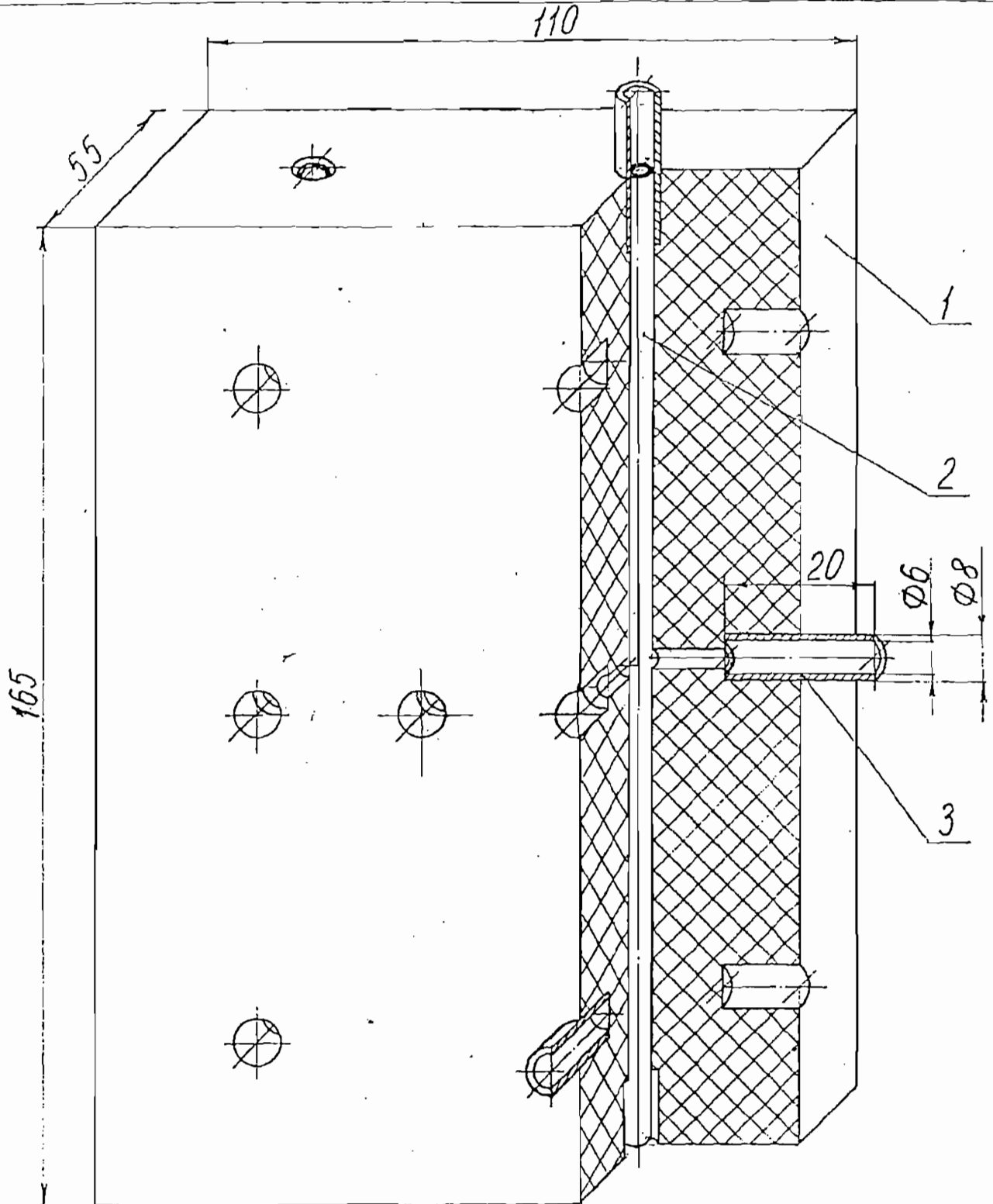
5 - colored label

a) one-piece source

b) half-piece source

Fig. 4.

