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I	0,3-0,5	-	-	-	99,9-80	<80
II	2	-	-	99,9-92	92-45	-
III	4	-	99,9-99	99-80	-	-
IV	8	>99,9	99-95	-	-	-
V	20	>99	-	-	-	-

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	V	IV	IV	III	III	II	II	I	I

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%,	80	80...99	45...92	92...99	80...99	99...99,9	95...99,9	99,9	99

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1	2	3	4	5	6	7	8
- - ,	100	100- 300	750- 1250	750- 1500	5000- 12500	750-1500	100-400
	<i>m</i>	S		<i>Stk</i>		<i>d</i> <0,3 <i>D</i> ; <i>d</i> >0,3 <i>Stk</i>	<i>K_E</i>
- - :							
:	<i>f(d²,C)</i>					<i>d</i> < 0,3 <i>f(c /d)</i> ; <i>d</i> >0,3 <i>f(d²/c)</i>	<i>f(d²,C)</i>

-	- -	f(C / ~)				d <0,3 f(C T / ~) ; d >0,3 f(C / ~)	f(C / ~)
-		- - -		-		- (20 / ^3)	C = $\frac{n\ e... \ d}{12v_0E}$
				-			- -
- - -<							

$$v = (1 - \frac{C}{V}) \cdot 100\% \quad (1.1)$$

$$v = 1 - \frac{C}{V} \cdot 100\%$$

$$v = 1 - \frac{C}{V} \cdot 100\%$$

$$v = \left(1 - \frac{C}{V}\right) \cdot 100\%$$

$$v = \left(1 - \frac{C}{V}\right) \cdot 100\%$$

$$v = \frac{m}{V}$$

$$m = \rho \cdot V$$

$$v = \frac{m}{V} \cdot 100 = \frac{\rho}{\rho_0} \cdot 100 = v \frac{\rho}{\rho_0}$$

$$\varphi =$$

$$\varepsilon$$

$$V = \frac{v_1 V_1 + v_2 V_2 + \dots + v_n V_n}{v_1 + v_2 + \dots + v_n}, \quad (1.2)$$

1, 2 ..., n - , ; $\varepsilon_1, \dots, \varepsilon_n$ -
2., ε_n -
,
:

$$\frac{M_1}{M} = u_1; \frac{M_2}{M} = u_2; \dots \frac{M_n}{M} = u_n.$$

$$V = u_1 V_1 + u_2 V_2 + \dots + u_n V_n \quad (1.3.)$$

$$v = 100\% \sum_1 u_i v_{i-1}.$$

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. (%) :

$$v = \frac{y}{y} \cdot 100 = \frac{y}{y} \cdot 100 = v \frac{y}{y},$$

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$$v = [1 - (1 - v_1) \cdot (1 - v_2) \dots (1 - v_n)] 100\%,$$

$\varepsilon_1, \varepsilon_2 \dots \varepsilon_n$ — , (

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 99 %, 98 %, 1 % 2 %
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 $v = v^n$,
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$$V^E = \frac{E_n}{E},$$
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2.1.

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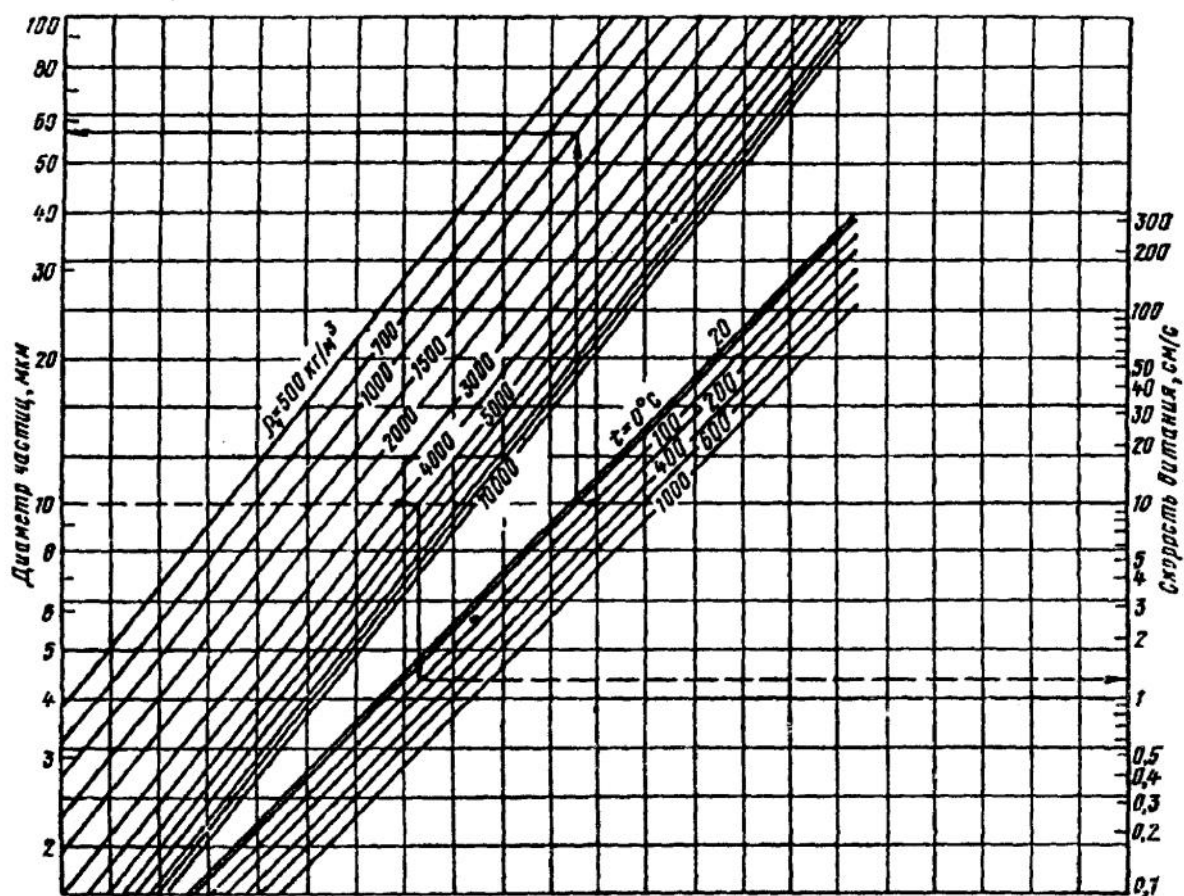
(100).

$$0,2...1 \quad / \quad ,$$

– 1...1,5 / .

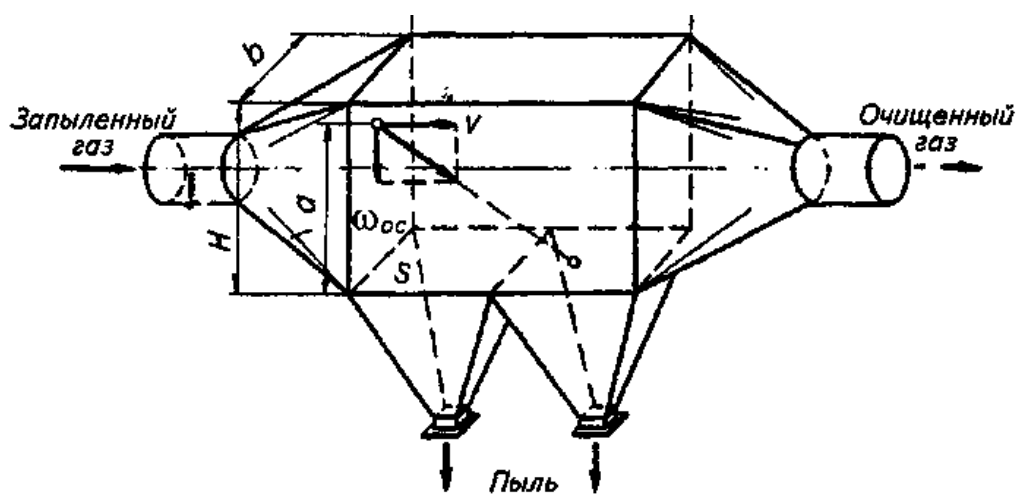
$$w_{oc} = \frac{g(\dots - \dots)d^2}{18\sim} \tag{2.1}$$

. 2.2.



. 2.2.

. 2.3



. 2.3.

$\quad , \quad , \quad v_0 \quad h \quad -$
 $\quad . \quad ,$

$$w_{oc}h_c = v_0l.$$

$$w_{oc} \quad h_c/H=v_0l/w_{oc}.$$

$$(H, L, B) \quad d^* \quad ,$$

$$\quad . \quad w_{oc}^* , \quad h_c/H = 1, \quad L =$$

$$w_{oc}^*/v. \quad v \quad , \quad ,$$

$$3,05 \quad / \quad , \quad , \quad . \quad ,$$

$$\quad = Q/v, \quad .$$

$$\quad ,$$

$$d \quad , \quad :$$

$$L=H\frac{v}{w}, \quad (2.2)$$

$$L - \quad , \quad - \quad .$$

$$\quad v \quad 0,2...0,8 \quad / \quad , \quad -$$

$$d \quad (2.1)$$

1.2.

$$\quad , \quad .$$

$$\quad , \quad -$$

$$\quad , \quad -$$

$$\quad , \quad -$$

$$(2.2).$$

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$$\quad .$$

$$L/H > 3 \quad -$$

$$(\quad \%) \quad -$$

:

$$v = 100 \left(1 - \frac{1}{i} \sum_0^i N_i \right),$$

i - , ; N_i -

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· ,
· , N
:

$$N = (x_1) + (x_2) - 1.$$

(x_1) (x_2) -

(2.1).

2.1

x	()	x	()	x	()	x	()
1	2	3	4	5	6	7	8
- 2,70	0,0035	- 1,06	0,1446	0,00	0,5000	1,08	0,8599
- 2,60	0,0047	- 1,04	0,1492	0,02	0,5080	1,10	0,8643
- 2,50	0,0062	- 1,02	0,1539	0,04	0,5160	1,12	0,8686
- 2,40	0,0082	- 1,00	0,1587	0,06	0,5239	1,14	0,8729
- 2,30	0,0107	- 0,98	0,1635	0,08	0,5319	1,16	0,8770
- 2,20	0,0139	- 0,96	0,1685	0,10	0,5398	1,18	0,8810
- 2,10	0,0179	- 0,94	0,1736	0,12	0,5478	1,20	0,8849
- 2,00	0,0228	- 0,92	0,1788	0,14	0,5557	1,22	0,8888
- 1,98	0,0239	- 0,90	0,1841	0,16	0,5636	1,24	0,8925
- 1,96	0,0250	- 0,88	0,1894	0,18	0,5714	1,26	0,8962
- 1,94	0,0262	- 0,86	0,1949	0,20	0,5793	1,28	0,8997
- 1,92	0,0274	- 0,84	0,2005	0,22	0,5871	1,30	0,9032
- 1,90	0,288	- 0,82	0,2061	0,24	0,5948	1,32	0,9066
- 1,88	0,0301	- 0,80	0,2119	0,26	0,6026	1,34	0,9099
- 1,86	0,0314	- 0,78	0,2177	0,28	0,6103	1,36	0,9131
- 1,84	0,0329	- 0,76	0,2236	0,30	0,6179	1,38	0,9162
- 1,82	0,0344	- 0,74	0,2297	0,32	0,6255	1,40	0,9192

- 1,80	0,0359	- 0,72	0,2358	0,34	0,6331	1,42	0,9222
- 1,78	0,0375	- 0,70	0,2420	0,36	0,6406	1,44	0,9251
- 1,76	0,0392	- 0,68	0,2483	0,38	0,6480	1,46	0,9279
- 1,74	0,0409	- 0,66	0,2546	0,40	0,6554	1,48	0,9306
- 1,72	0,0427	- 0,64	0,2611	0,42	0,6628	1,50	0,9332
- 1,70	0,0446	- 0,62	0,2676	0,44	0,6700	1,52	0,9357
- 1,68	0,0465	- 0,60	0,2743	0,46	0,6772	1,54	0,9382
- 1,66	0,0485	- 0,58	0,2810	0,48	0,6844	1,56	0,9406
- 1,64	0,0505	- 0,56	0,2877	0,50	0,6915	1,58	0,9429
- 1,62	0,0526	- 0,54	0,2946	0,52	0,6985	1,60	0,9452
- 1,60	0,0548	- 0,52	0,3015	0,54	0,7054	1,62	0,9474
- 1,58	0,0571	- 0,50	0,3085	0,56	0,7123	1,64	0,9495
- 1,56	0,0594	- 0,48	0,3156	0,58	0,7190	1,66	0,9515
- 1,54	0,0618	- 0,46	0,3228	0,60	0,7257	1,68	0,9535
- 1,52	0,0643	- 0,44	0,3300	0,62	0,7324	1,70	0,9554
- 1,50	0,0668	- 0,42	0,3372	0,64	0,7389	1,72	0,9573
- 1,48	0,0694	- 0,40	0,3446	0,66	0,7454	1,74	0,9591
- 1,46	0,0721	- 0,38	0,3520	0,68	0,7517	1,76	0,9608
- 1,44	0,0749	- 0,36	0,3594	0,70	0,7580	1,78	0,9625
- 1,42	0,0778	- 0,34	0,3669	0,72	0,7642	1,80	0,9641
- 1,40	0,0808	- 0,32	0,3745	0,74	0,7703	1,82	0,9656
- 1,38	0,0838	- 0,30	0,3821	0,76	0,7764	1,84	0,9671
- 1,36	0,0869	- 0,28	0,3897	0,78	0,7823	1,86	0,9686
- 1,34	0,0901	- 0,26	0,3974	0,80	0,7881	1,88	0,9699
- 1,32	0,0934	- 0,24	0,4052	0,82	0,7939	1,90	0,9713
- 1,30	0,0968	- 0,22	0,4129	0,84	0,7995	1,92	0,9726
- 1,28	0,1003	- 0,20	0,4207	0,86	0,8051	1,94	0,9738
- 1,26	0,1038	- 0,18	0,4286	0,88	0,8106	1,96	0,9750
- 1,24	0,1075	- 0,16	0,4364	0,90	0,8159	1,98	0,9761
- 1,22	0,1112	- 0,14	0,4443	0,92	0,8212	2,00	0,9772
- 1,20	0,1151	- 0,12	0,4522	0,94	0,8264	2,10	0,9821
- 1,18	0,1190	- 0,10	0,4602	0,96	0,8315	2,20	0,9861
- 1,16	0,1230	- 0,08	0,4681	0,98	0,8365	2,30	0,9893

- 1,14	0,1271	- 0,06	0,4761	1,00	0,8413	2,40	0,9918
- 1,12	0,1314	- 0,04	0,4840	1,02	0,8461	2,50	0,9938
- 1,10	0,1357	- 0,02	0,4920	1,04	0,8508	2,60	0,9953
- 1,08	0,1401	- 0,00	0,5000	1,06	0,8554	2,70	0,9965

$$x_1 \quad x_2, \quad , \quad :$$

$$x_1 = \frac{H + h - L \frac{w}{v}}{\sqrt{2D_t - l/v}}; \quad (2.3)$$

$$x_2 = \frac{H - h + L \frac{w}{v}}{\sqrt{2D_t - l/v}}; \quad (2.4)$$

h - ; D_t - .

$$w < L g / v, \quad -$$

,

:

$$D_t = 0,02 v \cdot H \sqrt{\quad},$$

} - , 0,03.

(2.3) (2.4) :

$$x_1 = \frac{1 + h/H - L/H(w/v)}{\sqrt{7 \cdot 10^{-3} \cdot L/H}}, \quad (2.5)$$

$$x_2 = \frac{1 - h/H + L/H(w/v)}{\sqrt{7 \cdot 10^{-3} \cdot L/H}}, \quad (2.6)$$

$$(w/v)_{50} \approx 1,5 \cdot H/L.$$

$$w/v, \quad -$$

$$v = f(d), \quad (w/v)_{50}. \quad -$$

:

$$v = \sum v \frac{N}{100} \Delta d, \quad (2.7)$$

N - , %/ ; Δd -

, .

$$x_2 = \frac{1 - \frac{h}{H} + \frac{L}{H} \cdot \frac{w}{v}}{\sqrt{7 \cdot 10^{-3} \frac{L}{H}}};$$

) x_1 x_2 2.1 $\Phi(x_1)$ $\Phi(x_2)$ -

N_i :

$$N_i = \Phi(x_1) + \Phi(x_2) - 100;$$

) N , -

:

$$N_{cp} = \sum_{i=1}^k \frac{N_i}{k};$$

) -

(-):

$$v_{\text{н}} = 100 - N_{cp}.$$

7. ε -

() (2.7):

$$v = \sum v \frac{N}{100} \Delta d.$$

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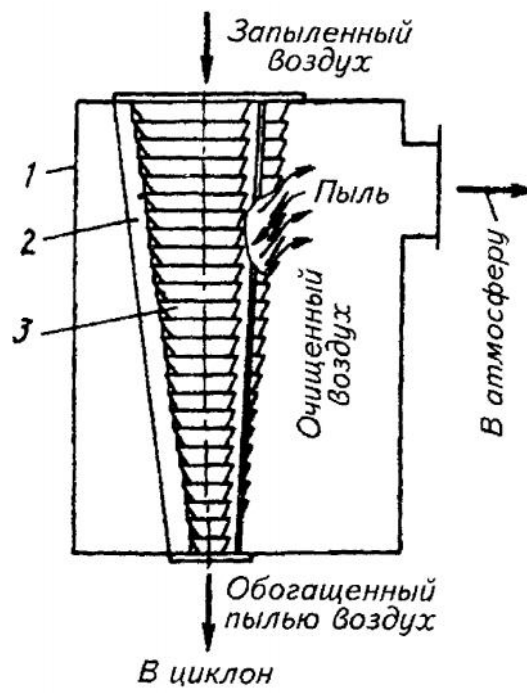
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.2.4.

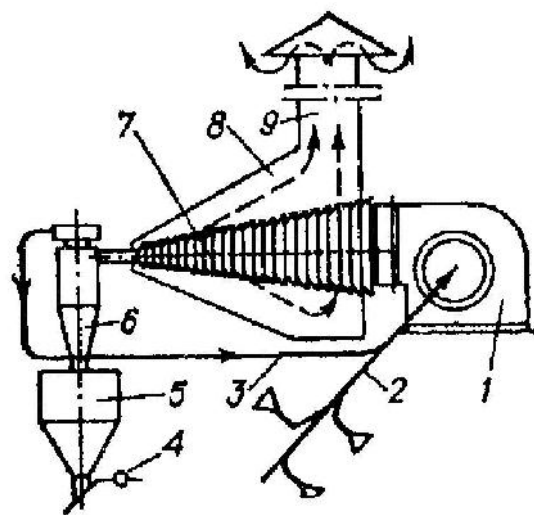
1 – ; 2 – ; 3 –

18 /

5...10 %

90 %.

(60...70)



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1 – ; 2 – ; 3 –
 ; 4 – ; 5 – ; 6 – ; 7 – ; 8 –
 ; 9 –

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 10 20%.

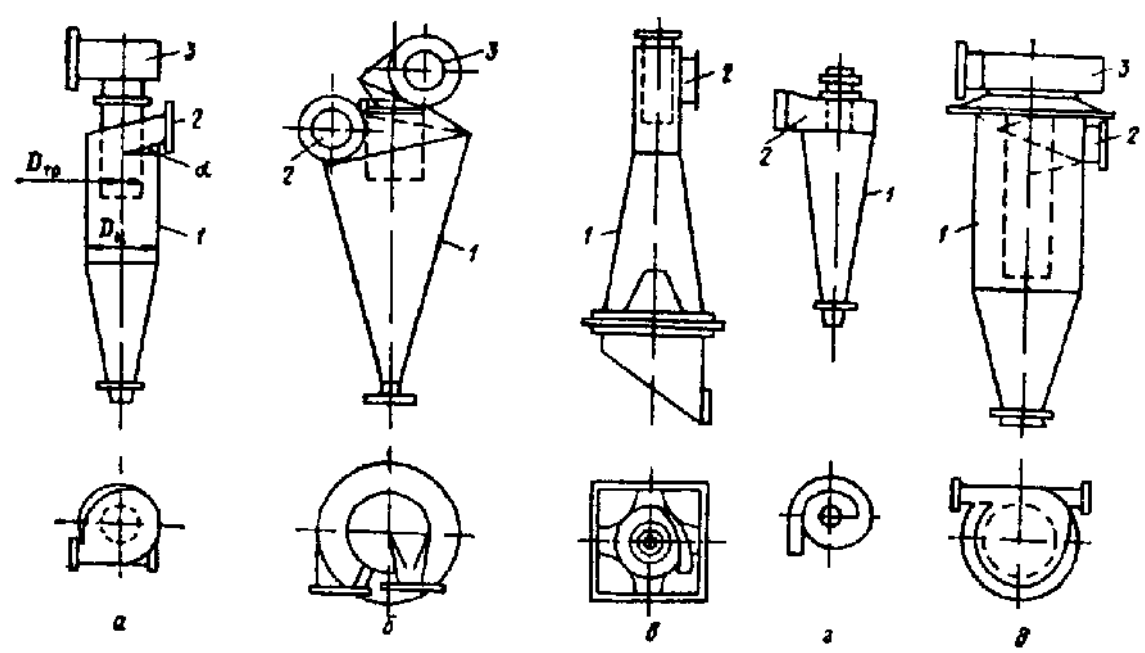
2.3.

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 m^{-2}/r . $= 15 / , r = 0,6$
 39
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 80...95 %
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 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1200, 1400, 1600, 1800, 2000, 2400 3000 .
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 $1,5 D$ $1,1...1,2 D$.
 $0,8 D$, $- 60^{\circ}$.
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 (500...600).
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I.6.

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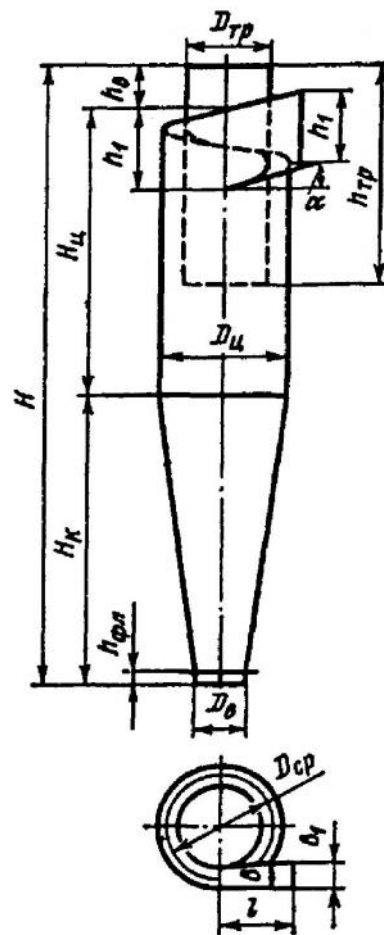
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2.3.1.

(. 2.7) -11, -15, -15 , -24.

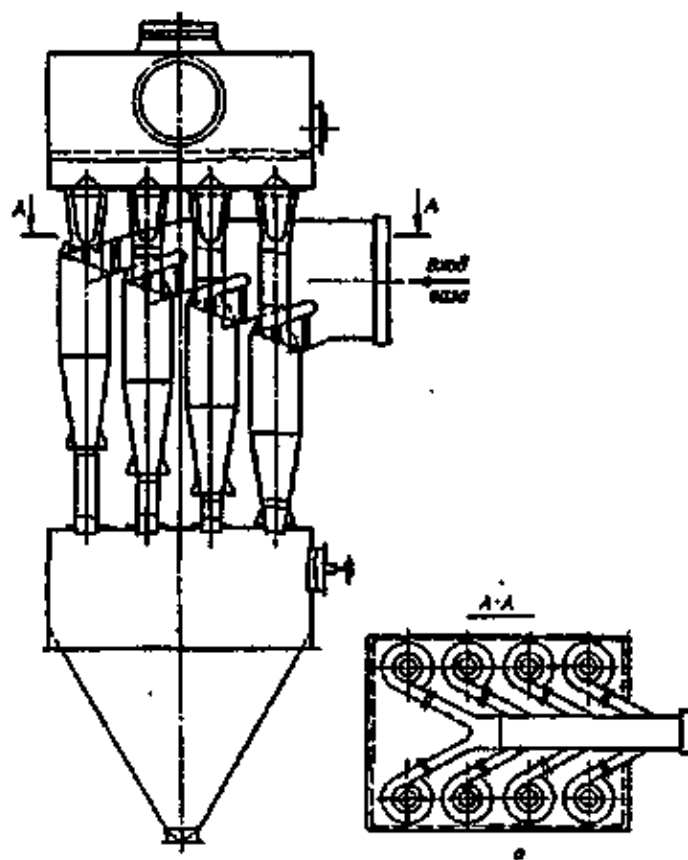
-15

-15.



. 2.7.

(.2.8).



.2.8.

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-11, -15,

-15 , -24

.2.2.

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-11, -15, -15 , -24

	-15; -15 ; -24	-11
1	2	3
- , d	0,59	
- , d_1	0,3-0,4*	
- (), b	0,2	
((), b_1	0,26	
, l	0,6	
, D_{cp}	0,8	
, h	0,1	
, α	15°; 15°; 24°	11°
(- ,)	0,66; 0,66; 1,11	0,48
, h	1,74; 1,5; 2,11	1,56
- ,	2,26; 1,51; 2,11	2,06
,	2,0; 1,50; 1,75	2,0
, h	0,3; 0,3; 0,4	0,3
,	4,56; 3,31; 4,26	4,38

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D

- -33, - -34, -

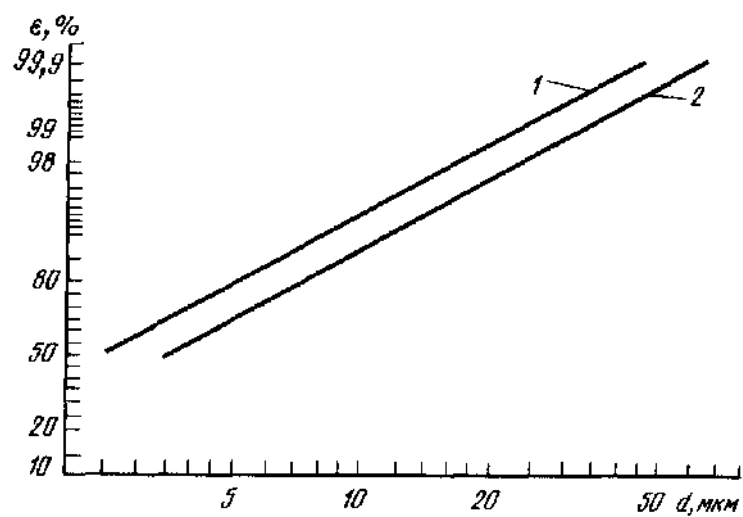
-34 (. 2.6, ; . 2.3).

(D)
 - -33, - -34, - -34

	- -33	- -34	- -34
D	3500		4000
,	0,535	0,515	0,4
,	3,0	2,110	2,6
d	0,334	0,340	0,22
d_1	0,334	0,229	0,18
b	0,264	0,214	0,18
h	0,2-0,3	0,2-0,3	0,3
h	0,1	0,1	0,1
a	0,535	0,515	0,4
l	0,6	0,6	0,6
h	0,535	0,515	0,4
ρ	$D/2+b\varphi/2\pi$	$D/2+b\varphi/\pi$	$D/2+b\varphi/\pi$

-11, -15

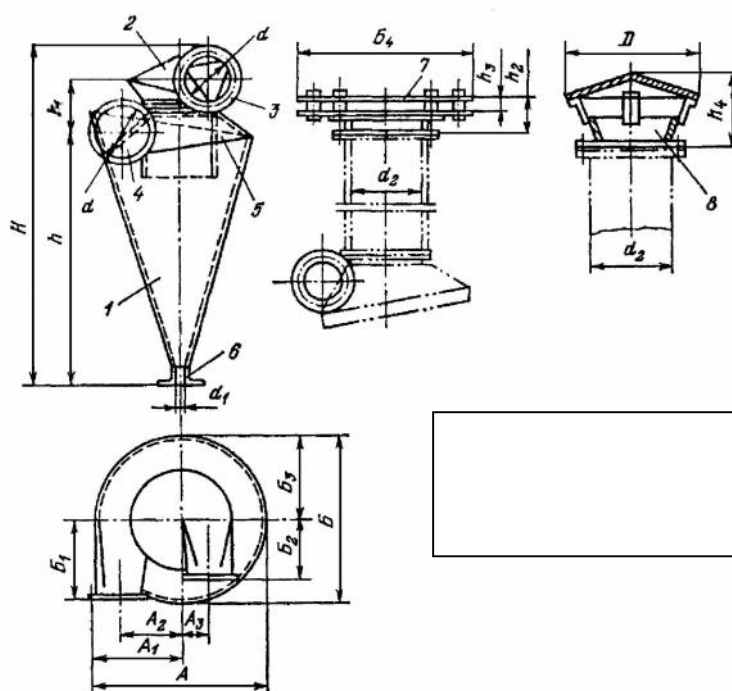
. 2.9.



. 2.9.

1 - -11, 2- -15

(. 2.10, . 2.4).



. 2.10.

1 - : 2 -

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; 7 -

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2.4

-	-	,									,
		1	2				h	h_1	d	d_1	
1	1,5	703	264	135	675	1720	1360	235	170	68	51
2	3	1045	380	195	970	2455	1960	335	245	98	102
3	4,5	1242	465	240	1184	2995	2400	407	300	120	148
4	6	1428	535	275	1363	3440	2765	460	345	138	195
5	7,5	1595	597	310	1520	3830	3075	525	385	154	244
6	8,5	1698	635	330	1620	4080	3280	555	410	164	275
7	10	1943	690	335	1758	4423	3555	605	445	178	323

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)(.2.11, .2.5).

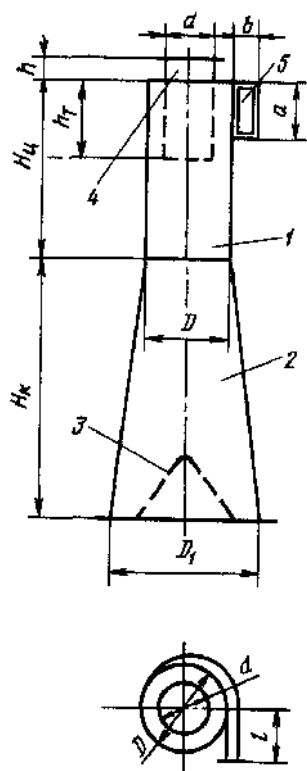
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. 2.11.

1 — ; 2 — ; 3 — ; 4 — ; 5 — -

2.5

(D)

1	2
, D	1000
,	2,0
,	3,0
, d	0,5
, D ₁	1,6
, D ₂	1,4
, d ₁	0,1
, h	0,68
, h	2,1

,	5,2
, <i>l</i>	0,6
,	1,0
, <i>b</i>	0,25

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17 %; -15 10 % , -11.

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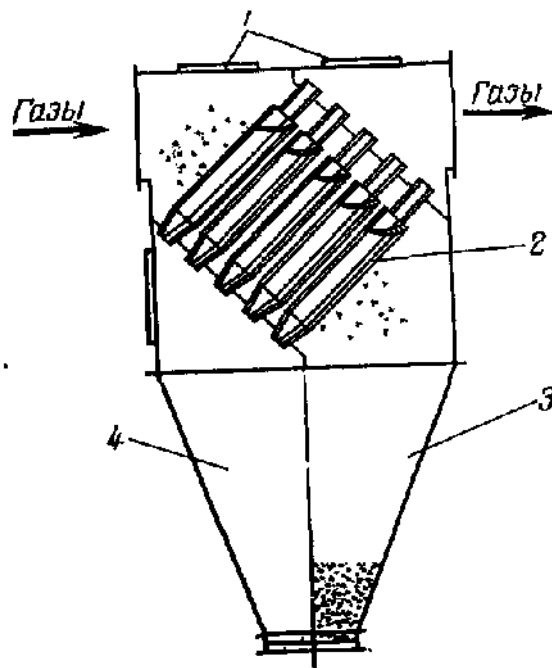
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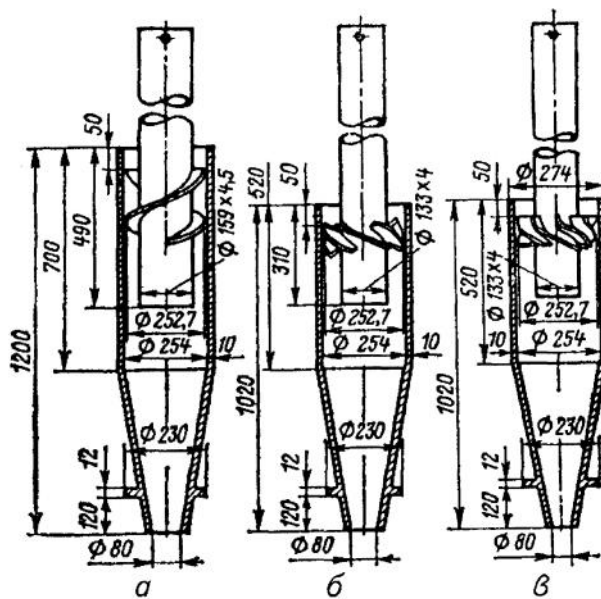
. 2.12.

1 —

; 2 —

; 3 —

; 4 —



. 2.13.

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« »; — « »;

« »

2.6,

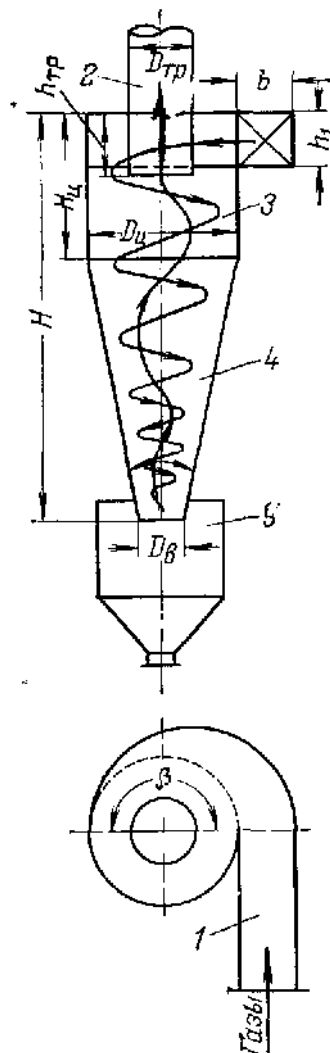
2.7.

2.6.

-	-	-	-	-	-	-
	,		, 3/	-	-	-
-254	25, 30, 40, 50, 60, 80	4,5	5,5...16	90		- - (400)
-2	20, 25, 30, 36, 42, 46	4,5	4,2; 5,25; 6,3; 7,55; 9,2; 11,7	65		- -
	24, 36, 48, 92, 116, 140	3,5	3,3; 7,0; 9,7; 13,9; 20,8; 27,8	120	-	- 150

$$V = (f/4) \{ [(H - H_1) / (D - D_1)] [(D^3 - D_1^3) / 3] + D^2 H - D_1^2 h_1 \}$$

$$v = 1 - \exp[-2(cE)^{1/(2n+2)}]. \tag{2.8}$$



2.14.

1 – ; 2 – ; 3 – ; 4 – ; 5 –

(2.8)

$$\begin{aligned} l/D &= 2,3(D/D)(D^2/F)^{1/3}; \\ D'/D &= [D - (D - D)(h + l - H)/(H - H)]/D. \end{aligned} \quad (2.7)$$

$$D'/D = [D - (D - D')(h + l - H)] / (H - H') / D.$$

$$n = 1 - (1 - 0,016D)^{0,14} (T / 283)^{0,3},$$

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(. .

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$$\Delta p = \zeta \cdot v^2 \cdot \rho / 2,$$

ζ –

; v –

, / .

-

()

v_0 ,

$$\Delta p = \zeta_0 \cdot v_0^2 \cdot \rho / 2,$$

ζ_0 -

,

; v_0 –

3...3,5 / .

ζ

Re.

. 2.8.