Unified module (one-piece)

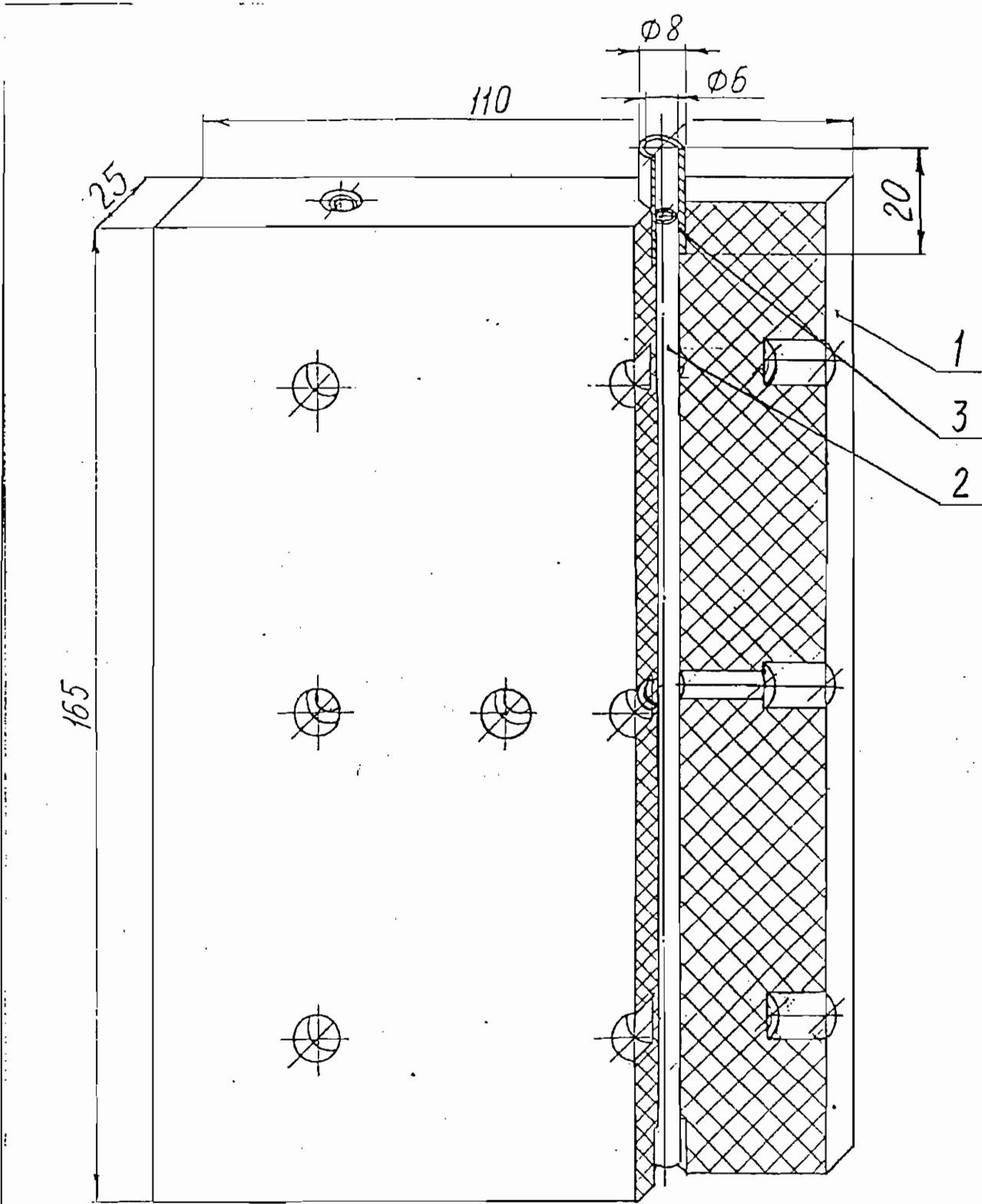


- 1 - scatterer
- 2 - rod radionuclide source
- 3 - connector

Fig. 5.