2.8

		ξ	ξ_0	ξ	ξ_0
-11	450	6,1	250	5,2	210
-15	450	7,6	160	6,7	140
-15	450	8,2	170	7,5	100
-24	450	10,9	80	12,5	90
		6,0	-	4,2	-
	370	9,3	-	10,4	-
1	2	3	4	5	6
	700	4,2	460	3,7	411
		5;2	-	-	-
		5,0	-	-	-

		9,6	-	-	-
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, () :
 $\zeta = K_1 K_2 \xi$. K_1 - (. 2.9); K_2 -
(. 2.10); ξ . -

. 2.8.

2.9

K_1

, 1	-11 2	-15; -15 ; -24 3	- -33; - - 34; - -34 4
150	0,94	0,85	1,0
200	0,95	0,90	1,0
300	0,96	0,93	1,0
450	0,99	1,0	1,0
500	1,0	1,0	1,0

2.10

K_2 ($D = 500$)

	K_2 , / ³						
	0	10	20	40	80	120	150
-11	1	0,96	0,94	0,92	0,90	0,87	0,5
-15	1	0,93	0,92	0,91	0,90	0,87	0,86
-15	1	0,93	0,92	0,91	0,89	0,88	0,87
-24	1	0,95	0,93	0,92	0,90	0,87	0,86
- -33	1	0,81	0,785	0,78	0,77	0,76	0,745
- -34 -	1	0,98	0,947	0,93	0,915	0,91	0,90
-34	1	0,99	0,97	0,95	-	-	-

:

- (), V , $^3/$;
 - ρ , $/^3$;
 - μ , ;
 - , : d_m $\lg \sigma$;: d_m - d_m ;
 - $\lg \sigma$ - ;
 - , $/^3$;
 - ρ , $/^3$;
 - ε , %.
1. . 2.11. -
- v .

2.11

	-24	-15	-15	-11	-	- -	-		
					-33	34	-34		
d_{50} ,	8,50	6,00	4,50	3,65	2,31	1,95	1,13	2,6	8,6
$\lg \sigma$	0,308	0,283	0,352	0,352	0,364	0,308	0,340	0,28	0,32
v , /	4,5	3,5	3,5	3,5	2,0	11,7	2,0	1,00	4,00

- :1. d_{50} ,
- : $v = 3,5 /$; $D = 0,6$;
- $\rho = 1930 /^3$; $\mu = 22,2 \cdot 10^{-6}$.

2. , 2 :

$$S = \frac{V}{v} .$$

3. , , N :

$$D = \sqrt{\frac{S}{0,785 N}} .$$

- 4.

$$v = \frac{V_p}{0,785 \cdot D^2 N}.$$

15 %.

5. . 2.8

. . 2.9 2.10.

6. , ,

$$\Delta p = g \frac{\dots v^2}{2}.$$

Δp ,

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7. . 2.11. $d_{50} \lg \sigma$, -

d_{50} (, , , -
)

$$d_{50} = d_{50} \left(\frac{D}{D} \cdot \frac{\dots}{\dots} \cdot \frac{\sim}{\sim} \cdot \frac{v}{v} \right)^{1/2}.$$

8. x

$$x = \frac{\lg \frac{d_m}{d_{50}}}{\lg^2 \uparrow + \lg^2 \uparrow}. \quad (2.9)$$

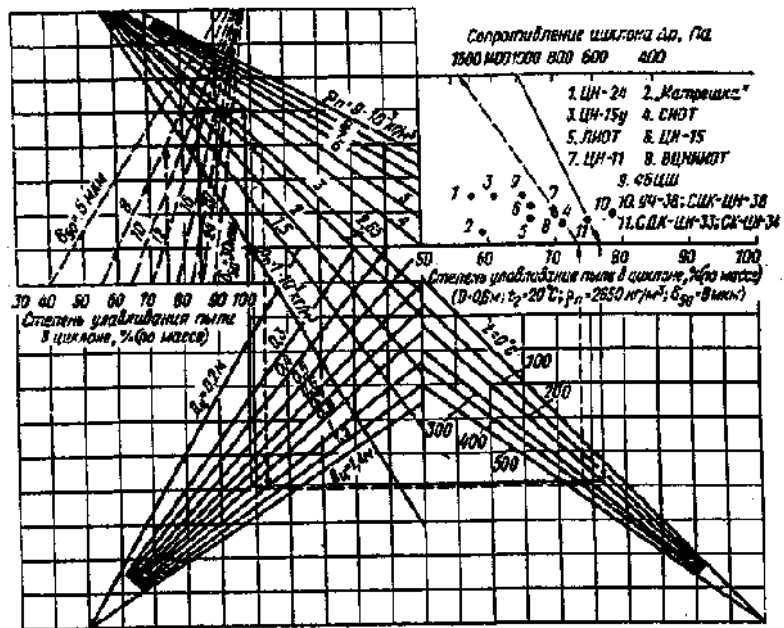
9. . 2.1. (),

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. 2.15.

$$\zeta = K_1 \cdot K_2 \cdot \zeta_0 + K_3,$$

K_3 -

(. 2.12).

2.12

K_3

()

	K_3
,	60
;	
,	60
,	35
,	28

1. w 3,5...5 / .
 , -

2. V_1 :
 $V_1 = 0,785 w D^2$, $^3/$.
 D 250 .

3. :
 $N = V / V_1$.

4. ,

5. Δp :

$$\Delta p = g \cdot w^2 / 2,$$

g .

6. ε_1 -
 d_{50} $\lg \dagger$.

20...25 % ,
 d_{50} $\lg \dagger$.
 .2.13.

2.13

-					
	$\alpha = 25$, $D=250$	$\alpha = 30$, $D=250$	“ ” $D=250$	“ ” $D=230$	- $D=250$
d_{50} ,	3,85	5,0	3,0	2,85	4,0
$\lg \sigma$	0,46	0,46	0,325	0,325	0,325

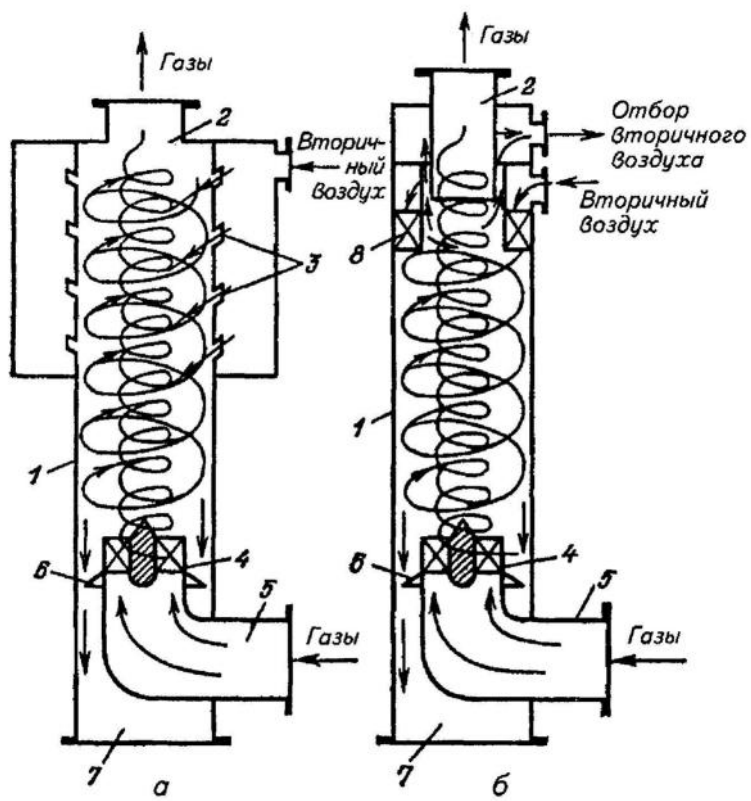
: d_{50} " " " "
 $4,5 /$, $23,7 \cdot 10^{-6}$, $2200 / ^3$,
 ∞

- 12 / , 2200 / ³ 10 %

18,8·10⁻⁶

2.4.

(. 2.16,).



. 2.16.

1 – ; 2 – ; 3 – ; 4 – « »; 5 – ; 6 – ; 7 – ; 8 –

« » .

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(. 2.16,)

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8 11

30°.

30°...40°

0,8...0,9.

(. 2.16,) , -

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: - 200

330 ^{3/}

3,7·10³ , 96,5 % , - 2,8·10³ 98 % (

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 , -
 . : -
 40...65 % .
 0,5 1,15 . -
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 , , ,
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 ,
 - 98...99 % . -
 (50
 115 %) () - 1 500 / ³.
 700 ° . -
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 330
 30000 ³/ ().
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		-
		, %
	4	98,0
	6	96,5
	10	98,0
	11	99,0
	22	98,0
	32	99,8

,
 :

$$D = (4V / f^{\wedge})^{0,5}.$$

V - , $^3/$; $^{\wedge}$ -
 , / (5...12 /).

,
 :

$$d = \{(\hat{\sim} / H) \ln(D / D) / [(1/18 \sim)(\dots - \dots) \check{S}^2]\}^{0,5};$$

$$d = (3/2fs)[(\sim / \dots) \ddagger \ln(1 + V_2/V_1)]^{0,5},$$

— , ; D -

, ; S - , $^{-1}$; s -

, $\ddagger = 1/2fR_1^2 H/(V_1 + V_2)$ - , ;

R_1 - , , ; V_1, V_2 -
 , $^3/c$.

(%) ,

,
 , :

$$v = [(c - c) / c] \cdot 100.$$

v_1, v_2 -
 $v_1 = v_2$ (%) :

$$v = (V_1 v_1 + V_2 v_2) / V,$$
 V_1, V_2 -
 $v_1 = [(D_1^2 - 4r_{1i}^2) / (D_1^2 - D^2)] \cdot 100;$
 $v_2 = [(D^2 - 4r_{2i}^2) / (D^2 - D_2^2)] \cdot 100,$
 D_1 - ; D - ;
 r_{1i}, r_{2i} - , ; D - ;
 D_2 - .
 $\Delta p = \langle \hat{\epsilon}^2 \dots \rangle / 2,$
 $\hat{\epsilon} - , / ; \langle -$
 $\hat{\epsilon} .$
2.5.
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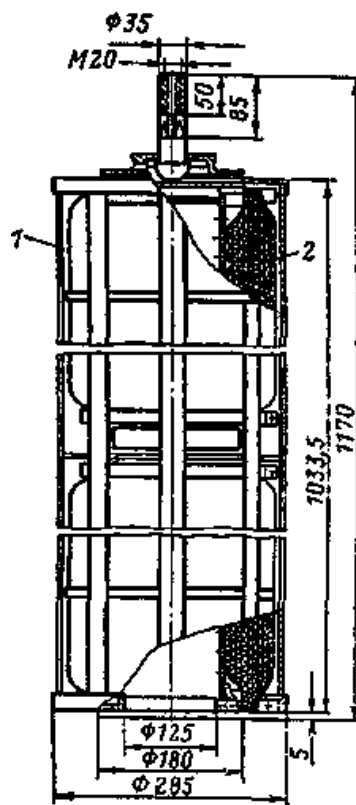
W_{sf}^* 0,01...0,1 $^3/(^2)$,
 - 200...300 , - 700...1500 .
 ()
 (0,5 / 3) , -
 .

2.15.

2.15

	2	- $^3/$	-	,	- $t_{max,}^0$
-0,5	0,5	0,02	-25	235×235×256	60
-2	2	0,06		330×300×390	
-10	10	0,285		510×510×552	

, 60
 , ()
 , , -
) (. 2.17). -
 200...1500 $^3/$, 200...1000 .
 (-
 -) (-
).
 , - 8...19 .
 0,3 2 0,3 .
 , -
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 , 10...20 .



. 2.17.

-500:

1 — ; 2 —

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10

1 20

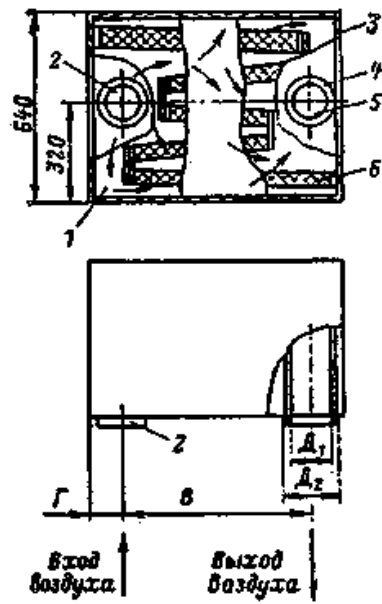
. 2.18,

A, B, D_1, D_2

(100)

$0,05...1 \text{ }^3/(\text{ }^2)$

1 .



. 2.18. :

- 1 - ; 2 - ; 3 - ; 4 - ; 5 -
; 6 -

2.5.2.

1 .

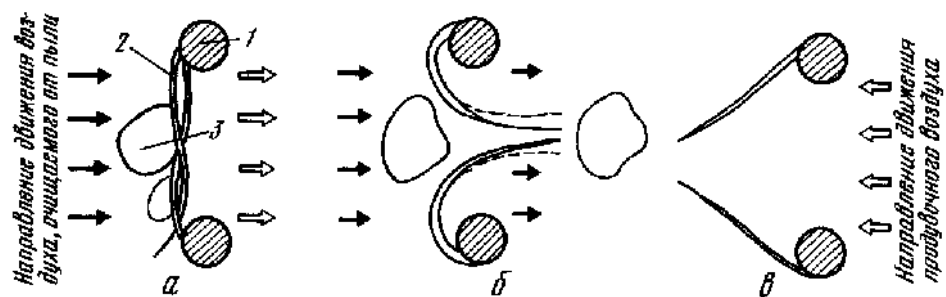
10...30 ,
100...200 .

0,5 .

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(. 2.19).



. 2.19.

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			- -	-		
1	2	3	4	5	6	7
		1520	65-85	90-95		X
		1320	95-100	120		
		1140 1380	80-90 220	120 260		
		1380	130	160	X	—
-		1170	120	150	X –	
-	- -	920	85-95	120		
-	, - ,	1380- 1470	65-70	80-90		
- -	- ,	2300	220	270		
-		-	250	270	X	-
-	-	2540	240	315	X	—

: — ; X – ;

. 2.16

		-	,	, %		, %, 20°	
-	- - -					φ = 65%	φ = 90÷95 %
8	9	10	11	12	13	14	15
			360-530	7-8		7-8,5	24-27
	X		130-200	30-40		13-15	21,9
	X		450-600	18-32		3,5-4,5	7-8,5
X	X		400-800	14-17		-	-
X	X		450-700	15-25		0,4	0,5
X			300-470	15-17		0,9-2	4,5-5
X	X		440-860	22-25		0	0
	- X		180-230	15-30	—	0,17-0,3	0,7-0,9
			350-400	50	-	0	0
			1600-3000	3-4		0,3	-

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90...450 . 2,5...10 .

15...20.

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0,3...2³/(²,)

5...40 .

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2.17

, ³/(².)

	(/ ³)			
	1	5	10	20
- 2	1	2	3	4
, , , - ,	120-150	80-100	60-70	40-50.
	60-90	50-60	40-50	30-50
- 2	5	6	7	8
, , , - ,	70-90 50-70		40-50	30-40
	50-60 40-50		30-50	30-40

2-

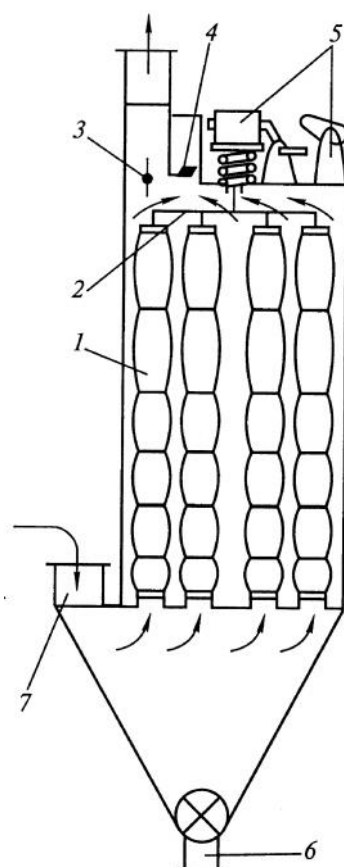
3-

4- 5-

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20 / ³.

1 / ³ .



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1 —

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; 5 —

; 6, 7

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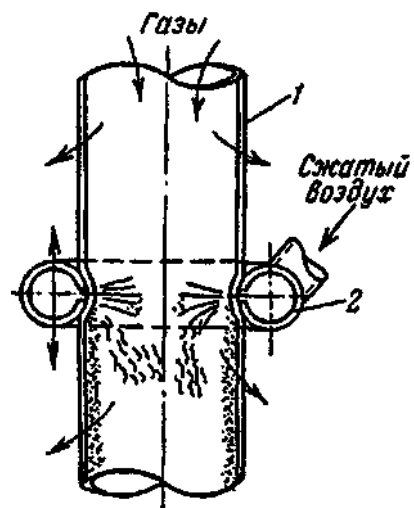
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10 %

(.2.21).



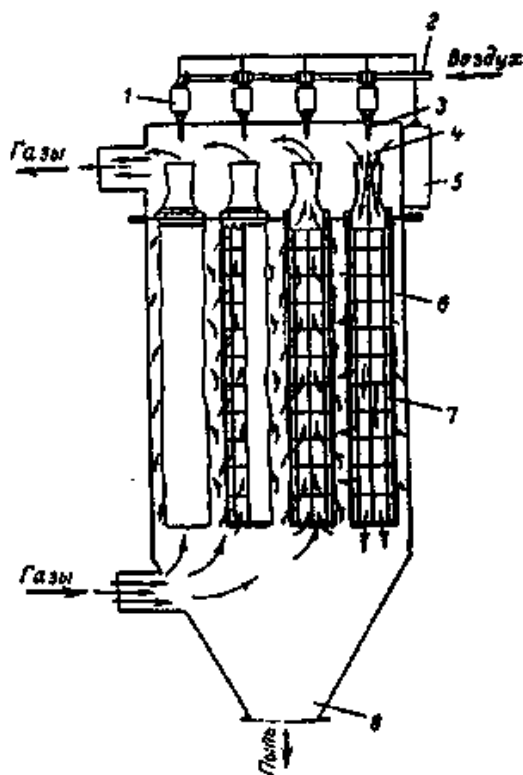
. 2.21.

1 - ; 2 -

10...30 / .

(. 2.22).

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. 2.22.

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1 -

; 2 -

; 3 -

; 4 -

; 5 -

; 6 -

; 7 -

; 8 -

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 0,1...0,2 , - 10 , 500...600
 0,1...0,2 % ().
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2.5.3.

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 $17...50^3/(^3)$, -
 - 99,8 %.
 0,5...1,5 .

2.5.4.

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$$\begin{aligned}
 F &= [(V + V)/60q] + F_p, \\
 V &= , ,^3/ ; V_p = , - \\
 & ,^3/ ; q = - \\
 & ,^3/(^2.) ; F_p = - \\
 1 & ,^2.
 \end{aligned}$$

$$\begin{aligned}
 F_p & \\
 F_p &= N F_c \ddagger'_p m_p / 3600, \\
 N_c &= ; F_c = ,^2; \ddagger'_p = - \\
 & , ; m_p = 1 .
 \end{aligned}$$

$$\begin{aligned}
 & , , - \\
 & , . \\
 0,3 & 6^3/(^2.). \\
 & ,
 \end{aligned}$$

$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$.

$$[\frac{3}{2} / (\frac{1}{2} \cdot \frac{1}{2})]:$$

$$q = q \cdot c_1 c_2 c_3 c_4 c_5,$$

q - , -

(,); c_1 - , -

; c_2 - , -

; c_3 - , -

(,); c_4 -

, (, -

); c_5 - , .

$$(q \frac{3}{2} / (\frac{1}{2} \cdot \frac{1}{2})) -$$

:

$q = 3,5:$		$q = 2,6$	
$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, - $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$; 		$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, - $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, - 	
$q = 2,0$	$q = 1,7$	$q = 1,7$	
$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$ - $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, 	$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$ - $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, - $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, - 	$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, - $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, - 	
$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$; 	$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$; 		

$\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$,
 $\frac{1}{2} \leq \frac{1}{2} \leq \frac{1}{2}$, -

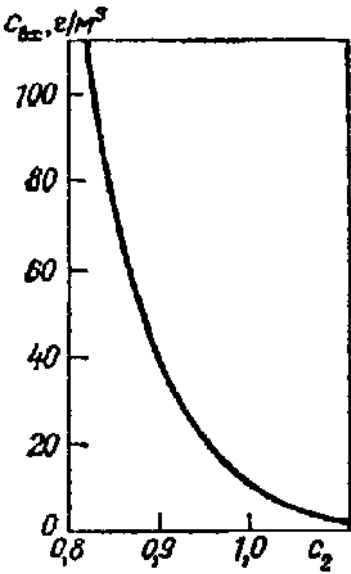
$$c_1 = 1. -$$

%.

$c_1 = 0,70...0,85.$

$c_1 = 0,55...0,70.$

$1...30 \text{ / } ^3 (\text{ . 2.23}).$



. 2.23.

c_2

c

c_3 , , -

. 2.18 (d_m -).

2.18

c_3

d_m ,	<3	3-10	10-50	50-100	>100
c_3	0,7-0,9	0,9	1,0	1,1	1,2-1,4

c_4 , ,

. 2.19.

2.19

c_4

t , °	20	40	60	80	100	120	140	160
c_4	1	0,9	0,84	0,78	0,75	0,73	0,72	0,70

c_5 , , -

30 / ³

$c_5 = 1$, 10 / ³ - $c_5 = 0,95$.

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Δp

Δp .

$\Delta p = \Delta p + \Delta p$.

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- 2) (，)；
- 3) ()；
- 4) ()；
- 5) ·

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1500 3000 (，
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3000 (-
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 ; 1)
 ; 2)
 ; 3)
 ; 4)
 ; 5)

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 50 %, . . .
 d_{50} .

,
 ,
 :

$$\Pi_d = \exp(-A_e d_i^{B_e}) = 1 - v ,$$

A_e - ; d_i - i - ; B_e - ; ε - , .
 " " ,
 ,
 ,
 ,
 .

,
 $v = f(A)$ - ()
) .

:

$$v = 1 - \exp(-B \cdot A^k), \quad (3.1)$$

- , / ³; k - - .

(,
) :

$$N = \ln(1 - v)^{-1}. \quad (3.2)$$

3.1 ,
(3.2).

3.1

N v , %.

η , %	N	η , %	N	η , %	N	η , %	N
90	2,303	99,0	4,605	99,90	6,908	99,990	9,210
95	2,996	99,1	4,710	99,91	7,013	99,991	9,316
95,5	3,101	99,2	4,828	99,92	7,131	99,992	9,433
96	3,219	99,3	4,962	99,93	7,264	99,993	9,567
96,5	3,352	99,4	5,116	99,94	7,419	99,994	9,721
97	3,507	99,5	5,298	99,95	7,601	99,995	9,903
97,5	3,689	99,6	5,521	99,96	7,824	99,996	10,127
98	3,912	99,7	5,809	99,97	8,112	99,997	10,414
98,5	4,00	99,8	6,215	99,98	8,517	99,999	11,513

(3.2) (3.1) :

$$N = B \cdot A^k. \quad (3.3)$$

B k 3.2.

$B \quad k$

	B	k
1	2	3
:	$5,53 \cdot 10^{-5}$	1,2295
-	$2,14 \cdot 10^{-4}$	1,068
-	$6,74 \cdot 10^{-3}$	0,478
-	$1,34 \cdot 10^{-2}$	0,631
,	$4,34 \cdot 10^{-3}$	0,3
:	$1,36 \cdot 10^{-2}$	0,621
-	$1,925 \cdot 10^{-1}$	0,326
-	$6,61 \cdot 10^{-3}$	0,891
-	$9,88 \cdot 10^{-2}$	0,466
--	$2,68 \cdot 10^{-1}$	0,259
-	$6,5 \cdot 10^{-4}$	1,053
-- ()	$0,82 \cdot 10^{-3}$	0,914
--	$1,74 \cdot 10^{-6}$	1,594
---	$1,565 \cdot 10^{-6}$	1,619
-- ()	$2,34 \cdot 10^{-2}$	0,532
--- ()	$6,49 \cdot 10^{-5}$	1,1
---- ()	$2,42 \cdot 10^{-5}$	1,26
---- ()	$6,9 \cdot 10^{-3}$	0,67
--	$9,05 \cdot 10^{-11}$	2,92
---	$4 \cdot 10^{-4}$	1,05
-	$2,34 \cdot 10^{-4}$	1,15
-- ()	$1,09 \cdot 10^{-5}$	1,415
-- ,	$9,3 \cdot 10^{-4}$	0,861
-- , -	$1,32 \cdot 10^{-3}$	0,861
-- ()	$1,2 \cdot 10^{-1}$	0,454
-	$2,06 \cdot 10^{-1}$	0,351
	10^{-5}	1,36

1. , , -
. -

2. (3.2) 3.1 .

3. k , 3.2,
, . -
 k , -
, . .

4. (3.3) , -
.

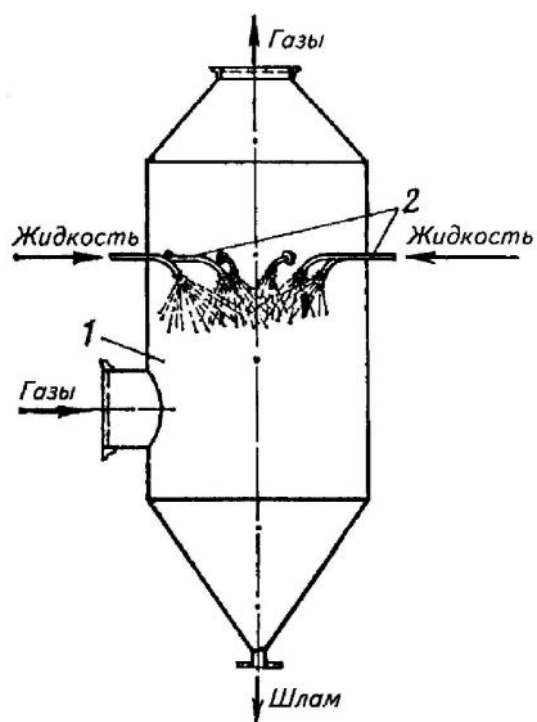
5. , -
, .

6. , -
.

7. -
. -
, -
. .

8. , -
, -
, -
, -
; .

3.1.
- (3.1) -
()
() .



3.1. - :

1 – ; 2 -

, -
 500 , -
 (0,8...1,2) / .
 (5 /)
 , (0,3...0,4) . -
 , -
 500 . -
 ,
 ,
 2...2,5 / ³,
 220...250 .
 10 .
 , -
 ,

1) $v = 1 \text{ / } ,$
 (200...250) $m = (0,5...8) \cdot 10^{-3} \text{ }^3 \text{ } 1 \text{ }^3 \text{ } .$

2) $f = V/v \text{ }^2 ,$
 $V - \text{ }^3/ ,$

$f = V/v \text{ }^2 ,$
 $V - \text{ }^3/ ,$
 $(150...200)^\circ$
 100°

h

2,5 $-$

3) $L = m \cdot V \text{ }^3/ .$

4) $\psi_i = d_i^2 \cdot v / (18 \mu l C_i') ,$ (3.4)

$d_i - \text{ } i - \text{ } , \text{ } ; \text{ } - \text{ } , \text{ } / \text{ }^3 ; C_i' - \text{ } -$
 $(3.3) ; \mu - \text{ } , \text{ } (19,3 \cdot 10^{-6} \text{ } .) ; l -$
 3.3

$d \cdot 10^6 ,$	0,003	0,01	0,03	0,1	0,3	1,0	3,0	10
C'	90	24,5	7,9	2,9	1,57	1,16	1,03	1

$(0,6...1) \cdot 10^{-3} .$

5) $i:$

$$y_i = \frac{\mathbb{E}_i^2}{(\mathbb{E}_i + 0,35)^2} . \quad (3.5)$$

$i = 150$ η_i $0,995;$ i 170 i
1.

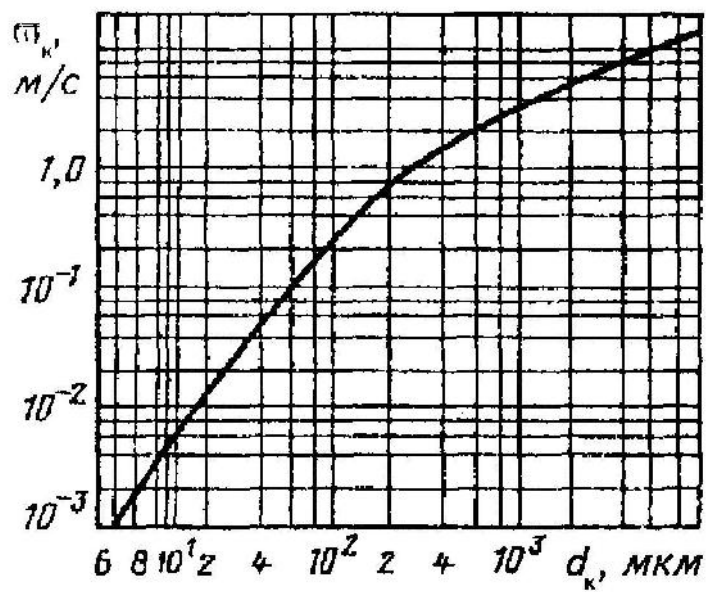
6) ()

$$v_i = 1 - \exp \left[- \frac{3 \cdot L \cdot y_i \cdot (v + w) \cdot h}{2 \cdot V \cdot d \cdot w} \right] \quad (3.6)$$

$$v_i = 1 - \exp \left(- \frac{3 L y_i h}{2 V d} \right). \quad (3.7)$$

(3.6) (3.7) w - , / ; d - , .

$(0,6...1) \cdot 10^{-3}$. (.3.2).



.3.2.

7) () -

ε ,

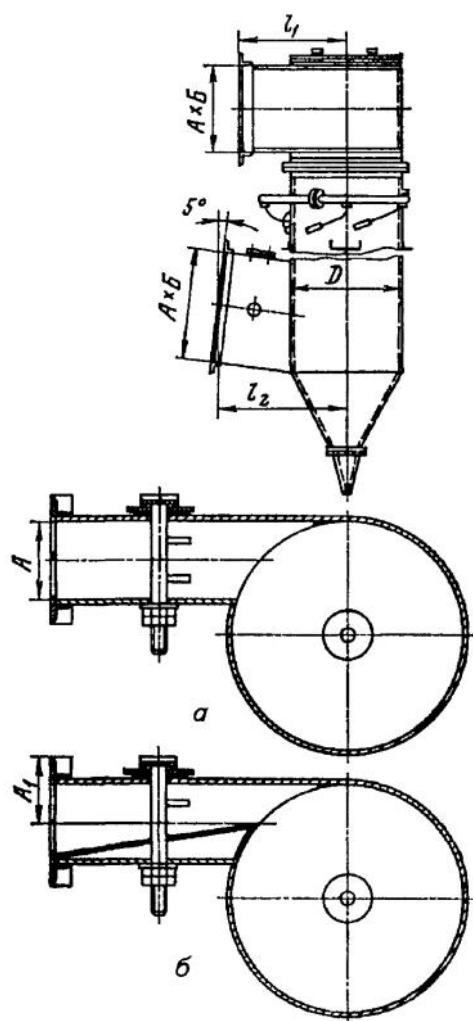
(3.8), :

$$V = \sum_{i=1}^N v_i \frac{g_i}{100}, \quad (3.8)$$

g_i - i - .

3.2.

(. 3.3)



. 3.3.

():

;

20 / .

.
 .
 2...2,5 .
 -
 - 0,05...0,3 / ³.
 1...20
 . ³/
 -
 .
 -
 ,
 -
 .
 -
 - 90 %,
 5...10 90...95 %.
 . 3.4.
 3.4

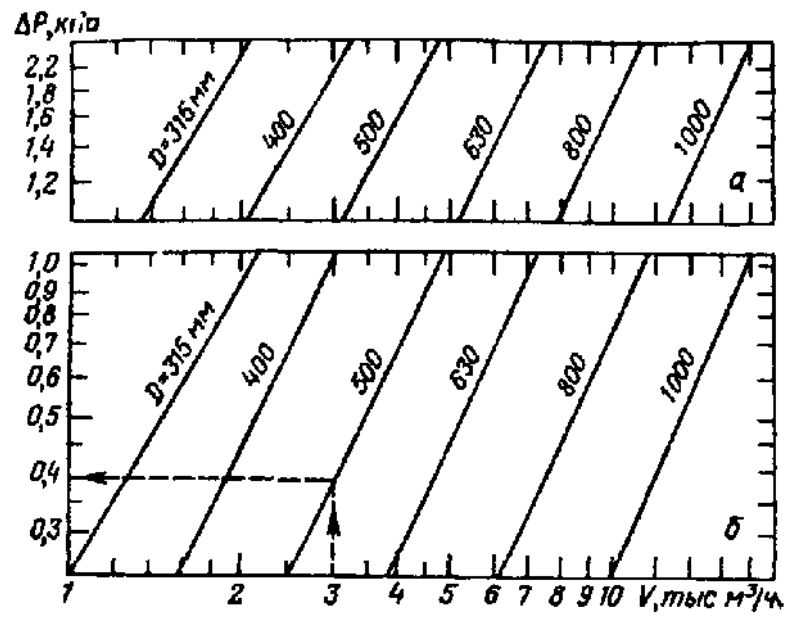
	, /				,			
	-		-		-	-	-	-
	- - *	- - **	- - *	- **			ν , ξ	ν_0 , ξ_0
	16	25,6	4,5	7,05	360	915	2,3	30
- -	32	44	4,5	6,0	940	1780	1,5	78

: * -

ν ; ** -

ν_0 .

. 3.4



. 3.4.

ΔP
 V D

. 3.5 3.6. . 3.5

%,

3.5,

: ... = 2650 / ³, $t = 20^\circ$, $\sim = 1,83 \cdot 10^{-5}$. , -

, 50 % (d_{50}),

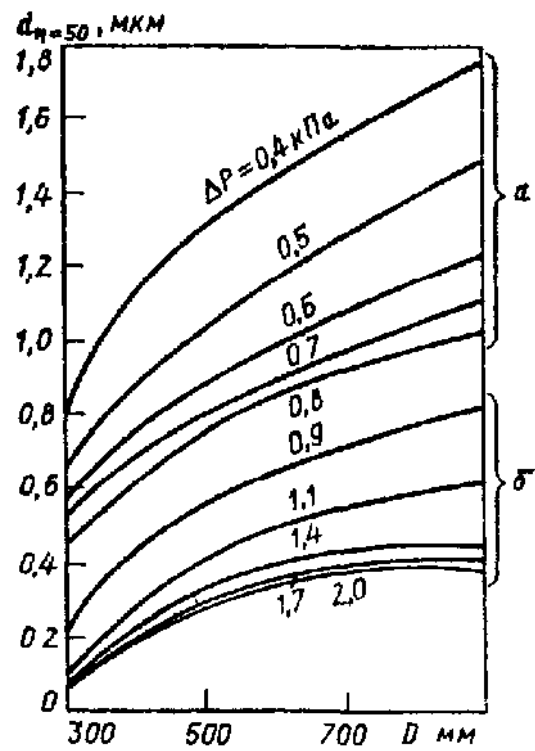
:

$$d_{50} = d_{50} \left(\frac{\dots \sim}{\dots \sim} \right)^{0,5},$$

d_{50} , d_{50} -

,

50%



3.5.

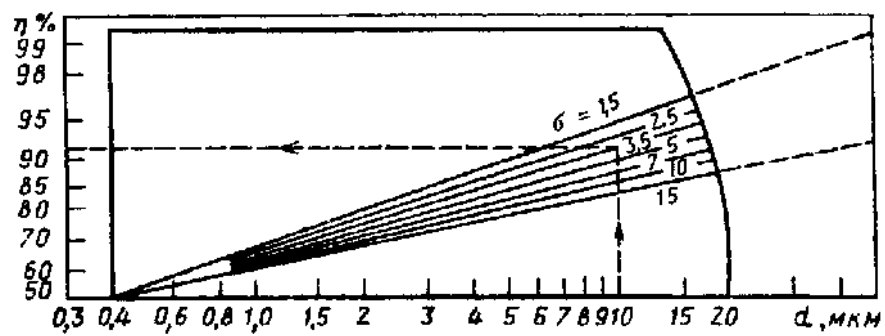
Δp

50% $d_{\eta=50}$,

()

()

3.6).