Unified module (half-piece)



- 1 - scatterer
- 2 - rod radionuclide source
- 3 - connector

Fig. 6.

Scheme for assembling phantoms  $P_1$ ,  $P_2$ , and  $P_3$  in geometry "standing (lying)"

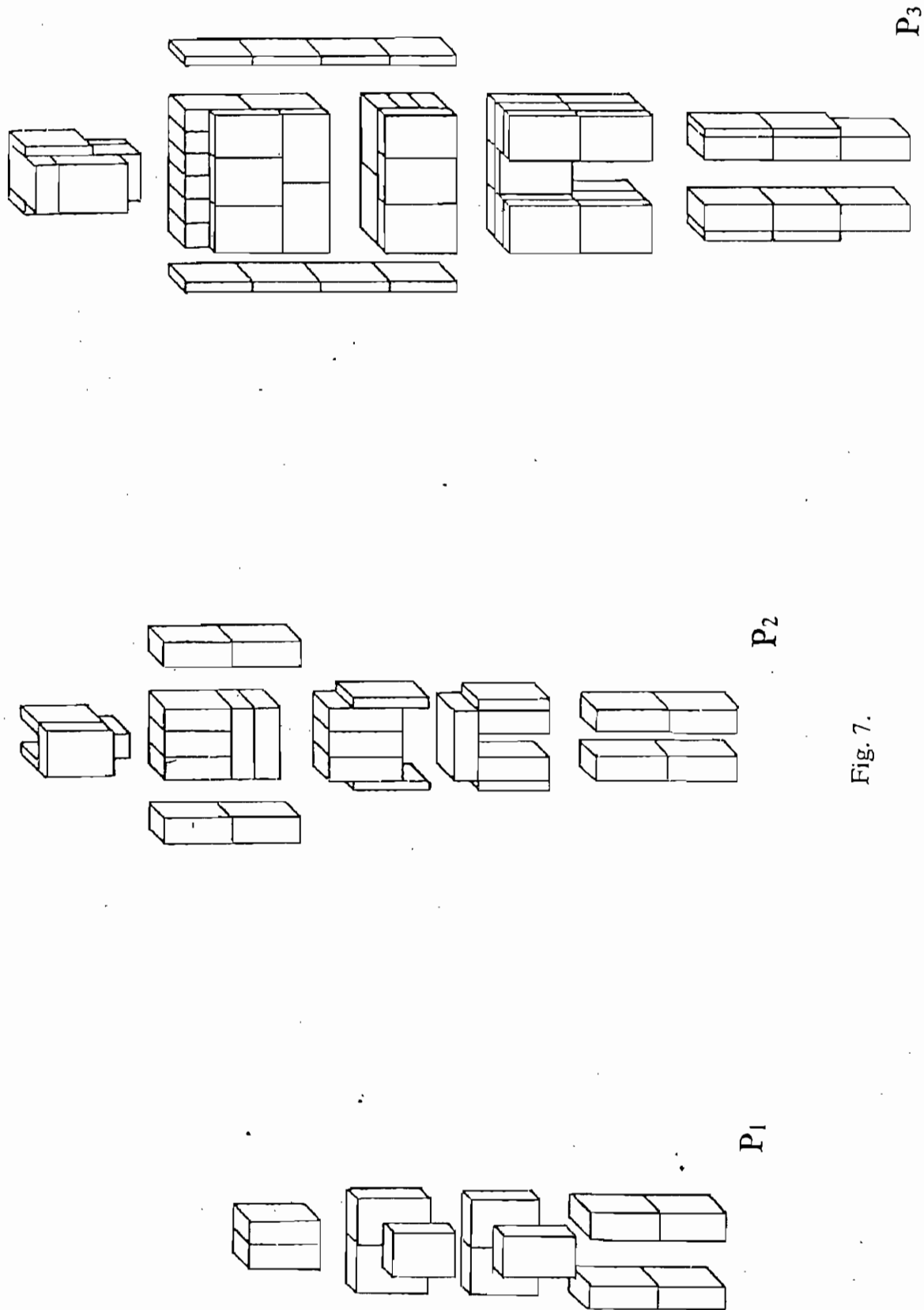


Fig. 7.

Scheme for assembling phantoms  $P_4$ ,  $P_5$ , and  $P_6$  in geometry "standing (lying)"

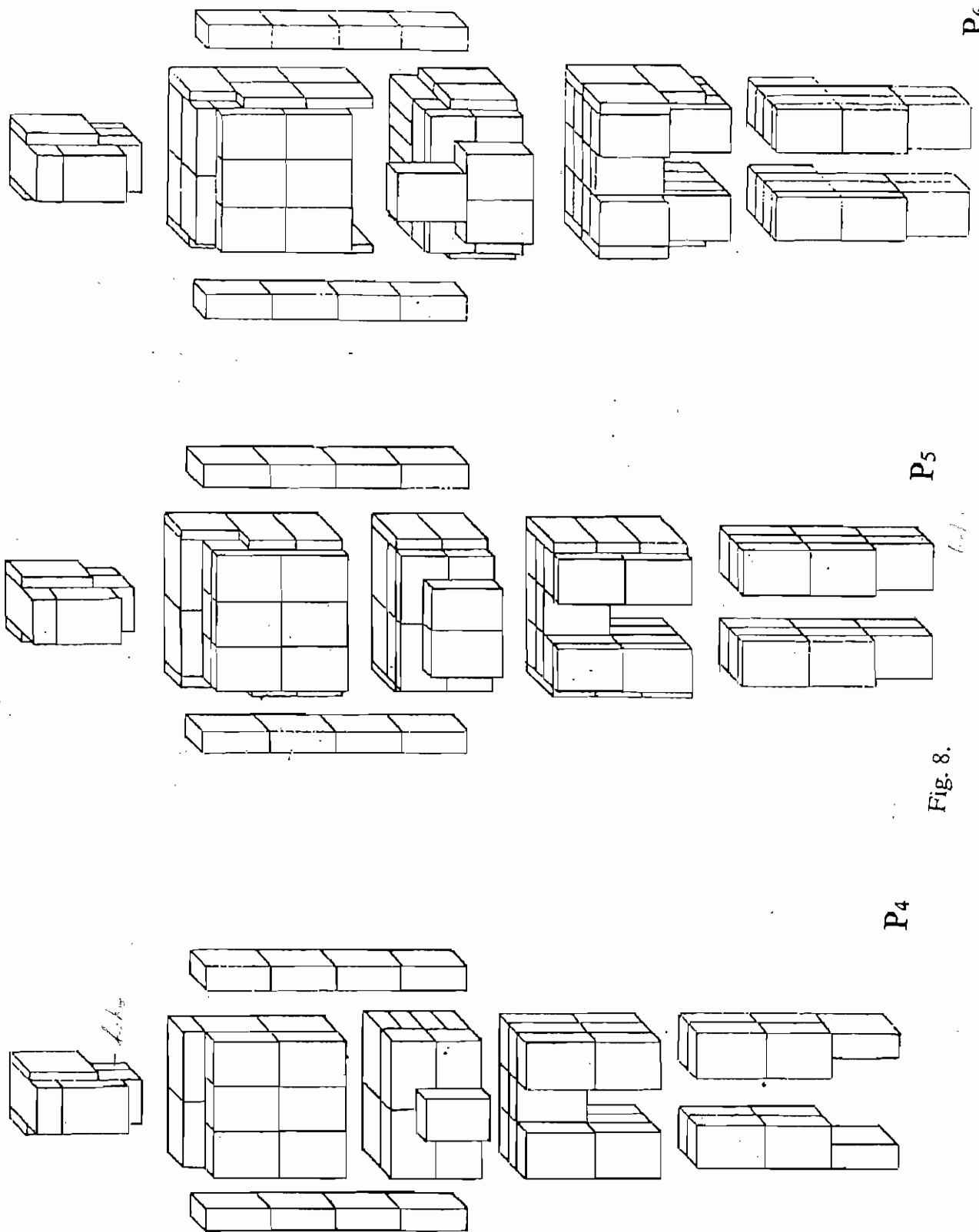


Fig. 8.