3.6.

$D(d)$,

$$\ln \uparrow = \ln(d_m/d_{16}) = \ln(d_{84}/d_m) \tag{3.9}$$

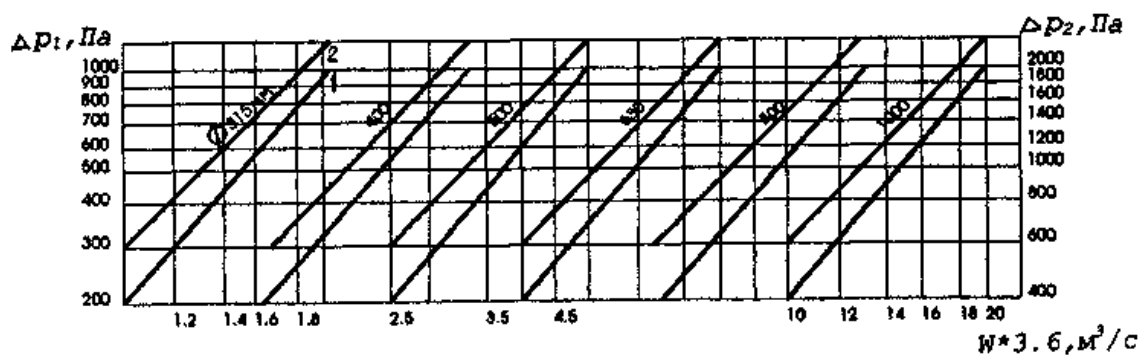
d_m - ,
 , d_m d_m ; d_{16}
 d_{84} - , 16 84 % $D(d)$.
 $d_{y=50}$ (. . 3.6)
 (3.9) \uparrow ,
 .

\uparrow .
 :

$$V = \sum_{i=1}^{i=n} \Delta R v_i ,$$

 ΔR_i - i - ; v_i - i -
 ; n - .
 , -
 $d_{y=50} = 5...32$,
 $(d_{50} < 3)$.
 , -
 $d_{y=50}$
 2,2 1,9 , 25...75 % - 1,5 1,4 .
 - -
 (14...20 /).
 ,
 (300 . ³/) .
 $5 / ^3$. -
 5 99 %.
 -
 2,5...3 , -
 .

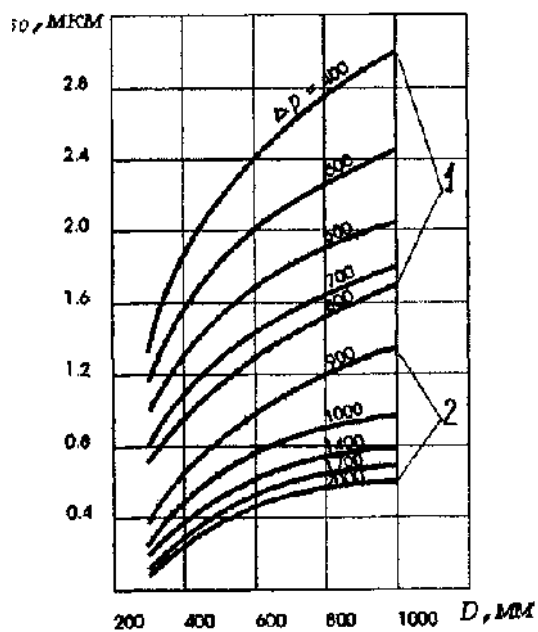
1. (1, Δ_1 .3.7; $\zeta =$
 30), (2, Δ_2 .130;
 $\zeta = 75$).



. 3.7.
 1 – ; 2 –

. 3.7

2. . 3.8 d_{50} $\lg \sigma$ 0,838.



. 3.8. d_{50} :

1 – ; 2 –

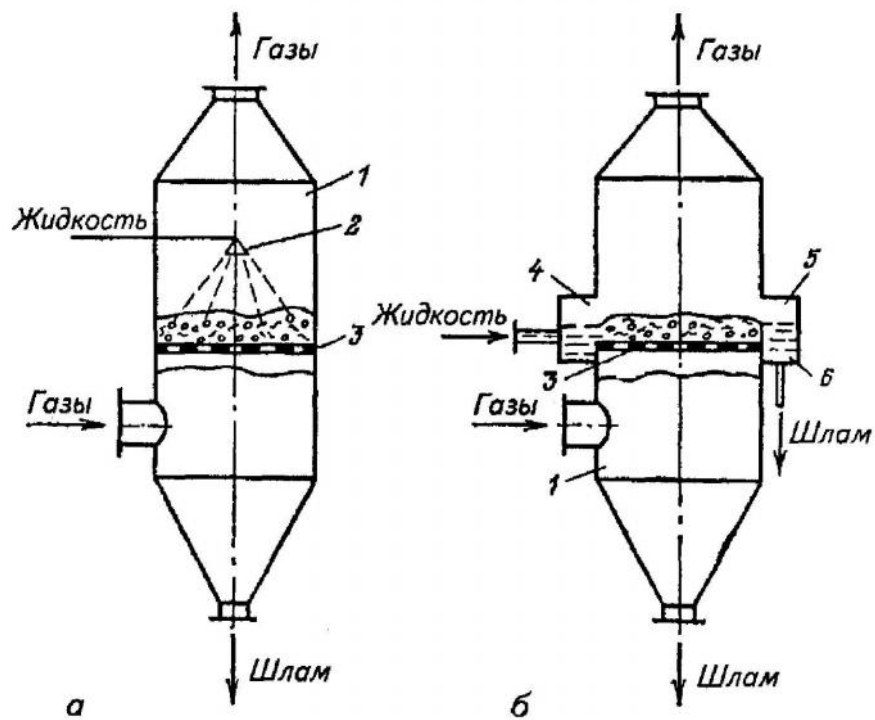
3. (2.9) 2.1 -

4. -

2 / 3.

3.3.

(. 3.9).



. 3.9.

:

: 1 - ; 2 - -

; 3 - ; - : 1 - ; 2 - ; 3

; 4 - ; 5 -

,
 .
 , -
 3...8 . 0,15...0,25
 $2/2$.

,
 :
 -
 -
 ,
 .
 3...8 , (-
) $f = 0,15...0,25$.

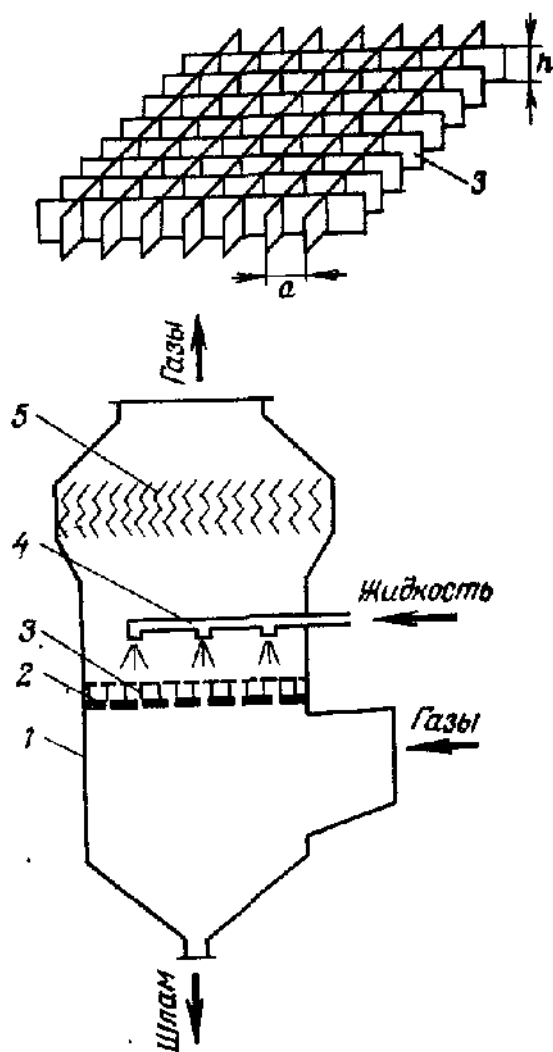
:

$$u = d_0 \sqrt{\frac{0,91}{f}}$$
 ,
 d_0 - , .

,
 ,
 b 4...5 , $f = (0,2...0,25)$.
 4...6 .
 0,4...0,6 1^3 .
 0,8...2,2 / ,
 , 1
 / .

, 4 / .
 . 3.10 ().
 $h = 60$

35×35 45×45 .



. 3.10.

1 – ; 2 – ; 3 – ; 4 – ; 5 – -

. 3.11

2,5

- , / ³ ; d₀ - , ; S₀ -
, ²/ ².

()

:

$$\Delta p_{\uparrow} = 4\uparrow / d_0 ,$$

σ - , / .

:

$$\Delta p^{\ast} = \sphericalangle_a^{\wedge^2} \ldots / 2 ,$$

◁_a = 25...28 - .

(%) :

$$y^{\ast} = 100[-87,1(1,37-d^{0,1})/(H^{0,9\sim 0,25})],$$

d - , ; H - , ; ^

- , / .

$$(1.2) \quad (1.3).$$

3.4. -

- (-

,

, , N).

-

,

,

-

.

400 . , , .

-

3.12, .

,

$$20 \quad /$$

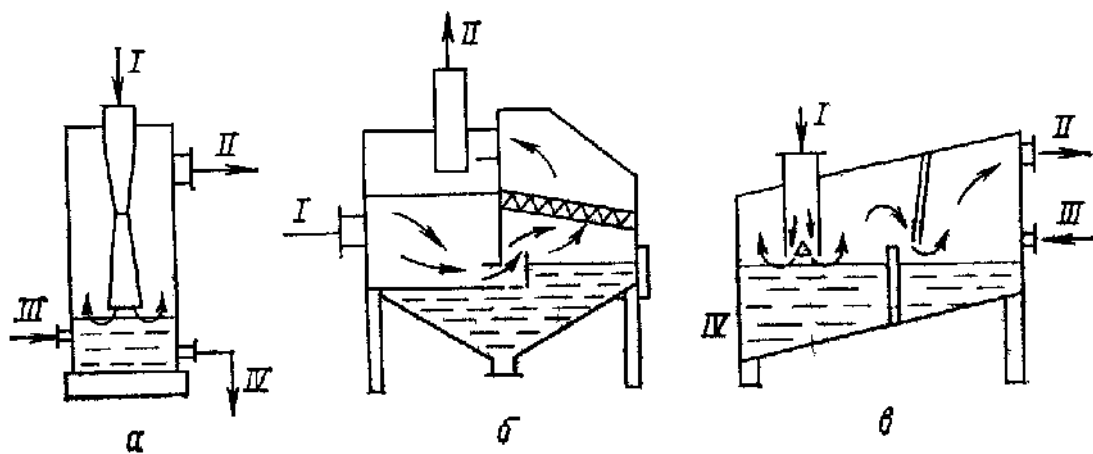
. (180°) -

,

.

-

20 .



3.12.

(3.12,), , 3.12, .
()

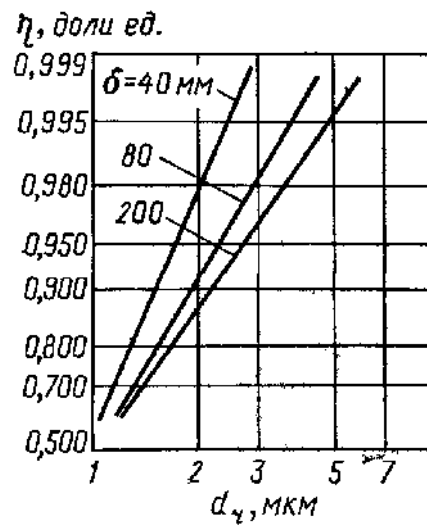
3.12, . 2 .

: 3000, 5000, 10000, 20000 40000 ³/ .

,
(35...55 /).

2...3
1,5 .

(3.13).



3.13.

δ

3.13

$\rho = 2600 \text{ / } ^3$.

; $2600 \text{ / } ^3$,

$$d' = d \sqrt{\frac{2600}{\dots}},$$

d' —

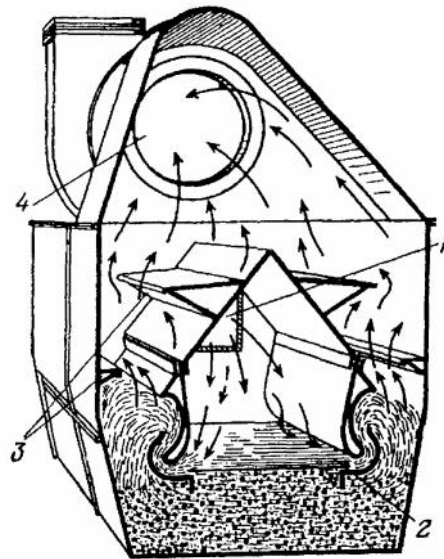
(1.2)

(1.3).

N (3.14),

()

3 40 $\cdot ^3/$



. 3.14.

N :

1 -

; 2 -

; 3 -

; 4 -

.
 ,
 , 15...16 / ,
 . (),
 - () .
 ,
 . () $\pm 15\%$.
 , 0,03 / 3 .
 1000...1500 .
 40
 ° $5 \cdot 10^{-6}$ $^3 / ^3$, - 20 1 . -
 1,6...2,0
 2,0...2,5
 .
 () -
 :

$$\Delta p = 10(\Delta H + V^{0.5}),$$

ΔH - , ; V - 1

, ³/ .

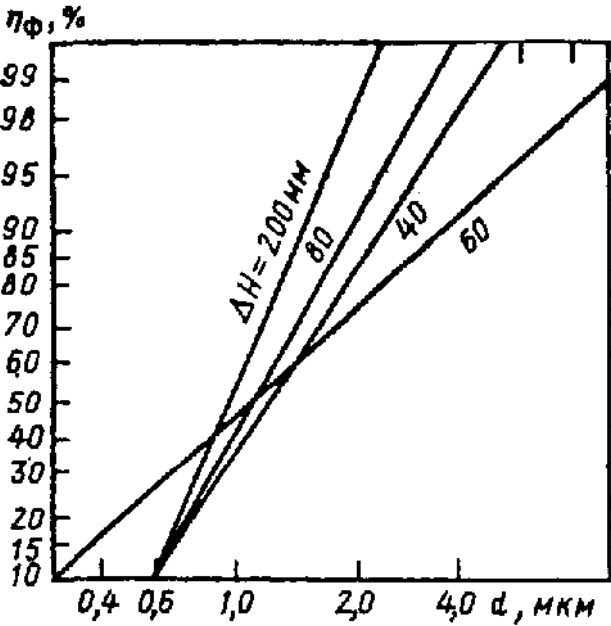
ΔH 20...60 ,

- 60 200 . 1 . -

2...7,5 . ³/ .

(. 3.15), ,

(1.2) (1.3).



. 3.15.

y

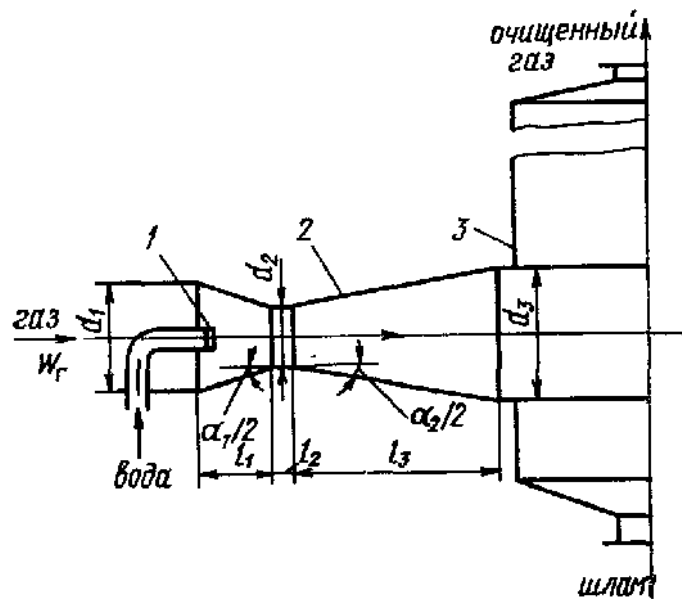
d

N

(

),

89,0...99,4 %.



3.16.

1 – ; 2 – ; 3 –

— 2,

1

($w = 15 \dots 20$ /)

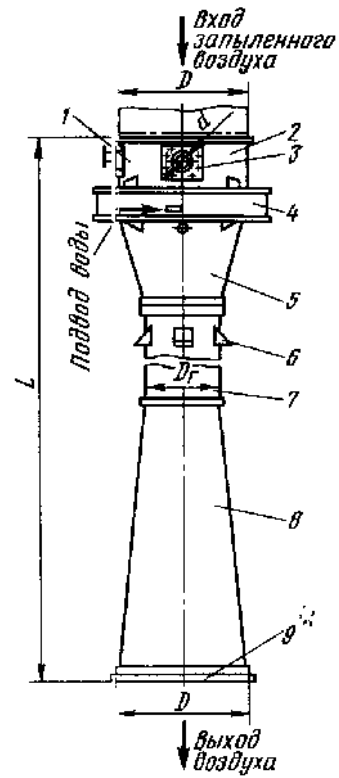
40...200 / .

15...20 / ,

3,

(3.16,

3.17),



. 3.17. :

1 — ; 2 — ; 3 — ; 4 — ; 5 —
 ; 6 — ; 7 — ; 8 — ; 9 —

0,5

. 3.16):

 $\alpha_1 = 15 \dots 28$, $l_2 = 0,15 d_2$, $\alpha_2 = 6^\circ \dots 8^\circ$.

)

.

,

-

.

,

-

(.3.18, , ,

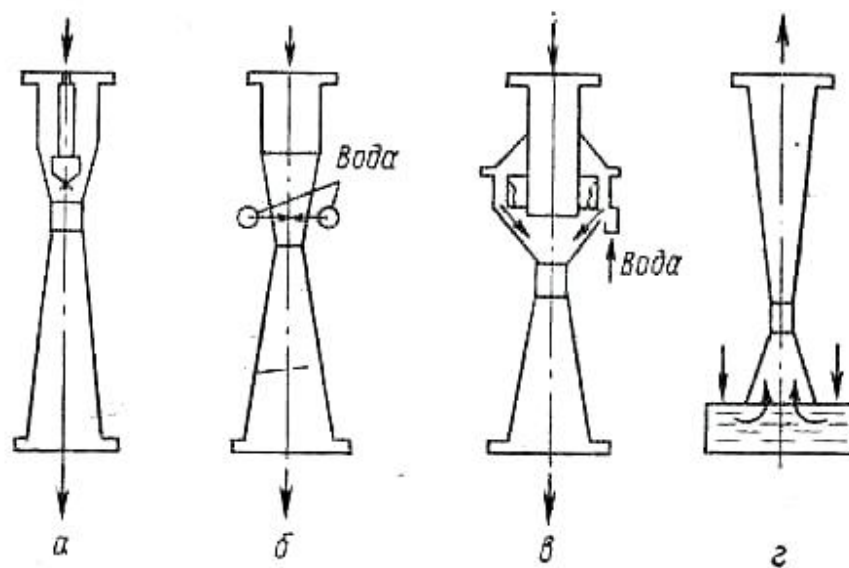
).

,

,

-

(.3.18,).



.3.18.

- :

- () ; - ; -

; -

,

(, -

).

, ,

1 80 100 ³

,

, 200...300

5 99,6 %.

,

,

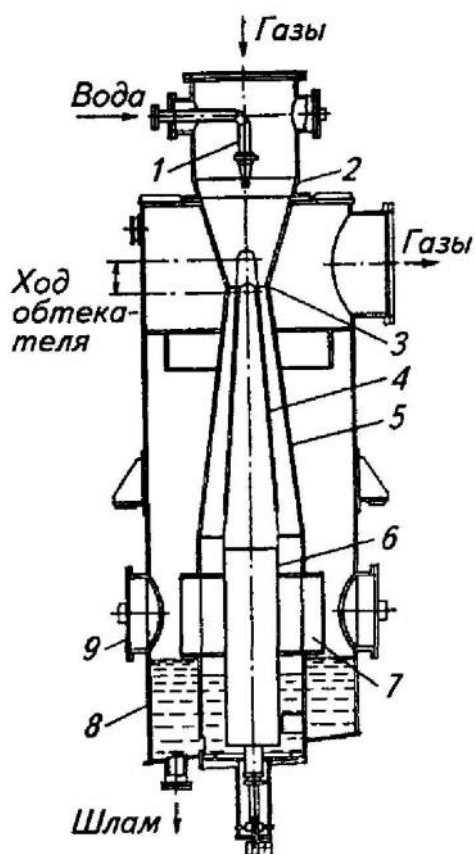
,

0,05...100 / ³.

(. 3.19),

2...500 . ³/

4 12 .



. 3.19.

:

1 – ; 2 – ; 3 – ; 4 – ; 5 – ; 6 –
; 7 – ; 8 – ; 9 –

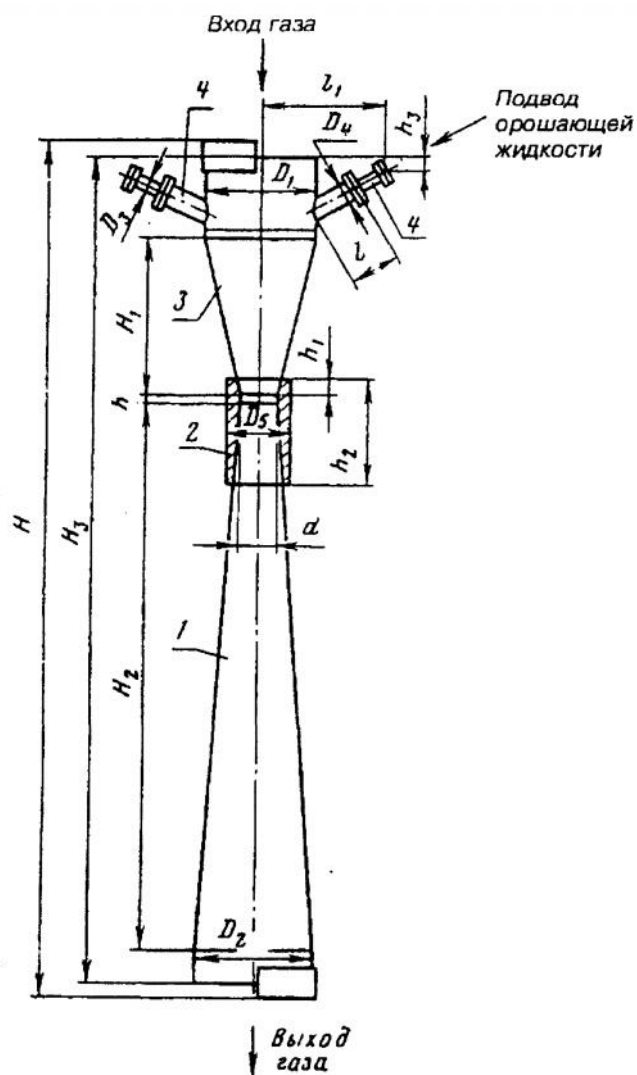
7°

,

85 145 / .

(. 3.20)

(. 3.21).



. 3.20.

:

1 – ; 2 – ; 3 – ; 4 –

,

60°.

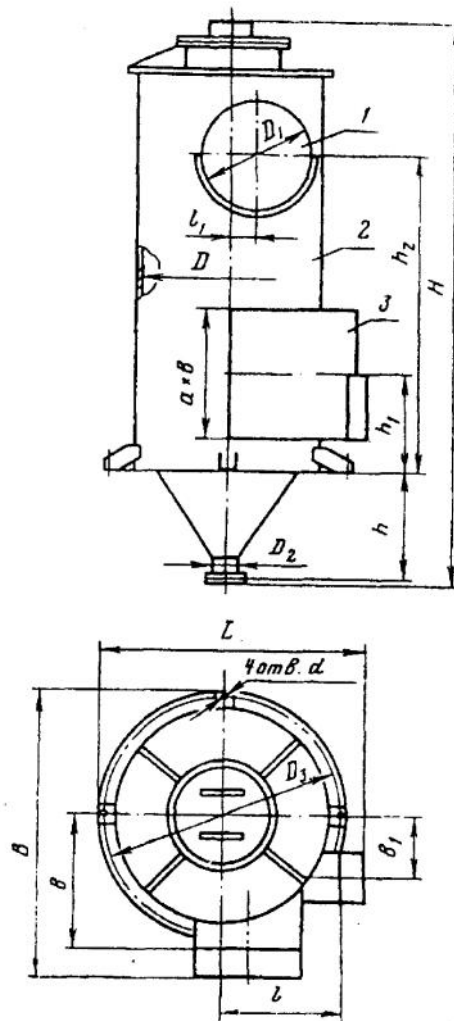
400 °

30 / ³.

,

,

500 / .



. 3.21.

1 – ; 2 – ; 3 –

1.

2.

0,12...0,15,

($l/D > 0,15$)

$$g = 0,165 + 0,034 (l/D)[0,06 + 0,28(l/D)],$$

D - ,
 ; - , -
 , .
 3. , ,
 , -
 (3.11 - 3.16) g .
 g (.3.18, ,) -
 l/D 0,15...12 80 /
 :
 $g = g_c 1,68(l/D)^{0,29}(L/V)^p$, (3.11)
 80 / - :
 $g = g_c 3,49(l/D)^{0,27}(L/V)^q$, (3.12)
 L, V - (,
 $), \quad ^3/ ; \quad p = 1 - 1,12(l/D)^{-0,045} ; \quad q = 1 - 0,98(l/D)^{0,026}$ - .
 -
 (. 3.18 41,) ξ $l/D = 0,15$
 80 / :
 $g_{op} = g_c 13,4(L/V)^{0,024}$, (3.13)
 80 / - :
 $g_{op} = g_c 1,4(L/V)^{-0,316}$. (3.14)
 , -
 , -
 $l/D = 0,15$ 40...150 / < :
 $g_{op} = g_c 0,215(L/V)^{-0,54}$. (3.15)
 ,
 40...150 / ζ -
 :
 $g_{op} = g_c 0,63(L/V)^{-0,3}$. (3.16)
 4. ζ Δ .
 Δ , , $\Delta p_c = g_c w^2 \dots / 2$

w / ... , / ³, -
 , -

$$\Delta$$

$$\Delta p_{op} = g_{op} \frac{w^{2 \cdot \dots}}{2} \cdot \frac{L}{V},$$

—

$$\Delta = \Delta + \Delta .$$

. 3.5. ζ -
 .

3.5

-

	ζ
-24	70
	30
	18
	5
, ,	4

5. -
 , 0,5...1,5 / ³.

6. -
 :

$$d = \frac{0,0585}{w} (10^3 \dagger / \dots)^{0,5} + 1,884 \left[\frac{\sim}{(10^3 \dagger \cdot \dots)^{0,5}} \right]^{0,45} \cdot \left(\frac{L}{V} \right)^{1,5}, \quad (3.17)$$

w - , / , -
 ; μ - , ; σ -
 , / ($20^\circ \mu = 10^{-3}$, $\sigma = 72,8 \cdot 10^{-3}$ /).
 (3.17) -

.

(3.1):

$$v = 1 - \exp(-B \cdot A^k).$$

7. (3.4) ψ -

:

$$\psi_i = d_i^2 \cdot w / (18 \mu l C_i).$$

8. (3.5) 1

:

$$y_i = \frac{\mathbb{E}_i^2}{(\mathbb{E}_i + 0,35)^2}.$$

9. ,

(1.3) :

$$v = \sum_{i=1}^N v_i \frac{g_i}{100}.$$

.

-

-

:

$$y = 100(1 - e^{-cm\sqrt{St}}),$$

St — :

$$St = \frac{d \cdot w \cdot \dots}{18 \cdot \sim d},$$

— , / ³; — , -

; l :

l ,	0,1	0,2	0,3	0,4
	1,25	1,45	1,52	1,56

l

l

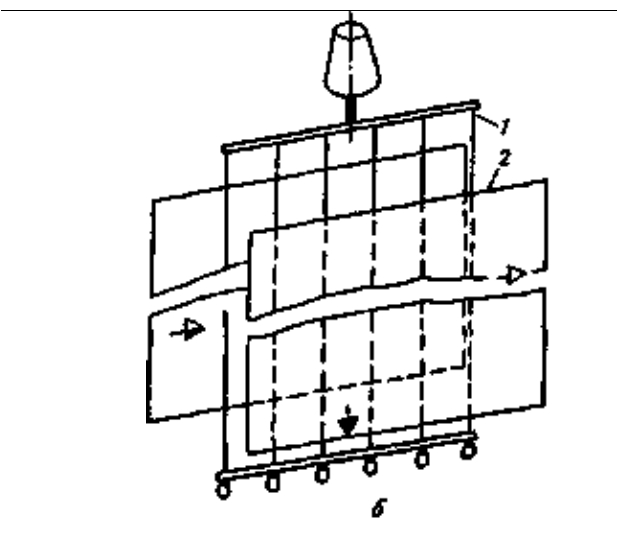
l . = 6° l' = 0,476 · d . (d . — -

).

, SO₃, NH₄ .)

4.1.

(4.145).


$$\vdots$$

• -
;

; 2 -

—

() - ,

0,2 ; (0,2...0,5)

$$Q = 12 f v_0 E_0 r_x^2 \left(\frac{v}{v+2} \right) \cdot \left(\frac{t}{t + \frac{4 v_0}{N_0 e K}} \right), \quad (4.1)$$

ε -
 ε_0 - , $8,55 \cdot 10^{-12}$ / ; ε_0 -
 r - ; K - ; -
 N_0 - ; t - .
 (4.1)

Q_s ,

$$Q_s = 12 f v_0 E_0 r^2 \left(\frac{v}{v+2} \right)$$

$$\frac{4 v_0}{N_0 e K}$$

$$t_0. \quad (4.1) \quad Q_s \quad t_0$$

:

$$Q = Q_s \frac{t}{t + t_0}.$$

90 % , $10 t_0$.

300...600 / ,
 1000 / .
 $10^{13} \dots 10^{14}$
 $10^{13} \dots 10^{14}$
 $10^{13} \dots 10^{14}$

t_0 0,11
 $10^{13} \dots 10^{14}$ 0,001
 $10^{15} \dots 10^{16}$

$10 \cdot t_0$
 $10^{14} \dots 10^{15}$ 0,1 .

0,1...0,2 ,

.

,

,

.

(15...20) / .

U ,

,

, / , U , ,

:

$$U = E \cdot R_1 \ln \frac{R_2}{R_1},$$

- :

$$U = E \cdot R_1 \left(\frac{f \cdot l_1}{l_2} - \ln \frac{2f \cdot R_1}{l_2} \right),$$

R_1, R_2 -

, ; l_1 -

, ; l_2 -

, .

R_1 0,001...0,002 ,

R_2 $l_1 - 0,1 \dots 0,15$, $U = 20 \dots 30$.

()

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,

,

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-

,
 .
 .
 ,
 .
 () ,
 ($10^6 \dots 10^9$) . :
 - . $< 10^4$
 . ,
 ,
 ,
 -
 ;
 - $10^4 \dots 10^{10}$. -
 ;
 - $> 10^{10}$.
 ,
 .
 (" "),
 , ,
 b , ZnO, PbS.
 , ,
 ,
 .
 130 °C 350 ° .
 -
 -
 , (. .)
 ,
 . -

4.2.

(4.1).

(),

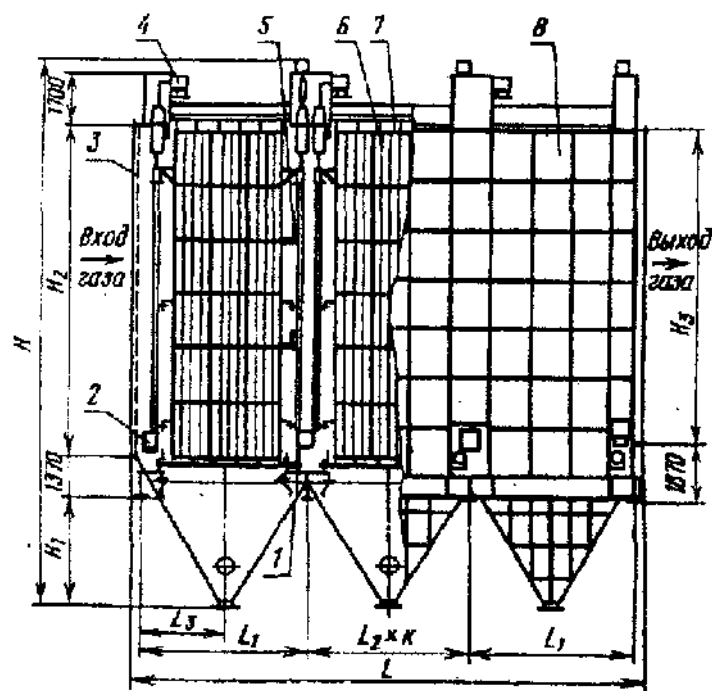
1

1 .

0,8...1,7 / .

(. 4.2)

330° .



.4.2.

:

1—

;2—

;3—

;4—

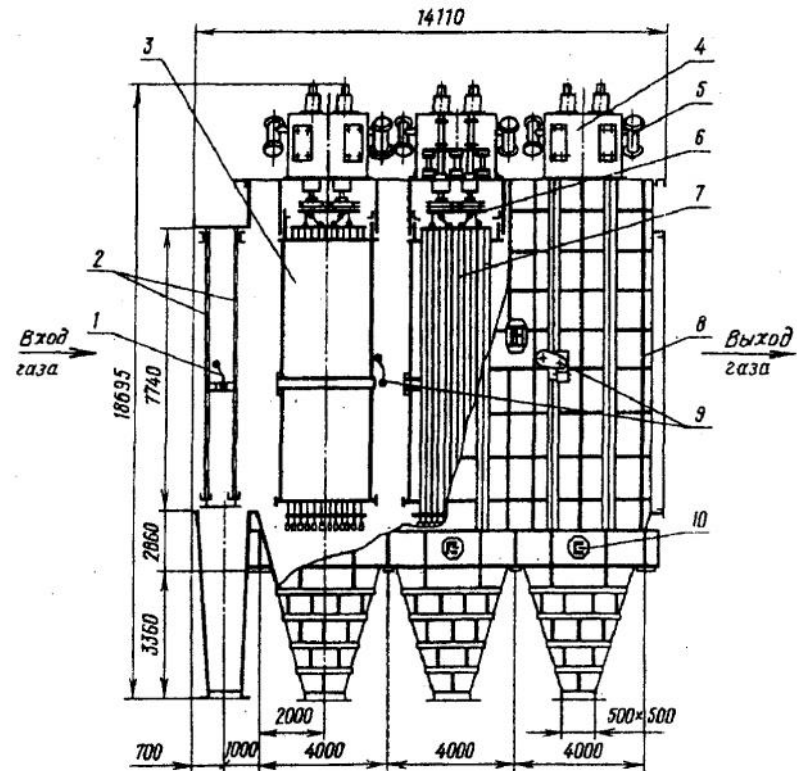
;5—

;6—

;7—

;8—

(.4.3)
400 °

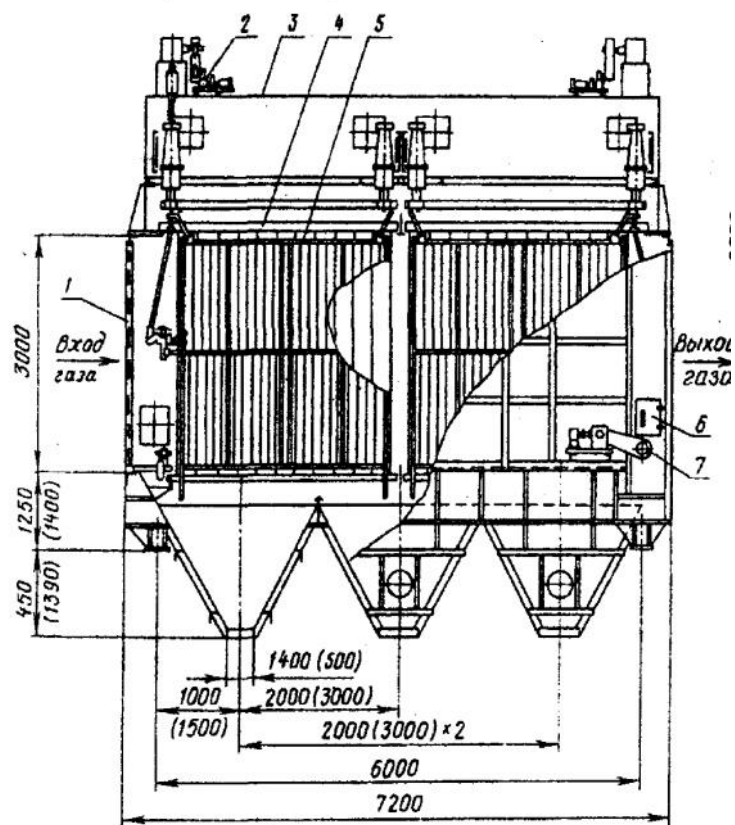


.4.3.