Scheme for assembling phantoms  $P_1$ ,  $P_2$ , and  $P_3$  in geometry "sitting"

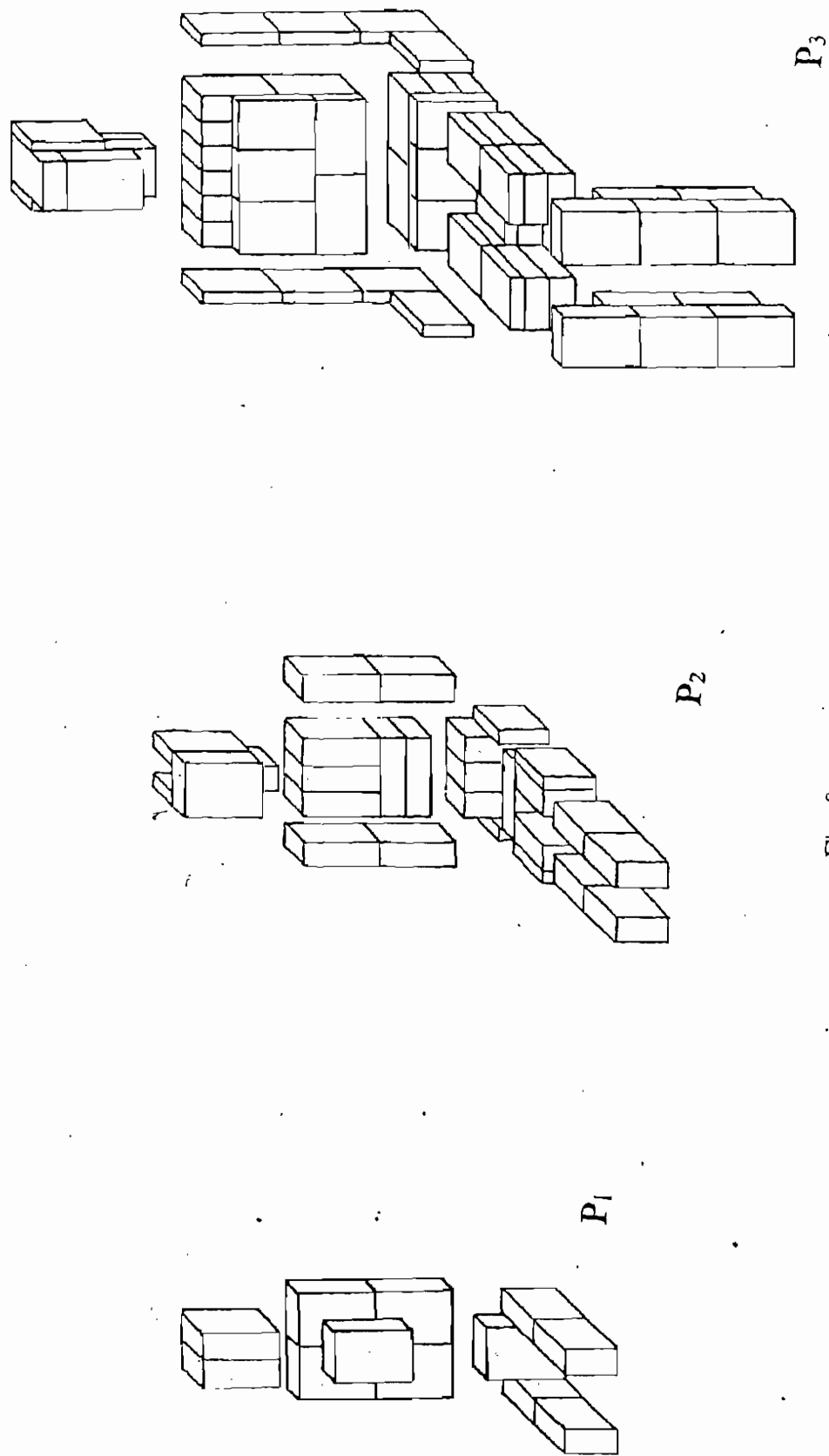


Fig. 9.