- 1 – ; 2 –
; 3 – ; 4 – ; 5 –
6 – ; 7 – ; 8 –
9 – ; 10 –

(.4.4)

250° .



.4.4.

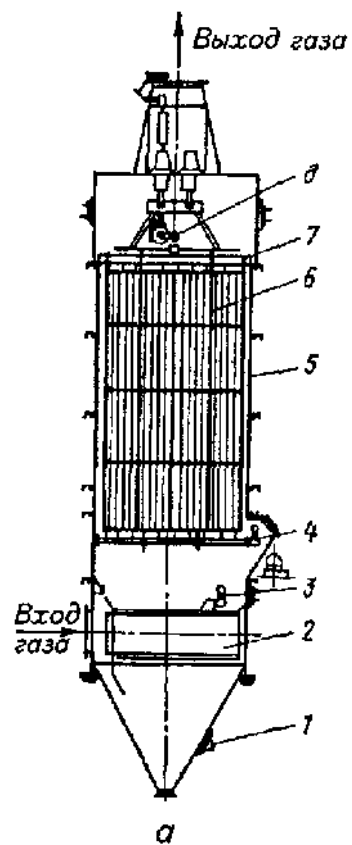
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1 – ; 2 – ; 3 – ;
4 – ; 5 – ; 6 – ; 7 –

4 .

(.4.5)

250° .



4.5. :

1 – ; 2 – ; 3 – -
 ; 4 - ; 5 – ; 6 – -
 ; 7 – ; 8 -

, (30 / ³),

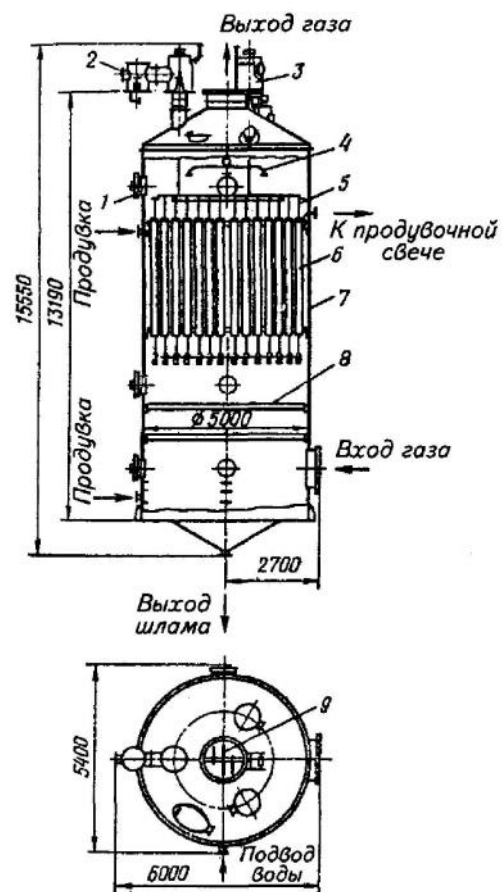
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(. 4.6) -

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. 4.6.

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4.3.

$$- \qquad \qquad \qquad d \geq 1$$

$$w = \frac{0,11810^{-10} E^2 d}{2 \sim};$$

$$- \qquad \qquad \qquad d \leq 1$$

$$w = \frac{0,1710^{-11} E}{\sim C},$$

$$\begin{array}{l} \text{---} \\ \text{; } \mu \text{ ---} \end{array} \qquad \qquad \qquad , \quad / \text{ ; } d \text{ ---} \qquad \qquad \qquad ,$$

$$\text{; } \quad = 1 + \frac{2 \cdot \}}{d} \text{ (---} \qquad \qquad \qquad , \qquad \qquad \qquad 0,815...1,63; \lambda \text{ ---}$$

$$\text{ , } \text{ ; } \lambda = 10^{-7} \text{).}$$

$$v = 1 - \exp(-K \cdot A \cdot S^{0,42}),$$

$$\begin{array}{l} K \text{ -} \qquad \qquad \qquad \text{; } \text{ -} \qquad \qquad \qquad , \qquad \qquad \qquad \text{ -} \\ \qquad \qquad \qquad \text{; } \beta \text{ -} \qquad \qquad \qquad , \text{ -} \\ \qquad \qquad \qquad . \end{array}$$

$$\begin{array}{l} \qquad \qquad \qquad \gamma(\text{)} \qquad \qquad \qquad , \text{ } \dots \\ \gamma(\text{)} \mathrm{d} x \text{ -} \qquad \qquad \qquad , \qquad \qquad \qquad \gamma(\text{)} \text{ } \gamma(\text{ } + \mathrm{d} x) . \end{array}$$

$$v = 1 - \int\limits_0^{\infty} \chi \left(x \right) \exp \left[\frac{A \cdot w \left(x \right)}{v} \right] . dx,$$

$$\begin{array}{l} \qquad \qquad \qquad , \qquad \qquad \qquad \text{ -} \\ \qquad \qquad \qquad \text{ -} \qquad \qquad \qquad , \text{ -} \\ \qquad \qquad \qquad . \\ \qquad \qquad \qquad \text{ :} \qquad \qquad \qquad , \qquad \qquad \qquad , \text{ -} \\ \qquad \qquad \qquad , \qquad \qquad \qquad \dots \\ \qquad \qquad \qquad , \qquad \qquad \qquad , \text{ -} \\ \qquad \qquad \qquad , \qquad \qquad \qquad \dagger \text{ .} \\ \qquad \qquad \qquad \text{ :} \end{array}$$

$$\ddagger = u/w \text{ ,} \tag{4.2}$$

δ - , ; w -

(
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$$\ddagger$$

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$$\ddagger \leq \ddagger \text{ .}$$

\ddagger :

$$\ddagger = l/v \tag{4.3}$$

l - , ; v -

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$$\text{ .} \text{ ,} \tag{4.2}$$

(4.3), -

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$$v = w \cdot l/u \text{ .}$$

$$d = 2...50$$

:

$$w = 0,059 \cdot 10^{-10} E^2 d / \sim \text{ ,}$$

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$$\text{ .} \quad (\quad^2)$$

:

$$S = (1,5...2)[V/(3600 \cdot v)]u/l \text{ .}$$

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(%) :

$$v = [1 - \exp(-w \cdot f)]100 \text{ ,}$$

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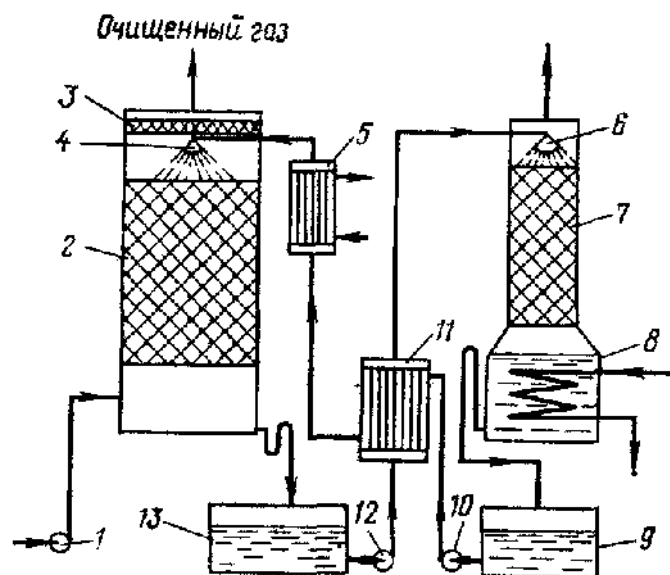
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, . 6.1.

N_2O_3 , NO_2 , N_2O_5	, : NaOH , Na_2CO_3 , NaHCO_3 , K , K_2 , K , $()_2$, a , $\text{Mg}(\text{OH})_2$, MgCO_3 , $\text{Ba}(\text{OH})_2$, NH_4HCO_3
NO	FeCl_2 , FeSO_4 , $\text{Na}_2\text{S}_2\text{O}_3$, NaHCO_3 , Na_2SO_3 , NaHSO_3
SO_2	, : Na_2SO_3 (18...25 %-), NH_4OH (5...15 %-), $()_2$, Na_2CO_3 (15...20 %-), NaOH (15...25 %-), K , $(\text{N}_4)_2\text{S}_3$ (20...25 %-), ZnSO_3 , K_2 ; CaO , MgO , ZnO ; - 1:1, $\text{C}_6\text{H}_3(\text{CH}_3)_2\text{NH}_2$
H_2S	$\text{Na}_2\text{CO}_3 + \text{Na}_3\text{AsO}_4$ (Na_2HAsO_3); s_2 N_3 (8...10 /) + N_3 (1,2...1,5 /) + $(\text{NH}_4)_3\text{AsO}_3$ (3,5...6 /); (10...15 %-); K_3O_4 (40...50%-), NH_4H , K_2CO_3 , Na_2CO_3 , CaCN_2 , -
	; - $[(\text{N}_3)]n \times$
2	N_2 , K_2 , NaOH , K , $()_2$, NH_4OH , RNH_2 , R_2NH_4
I_2	NaOH , K , $()_2$, Na_2CO_3 , K_2 , MgCO_3 , $\text{Na}_2\text{S}_2\text{O}_3$; CCl_4
HCl	, NaOH , K , $\text{Ca}(\text{OH})_2$, Na_2CO_3 , K_2CO_3
HF , SiF_4	, Na_2CO_3 , NaOH , $()_2$

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HCl, SO₂, NO₂, HF, SiF₄, NH₃ H₂S. -

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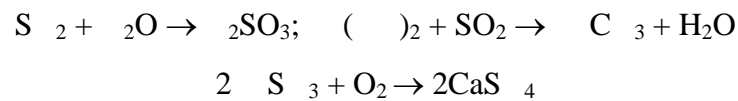
SO₂ , -

SO₂ , SO₂

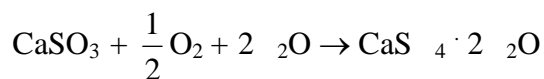
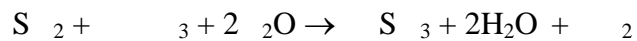
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S_2 -
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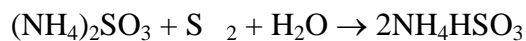
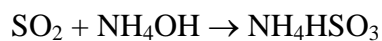
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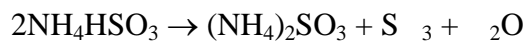
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SO_2 :



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CO_2 , -

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$$\text{SO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_3 + \text{H}_2\text{O}$$

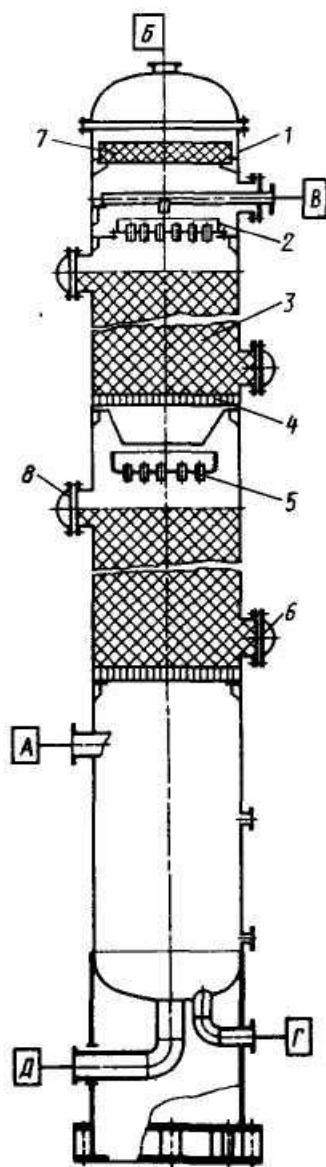
$$\text{Na}_2\text{SO}_3 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaSO}_3 + 2\text{NaOH}.$$
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 SO₂
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 NH₃ .
 SO₂
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 MgO ,
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 NH₃ ,
 HCl HNO₃, HCl , NH₃.
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1. 氧化性：KMnO₄、NaClO₄、HNO₃、H₂O₂、Na₂SO₃、H₂SO₄、NO₂、NO、Fe₂O₃、H₂S。

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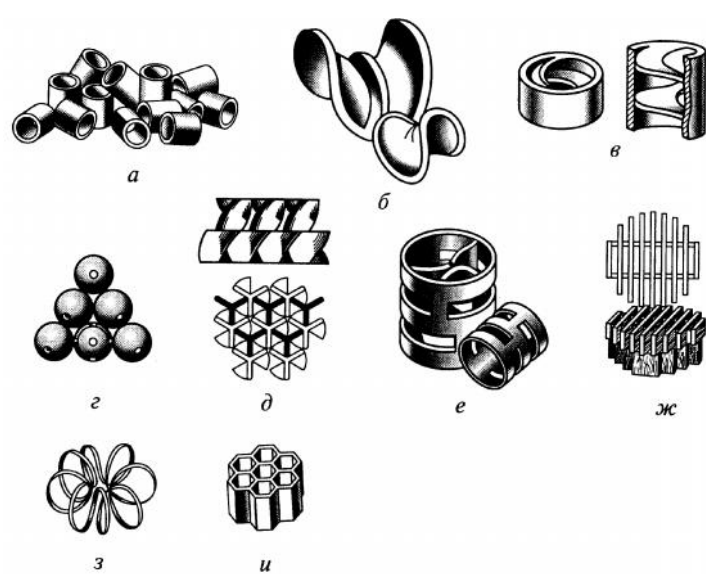
1 – ; 2 – ; 3 – ; 4 – ; 5 –
; 6, 8 – ; 7 –

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6.2

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	50	93	0,74	0,0318	5530	580
	25	230	0,77	0,0134	76600	575
	44	130	0,77	0,0237	14000	.550
	50	100	0,81	0,0324	3400	505
	25	235	0,74	0,0126	70000	840
:	50	112	0,86	0,0307	6800	100
-	35	170	0,9	0,021	19200	455
-	50	108	0,9	0,033	6400	415

($2/3$)

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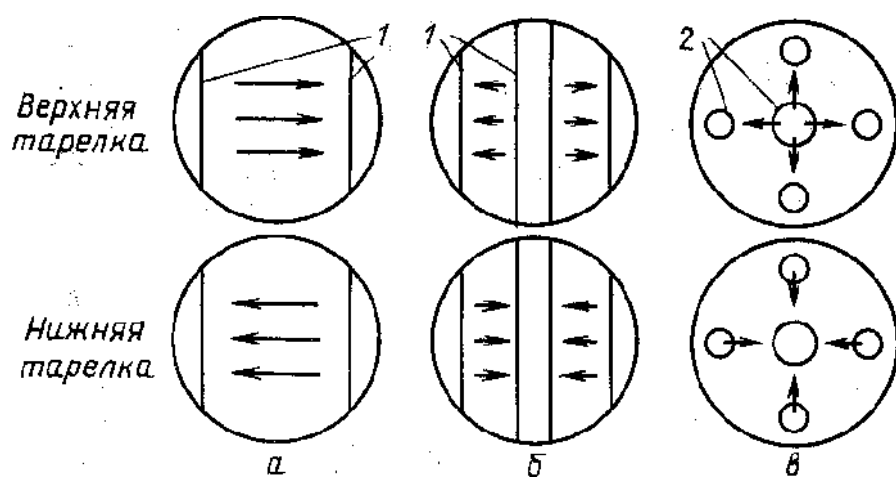
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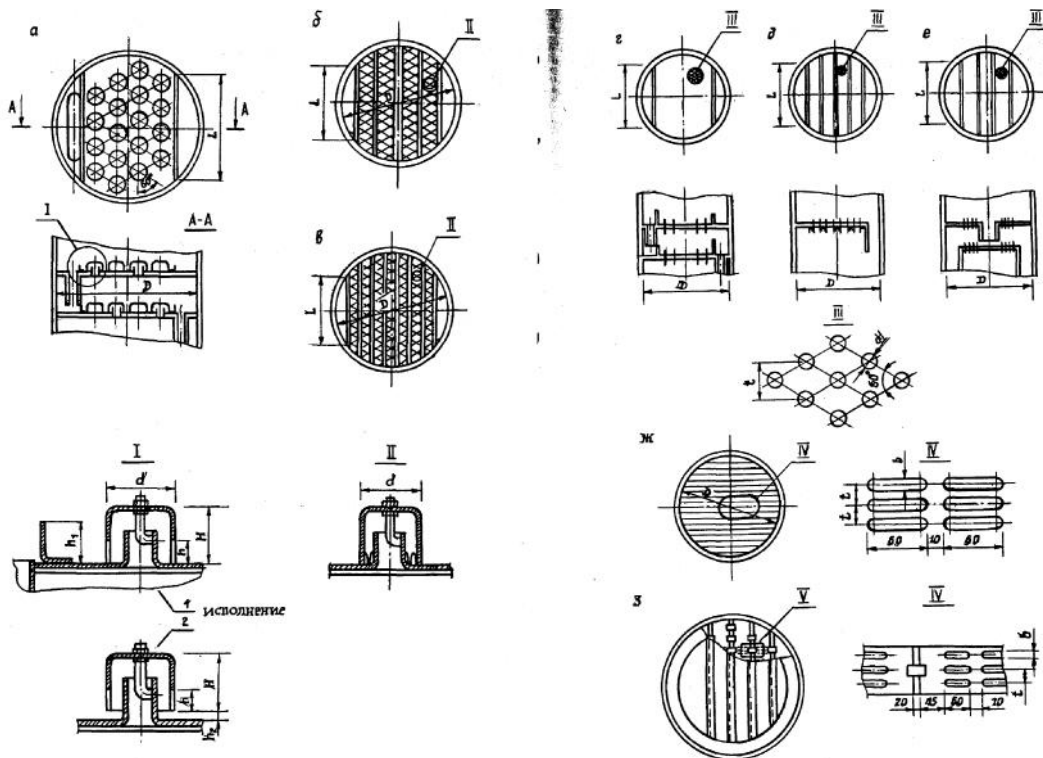
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(. 6.4,)

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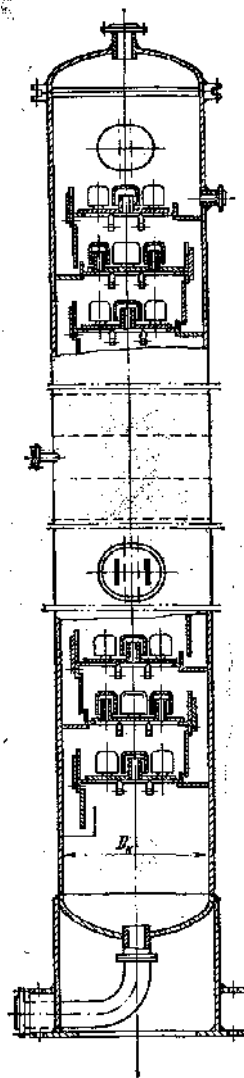


. 6.5 55.

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. 6.6.



. 6.6 56.

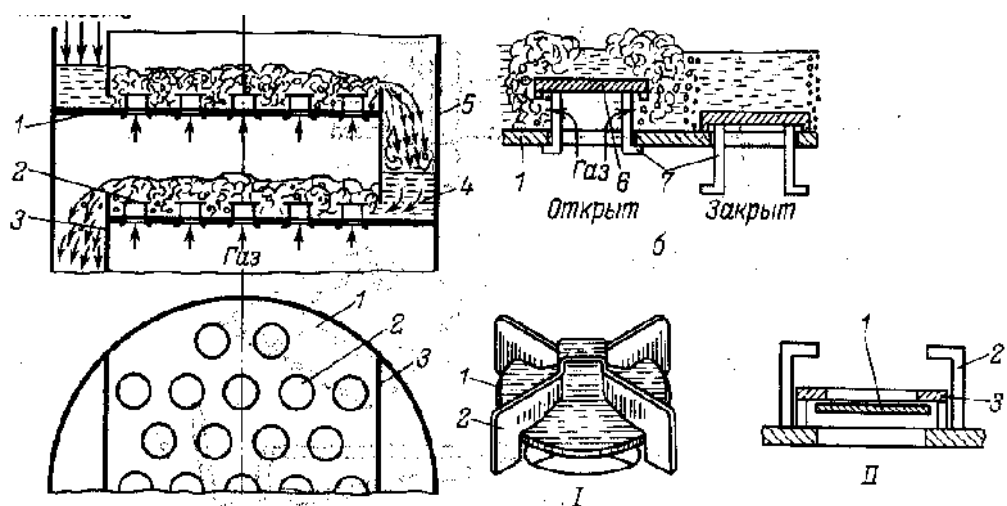
2...8

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; 2 - ; 3 - ; 4 - ; 5 - -

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 (I) (II): 1 - ; 2 - ; 3 - -

7 (. 6.7,).

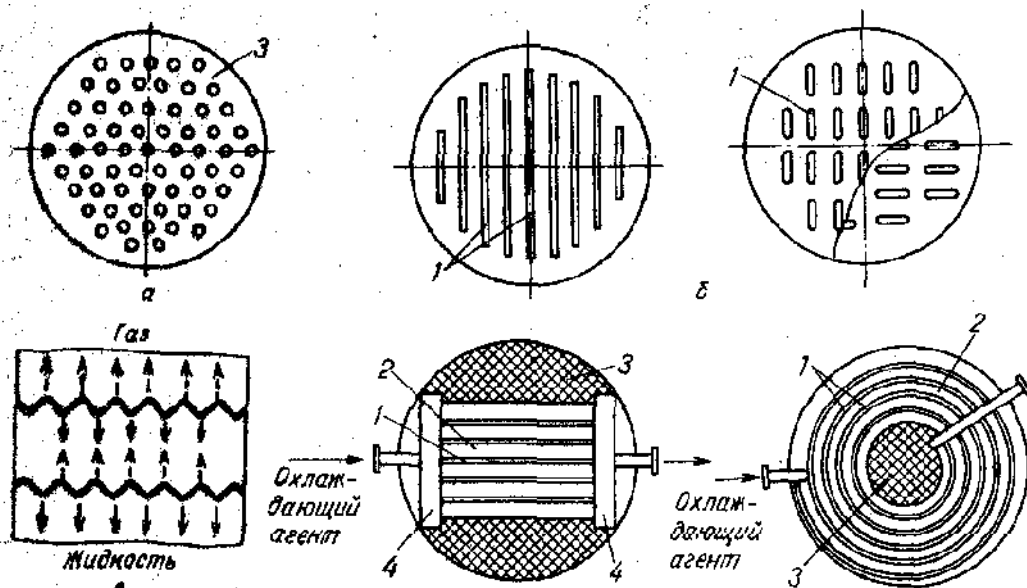
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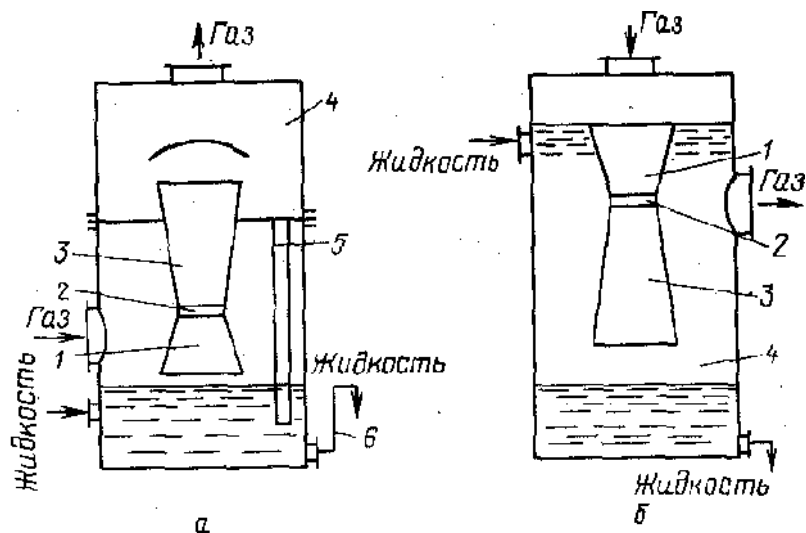
(20...30 /)

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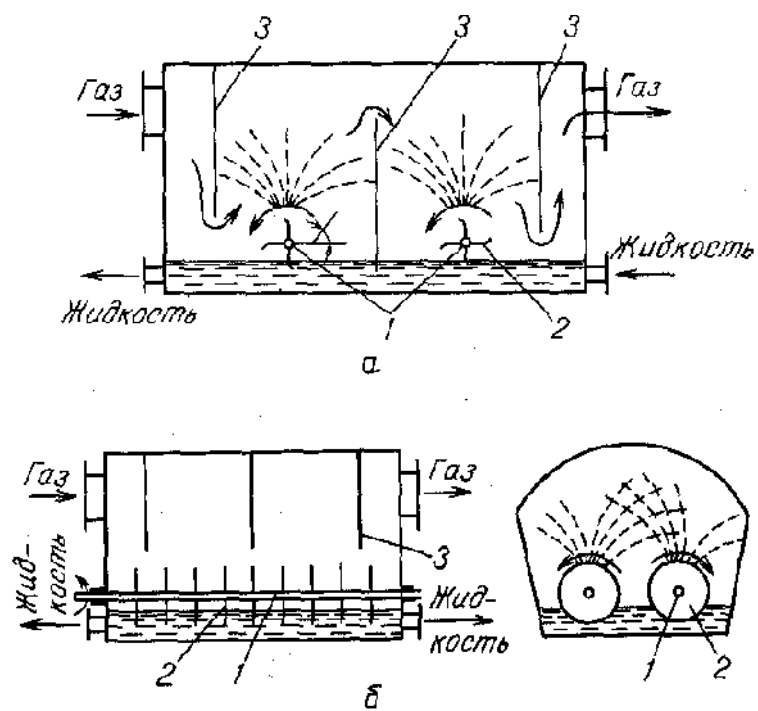
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$$i$$

$$, \quad -$$

$$i \qquad y_i, \qquad x_i$$

$$i^* \qquad x_i^*,$$

$$y_i - y_i^*, \qquad x_i^* - x_i.$$

$$, \qquad \vdots$$

$$G_i = S_y(y_i - y_i^*) = S_x(x_i^* - x_i),$$

$$S_y \quad S_x - , \quad -$$

$$.$$

$$,$$

$$. \quad -$$

$$, \quad -$$

$$.$$

$$y - y^* \qquad p_i - p_i^*$$

$$(p_i - , p_i^* - -$$

$$,$$

$$).$$

$$, \quad -$$

$$, \quad -$$

$$, \qquad y_i^* \quad x_i^*.$$

$$i$$

$$y_i, \qquad y_i^*, \qquad ,$$

$$i \qquad x_i.$$

$$, \qquad : x_i^* -$$

$$x_i, \qquad x_i^* - \qquad i \qquad -$$

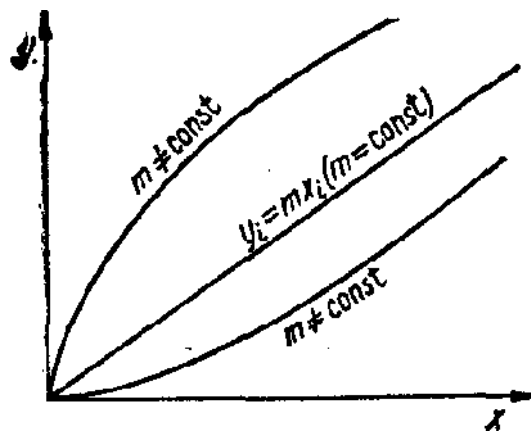
$$y_i. \qquad M_i, \quad -$$

$$S, \qquad t$$

$$M_i = K_{oy}S(y_i - y_i^*)t = K_{ox}S(x_i^* - x_i)t,$$

$$K_{oy} \quad K_{yx} - ,$$

$$.$$

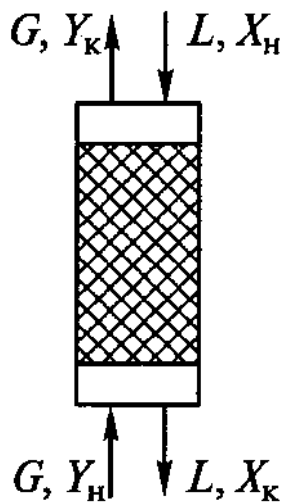


. 6.11.

$$S_{Vy} = aS_y; \quad S_{Vx} = aS_x; \quad K_{Voy} = aK_{oy}; \quad K_{Vox} = aK_{ox},$$

$$M_i = K_{Voy}V(y_i - y_i^*)t = K_{Vox}(x_i^* - x_i)t.$$

(6.12),
 G () L
 G / ,
 L / .
 G Y , L - X .



6.12 . :

$G - L$ —

:

$$dG = dL; \quad d(G_y) = d(L_x).$$

:

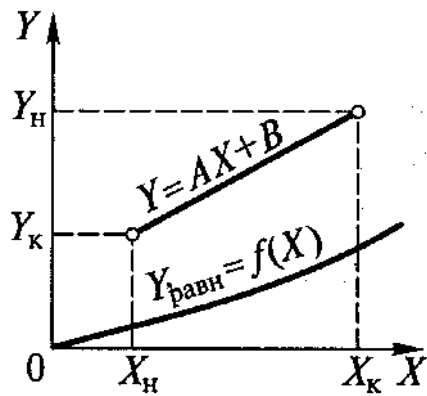
$$G - L_x = G_y - L_x = G_y - L_x.$$

$$G \approx G \quad L \approx L,$$

$$Y = Y - \frac{L}{G}(X - X) = Y + \frac{L}{G}(X - X). \quad (6.1)$$

(6.1), $L/G = \text{const}$ $Y - X$ -
 L/G .

6.13 $Y - X$,



. 6.13.

$$G \tilde{O} G$$

$$L \tilde{O} L$$

$$l = \frac{L}{G} = \frac{Y - Y}{X - X}. \quad (6.2)$$

$$l, \quad (6.2),$$

$$(\quad / \quad).$$

$$0(\quad),$$

$$GY.$$

$$G(Y - Y),$$

$$v = \frac{G(Y - Y)}{GY} = \frac{Y - Y}{Y} = 1 - \frac{Y}{Y}.$$

:

$$G i - L j + Q' = G_i - L_j = G i - L j - Q'',$$

$$i - j -$$

$$G - L; Q' -$$

$$G$$

$$; Q'' -$$

$$, \dots Q = 0,$$

$$G_i + L_j = G_i + L_j.$$

$$(Y, X) \quad (Y, X).$$

$$(6.2).$$

$$(Y, X)$$

$$Y,$$

$$(6.1)$$

$$Y.$$

$$*,$$

$$*$$

$$X \quad Y$$

$$Y,$$

$$X,$$

$$dH,$$

$$dM = K_{oy}aS(Y - Y^*)dH = K_{ox}aS(X^* - X)dH, \quad (6.3)$$

$$S -$$

$$dG = G dY = L dX, \quad (6.4)$$

$$G \quad L —$$

$$(6.3), (6.4)$$

$$\frac{K_{oy}aSdH}{G} = \frac{dY}{Y - Y^*};$$

$$\frac{K_{ox}aSdH}{L} = \frac{dX}{X^* - X}.$$

$$, \quad K_{oy}aS/G \quad K_{ox}aS/L$$

$$H = \frac{G}{K_{oy}aS} \int_Y^Y \frac{dY}{Y - Y^*} = \frac{L}{K_{ox}aS} \int_X^X \frac{dX}{X^* - X}.$$

:

$$dY = m dX,$$

$m =$

dH

$$d(Y - Y^*) = dY - dY^* = dG \left(\frac{m}{L} - \frac{1}{G} \right).$$

,

$$G = L.$$

,

$$m = \text{const},$$

$$M_i = G(Y^* - Y) = L(X^* - X) = \frac{L}{m}(Y^* - Y),$$

$$Y^* - Y =$$

$$X^* - X.$$

$$\frac{m}{L} - \frac{1}{G} = \frac{1}{M_i} [(Y^* - Y) - (Y^* - Y)] = \frac{1}{G_i} (\Delta Y - \Delta Y), \quad (6.5)$$

$$\Delta Y = Y^* - Y \quad \Delta Y = Y^* - Y =$$

i

$$dG \quad (6.4) \quad (6.3), \quad :$$

$$\frac{1}{\frac{m}{L} - \frac{1}{G}} \int_Y^Y \frac{d(Y - Y^*)}{Y - Y^*} = K_{oy}aS \int_O^H dH. \quad (6.6)$$

$$\frac{m}{L} - \frac{1}{G} \quad (6.5), \quad :$$

$$H = \frac{M_i}{K_{oy}aS\Delta y},$$

$$\Delta Y = (\Delta Y - \Delta Y) \ln \frac{\Delta Y}{\Delta Y} -$$

,

,

$$Y.$$

$$H=\frac{M_i}{K_{ox}aS\Delta x}\,,$$

$$\Delta X_{\text{max}}=(\Delta X_{\text{max}}-\Delta X_{\text{min}})/\ln\frac{\Delta X_{\text{max}}}{\Delta X_{\text{min}}}-$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$(6.6)$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$\int\limits_Y^Y\frac{dY}{Y-Y^*}=N_{oy}\qquad\int\limits_X^X\frac{dX}{X^*-X}=N_{ox}.$$

$$\frac{L}{K_{ox}aS},\qquad\qquad\qquad\frac{G}{K_{oy}aS}$$

$$H=BE_y\cdot N_{oy}=\qquad\qquad\qquad N_{ox}.$$

$$N_{oy}\qquad N_{ox},$$

$$x^{\text{max}}\qquad\qquad\qquad N_{oy}\qquad N_{ox}$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

$$\frac{1}{\Delta X_{\text{max}}}-\frac{1}{\Delta X_{\text{min}}}=\frac{1}{X_{\text{max}}}-\frac{1}{X_{\text{min}}}.$$

X_A . B — ; R —
 , ; —
 , 1 ; 1 2 .
 , — .

$$l_{min} = \pm L_{min}/G = (Y_1 - Y_2) / \lambda_B,$$

L_{min} — .

$$Y = Y_1 - l(C - C_1)$$

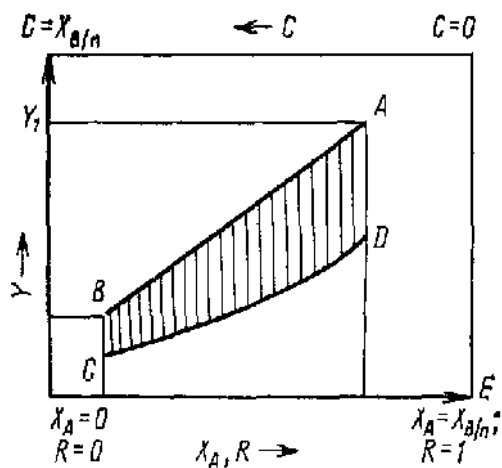
():

$$Y = \frac{Y_1 - l(C - C_1)}{1 + Y_1 - l(C - C_1)},$$

$$l = \pm L/G.$$

Y — , ,

. 6.14.



. 6.14.

$Y - X$

(

CD

$Y - Y$; — ;

$CD - Y$)

*

, .

N_0

(

K):

$$N_0 = \int_{Y_1}^{Y_2} \frac{dY}{Y - Y} = \frac{K F}{G}.$$

$$Y^* = 0,$$

Y .

$$N_0 = \int_{Y_2}^{Y_1} \frac{dY}{Y - Y} = \frac{S}{G} \frac{F}{G},$$

Y —

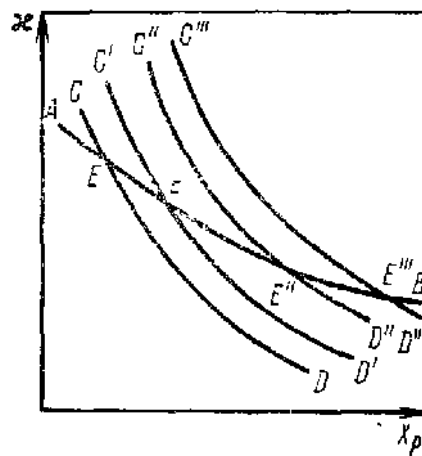
$$(Y - Y) =$$

$$Y_p = mX_p$$

$$= (\text{ } / \text{ })(Y/X - m), \tag{6.7}$$

—

$$Y, \tag{6.15}$$



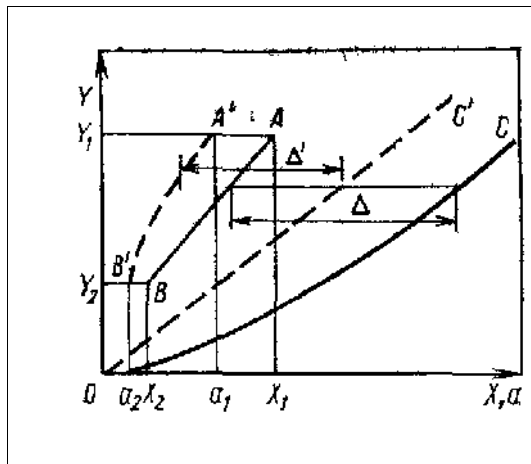
. 6.15.

$$CD, C'D', C''D'' \quad C'''D''' \tag{6.7}$$

, ; " "

$$Y \quad CD, \quad Y = f(R).$$

$$Y. \quad Y = m$$



. 6.17.

$Y - X$

(— ; ' ' - ; — ; ' - -)

():

$$= a + b = Y / m + f(),$$

— ; b —

, —

;

Y -

,

$$Y = .$$

:

$$Y_1 - Y = l\{[a_1 + f(a_1)] - [a + f(a)]\}.$$

, Y .

, — .

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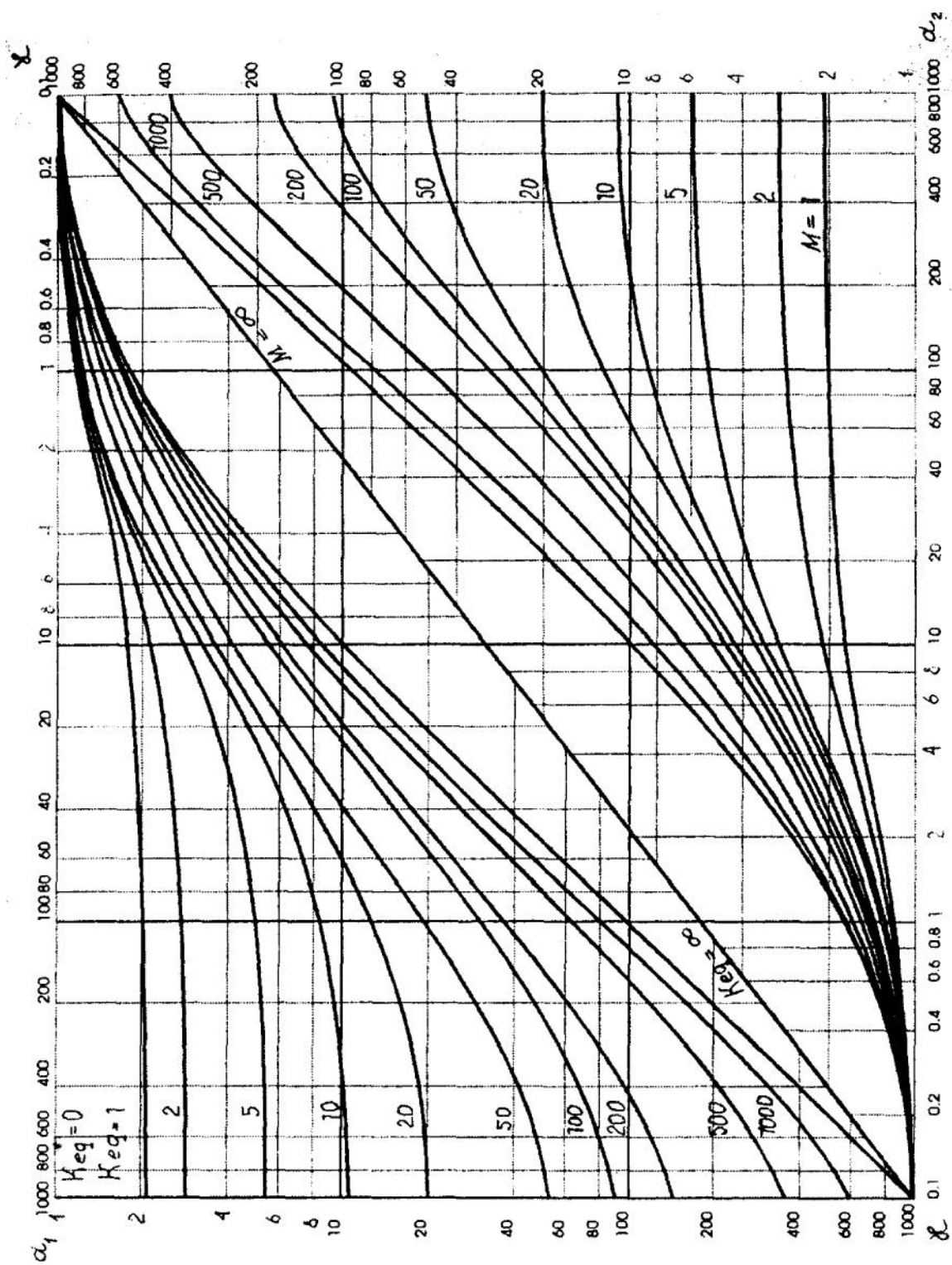
. -

χ , . 6.18.

$A \leftrightarrow B$, -

χ

. 6.18.



. 6.18.

α_1 ,

$$r_1=\frac{(D_Ak_1)^{1/2}}{S}\;,$$

D_A - , $^2/c$; k_1 -
, $^{-1}$; β -
, / .

, $K_{eq}=0$,
 $\chi=1$, $K_{eq}=\infty$
.

. 6.18.

α_2 , :

$$r_2=\frac{(D_Ak_2C\;)}{S}\;,$$

k_2 - , $^3/(\;)$; -
, 1^{-3}
(K_{eq}) :

$$M=\frac{C\;D_B}{N\;C_A\;D_A}\;,$$

N - , 1 ; -
.

. 6.18 , χ
.

α_2 (0,5) $\chi\approx 1$, . .

,
. $\alpha_2>2\rightarrow\chi$ α_2 .
 α_2 , (,
), χ α_2 , $+1$ (
).

, χ ,
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h -

.

$$H^{\quad} = H^{\quad} + H + H^{\quad} \quad ,$$

H^{\quad} - , ; -

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-

() . (1,0... 1,5)

D^{\quad} .

H -

, -

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D

H :

D^{\quad} , 0,4 – 1,0 1,2 – 2,2 2,4

H^{\quad} , 0,6 1,0 1,4

H^{\quad} , 1,5 2,0 2,5

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D

w^{\quad} (,), :

$$D^{\quad} = (G_V/0,785w^{\quad})^{0,5},$$

G_V — ().

w^{\quad} , -

w^{\quad} :

$$w^{\quad} = 0,8\, w^{\quad} .$$

() , ,

$$\lg\left(\frac{w^2}{g} \cdot \frac{a}{v^3} \cdot \frac{\dots_y}{\dots_x} \sim_x^{0,16}\right) = b - c \left(\frac{L}{G}\right)^{0,25} \left(\frac{\dots_y}{\dots_x}\right)^{0,125} \quad (6.8)$$

$$b = 0,022; \quad = 1,62; \quad b$$

$$= - 0,125; \quad = 1,75.$$

$$w = K_1 \left(\frac{\dots_x}{\dots_y}\right)^{0,5} [11 - K_2 f(\sim_x) L^{0,5}];$$

$$f(\sim_x) = 0,775 + 0,225 \sim_x^{0,25}. \quad (6.9)$$

$$(6.9) \quad \sim_x > 1 \quad .$$

$$K_1 \quad K_2 \quad . 6.3.$$

6.3

$$K_1 - K_6$$

	,	K_1	K_2	K_3	$K_4 \cdot 10^8$	K_5	K_6
, ,	0,015	0,050	0,110	45,5	1460	0,3	0,115
	0,025	0,062	0,095	44,4	1400	0,3	0,1
	0,035	0,074	0,083	16,7	1300	0,3	0,09
	0,050	0,083	0,077	15,5	955	0,3	0,08
: - , -	0,025	0,100	0,071	12,9	1260	0,6	0,1
	0,035	0,107	0,064	9,9	1140	0,55	0,09
	0,050	0,113	0,058	7,1	1025	0,45	0,08
	0,050	0,113	0,062	7,1	650	0,3	0,08
: - -	0,035	0,083	0,070	7,8	730	0,35	0,09
	0,050	0,093	0,065	7,1	650	0,3	0,08

$$0,05 \quad (\quad - \quad -$$

$$) \quad (6.8) \quad b = - 0,099, \quad =$$

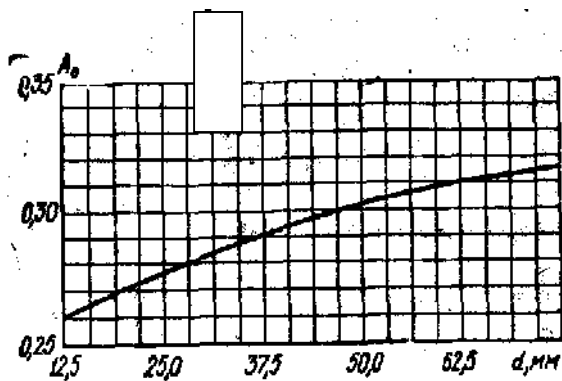
$$1,505; \quad w = 0,7 w .$$

$$w = G_v / 0,785 D^2;$$

$$D = 0,339 \left[37 \frac{G}{A_0} \left(\frac{\dots_y}{\dots_x - \dots_y} \right)^{0,5} - 510 L \lg A_1 \right]^{0,5},$$

$A_0 \quad A_1 -$

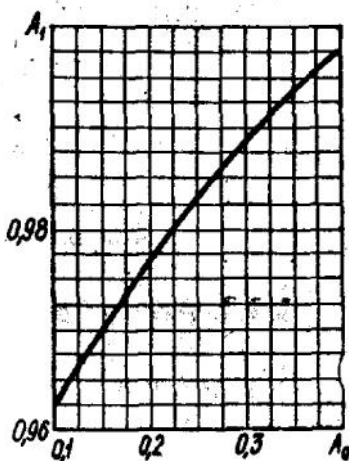
, . 6.19 6.20.



. 6.19.

0 (

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. 6.20.

1

$K_7,$

-

$$D = G_v K_7 / 0,785 w .$$

D

-

$D_{\max}.$

-

$D_{\max},$

$D . p.$

$$D_{\rm p} \qquad \qquad \qquad w_{\rm p},$$

$$w_{\rm .max},$$

$$D_p=\left(G_VK_7/0,785w_p\right)^{0,5},$$

$$w_p=0,8w_{\rm .max}\,;$$

$$w_{\rm .max}=K_1\left(\cdots_x/\cdots_y\right)^{0,5}\left(1-K_2A60L_V^{-0,5}\right).$$

$$K_1-K_2\qquad\qquad\qquad.~6.3.\qquad\qquad\qquad=f(\sim_x)-(\quad).$$

$$(6.9)).$$

$$L_V\quad=L_V/f\quad,$$

$$f\quad=0,785D^{-2}.$$

$$D_{\rm p} \qquad \qquad \qquad -$$

$$D \qquad \qquad \qquad .$$

$$D_{\rm p}>2,8\quad,\qquad\qquad\qquad -$$

$$.$$

$$,\qquad\qquad\qquad:$$

$$- \qquad \qquad \qquad f=0,785\cdot D^{-2};$$

$$- \qquad \qquad \qquad L_{Vf}=L_V/f\,;$$

$$- \qquad \qquad \qquad w=G_V/f\,;$$

$$- \qquad \qquad \qquad F=w\,(\cdots_y)^{0,5}.$$

$$H=N\,h$$

$$N\quad - \qquad \qquad \qquad ;\,h\quad - \qquad \qquad \qquad , \qquad \qquad \qquad -$$

$$.$$

$$,\qquad\qquad\qquad,$$

$$\frac{h}{d}=5,2\mathrm{Re}_y^{0,2}\left(\frac{G}{L}\right)^{0,35}\left(\frac{\cdots_x}{\cdots_y}\right)^{0,8}\frac{\lg\frac{L}{mG}}{1-\frac{mG}{L}},$$

$$d\quad=4\varepsilon/\quad - \qquad \qquad \qquad ;\quad m\quad -$$

$$.$$

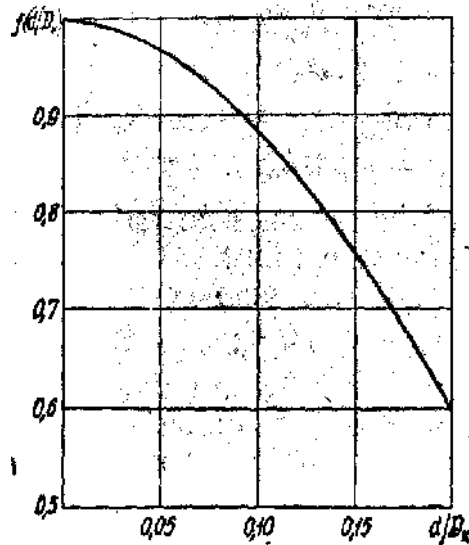
$$h$$

$$h = \left[\frac{K_5}{w} \sqrt{\frac{\dots_x}{\dots_y}} \cdot \frac{1}{1+D} \sqrt[4]{\frac{1}{h}} (1 - 60K_6 \sqrt{L_{vf}}) f\left(\frac{d}{D}\right) \right]^{-1}.$$

$$K_5 \quad K_6 \quad . \quad 6.3.$$

$$f(d/D) \quad . \quad 6.21$$

$$f\left(\frac{d}{D}\right) = 0,62 \left(\frac{d}{D}\right)^{-0,15}.$$



$$. \quad 6.21.$$

$$f(d/D)$$

$$d/D$$

+

$$d/D \leq 0,043,$$

$$f(d/D) = 1.$$

$$\left(\frac{\Delta p}{H}\right) = \left(\frac{\Delta p}{H}\right) \left[1 + A \left(\frac{L}{G}\right)^m \left(\frac{\dots_y}{\dots_x}\right)^n \left(\frac{\sim_x}{\sim_y}\right)^c \right], \quad (6.10)$$

$$\left(\frac{\Delta p}{H}\right) -$$

,

$$(\quad 1 \quad); L/G -$$

-

$$(\quad); \left(\frac{\Delta p}{H}\right) - (\quad 1 \quad).$$

$$, m, n$$

$$. \quad 6.4.$$

(6.10)

	A	m	n	c
— $\left(\frac{L}{G}\right)^{1,8} \left(\frac{\dots_y}{\dots_x}\right) \left(\frac{\sim_x}{\sim_y}\right)^{0,2} < 0,5$	8,4	0,405	0,225	0,045
— $\left(\frac{L}{G}\right)^{1,8} \left(\frac{\dots_y}{\dots_x}\right) \left(\frac{\sim_x}{\sim_y}\right)^{0,2} < 0,5$	10	0,945	0,525	0,105
— $\left(\frac{L}{G}\right)^{1,8} \left(\frac{\dots_y}{\dots_x}\right) \left(\frac{\sim_x}{\sim_y}\right)^{0,2} < 0,5$	0,352	0,342	0,190	0,038

$$\Delta p = \left\{ \frac{H}{d} \cdot \frac{\dots_y w_p^2}{2} = \frac{1}{4} \cdot \frac{Ha}{\nu^3} \cdot \frac{w^2 \dots_y}{2} \right\};$$

$$d = 4R = 4\nu / a;$$

() -

$$w_p = w / \nu,$$

- , ; λ - ; w -

, , / ; -

, $2/3$; ε - , $2/3$; R -

, .

$$\lambda \quad Re_y$$

() :

$$Re_y = \frac{w_p d \dots_y}{\sim_y} = \frac{4w \dots_y}{\sim_y a}$$

λ :

$$Re_y < 80 \quad \left\{ = \frac{400}{Re_y^{0,85}} \right\};$$

$$80 < Re_y < 400 \qquad \} = \frac{70}{Re_y^{0,45}} \, ;$$

$$Re_y > 400 \qquad \} = \frac{16,5}{Re_y^{0,2}} \, .$$

$$\Delta p \; = \Delta p \; + ... \cdot g \cdot H \; ;$$

$$... \; = ..._y + 0,43 \Big(..._x - ..._y \Big) \Big(\frac{L}{G} \Big)^{0,325} \Big(\frac{..._y}{..._x} \Big)^{0,18} \Big(\frac{\sim_x}{\sim_y} \Big)^{0,0362} \; ,$$

$$- \qquad \qquad \qquad .$$

$$,$$

$$h \; = \frac{\Delta p \; + ... \cdot g \cdot H}{..._x \cdot g} \; ,$$

$$- \qquad \qquad \qquad .$$

$$1$$

$$\Delta p = K_3 \cdot ... \cdot w^2 \cdot H \cdot 10^{K_4 \cdot L \cdot 3600} \, .$$

$$K_3 \; \; K_4 \qquad \qquad \qquad . \; 6.3.$$

$$\Delta p \; \; = \Delta p \cdot H \; ,$$

$$.$$

$$p \; = p \; + \Delta p \; \; ,$$

$$p \; - \qquad \qquad \qquad .$$

$$.$$

$$:$$

$$- \qquad \qquad \qquad , \qquad \qquad \qquad ;$$

$$- \qquad \qquad \qquad ,$$

$$;$$

$$- \qquad \qquad \qquad .$$

$$- \qquad \qquad \qquad ;$$

$$- \qquad \qquad \qquad ;$$

$$- \qquad \qquad \qquad ;$$

(6.11)

	q	n	z	
			$\mu < 1$	$\mu > 1$
- -	0	- 0,25	0	- 0,25
-	0	- 0,25	- 0,43	- 0,25
- -	0,3	0	0,25	0
-	0,3	0	- 0,18	0

,

$$Nu = 0,12 \cdot Re^{0,7} Pr^{0,5} \left(\frac{d}{d} \right)^{0,5},$$

(6.12)

$$Nu = 1,2 \cdot Re^{0,7} Pr^{0,5} \left(\frac{d}{d} \right)^{0,5},$$

(6.13)

$$Nu = \frac{s \cdot d}{D} \text{ — };$$

$$Re = \frac{w \cdot d}{\{ \epsilon \text{ — } , \quad w \text{ — } , \quad / ;$$

$$Nu = \frac{s \cdot d}{D} \text{ — } ;$$

$$Re = \frac{w \cdot d}{(1 - \{ \text{)} \epsilon \text{ — } .$$

φ

$$\{ = 0,6 \left(\frac{w^2 h_0}{q} \right)^{0,1} .$$

-

$$(\quad^3/ \quad):$$

$$V=\langle f(\frac{2p}{\dots})^{1/2},$$

$$p\text{---},\quad;\quad\text{---},\quad/{}^3;f\text{---},\quad^2;\quad\text{---},\quad,$$

$$0,2...0,3.$$

$$d$$

$$\frac{d}{d_0}=A(\frac{\sim^2}{\dots\uparrow d_0})^{-m}(\frac{w}{\epsilon}\frac{d_0}{})^{-n},$$

$$d_0\text{---};\,A\text{---};\\w\text{---}.$$

$$a=\frac{6U}{u\,d},$$

$$U\text{---},\quad^3/(\quad^2\quad);\quad\text{---},\quad/\quad,u=w_0\pm w\,(w_0\text{---}\quad,\quad/\quad,w\text{---}\quad,\quad/ \,).$$

$$Nu'=2+0,552Re^{0,5}(\quad r\quad)^{0,33};\\Nu'=1,65\,(d/d_0)^{0,73}Re^{0,5}(\quad r\quad)^{0,33},\\Nu'=1,13/(Fo')^{1/2};\,\,Fo'=D\cdot\tau/d^2;\,\,\tau\text{---}.$$

$$APT\quad-.$$

$$\Delta p=\langle_c\frac{w^2\ldots}{2}+\langle\quad\frac{w^2\ldots}{2}m;$$

$$\langle\quad=0,165+0,034\frac{l}{d}[0,06+0,028\frac{l}{d}]\frac{w}{w};$$

$$\langle\quad=\quad\langle\quad m^{1+B},$$

с — — ; — ; w — , / ; , — , /³; l — , ; d — ; w — , / ; w/w = — ; — , . ,

$$d = \frac{585 \cdot 10^{-3} \uparrow^{1/2}}{w \dots^{1/2}} + 53,4 \left[\frac{\sim}{(\dots \uparrow)^{1/2}} \right]^{0,45}.$$

$$a = \frac{6U}{w \ d} = \frac{0,006 \ m}{d}.$$

$$\begin{aligned} Nu' &= 0,36 \cdot 10^{-4} Re^{0,81} (Pr')^{0,67}; \\ Nu' &= (0,145 - 0,0081w) (Re - 30)^p (Pr')^{0,5}, \\ Nu' &= (\mu/\mu)(\sqrt{v}RTd_0/D)(\sqrt{g'})^{1/2}; Nu' = \sqrt{v'} \cdot d_0/D; \sqrt{v} \sqrt{v} = \\ &, 1/; = (\mu^2/\sqrt{2} \cdot g)^{1/3} — \\ ; p &= 7,4 \cdot 10^{-4} \cdot w^{164}; Re \ R \\ d_0. \end{aligned}$$

$$p = p + 18 \cdot w^{1,08} \cdot m^{0,63}.$$

:

$$N_0 = 0,847(L/G)^{0,32}.$$

:

$$N_0 = 0,477 \cdot w_0^{0,35} (L/G)^{0,44}.$$

APT

:

$$= 1,32 (1 + \sqrt[n]{m^n}),$$

$$N_0 = 0,43 + B \cdot m,$$

$$= (w) \quad B = (w); \quad n = 0,68; \quad n = 1,9.$$

6.4.

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. (H₂O₂, H₂IO₄, K₂IO₄, KMnO₄, HNO₃), (

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7.1

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	1-5	350	-	0,26	-
	1-3,5	380-500	70	0,45-0,59	
-3	1,5-2,7	450	38	0,3	
-5	1-1,5	450	45	0,3	
	1-5	450	-	0,36	
	1-5	400	-	0,33	
-3	1-5,5	550	-	0,33	-
	1-6	550-600	-	0,33	
-3	1-3,5	420-450	-	0,46	

(,).
 0,2...7 , 400... 900 / ³.
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 (100...200 °),
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 (2,5...5,0 3...7 ,
 500...700 / ³, 6·10⁻⁹...10⁻⁸),

($3 \dots 4$, $600 \dots 900$ / 3 , $3 \cdot 10^9 \dots 4 \cdot 10^{-9}$).

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 $(3,5 \dots 4) \cdot 10^{-10}$, $0,15$ $^3/$.

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 NaA CaA CaX NaX
 « », $3 \cdot 10^{-10}$ $4 \cdot 10^{-10}$ $5 \cdot 10^{-10}$ $8 \cdot 10^{-10}$ 10^{-9}

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(
 $2 \dots 5$) $(d = 2 \dots 4$ $2 \dots 4$).

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 $4 \cdot 10^{-10}$ (, , -
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 CaX NaX « »
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7.1.

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7.2.

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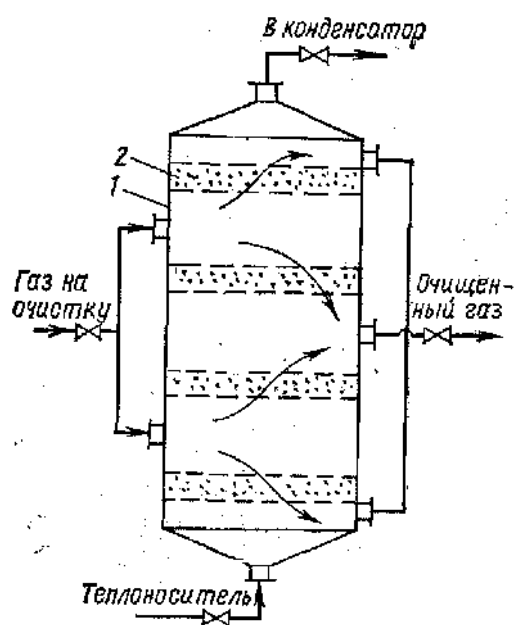
1)

2)

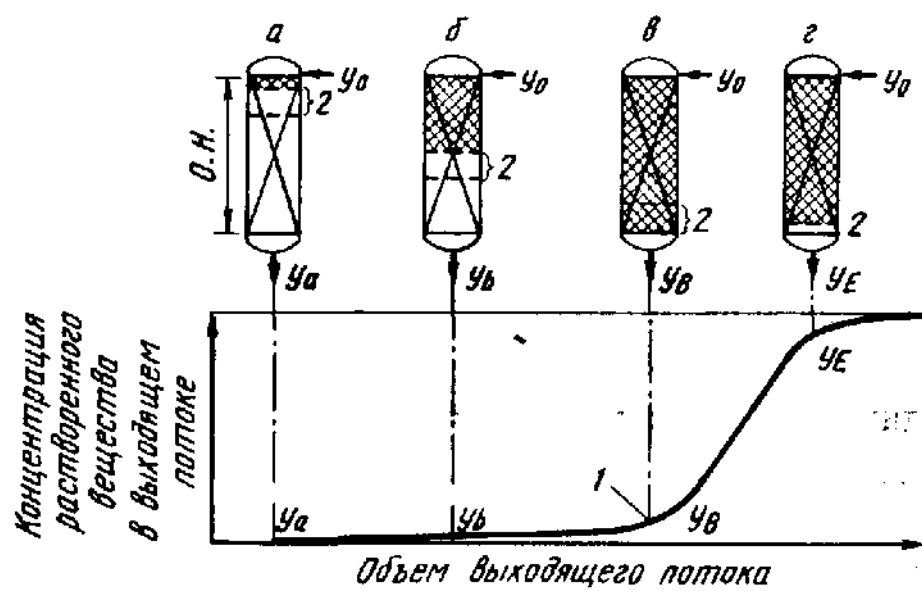
3)

4)

(7.2).



. 7.2.



.7.3.

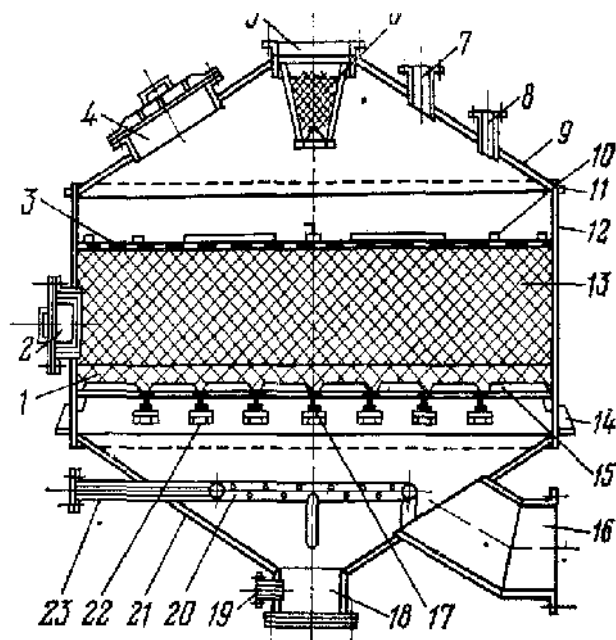
1 -

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(. 7.4)

8...10



. 7.4.

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- 1 – ; 2 – ; 3, 6 – ; 4 – ; 5 –
; 7 – ; 8 –
; 9 – ; 10 – ; 11 – ; 12 – ; 13 –
; 14 – ; 15 – ; 16 –
; 17 – ; 18 – ; 19 – ; 20 –
; 21 – ; 22 – ; 23 –

2,2

2; 2,5 3

0,5 1,2 .

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100...200 .

: — $3,2 \times 3,2$ 4×4 -

0,9...1,0 ; - $1,4 \times 1,4$ $1,8 \times 1,8$

0,65...0,7 . 25...30

, — 15...20 , — 7...15 , — 5...7 .

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2,2×2,2 2,5×2,5 0,7...0,8 . -

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25×25 , 600...900 .

2,2×2,2 0,8 . -

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(. 7.5) 1,8 2 -

3...9 ; ; 0,5...1,0

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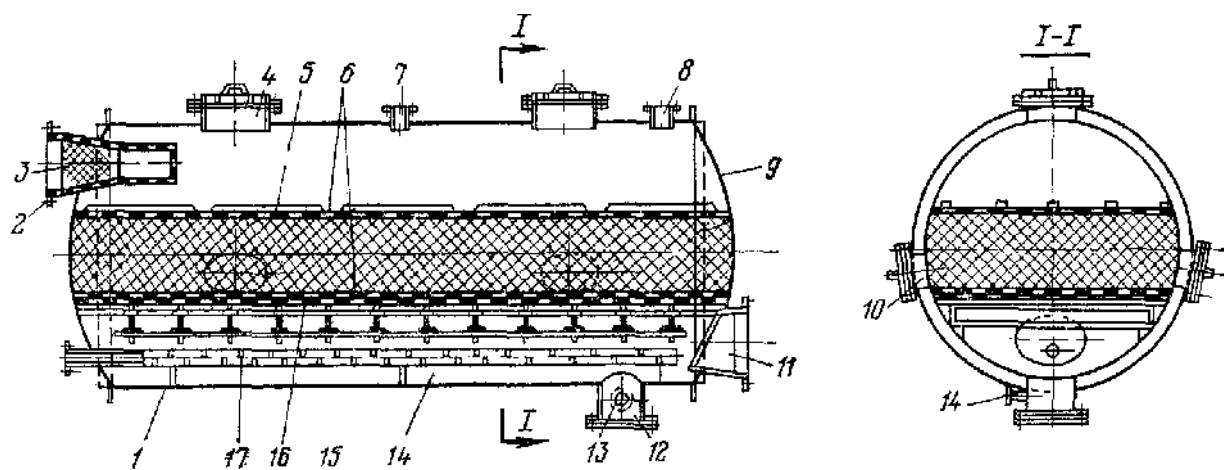
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2,2×2,2 0,8 . -

,

4...6 . -

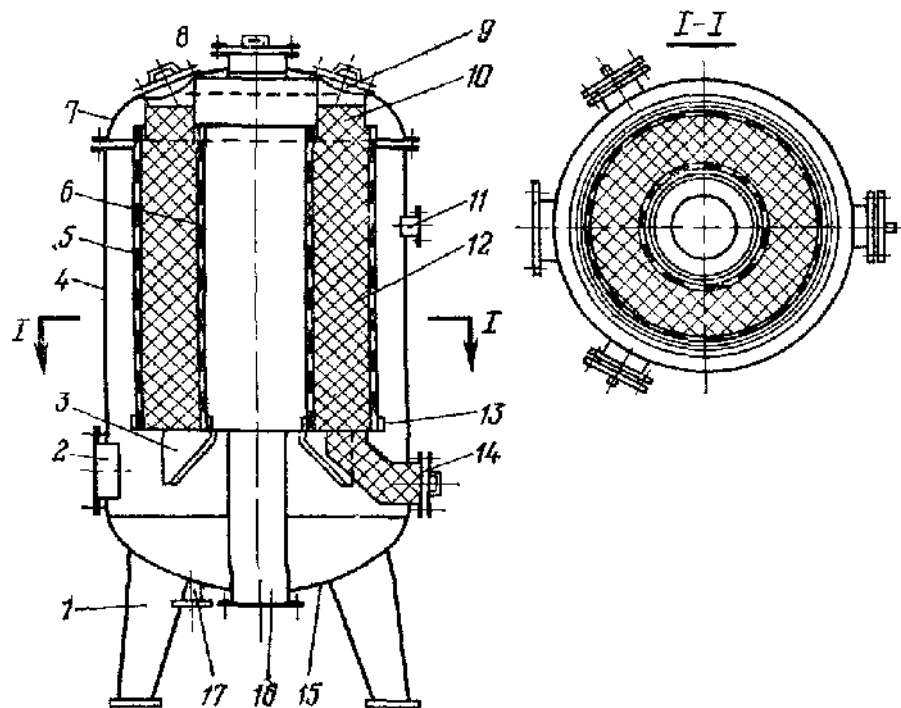


. 7.5.

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- 1 – ; 2 –
; 3 – ; 4 –
; 5 – ; 6 – ; 7 – ; 8 –
; 9 – ; 10 –
; 11 –
; 12 – ; 13 –
; 14 – ; 15 – ; 16 – ; 17 –

. 7.6,



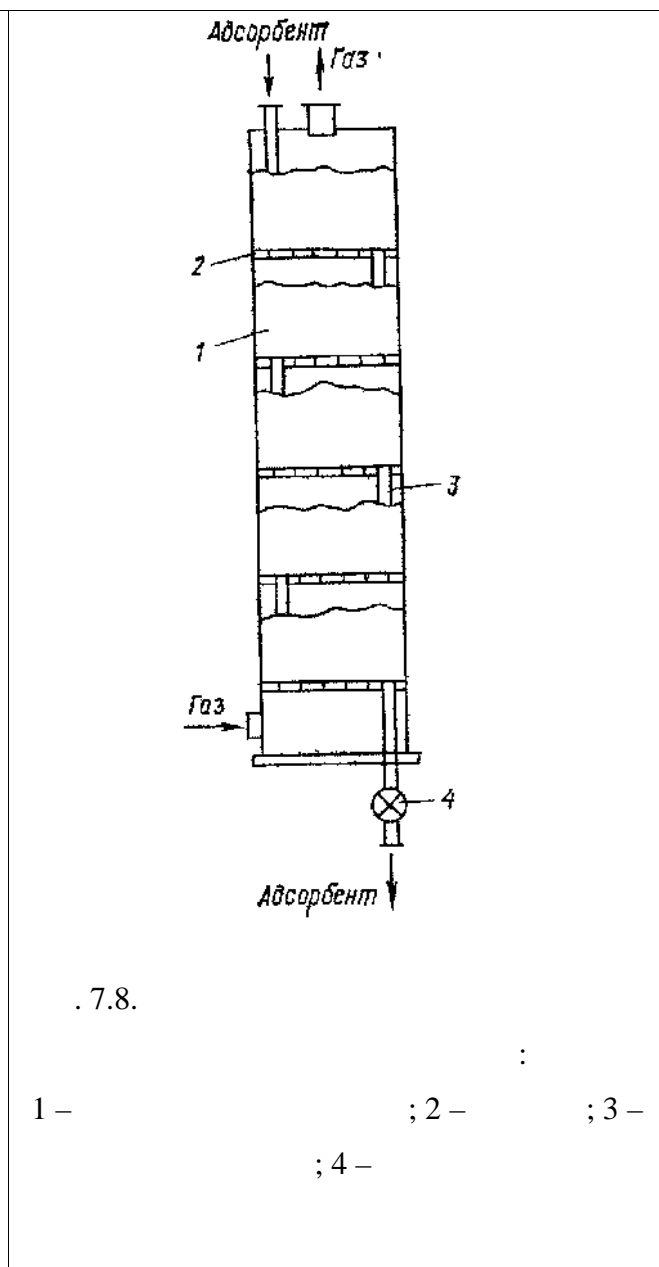
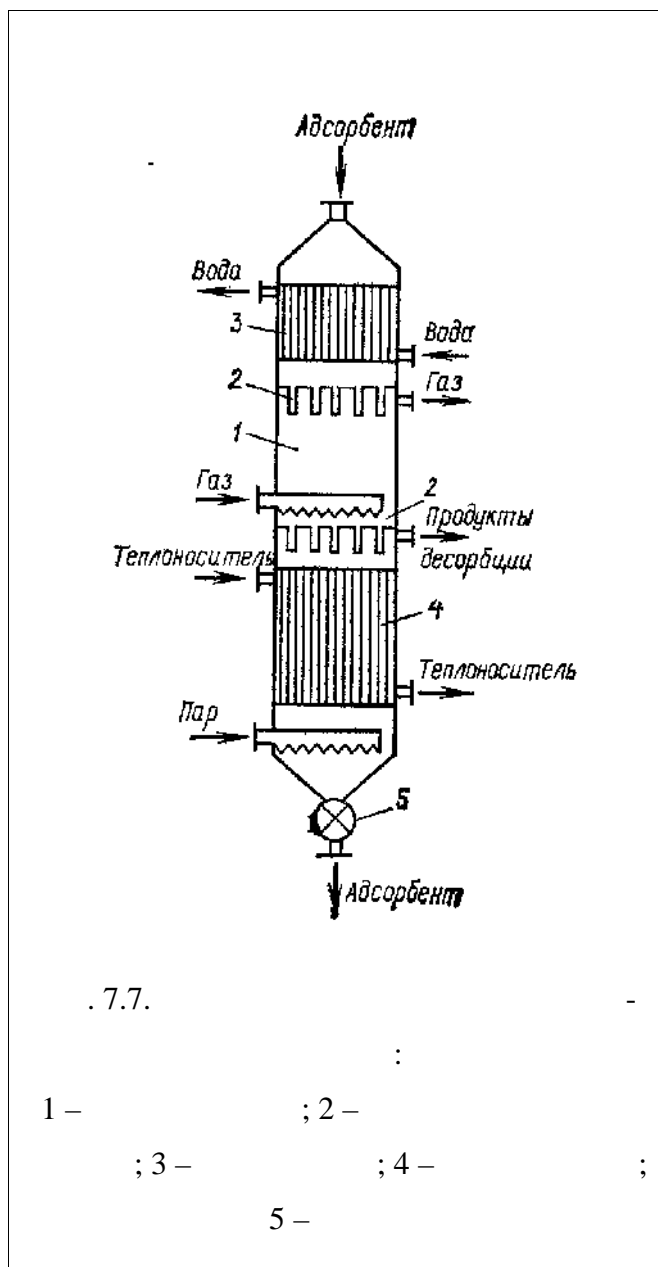
. 7.6.