Scheme for assembling phantoms  $P_4$ ,  $P_5$ , and  $P_6$  in geometry "sitting"

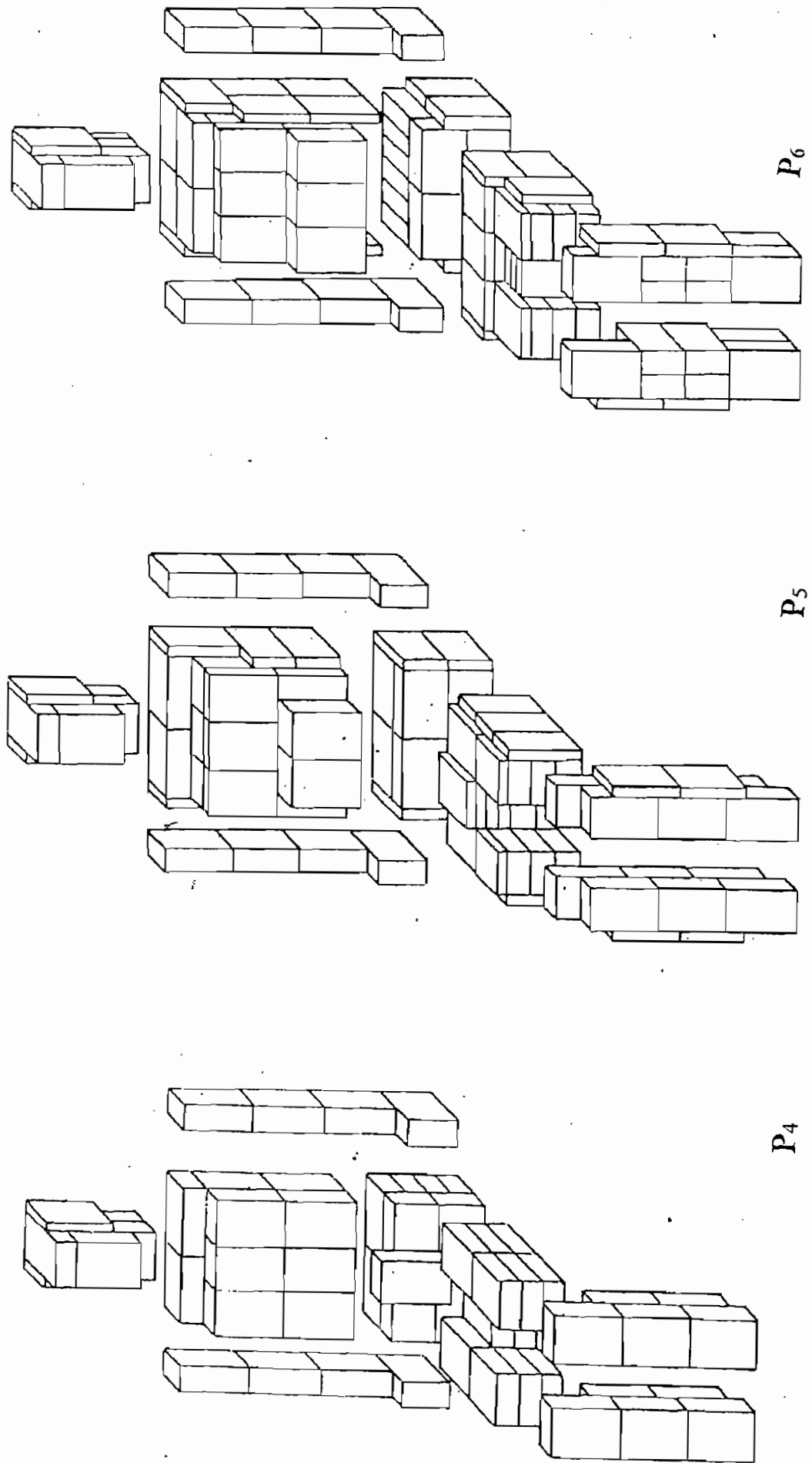


Fig. 10.