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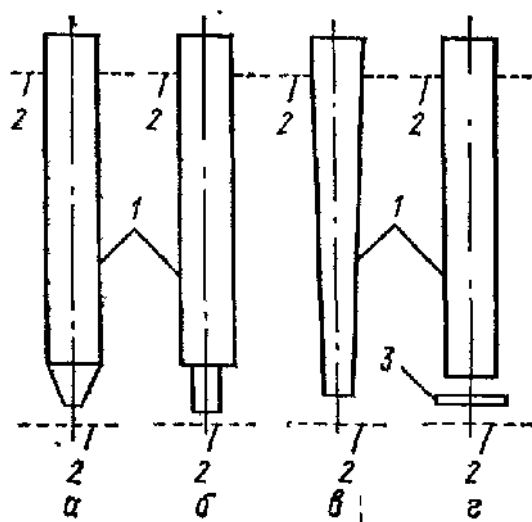
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(7.9).



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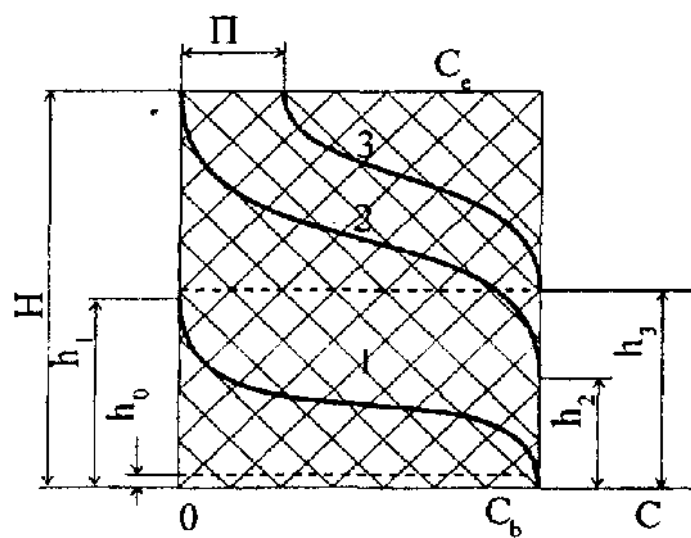
7.3.

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$$\hat{p} = k p^{1/n}.$$

$$\vdots$$

$$\ln \hat{\tau} = \ln k + \ln P/n.$$

$$\hat{p} = \frac{b \hat{p}_m}{1 + b p}.$$

,

$$(\quad), \quad (\quad),$$

.

, - ,

:

$$\frac{\hat{\quad}}{\hat{\quad}_m} = \left(\frac{cx}{1-x} \right) \left[\frac{1 + nx^{n+1} - (n-1)x^n}{1 + (c-1)x - cx^{n+1}} \right] \quad (7.1)$$

- ,

.

$$, \quad = 1, \quad (7.1) \quad :$$

$$\frac{\hat{\quad}}{\hat{\quad}_m} = \frac{cx}{1+cx}.$$

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$$n \rightarrow \infty$$

$$, \quad x \rightarrow p/p_0, \quad p_0 -$$

:

$$\frac{\hat{\quad}}{\hat{\quad}_m} = \frac{cp}{(p_0 - p) \left[1 + (c-1) \frac{p}{p_0} \right]}.$$

:

$$C = \frac{k_1}{\hat{\quad}} \exp \left[-b_1 \left(\frac{T}{z} \lg \frac{p}{p} \right)^2 \right] + \frac{k_2}{v} \exp \left[-b_2 \left(\frac{T}{z} \lg \frac{p}{p} \right)^2 \right], \quad (7.2)$$

$$C - , (\quad / \quad); \quad k_1, k_2 - ,$$

$$; \quad b_1, b_2 - , -$$

$$; \quad T - , \quad ; \quad p, p -$$

$$, \quad ; \quad \hat{\quad} - \quad 273 ,$$

$$^3/ \quad ; \quad z - .$$

. 7.2.

-				
	$k_1 \cdot 10^4, \text{ }^3/$	$k_2 \cdot 10^4, \text{ }^3/$	$b_1 \cdot 10^6, \text{ }^{-2}$	$b_2 \cdot 10^6, \text{ }^{-2}$
	2,2-2,6	-	0,55-0,7	-
-	2,53	1,39	1,2	4,4
-	3,4	-	1,0	-
-	2,3	-	0,7	-
-	1,9	1,8	0,74	3,42
-	3,0	-	0,7-0,8	-
-3	4,8	-	0,73	-
-	2,3	1,3	0,7	3,1

• ,
- .
 ,
 $Gdy = Ldx$,
 G - , ()/ ; L - ,
()/ ; y - -
 , /() ; x -
 , /().

-
 $G(y - y) = L(x - x)$.
 , -
 .
 $-Gdydt = SdH \text{ } dx$,
 S — , 2 ; — , ;
— , / 3 .

•
 ,
 :

$$\frac{\bar{C}-\bar{C}_-}{\bar{C}_-}=f(\text{Bi}_-, \text{Fo}_-, \frac{Z}{\delta}).$$

$$\text{Bi}=\frac{Sl}{\alpha},$$

$$; \text{Fo}=\frac{\tau}{l^2}-$$

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:

$$dH=K\left(y-y\right)dS.$$

:

$$\frac{1}{K}=\frac{1}{S_1}+\frac{1}{S_2}.$$

:

$$\begin{aligned} Nu' &= 0,395 \cdot Re^{0,64} (Pr')^{0,33} & Re > 30; \\ Nu' &= 0,725 \cdot Re^{0,47} (Pr')^{0,33} & Re = 2...30; \\ Nu' &= 0,515 \cdot Re^{0,85} (Pr')^{0,33} & Re < 2. \end{aligned}$$

2

$$_2=4^{-2}\cdot D_i/d^2,$$

$$Nu'=\alpha_1d/D---;Re=w d/(\rho \nu)---;Pr'=\alpha_2D---$$

$$;d---;D---$$

$$;w---;---$$

$$;Di---$$

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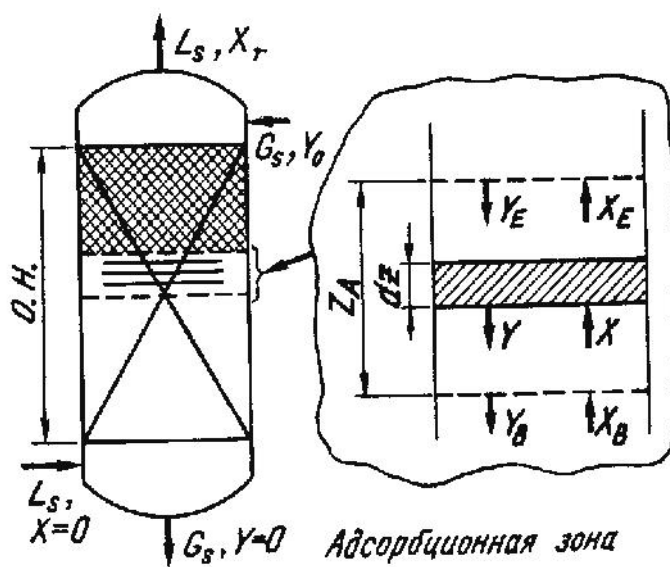
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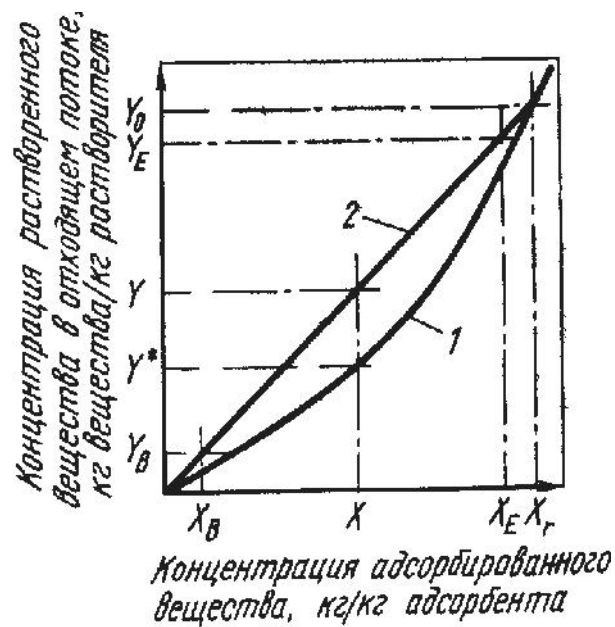
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(.7.11).



.7.11.

.7.12.



.7.12.

(1)

(2)

$$(\quad .7.11), \qquad X_r, \qquad -$$

$$, \qquad Y_0, \quad . \quad X_r = Y_0, \qquad -$$

$$, \qquad (\qquad -$$

$$). \qquad , \qquad -$$

$$. \qquad -$$

$$:$$

$$G_S(Y_0 - 0) = L_S(X_r - 0); \qquad G_S Y_0 = X_r L_S,$$

$$G_S \, Y = X \, L_S,$$

$$G_S - \qquad - \qquad , \quad /(\cdot^2); L_S - \qquad -$$

$$, \qquad , \quad /(\cdot^2).$$

$$, \qquad :$$

$$G_S \, dY = K_Y \, a_S(Y - Y^*)dZ,$$

$$K_Y - \qquad , \quad /(\cdot^2); \quad a_S -$$

$$, \quad ^2/ \, ^3; \, Y^* - \qquad (\qquad) \qquad -$$

$$, \quad / \quad .$$

$$(\qquad)$$

$$Z_A = \int\limits_0^{Z_A} dz = \int\limits_{Y_B}^{Y_E} \frac{G_S}{K_Y a_S} \frac{dY}{Y - Y^*} .$$

$$:$$

$$N_Y = \int\limits_{Y_B}^{Y_E} \frac{dY}{Y - Y^*} ,$$

$$H_Y = \frac{G_S}{K_Y a_S} .$$

$$,$$

$$Z_A = H_Y N_Y.$$

$$, \qquad , \qquad -$$

$$(\qquad). \qquad V -$$

$$V = S Z.$$

$$, \, Z = V/S -$$

$$S.$$

$$\begin{aligned}
& \qquad \qquad \qquad , \qquad \qquad \qquad : Z \dot{S} \dot{S} \dot{S} - \qquad \qquad \qquad ; Z \dot{S} \dot{S} \dot{S} X - \qquad - \\
& \qquad \qquad \qquad , \qquad \qquad \qquad ; (Z - Z_A) \dot{S} \dot{S} \dot{S} X_1 - \\
& \qquad \qquad \qquad , \qquad \qquad \qquad , \qquad \qquad \qquad - \\
& ; Z \dot{S} \dot{S} \dot{S} X (1 - \qquad) - \qquad \qquad \qquad , \qquad \qquad \qquad , \\
& \qquad \qquad \qquad ; \qquad - \qquad \qquad \qquad - \\
& \qquad \qquad \qquad . \\
& \qquad \qquad \qquad (\qquad)
\end{aligned}$$

$$CHC = \frac{\qquad \qquad \qquad}{\qquad \qquad \qquad}$$

$$\begin{aligned}
& \qquad \qquad \qquad , \\
& = \frac{(Z - Z_A) \dot{S} \dot{S} \dot{S} X \qquad + Z_A \dot{S} \dot{S} \dot{S} X \qquad (1 - \{ \})}{Z_A \dot{S} \dot{S} \dot{S} X} ; \\
& \qquad \qquad \qquad = (Z - Z_A)/Z.
\end{aligned}$$

$$\begin{aligned}
& \qquad \qquad \qquad , \qquad \qquad \qquad , \\
& \qquad \qquad \qquad ,
\end{aligned}$$

$$T_B = \frac{\qquad \qquad \qquad}{\qquad \qquad \qquad}$$

$$T_B = (\qquad) Z \dot{S} \dot{S} X / (G_S Y_0) .$$

$$\begin{aligned}
& \qquad \qquad \qquad (7.2) \qquad \qquad \qquad . \\
1. \qquad \qquad \qquad . \\
& \qquad \qquad \qquad , \qquad \qquad \qquad , \qquad \qquad \qquad , \\
& \qquad \qquad \qquad , \qquad \qquad \qquad . \\
& \qquad \qquad \qquad , \qquad \qquad \qquad , \qquad \qquad \qquad , \\
& \qquad \qquad \qquad , \qquad \qquad \qquad . \\
& \qquad \qquad \qquad C_{eq} = f(C) \qquad \qquad \qquad . \\
& \qquad \qquad \qquad , \qquad \qquad \qquad , \qquad \qquad \qquad , \\
& \qquad \qquad \qquad . \qquad \qquad \qquad . \\
& \qquad \qquad \qquad . \\
& \qquad \qquad \qquad . \\
& \qquad \qquad \qquad . \\
& \qquad \qquad \qquad , \qquad \qquad \qquad , \qquad \qquad \qquad , \\
& \qquad \qquad \qquad :
\end{aligned}$$

$$z = \frac{\hat{n}}{\hat{n.}},$$

\hat{n} , $\hat{n.}$ - , $^3/$.

. 7.3.

7.3

		z
	3	0,4
	CH ₃ Br	0,57
	C ₂ H ₅ Br	0,61
	2 5	0,61
		0,61
	CS ₂	0,7
	C ₂ H ₅ Cl	0,76
	C ₃ H ₈	0,78
	CHCl ₃	0,86
	(CH ₃) ₂ CO	0,88
	4 10	0,9
	3	0,97
	6 6	1,0
	6 12	1,03
	CCl ₄	1,05
	(C ₂ H ₅) ₂ OCO	1,09
	5 12	1,12
	7 8	1,25
	CCl ₃ NO ₂	1,28
	C ₆ H ₁₄	1,35
	C ₇ H ₁₆	1,59

273

:

$$\hat{m}_n = \frac{m_n}{\dots};$$

$$\hat{m}_{n.} = \frac{m_{n.}}{\dots},$$

$$m_n, m_{n.} \quad - \quad , \quad / \quad ; \quad \dots, \dots \quad - \quad 273 \quad , \quad / \quad ^3.$$

$$2. \quad \nu = 0,3...0,5 \quad / \quad ,$$

$$3. \quad$$

$$: \quad Nu = 0,355 \operatorname{Re}^{0,64} \operatorname{Pr}^{0,333} / \nu , \quad \nu = 1 - \frac{\dots}{\dots},$$

$$\varepsilon \quad - \quad ; \quad \rho \quad - \quad , \quad / \quad ^3; \quad \rho \quad - \quad :$$

$$d \quad - \quad , \quad ; \quad D \quad - \quad , \quad ^2/ \quad .$$

$$d\cdot 2\cdot 10^{-3}\cdot$$

(

$$)\beta \qquad \qquad \qquad \text{Nu:}$$

$$S=Nu\frac{D}{d}\cdot$$

:

$$S=10\frac{D}{d},$$

$$D-\qquad\qquad\qquad,~^2/,~\qquad\qquad\qquad-$$

.

$$,~\qquad\qquad\qquad D~\qquad\qquad\qquad-$$

:

$$D=\frac{v\cdot D}{2}\left[1-\exp\left(-\frac{2d}{3D}\sqrt{\frac{8RT}{m_n}}\right)\right],$$

$$\varepsilon-\qquad\qquad\qquad(\qquad\qquad\qquad);~d-\qquad\qquad\qquad$$

$$,~;~R-\qquad\qquad\qquad,~/(~\qquad\qquad\qquad);~-\qquad\qquad\qquad-$$

$$,~\qquad\qquad\qquad/$$

-

$$6\cdot 10^{-9}\cdot$$

:

$$v=1-\frac{\cdots}{\cdots},$$

$$\rho-\qquad\qquad\qquad,~\qquad\qquad\qquad/{}^3.$$

:

$$K=\frac{1}{\frac{1}{S}+\frac{1}{S}}.$$

-

-

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-

:

$$C=0,0567\cdot\frac{v\cdot\text{Re}^{0,22}}{1-v}.$$

$$(\quad/ \quad)$$

$$:$$

$$K^{' }=\frac{1}{\frac{1}{K}+\frac{1}{C}}.$$

$$(\quad^{-1}):$$

$$K_{\cdot v}^{' }=K^{' }f$$

$$,\quad -$$

$$1,7...2,2\quad w$$

$$=0,3...2\quad / \quad:$$

$$K_{\cdot v}^{' }=1,6\cdot \frac{D}{d^2}\cdot \mathrm{Re}^{0,54},\quad^{-1}.\tag{7.3}$$

$$(7.3)\quad ,\quad -$$

$$\cdot$$

$$4.\quad .\quad h\quad -$$

$$:$$

$$N\,=\,\frac{K_{\cdot v}^{' }h}{v}.$$

$$\tau\,(\quad):$$

$$\dagger=h\frac{\cdots C^*+v\cdot C}{vC},$$

$$*\quad _\quad ,\quad -$$

$$\cdot$$

$$:$$

$$\text{---}=J(\mathfrak{r},\mathfrak{x})\,,$$

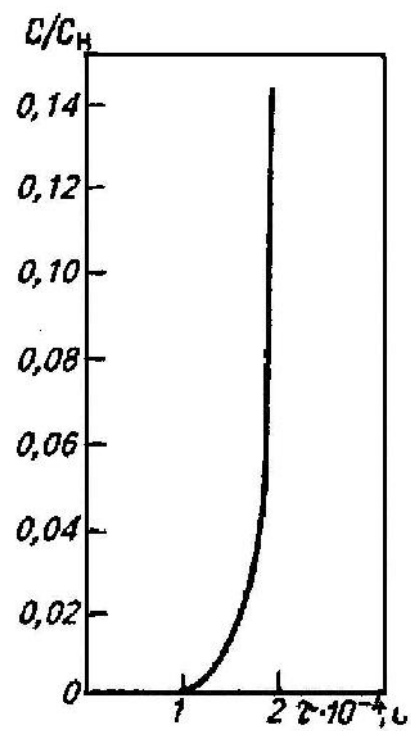
$$J(\alpha,\gamma)-\quad \alpha\quad \gamma,\quad N\quad N\cdot$$

$$-$$

$$\quad / \quad \tau\,(\quad\quad.7.13).$$

$$(\quad\quad\quad) \quad /$$

$$\tau.$$



. 7.13.

5.

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 (1,5...2), -

6.

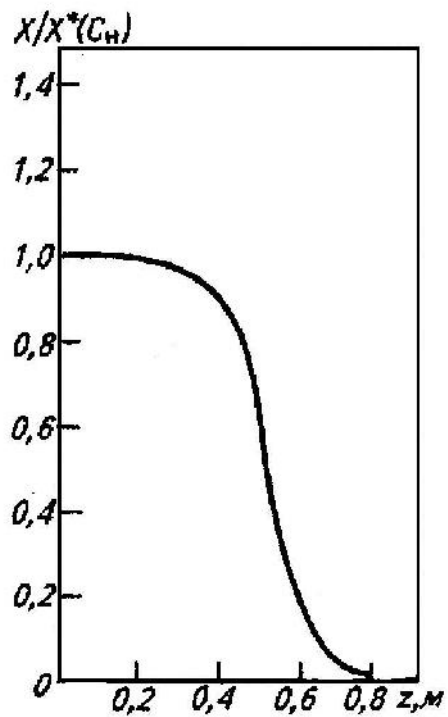
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 :

$$\frac{C_x}{C^*} = 1 - J(N \ddagger, N),$$

(. 7.14).

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. 7.14.

, ():

$$M = G \ddagger \cdot C \text{ .}$$

(), :

$$M_x = \dots f \cdot C^* \int_0^H \frac{C_z}{C^*} dz, \quad (7.4)$$

f – , ².

() :

$$M_y = v \cdot V \frac{C - C}{2},$$

V – , ³.

(), :

$$M = GC \int_{\ddagger_0}^{\ddagger} \frac{C}{C} d\ddagger, \quad (7.5)$$

τ_0 – , ; τ – -

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(7.4) (7.5) -

(. 7.14)

(. 7.13).

$$M = M_x + M_y + M_z$$

8.

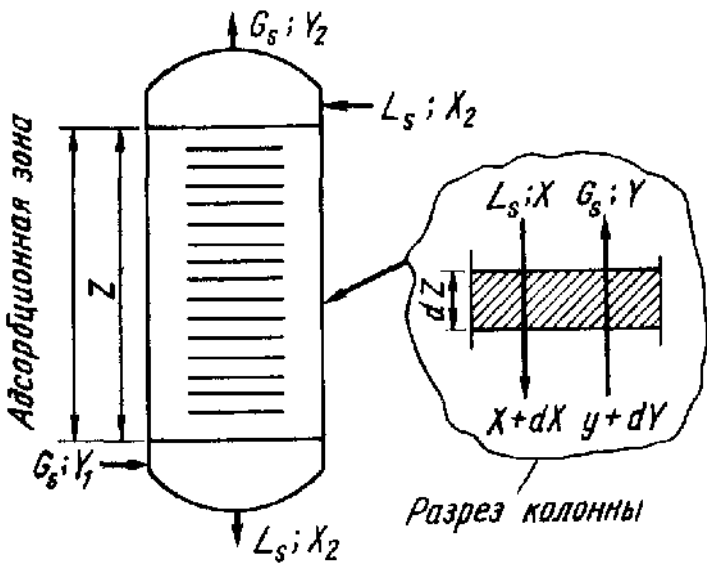
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2- 3-

0,5...1

Y — G_s
 L_s — X Y dY
 $X+dX$ $Y+dY$

7.15



7.15.

$$G_s(Y_1 - Y_2) = L_s(X_1 - X_2) \tag{7.6}$$

$$G_s(Y - Y_2) = L_s(X - X_2) \tag{7.7}$$

$$(7.7)$$

Y:

$$Y = (L_s/G_s) + [Y_2 - (L_s/G_s) X_2].$$

$$Y$$

$$(L_s/G_s), \qquad \qquad \qquad [Y_2 - (L_s/G_s) X_2].$$

$$(\qquad \qquad \qquad), \quad s.$$

$$dZ \qquad \qquad \qquad :$$

$$L_s dX = G_s dY = K_Y a_s (Y - Y^*) dZ .$$

$$Z = \int_{Y_2}^{Y_1} \frac{G_s}{K_Y a_s} \frac{dY}{Y - Y^*} .$$

$$H_Y = \frac{G_s}{K_Y a_s} ,$$

$$N_Y = \int_{Y_2}^{Y_1} \frac{dY}{Y - Y^*} .$$

$$N_G \qquad \qquad \qquad :$$

$$N_Y = \frac{Y_1 - Y_2}{\Delta Y_m} ;$$

7.4.

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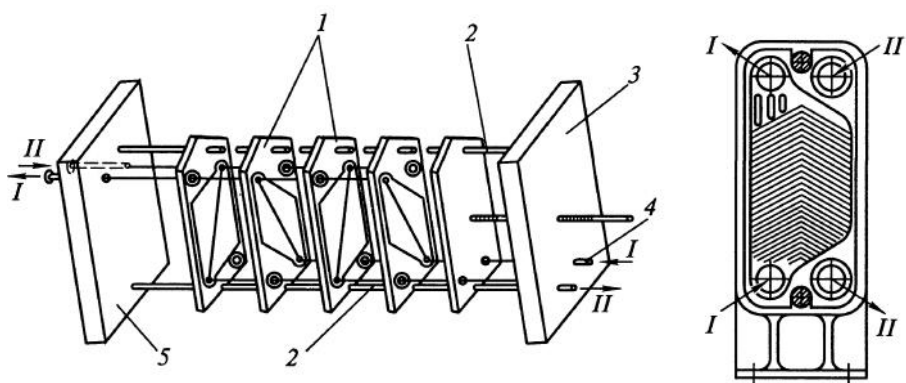
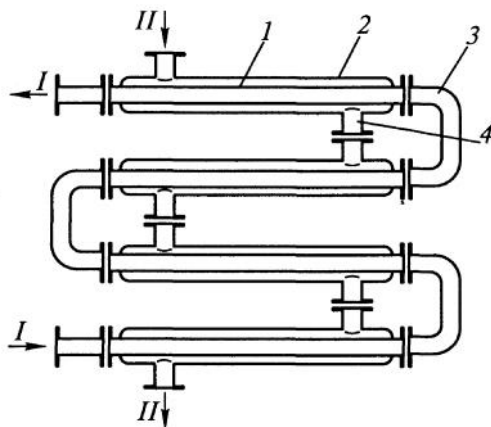
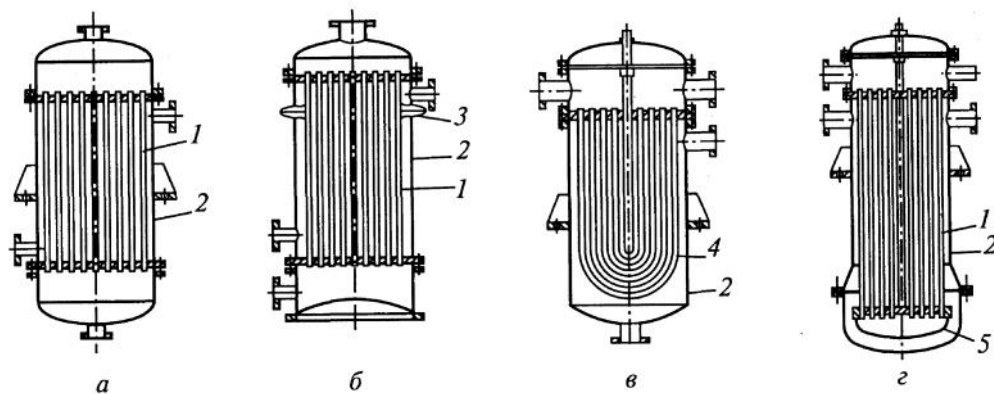
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8.1. - :

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« »: 1, 2 — ; 3 — « »; 4 — ; I, II — ;

— : 1 — ; 2 — ; 3, 5 — -

; 4 — ; I, II —

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- (8.1,) .

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(8.1,). U- W- (8.1,)

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1...2.5 .

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- 20... 180 ° , - 4 -100...300 ° .

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(8.1)

(8.2)

(8.1) (8.2)

$$G = 0,000025D + 0,01D \approx 0,01 D.$$

$$V = \frac{29,27G (273 + t)}{p},$$

$$= (p - p) -$$

$$: t = t \text{ .}$$

$$:t=t_{\cdot}.$$

$$Q/F,$$

$$1^{-2}$$

$$\frac{Q}{S}=K_t\Delta t_m,$$

$$Q-\quad,\quad /;\;S-\quad,\quad^2;\;t_m-$$

$$;\;K_t-$$

$$,\quad /(\quad^2\quad),$$

$$;$$

$$,$$

$$,$$

$$\cdot$$

$$\cdot$$

$$\cdot$$

$$H=c\,(t-t_{\cdot})+r+c\,t$$

$$(8.1)\quad:$$

$$DH+Wc\,t_{\cdot}=Dc\,t_{\cdot}+Wc\,t_{\cdot}+Q,\tag{8.3}$$

$$H-\quad,\quad /;\;c-\quad,$$

$$/(\quad); \;t-\quad,\quad^0;\;t-\quad-$$

$$(\quad),\quad^0;\;r-\quad(\quad),$$

$$/\;c-\quad,\quad /(\quad); \;D-$$

$$,\quad /;\;W-\quad(\quad),\quad /;\;c-\quad-$$

$$(\quad),\quad /(\quad); \;t_{\cdot}-$$

$$(\quad),\quad^0;\;t-\quad,\quad^0;\;t_{\cdot}-\quad-$$

$$(\quad),\quad^0;\;Q-\quad,\quad /.$$

$$(8.3)\quad(\quad):$$

$$W=\frac{D(H-c\,t_{\cdot})-Q}{c\,(t_{\cdot}-t_{\cdot})}.$$

$$:$$

- $\dot{Q}_1 = Dc(t_1 - t_2)$;

- $\dot{Q}_2 = Dc(t_2 - t_1)$;

- $\dot{Q}_3 = Dc(t_1 - t_2)$.

• $\dot{Q}_1 = Dc(t_1 - t_2)$,

,

$$t_1 - t_2.$$

,

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:

-

$$\dot{Q}_1 = Dc(t_1 - t_2) = W(t_1 - t_2); \quad (8.4)$$

-

$$\dot{Q}_2 = Dc(t_2 - t_1) = W(t_2 - t_1);$$

-

$$\dot{Q}_3 = Dc(t_1 - t_2) = W(t_1 - t_2). \quad (8.5)$$

$$(8.4) \quad (8.5)$$

:

$$t_1 = t_2 - \frac{\dot{Q}_1}{W};$$

$$t_2 = t_1 - \frac{\dot{Q}_2}{W}.$$

(K_1) , (K_2) (K_3) ,
 (K_1^2) :

$$S_1 = \dot{Q}_1 / (K_1 - t_1), \quad ^2;$$

$$S_2 = \dot{Q}_2 / (K_2 - t_2);$$

$$S_3 = \dot{Q}_3 / (K_3 - t_3).$$

t_1, t_2, t_3 ,

$$\Delta t_i = \frac{\Delta t_1 - \Delta t_2}{\ln \frac{\Delta t_1}{\Delta t_2}},$$

Δt , Δt –

, .

$K_{\text{с}} = 20...50$ /($^{\circ}\text{C}$), $K = 100...150$ /($^{\circ}\text{C}$) $K_{\text{с}} = 150...250$ /($^{\circ}\text{C}$).

:

$$S = S_{\text{с}} + S + S_{\text{с.с.}}$$

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8.2.

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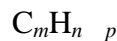
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$$\begin{aligned} & \text{ ,} \\ & \text{ :} \end{aligned} \tag{8.6}$$

$$\frac{1}{V} \cdot \frac{dG_A}{dt} = kC_{A0} \quad .$$

:

$$-\frac{1}{S} \cdot \frac{dG_A}{dt} = \frac{1}{S/(k \cdot V) + 1/S} C_{A0}$$

$$\frac{1}{V} \cdot \frac{dG_A}{dt} = \frac{1}{1/(k \cdot) + V/(S \cdot S)} C_{A0} .$$

r :

$$-\frac{1}{S} \cdot \frac{dG_A}{dt} = \frac{1}{1/S + 3/(k \cdot r)} C_{A0}$$

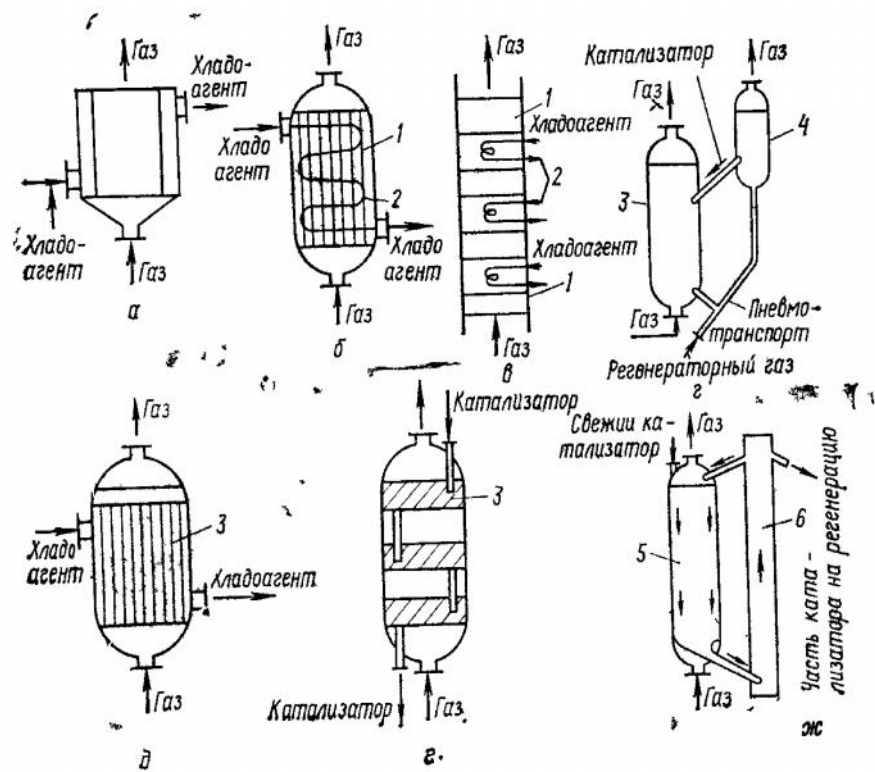
$$\frac{1}{V} \cdot \frac{dG_A}{dt} = \frac{1}{1/(k \cdot) + r/(3S \cdot)} C_{A0} ,$$

$$\begin{aligned} V & \text{ —} & ; k & \text{ —} & , & 1 & ^3 & \text{ —} \\ & ; & = & \text{ —}_A / C_A , & \text{ —} & & & \text{ —} \\ & & & & & & 0 & \text{ —} \end{aligned}$$

8.3.

$$\begin{aligned} & \text{ ,} \\ & (\quad . 8.2). \end{aligned}$$

$$\begin{aligned} & \text{ ,} \\ & \text{ .} \end{aligned}$$



8.2.