Scheme for assembling phantoms  $P_1$ ,  $P_2$ , and  $P_3$  in geometry "sitting bending"

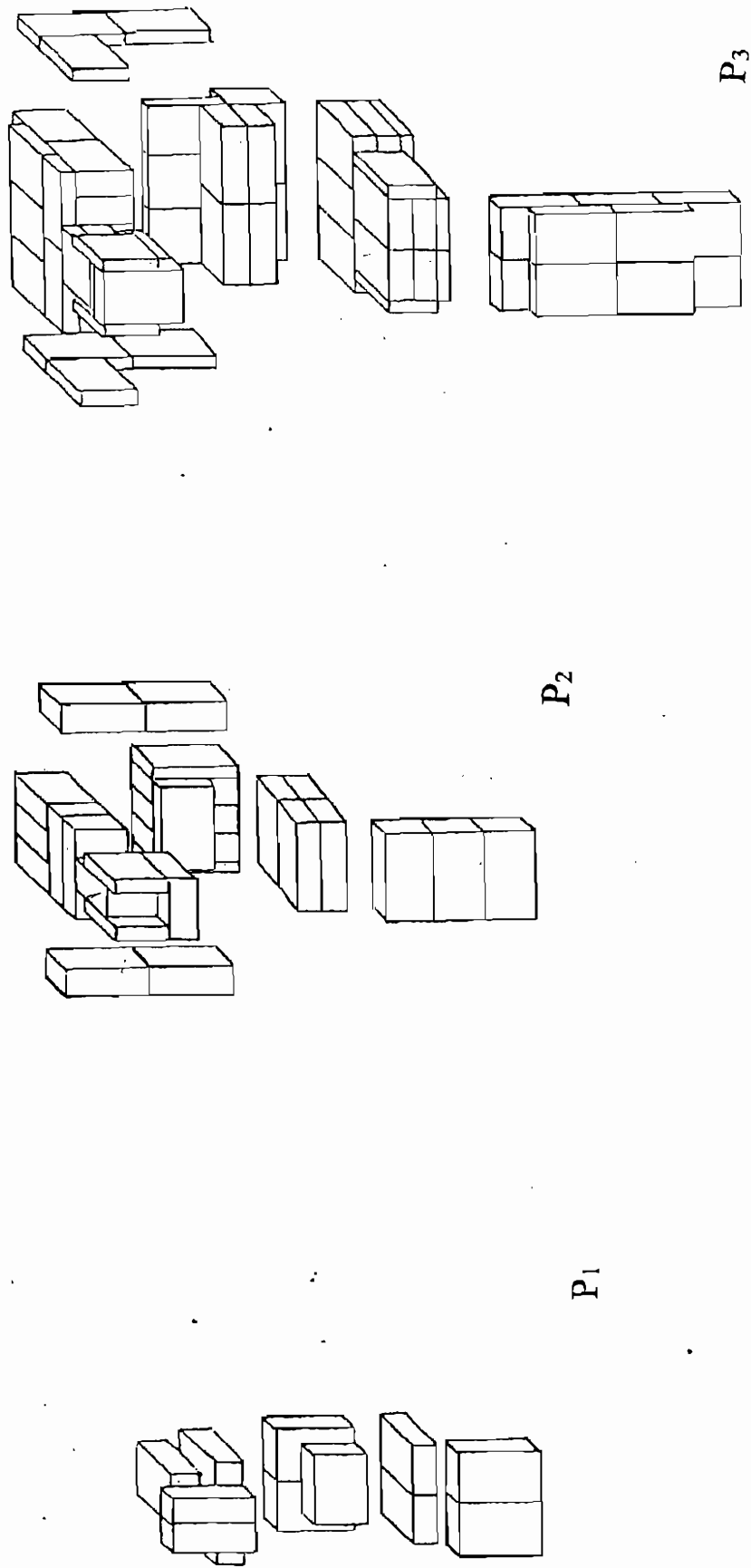


Fig. 11.