— ; — ; —
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 ; — ; 1 — ; 2 —
 ; 3 — ; 4 — ; 5 — ; 6 —

$$H = h \cdot N_0$$

$$N_0 = \int_{p_A}^{p_{As}} \frac{p \, dp_A}{(p + p_A x_A)(p_A - p_{As})} = \int_{N_A}^{N_{As}} \frac{N \, dN_A}{(1 + N_A x_A)(N_A - N_{As})} \quad (8.7)$$

, (h):

$$h = \frac{G}{M \, S \, a \, \Delta p}. \quad (8.8)$$

$$\Delta p = \frac{(p + p_A x_A) - (p - p_{As} x_A)}{\ln[(p + p_A x_A)/(p + p_{As} x_A)]}.$$

$$H = \qquad \qquad \qquad ; G = \qquad \qquad \qquad , \quad /(\ ^2.); M_{cp} =$$

$$; a = \qquad \qquad \qquad ,$$

$$^2/^{-3}; p =$$

$$; p_A = \qquad \qquad \qquad , \quad ; p_{As} = \qquad -$$

$$, \quad ; A = \qquad -$$

$$(\quad 1 \qquad \qquad \qquad); N_{cp} = p_{cp}/p =$$

$$; N_A = N_{As} =$$

.

$$p_A, \qquad \qquad \qquad p = \sqrt{[(p + p_{A-A})(p_A - p_{As})]}.$$

$$h = N_0 \qquad \qquad \qquad (8.7) \quad (8.8).$$

-

.

$$p = (a/\ ^3)(\ ^2/z)H_0,$$

$$\qquad \qquad \qquad , \quad \text{Re} < 50 \qquad \qquad \qquad = 220/\text{Re}; \quad \text{Re} > 50 \quad -$$

$$= 11,6/\text{Re}^{0,25}; \ v = \qquad \qquad \qquad , \quad /; \ 0 = \qquad -$$

$$\qquad \qquad \qquad , \quad ; \ 0 = \qquad \qquad \qquad .$$

$$\text{Re} = \frac{Ar}{1400 + 5,22Ar^{0,5}}.$$

$$p = g \quad (1 -)H.$$

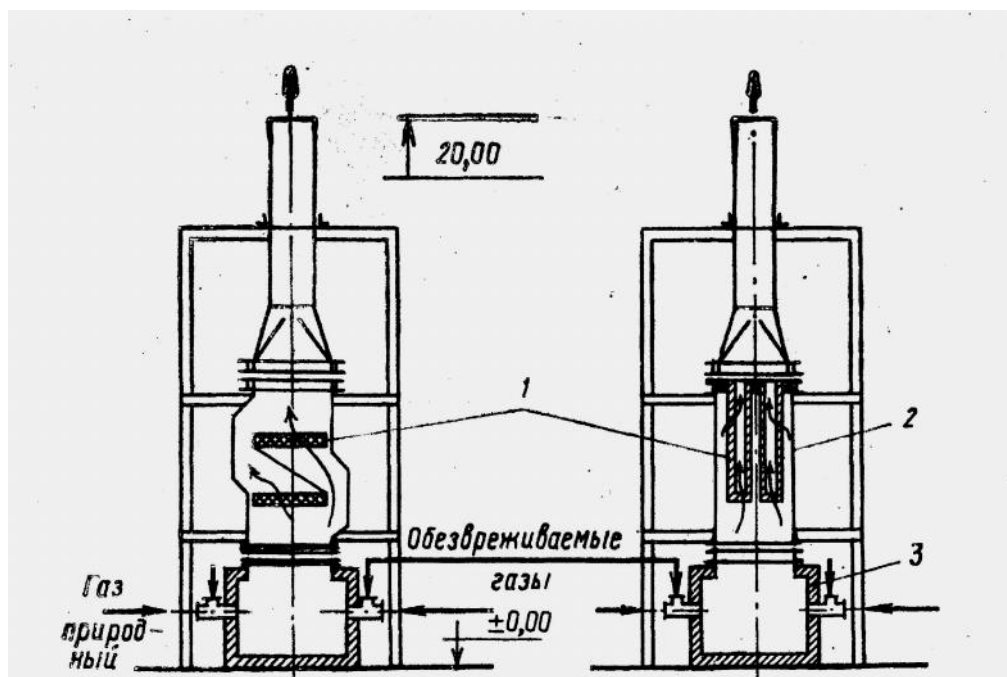
$$H = \frac{H_0(1-v_0)}{1-v};$$

$$= \left(\frac{18\text{Re} + 0,36\text{Re}^2}{Ar} \right)^{0,21},$$

$$= \qquad \qquad \qquad ; H = \qquad \qquad \qquad .$$

$$(\qquad \qquad \qquad) \qquad \qquad \qquad -$$

$$, \qquad \qquad \qquad , \qquad \qquad \qquad = \qquad -$$



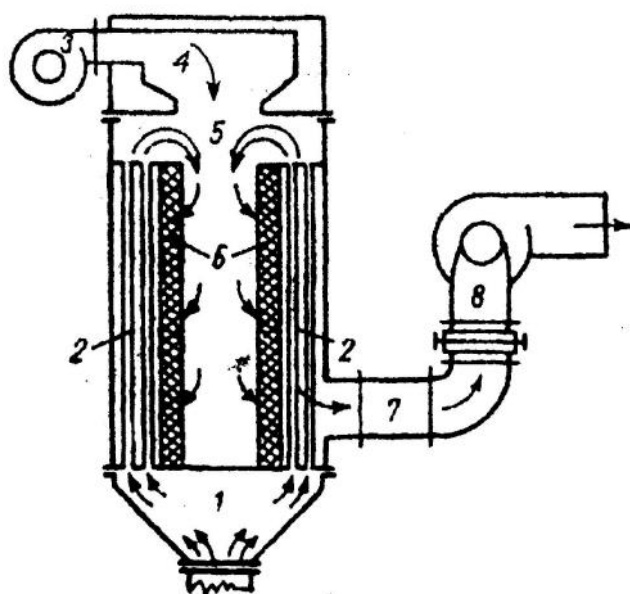
. 8.3.

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. 8.4.

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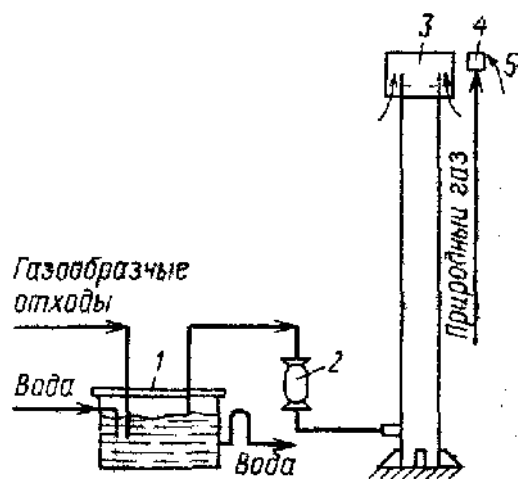
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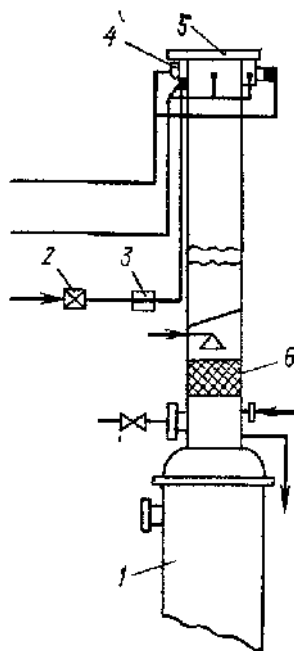
8.5. :

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4 – ; 5 –

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8.6. , -

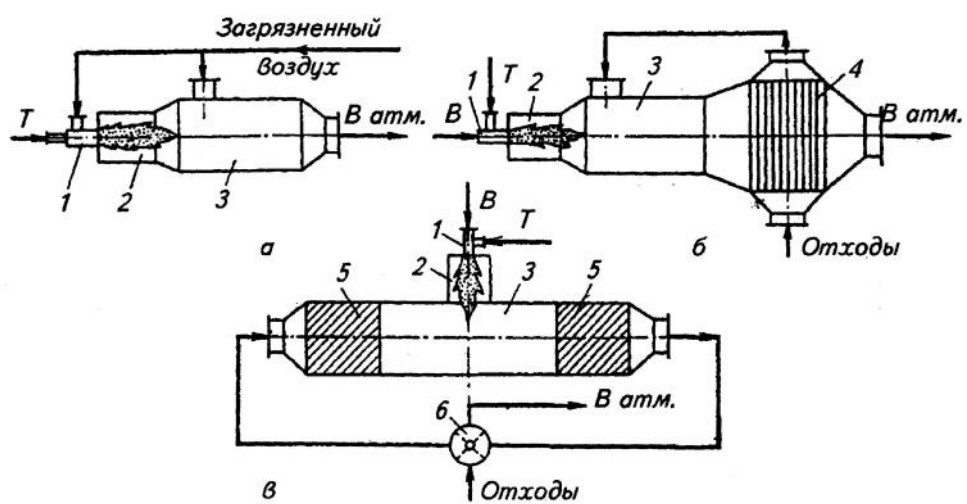
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. 8.7.

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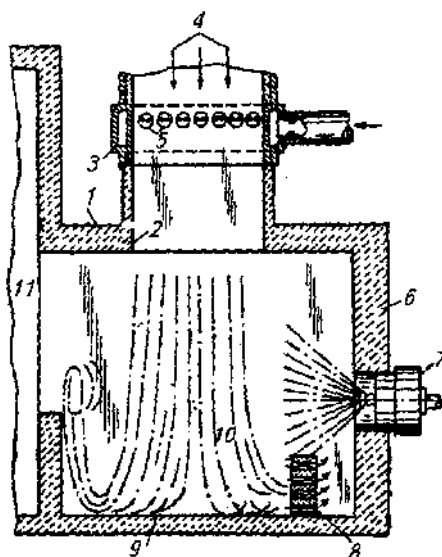
100...150 C



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$W, \quad ^3/ \quad ,$

r_i .

W

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$$W = W (1 - \sum_{i=1}^N r_i) / (\quad), \quad ^3/ \quad ,$$

$N -$

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$^3/ \quad ^3$.

$\alpha = 1,05...1,2.$

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$\alpha \approx 3).$

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$$V = \sum_{i=1}^N w_i Q_i / [q_v], \quad ^3,$$

-

$$V[q_v] = \sum_{i=1}^N W_i Q_i, \quad ,$$

$$W_i, Q_i - \quad , \quad ^3/ \quad , \quad / \quad ^3, \quad (\quad)$$

$$, \quad ; [q_v] -$$

$$, \quad / \quad ^3; N -$$

$$50...100$$

$$/ \quad ^3 \quad Q$$

$$[q]$$

$$200 \quad / \quad ^3. \quad 4...5 \quad .$$

$$t \quad = 700...1000$$

$$:$$

$$= 25(1 - t \quad / 1060), \quad .$$

$$:$$

$$t \quad = \quad t \quad , \quad ,$$

$$-$$

$$,$$

$$0,75...0,85, \quad -$$

$$0,5...0,8, \quad - \quad 0,8...0,09; \quad t \quad - \quad -$$

$$.$$

$$100...150 \quad / \quad ^3$$

$$.$$

$$:$$

$$V \quad W \cdot (273 + t \quad) / (273 \cdot K), \quad ^3,$$

$$K \quad -$$

$$,$$

$$0,7 \quad 0,95 \quad ; W \cdot \quad - \quad -$$

$$, \quad ^3/ \quad .$$

$$200 \quad / \quad ^3 \quad W \cdot \quad -$$

$$:$$

$$W \cdot = W (V_{CO_2} + V_{H_2O} + V_{N_2} + V_{O_2}), \quad ^3/ \quad ,$$

$$V_{CO_2}, V_{H_2O}, V_{N_2}, V_{O_2} - \quad , \quad -$$

$$1 \quad ^3$$

$$.$$

:

$$W_{\text{н}} = W (V_{CO_2} + V_{H_2O} + V_{N_2} + V_{O_2}) / R, \quad ^3/ ,$$

$V_{CO_2}, V_{H_2O}, V_{N_2}, V_{O_2}$ -

$$1 \quad ^3$$

; R -

$$D \quad l (\quad h)$$

$$D = 0,8 V^{1/3} \quad ;$$

$$l = (2,0 \dots 2,3) D \quad ;$$

$$h = (1,7 \dots 2,0) D \quad .$$

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 12 %.
 3^{3/} , — 6^{3/}
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$$G = A \frac{n}{100},$$

G - , ; A - ,
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H ₂ ()	3,0—5,5	0,5—4,0
2	5,0—12,0	1,0—10,0
	5,0—10,0	0,01—0,50
	0—0,8	2·10 ⁻³ —0,5
	0,2—3,0	1·10 ⁻³ —0,5
	0—0,2	1·10 ⁻³ —9·10 ⁻³
	0—0,4 / ³	0,01—1,1 / ³
	(10—20)·10 ⁻⁶ , / ³	1·10 ⁻⁵ / ³

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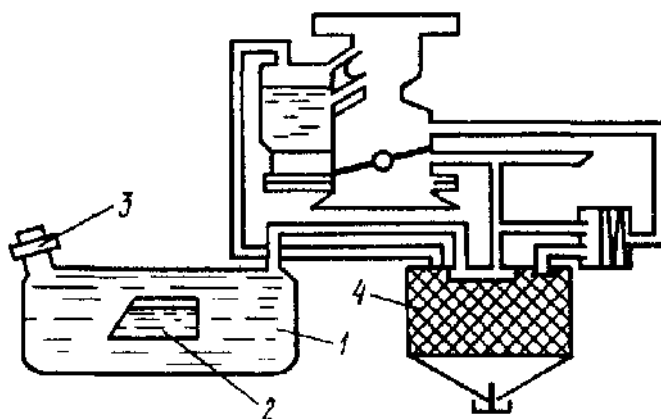
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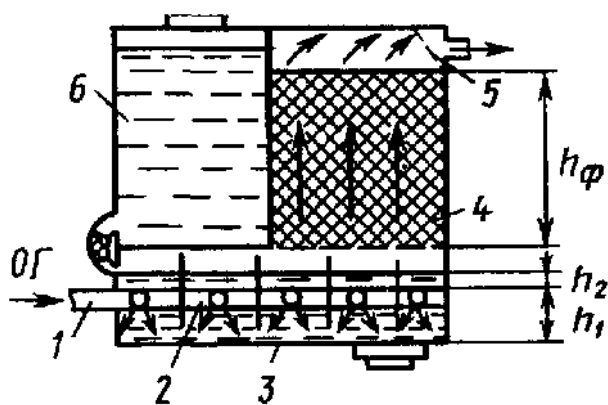
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. 9.3.

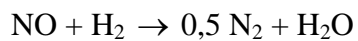
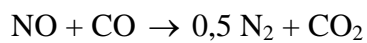
9.3 42

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CO	0,06	0,06	0
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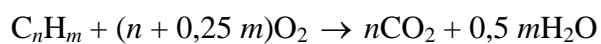
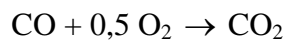
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NO_x 99 % NO)



$n \cdot m \cdot$

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$$\frac{c_x}{c_0} = \exp \left[- \frac{a x}{1,38 Sc^{2/3} (\text{Re}^{0,41} - 1,5)} \right],$$

$c_x -$; $c_0 -$

; $a = 6(1 -)d -$

; $-$; $d -$

; $\text{Sc} = /D -$; $-$; $D -$

; $\text{Re} = v d / -$; $v -$

, .

$$x = l \qquad = 1 - c_l/c_0, \qquad l -$$

:

$$= \quad + \quad + \quad .$$

—

$$= \quad v^2 l / (2 d),$$

$$= \frac{152}{\text{Re}} (1 + 0,0056 \text{Re}^{0,9} v^{-1,72}) .$$

Re

$$, \qquad v = Q / (S \quad), \qquad Q - \qquad ; S —$$

$$\text{Re} = v d / \nu, \qquad d = 2 \quad d / [(1 - \quad)^3].$$

2...2,5.

10...15

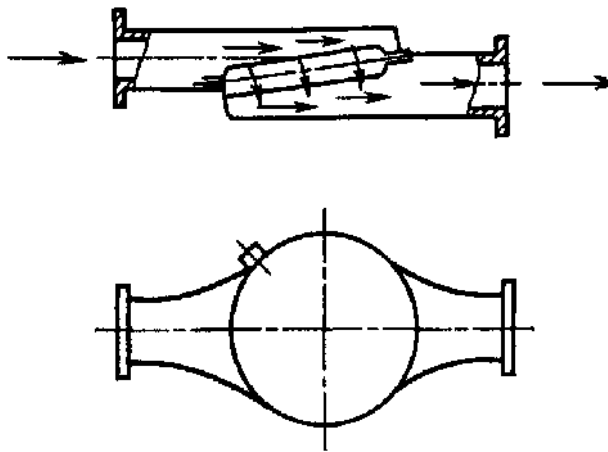
2...2,5

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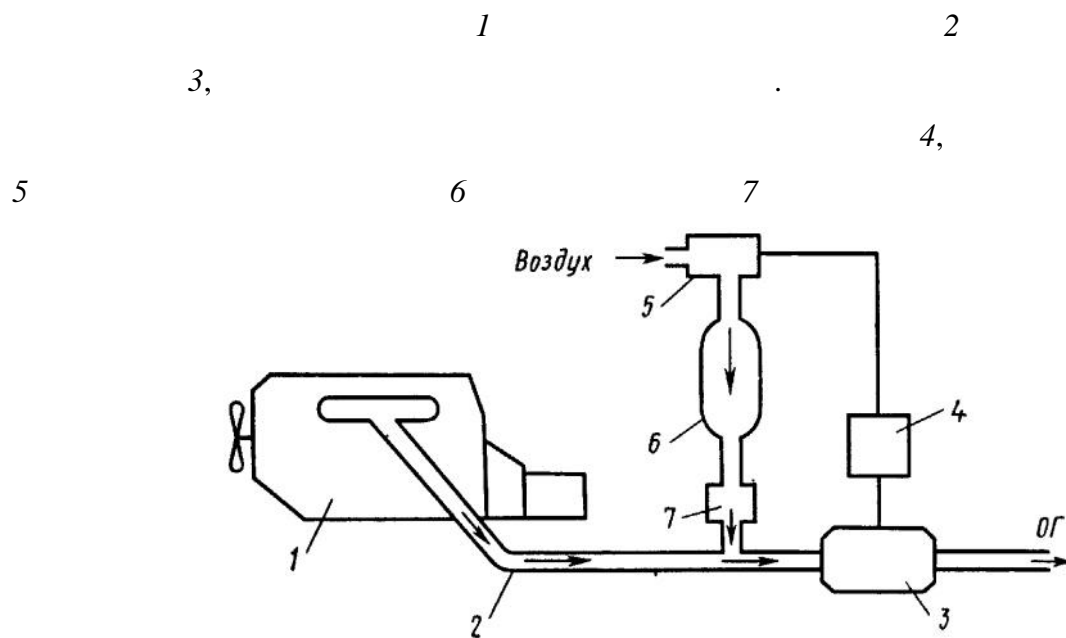
(\quad . 9.4)

70...90 %. \quad _n \quad _m — \quad 50...85 %.



. 9.4.

. 9.5.



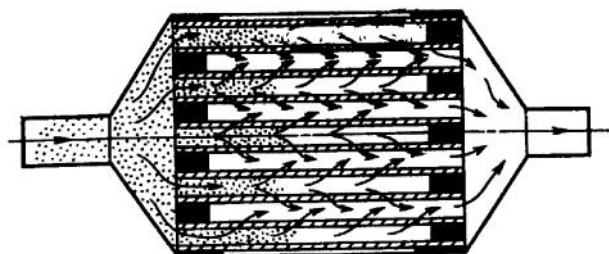
. 9.5.

9.3.

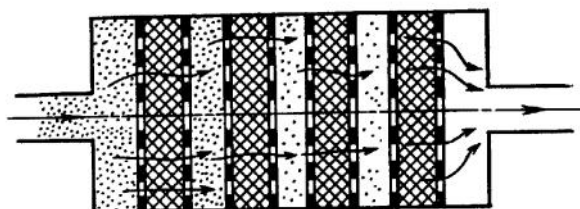
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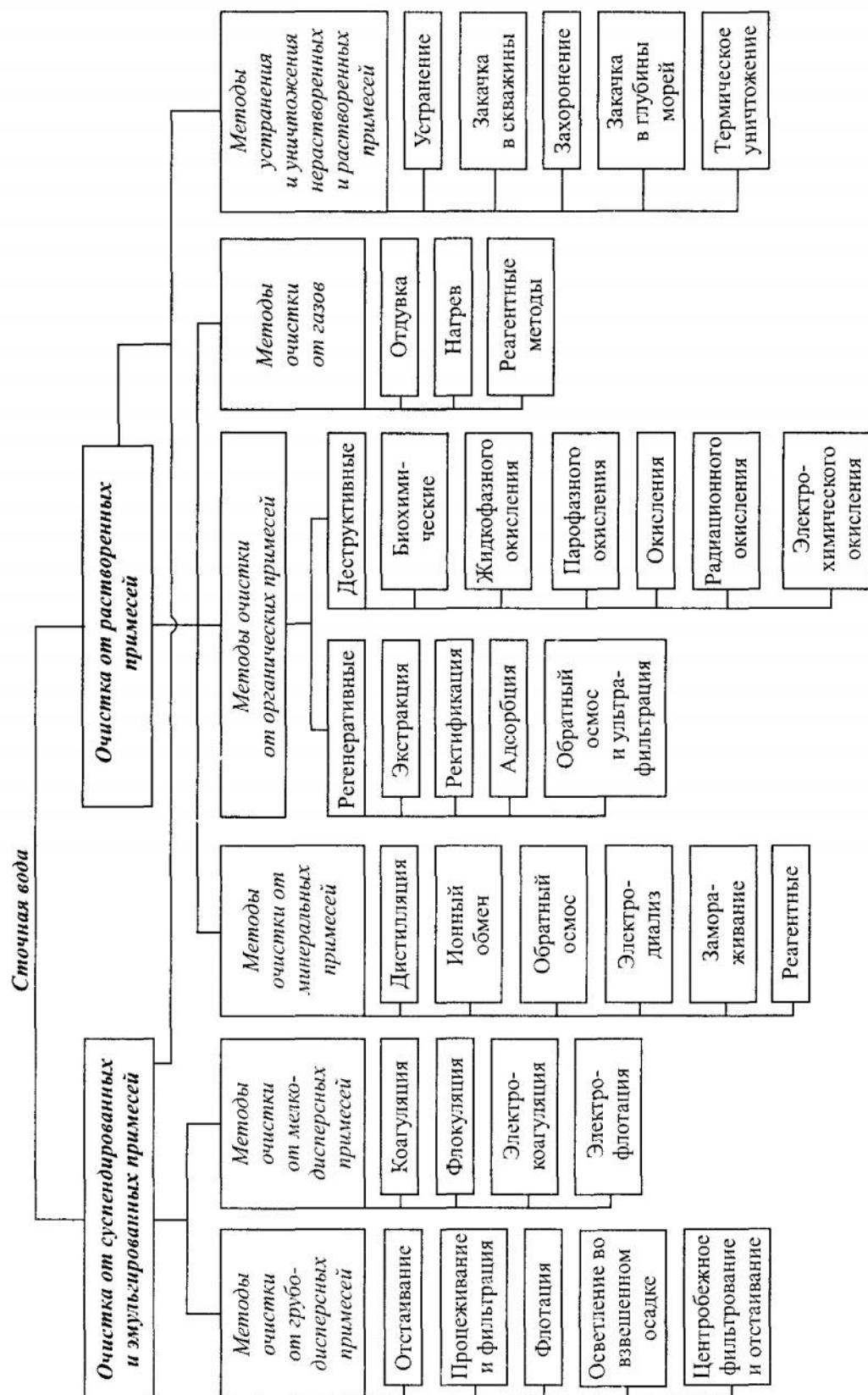
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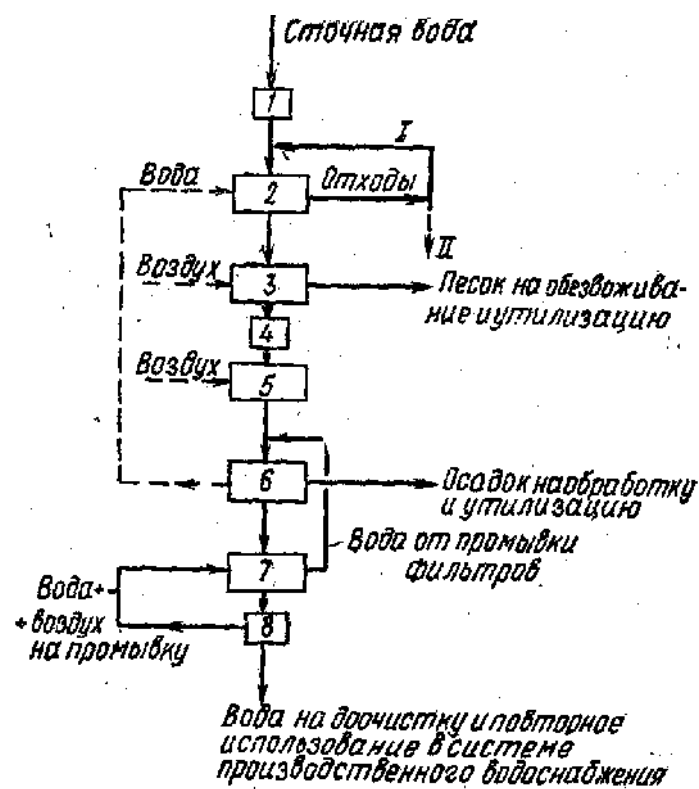
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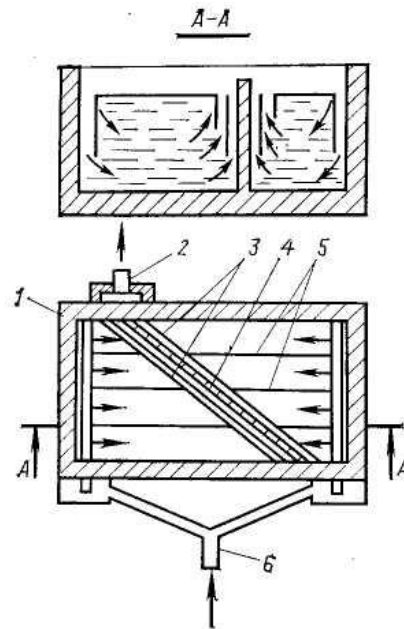
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(. 11.3).



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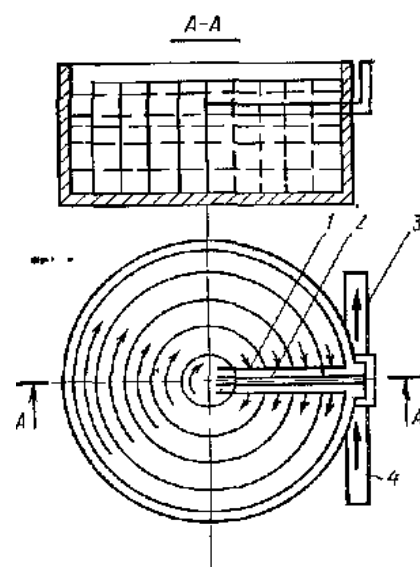
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, 6 —

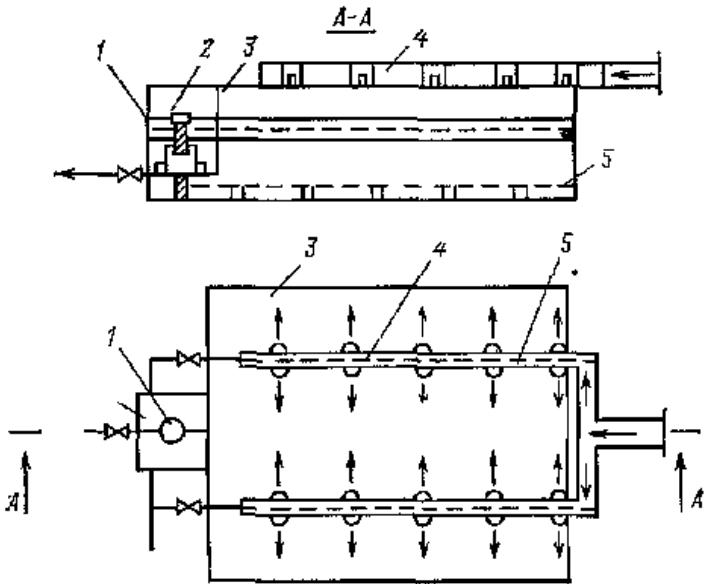


. 11.3.

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1 — , 2 — , 3 — ; 4 —

(. 11.4).



. 11.4. :

1 — , 2 — ; 3 — ; 4 — ; 5 —

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$$V = \frac{Qt}{\ln \frac{k}{k-1}},$$

Q — , $^3/$; k — , $k = \frac{C_{\max} - C}{C - C}$; t —

, ; max, , „ — , / 3 .

$$k \geq 5$$

$$V = k Qt .$$

t

$$V=0,16k\;Qt\;.$$

n

u_c

$$S\,(\,^2).$$

$$2,5\quad /$$

:

$$u_c=\frac{Q\cdot1000}{nS\cdot3600}\cdot$$

$$(\quad)$$

V

,

$$V_{\min}\,(\,^3),$$

$$V\,(\,^3).$$

$$C_0=\sum_{i=1}^tq_iC_i\Big/V_{\min},$$

$$t\text{---},$$

$$V_{\min},\;\; ;q_i\text{---}$$

$$;\quad i\text{---}$$

i -

.

$$V=\sum_{i=1}^tq_i\;.$$

$$C\quad=\sum_{i=1}^tq_iC_i\Big/V\;.$$

,

.

$$V\quad=\sum_{i=1}^tq_i+\sum_{k=t+1}^{t+\Delta t}q_k\; ,$$

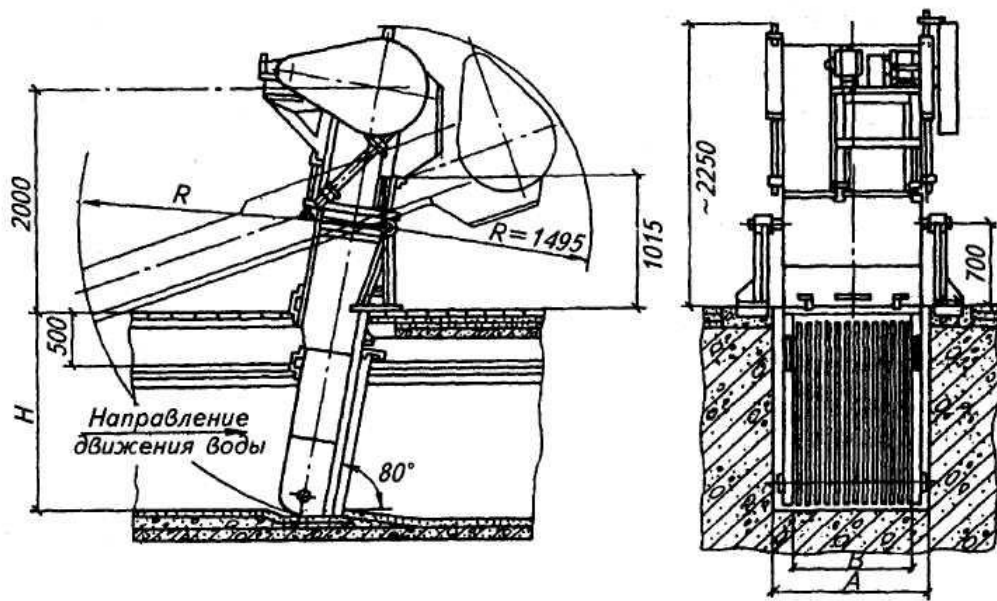
Q_{yc} — , $^3/$; \sim — , 0,6...0,82;
 h_0 — , .

$$S = \frac{Q}{\sim \sqrt{2 g h_0}},$$

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 16...19 .

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. 11.5.

(^{3/} ^{3/})

(^{3/}).

(Q_{\max})

$v = 0,8...1$ / .

S_{Σ} ,

n ,

S_1 :

$$S_{\Sigma} = \frac{Q_{\max}}{u}; \quad S_1 = \frac{F_c}{n}.$$

$$H_p = s \left(\frac{s}{b} \right)^{\frac{4}{3}} \sin r \cdot \frac{v^2}{2g} y,$$

2,42 —

1,72

; s

; b —

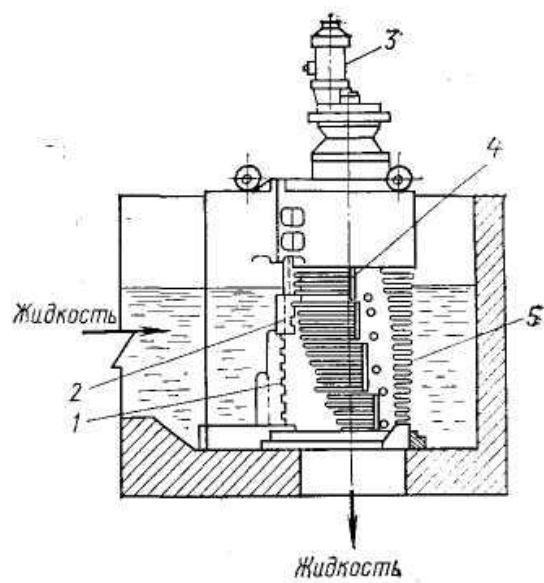
; r —

; g —

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= 3.

(. 11.6.).

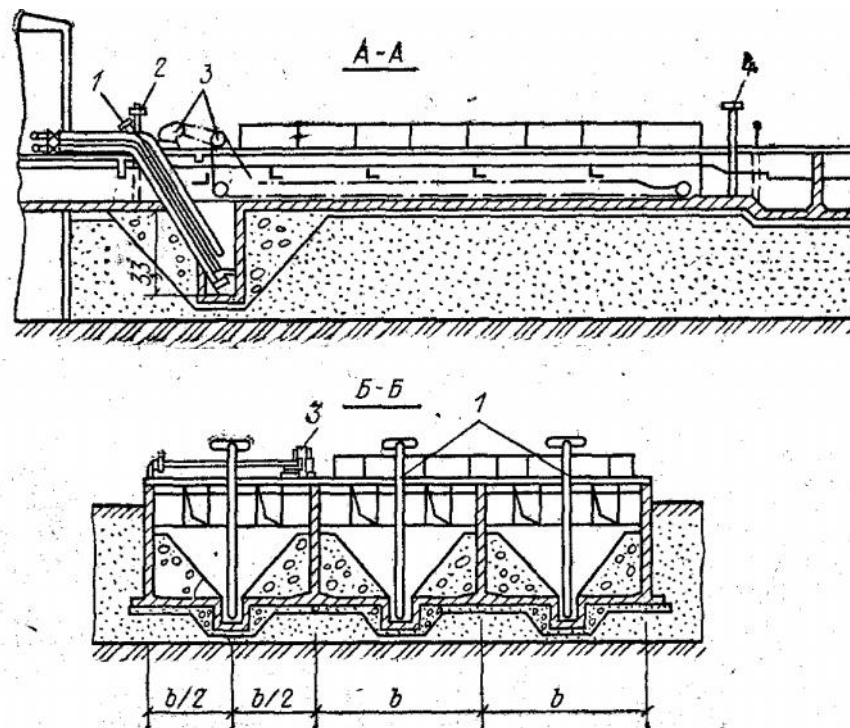


. 11.6.

1 – ; 2 – ; 3 – ; 4 – ; 5 –

11.2.

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 $100^{3/}$



. 11.7.

1 — ; 2, 4 — ; 3 —
; 4 –

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()

$$L = k H \frac{v}{w_0}, \quad (11.2)$$

k — ,

k

$$k = \frac{w_o}{\sqrt{w_o - 0,05 v}}. \quad (11.3)$$

S (2),

H_p ()

q_0 [$^3/(^2)$]

$$S = \frac{Q}{q_0} = B L; \quad H_p = \frac{Q}{B v}; \quad q_0 = \frac{-0,43 w_o}{\lg(1 -)}. \quad (11.4)$$

$v = 0,3$ / ,

0,2...0,25 ,

30 .

$$\Delta h = \frac{h_{\max} - k_q^{2/3} h_{\min}}{k_q^{2/3} - 1};$$

$$b_c = \frac{q_{\max}}{(m\sqrt{2q})(P + h_{\max})^{3/2}},$$

Δh —

; h_{\max} , h_{\min} —

q_{\max}

q_{\min}

$$0,3 / ; k_q = \frac{q_{\max}}{q_{\min}}; b_c —$$

; m —

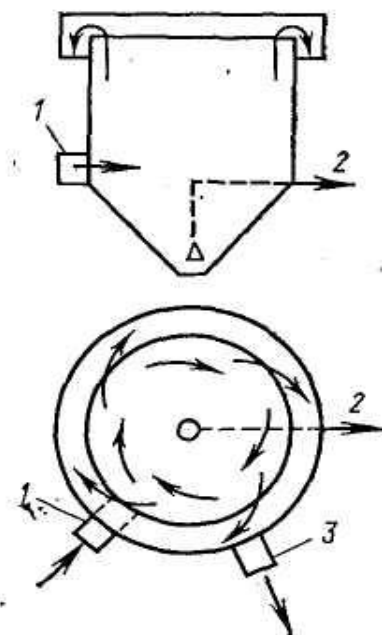
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(. 11.8).

7000 ^{3/} .

(11.2) — (11.4).



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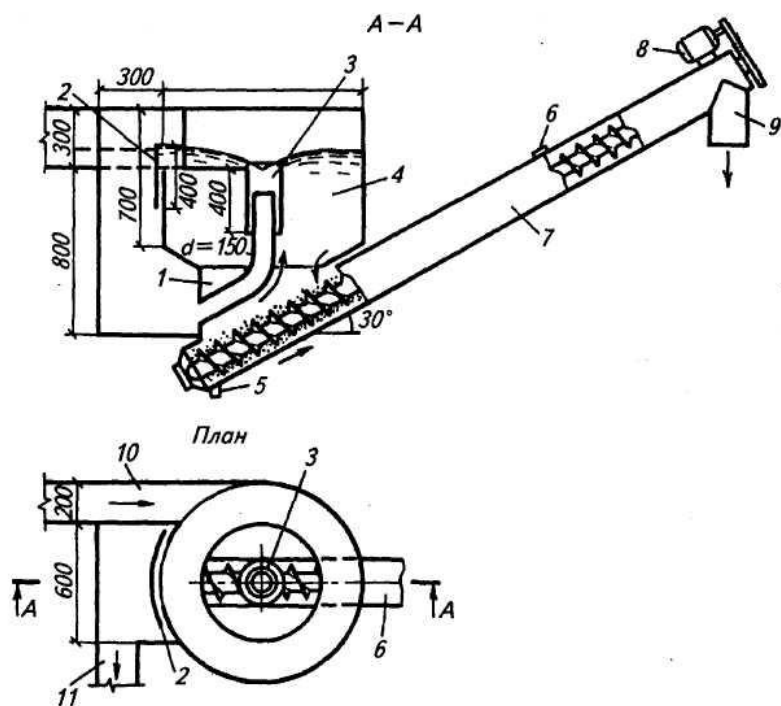
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110...130 ^{3/}(^{2.}),

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. 11.9.

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; 8 — ; 9 — ; 10 —
; 11 —

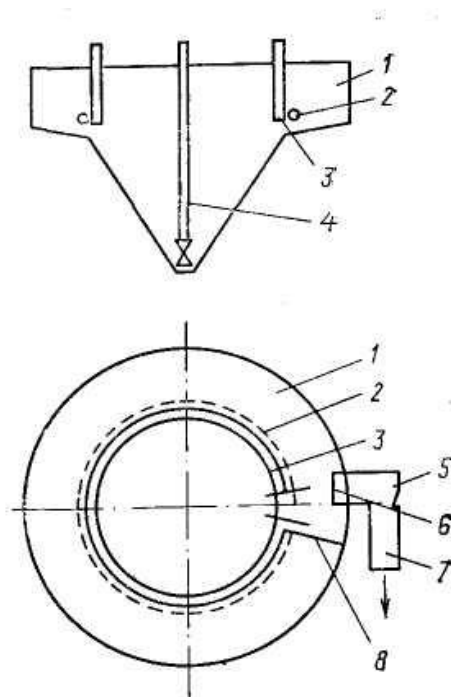
0,6...0,8 /

90 %

$$S = \frac{Q}{q_0}.$$

(. 11.10)

13...18 / .



. 11.10.

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 240...280 . ^{3/} . -

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 2. $C_1, \text{ } / ,$ (-
)
 3. ,
 , / ,
 (,
 ,
 100...150 /).
 (-
) (%)

$$= \frac{C_1 - C_2}{C_1} 100 .$$
 40...60 %
 1...1,5 ; 70 %.
 4. ,
 , 50... 98 %.
 5. , $= f(t),$

(.

The technical drawing illustrates a centrifugal pump assembly in two views: a cross-section (top) and a plan view (bottom).

Cross-section view (top): This view shows the internal components of the pump. A central shaft (4) is connected to an impeller (5) mounted on a pump housing (6). The impeller has curved blades (7) that create a centrifugal flow of liquid, indicated by arrows. The liquid is collected in a volute casing (9). The entire assembly is mounted on a base (10). A vertical dashed line labeled "A-A" indicates the plane of the section. Various components are numbered: 1 (inlet pipe), 2 (seal), 3 (seal ring), 4 (shaft), 5 (impeller), 6 (pump housing), 7 (impeller blades), 8 (outlet pipe), 9 (volute casing), and 10 (base).

Plan view (bottom): This view shows the pump from above. It features a circular impeller (5) with radial blades (7) mounted on a central shaft (4). The impeller is surrounded by a pump housing (6). The liquid is collected in a volute casing (9). The entire assembly is mounted on a base (10). A horizontal dashed line labeled "A-A" indicates the plane of the section. Various components are numbered: 1 (inlet pipe), 2 (seal), 3 (seal ring), 4 (shaft), 5 (impeller), 6 (pump housing), 7 (impeller blades), 8 (outlet pipe), 9 (volute casing), and 10 (base). The word "План" (Plan) is written above the view.

1 — ; 2 — ; 3 —
 ; 4 — ; 5 — ; 6
 — ; 7 — ; 8 —
 ; 9 — ; 10 —

60...70 %

$$R = \sqrt{\frac{Q}{3,6f \, k \, w_o}}, \quad (11.5)$$

$$k = \frac{0,35}{0,65 \dots 0,7},$$

$$u = R - \sqrt{R^2 - \frac{Q}{3,6f v_0}},$$

$$v_0 = \dots, \quad 5 \dots 7 \quad / \quad .$$

8 ; 0,7 H;

2 ; 0,4...0,5 / ;

 $0,5R;$
$$6 \text{ } / (\text{ } \cdot \text{ });$$

50°.

15000 ³/₈...12 (20).

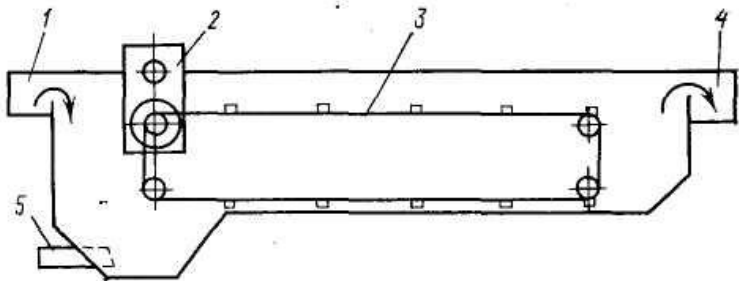
$$H \quad 1,5 \dots 4 \quad ,$$

6...9 .

(. 11.12),

()

50...60°.



. 11.12.

1 —

, 2 —

, 3 —

4 —

, 5 —

$$L = \frac{H}{k} \frac{v}{w_o} ,$$

v —

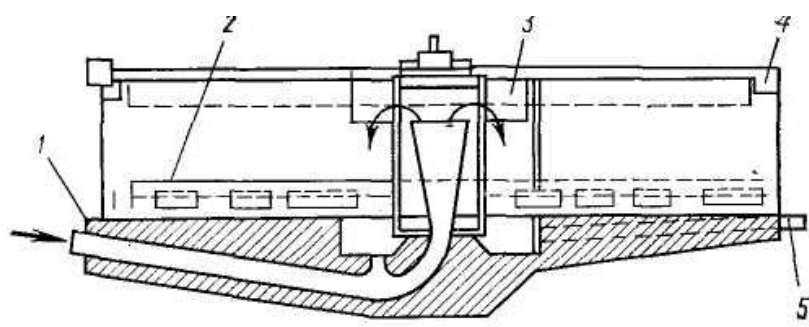
$/ ; k$ —

5...10

0,5.

20 . ^{3/} .

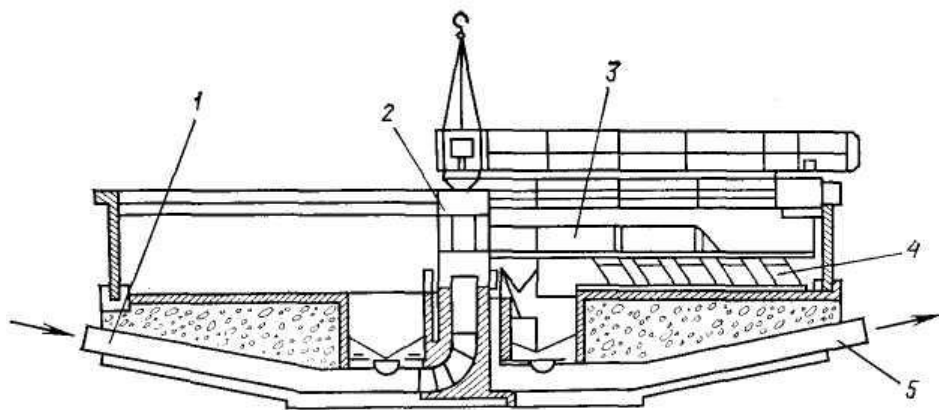
(. 11.13).



.11.13.

1 — ; 2 — ; 3 — ; 4 — ; 5 —

0,8...3⁻¹.
 (11.5), k — , 0,45.
 18 ; 6...30;
 1,5 5 ; 0,3 .
 10 / (°).
 1,2...1,3 -
 1,3...1,6 , -
 , .
 , .
 .
 1 .
 - (. 11.14)
 , 500 / -
 -
 , 40 % , -



. 11.14.

1 — ; 2 — ; 3 —
; 4 — ; 5 —

0,5...1,5 ,

0,3 . 0,8...1,2 , 0,7 ,
18, 24 30 .
65 %. (11.5),
 k 0,85.

$$t = \frac{h_0}{w_o},$$

h_0 — , 0,85

$$V = qt = k h f R^2.$$

$$H = h + h + h ,$$

q — ; h — ;
 $h = 0,5$ — () ,
305

; $h = 0,5$ — -

l

$$b = n\sqrt{R^2 - l^2},$$

n — -

($n = 0, 1 \dots 0, 12$).

,

, 10 -

$2 \dots 3^3 / (2^2)$.

50...100 % -

,

20...30 %, -

(. 11.15). ,

; , .

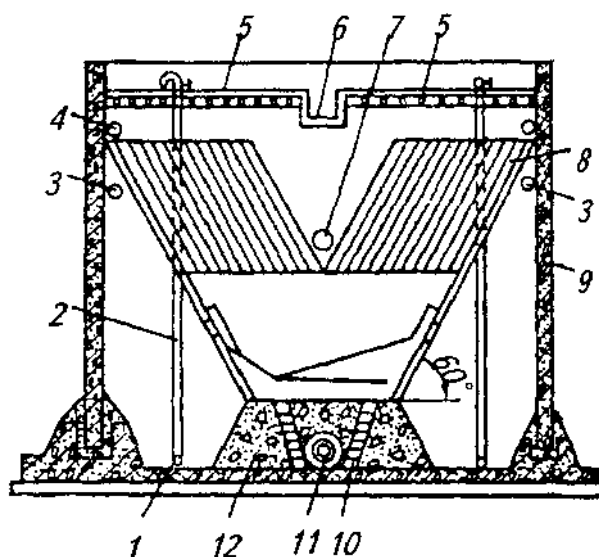
(150). ,

:

;

() ;

() .



1 — . 11.15. ; 2 — ; 3, 7 — ; 4 — ; 5 — ; 6 — ; 8 — ; 9 — ; 10 — ; 11 — ; 12 —

(, ,). ()

45...60°.

Q ($^3/$),

1)
 $H_0 = 50...150$;

2) u (/)

$$10w_o \leq v \leq 500/R,$$

$$R \text{ --- } ;$$

$$3) \qquad \qquad \qquad \text{r}$$

$$\text{r} = \arcsin\left(\frac{w_o}{v}\right);$$

$$4) \qquad \qquad \qquad (\quad)$$

$$L_p = 1,1H_0\sqrt{\frac{v^2}{w_o^2}-1};$$

$$5) \qquad \qquad \qquad (\quad)$$

$$L \quad = 1,3 \cdot 10^{-3} \frac{(C_1 - C_2)v}{(100 - W) \dots};$$

$$6)$$

$$N = 10^9 \frac{Q}{S \, v},$$

$$C_1, \, C_2 \text{ --- } , \quad / \, ; \, W \text{ --- } -$$

$$, \, \%, \, S \text{ --- } -$$

$$, \quad ^2;$$

$$7) \qquad \qquad \qquad t_0 \, (\quad).$$

$$-$$

$$\text{Re} \quad = \frac{u_{\max} 4R}{\epsilon} < 2800 \, ,$$

$$v_{\max} = \frac{\text{Re} \, \epsilon}{4R} \, , \tag{11.6}$$

$$\text{---} \qquad \qquad \qquad , \quad ^2/ \, .$$

$$:$$

$$Fr = \frac{v_{\max}^2}{gR} \geq 10^{-5} , \tag{11.7}$$

$$: \, v_{\max} = 0,1\sqrt{R} \, .$$

$$(11.6) \quad (11.7) \qquad \qquad \qquad -$$

$$v_{max} \quad 0,412 \quad / \, ; \, R \quad 16,9 \quad .$$

$$\begin{array}{l} \cdot \qquad \qquad \qquad 50, 50\dots 500, 500\dots 5000 \quad >5000 \quad / \qquad \qquad \qquad - \\ 0,015; 0,017; 0,02 \quad 0,025 \quad / \cdot \\ \qquad \qquad \qquad (\qquad \qquad \qquad) \end{array}$$

$$R=\frac{BH}{2(B+H)}.$$

$$\begin{array}{l} / \quad , \\ h \qquad \qquad \qquad H_0=H+h\, . \end{array}$$

$$q=v\ BH=\frac{v_{\max}}{1,5\div2,5}BH\, .$$

$$N=\frac{Q}{q}.$$

$$L=v_{\max}t\,,$$

$$L=\frac{B}{2tg\mathfrak{r}}+v_{\max}t_o\,.$$

$$t_o=\frac{H}{w_o\cos\mathfrak{r}}\,.$$

$$120$$

$$\dots' \qquad \qquad \qquad d \qquad \qquad \qquad :$$

$$w_o=\frac{d_1^2\big(\dots'-\dots\big)g\,k_0'}{18\sim};$$

$$\dots'=\frac{\dots\,d^3+\dots\big(d_1^3-d^3\big)}{d_1^3};$$

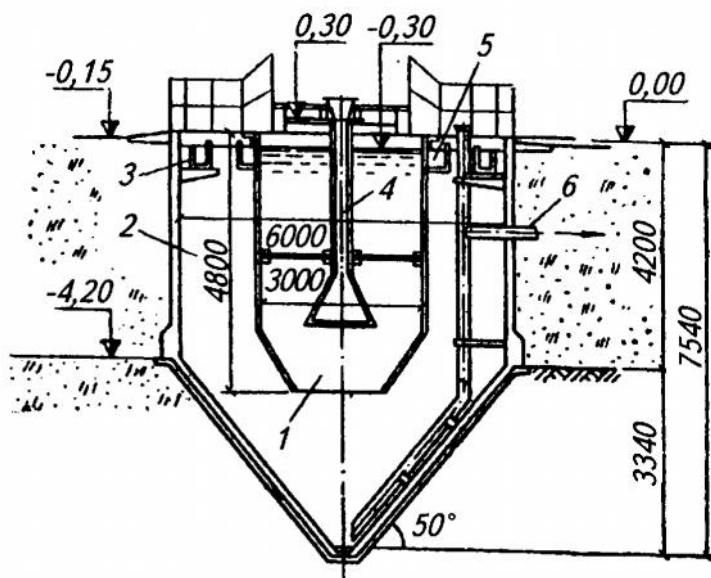
$$:$$

$$V\,=\frac{t_oQC}{C},$$

... ' — (); $d_1 = d + 2 \cdot 0,15$ —
 , ; t_o — ; — ;
 k'_0 — .

70 %.

(. 11.16).



. 11.16.

1 — ; 2 — ; 3 —
 ; 4 — ; 5 — ;
 6 —

75 %.

6

1,5 — 85³/ , 9 — 193³/ .

.

() 0,6 .

20-

4...5 . 0,5...0,7 / ,

2...3 .

:

1200 (

20 %) 300 / (25 %), 200

90 / .

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() — , , , —

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100 / .

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(. 11.17) ,

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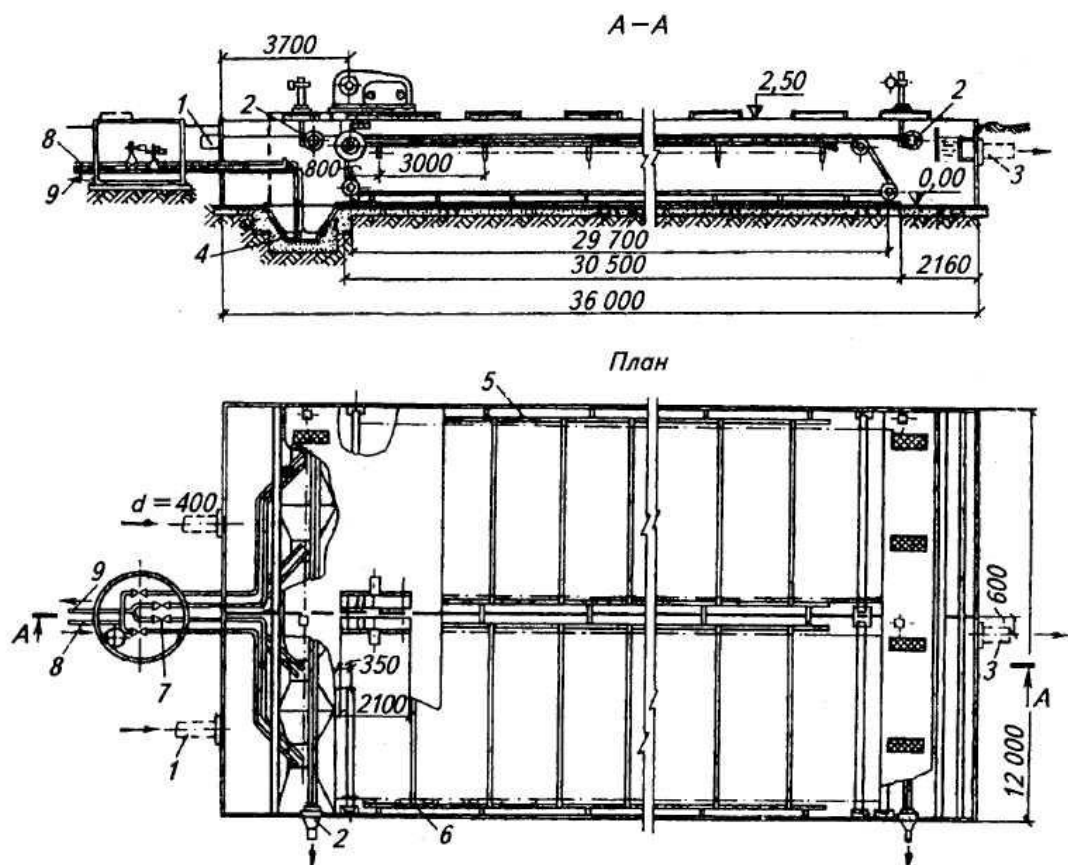
.

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.

.

— 100 / .



. 11.17.

1 — ; 2 — ; 3 —
; 4 — ; 5 —
; 6 — , ; 7 —
; 8 — ; 9 —

, 2...3 , 1,2...1,5 , 45 / .

6

2 .

$$L = \frac{ahv}{w_o},$$

a — , ; $\frac{v}{w_o} = 15$ a

$= 1,65$, $\frac{v}{w_o} = 10$ $a = 1,5$; h — .

$$v = 4 \dots 6$$

$$/ , \quad w_o = 0,4 \dots 0,6 \quad / .$$

$$t_o \quad 2 \quad ;$$

$$t' = \frac{h}{w_o} . \quad t' \leq t_o .$$

$$0,1 \quad . \quad -$$

$$0,4 \dots 0,5 \quad . \quad (\quad) \quad -$$

$$. \quad -$$

$$, \quad . \quad 2 \dots 3 \quad -$$

$$2,5 \dots 5 \quad . \quad ;$$

$$w_o = 0,15 \quad / ; \quad 0,1 \quad ; \quad -$$

$$100 \quad / ; \quad h = 50 \quad ;$$

$$45^\circ; \quad 0,65 \dots 0,75 \quad ; \quad 1,5 \dots 1,6$$

$$. \quad t' = \frac{h}{w_o} .$$

$$L = 1,3 \, v t' . \quad 5 \dots 6$$

$$. \quad 0,5 \dots 0,6 \quad . \quad -$$

$$.$$

$$.$$

$$:$$

$$1) \quad ;$$

$$2) \quad ;$$

$$3) \quad , \quad -$$

$$; \quad ;$$

$$4) \quad .$$

$$-$$

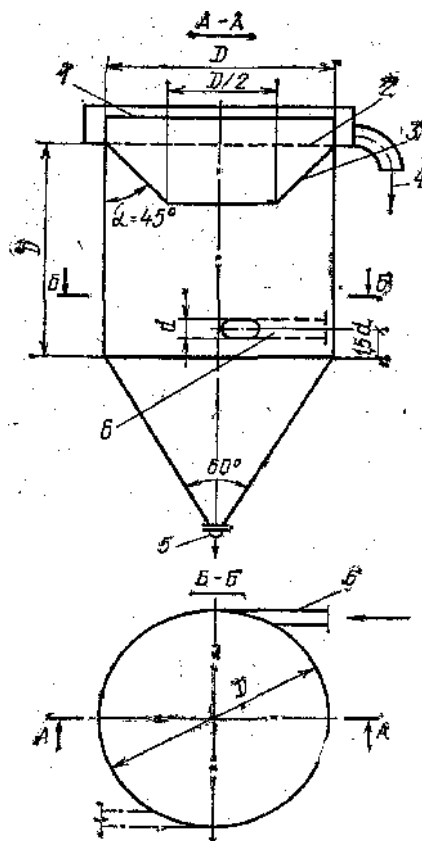
$$(\quad -$$

$$) \quad . \quad ,$$

$$, \quad -$$

(. 11.18)

0,2 /



. 11.18.

:

1 —
; 4 —

; 2, 3 —
; 5 —

; 6 —

(2...20³/(²))

(0,5).

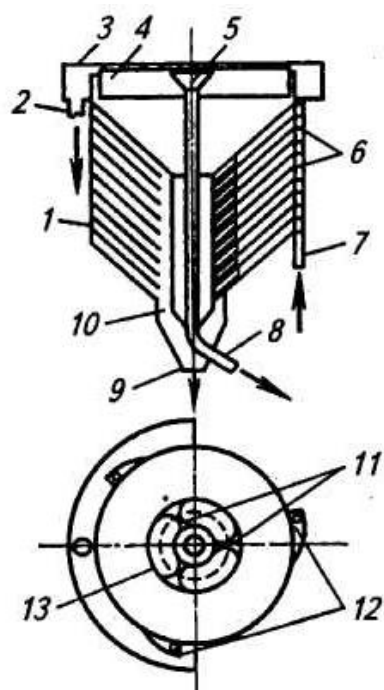
0,1...0,5 / .

:

;

II.20)

(. 11.19)



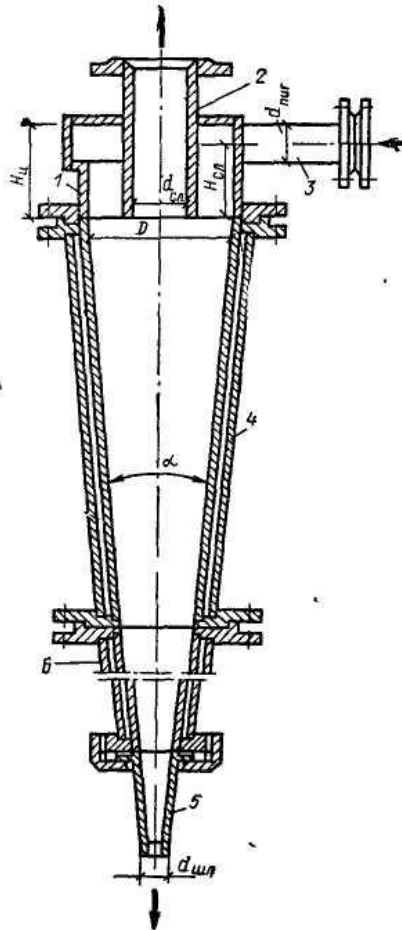
. 11.19.

1 — ; 2 — ; 3 — ; 4 — ; 5 —
; 6 — ; 7 — ; 8 — ; 9 —
; 10 — ; 11 — ; 12 — ;
13 —

8...10

$q, \sqrt[3]{(D^2 - d^2)},$
 $q = 3,6 k w,$
 $w —$
 $;$
 $h = 200$
 $; k —$
 $0,61;$
 $1,98;$
 $k = \frac{0,75n(D^2 - d^2)}{D^2},$
 $n — ; D — ; d —$
 $;$
 $k = \frac{1,5n(D^2 - d_2^2)}{D^2},$
 $n — ; d_2 —$
 $Q, \sqrt[3]{},$
 $Q = 0,785 q D^2.$
 $, \sqrt[3]{},$
 $= q/H,$
 $0,075$
 $0,033.$
 $0,5 \sqrt[3]{}.$
 $:$
 $2...6, \quad h = 100...250, \quad 4...20,$
 $d = 0,6...1,4, \quad b = 100...150,$

$$\begin{aligned}
 n_1 &= 3, & v_1 &= 0,3 \dots 0,4 \quad / \quad , & n_2 &= 2 \dots 3, & - \\
 v_2 &\leq 0,1 \quad / \quad , & & & & & - \\
 \Delta R &= 50 \dots 70 \quad , & r &= 60 \dots 90^\circ. & & & \\
 & & & (\quad . 11.20) & & &
 \end{aligned}$$



. 11.20. :
 1 – ; 2 – ; 3 – ; 4 –
 ; 5 –

:

$$w_o = 15,33 \frac{k D^3}{r Q} ,$$

Q — , $^3/$; k — ,

; - -

$k = 0,04$; r — ,

, 0,45.

δ , ,

$$u = 2,710^3 \frac{D^{0,543} d^{1,643} d^{0,014} \sim 0,5}{d^{0,57} H^{0,507} H^{0,714} (x - x) p^{0,222}} .$$

, :

$$q = Q \frac{d^2}{d^2 + d^2} ; \quad q = Q \frac{d^2}{d^2 + d^2} .$$

:

1) ;

2) ;

3) ;

4) -

;

5) ;

6) ;

7) .

• ,

• , -

•

: 1)

, , -

; 2) ,

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—

,

$$= \frac{\check{S}^2 r}{g},$$

— , / ; r — , .

2500.

2...3 /

20 ³/ ,
/ .

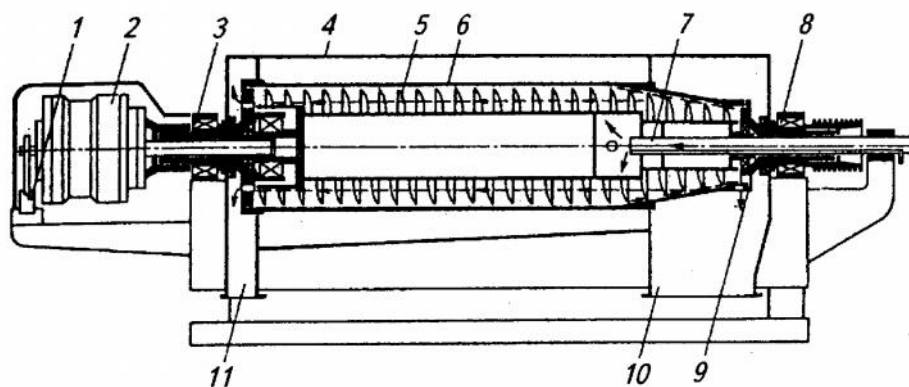
0,05...0,01

(. 11.21).

0,2 / (

) 0,05 / ().

50...100 ³/ .



. 11.21.

:

1 — ; 2 — ; 3, 8 — ; 4 — ; 5 — ; 6 —
; 7 — ; 9 — ; 10 — ;
11 —

w_o . -

· , h , -
‡ , . . , ,

·

$$Q=\frac{V}{t},$$

V — $h=D-\frac{D_c}{2}$ (D —

$; D_c$ —); t —

·

, -

$Q = kQ$, k — ; $k =$

0,4...0,6.

·

(. 11.22),

().

·

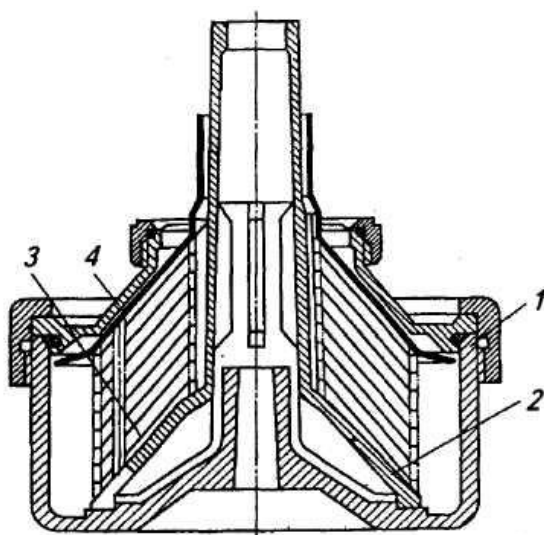
99,4...99,6 %

88,1...91,4 %.

, 89,3...92,1 %.

95,6...97,9 %.

, ·



. 11.22.

:

1 –

; 2 –

; 3 –

; 4 –

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$L, /$,

$$L = 0,04 S t z y V n^2 ,$$

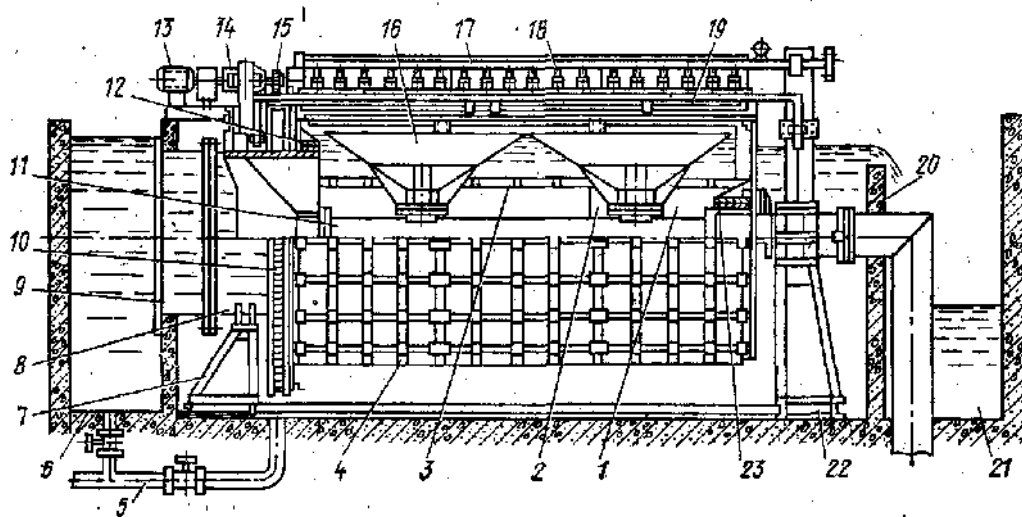
β — ; t —
 ,
 ; z — ; — ; V —
 , 3 ; — , $^{-1}$.

11.3.

, , , .
 .
 , 300 /
 .
 .
 ()
 , (250 /) 25...45 %.
 .
 , , , ,
 .
 ,
 250 / .
 25 %.
 , , , .
 () :
 , .
 40...60 %, .
 .
 ().
 25... 30 %.
 300 / .

:
 , / 30
 , -' 10
 , 9
 , 90
 , % 45.

(. 11.23). 0,3...0,8 ,
 40...70 . 0,6...0,85 -
 0,1...0,5 / . -
 40...50 $\frac{3}{(2)}$.
 0,15...0,2 .
 1...2 %



. 11.23.

1 — ; 2 — ; 3 — ; 4 — ; 5 — -
 : 6 — ; 7 — ; 8 — ; 9 —
 ; 10 — ; 11 — ; 12 — ; 13 —
 ; 14 — ; 15 — ; 16 — ; 17 — -
 ; 18 — ; 19 - ; 20 — ; 21 —
 ; 22 — ; 23 —

$$F_c=\frac{Qk}{v_c}k_1k_2,$$

$$k_1$$

$$k_1\!=\!\left(\frac{b-d}{b}\right)^2(1+S_1),$$

$$\begin{array}{l} Q\text{---},\quad^3/ \quad; k\text{---} \quad; v_c\text{---} \\ \quad; \quad v_c=0,2...0,4 \quad / \quad v_c=0,4...1 \quad / ; b\text{---} \\ \quad, \quad 0,5...5 \quad; d\text{---} \quad, \quad 0,3...2 \quad; S_1 \\ \text{---} \quad, \quad; k_2\text{---} \\ 1,2...1,8. \end{array}$$

$$S_{\quad}=\frac{k_1Qk}{k_2tw},$$

$$\begin{array}{l} t\text{---} \quad, \quad; w\text{---} \quad, \quad- \\ 20...90 \quad / ; k_1,k_2\text{---} \quad; k_1=1,03, \, k_2=0,63. \end{array}$$

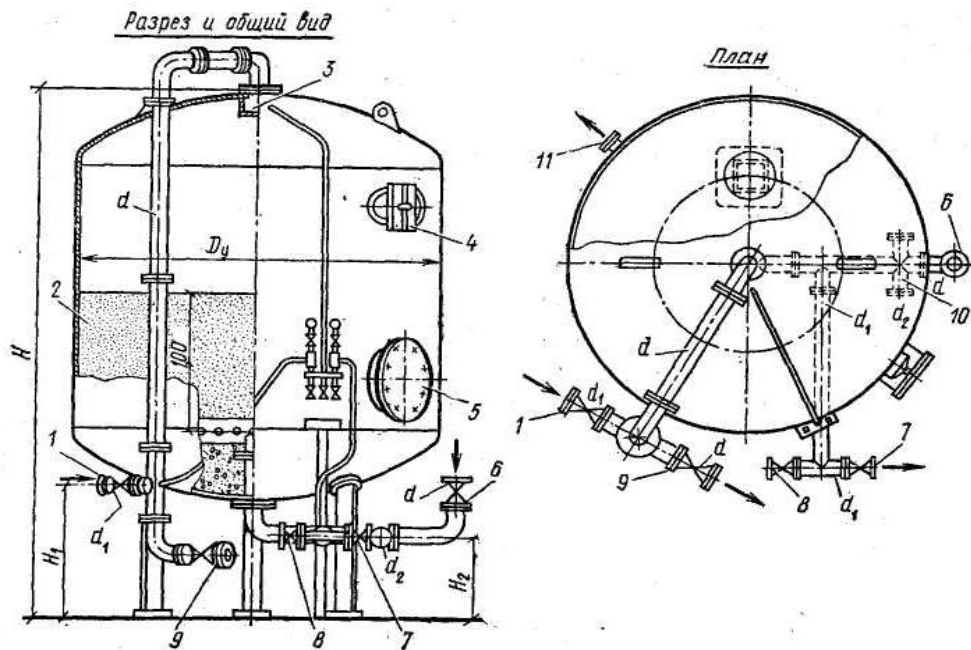
$$h_0=\textless_0\frac{\ldots v_1^2}{2A^2}.$$

$$\dagger$$

$$h_4=\textless_t\frac{\ldots v_1^2}{2A^2(1-s_k)^2},$$

$$\begin{array}{l} \textless_0\text{---} \quad, \quad \text{Re}_c<4 \\ \textless_0=\frac{6,7}{\text{Re}_c} \quad \text{Re}_c>4 \quad \textless_0=\frac{2,38}{\text{Re}_c^{1/3}}; \, v_1\text{---} \quad - \\ \quad, \quad / ; \text{---} \quad, \quad; \textless_t\text{---} \quad - \\ \quad t \, (\quad); \, S_k\text{---} \\ (\quad); \, \text{Re}_c=\frac{u_1R_c}{\epsilon}\text{---} \quad; R_c\text{---} \quad - \\ \quad; \, R_c=\frac{A}{2f \, N}; \, N\text{---} \quad; \text{---} \quad - \\ \quad, \quad^2/ \, . \end{array}$$

(. 11.24) ,



. 11.24.

- 1 — ; 2 — ; 3 —
; 4 — ; 5 — ; 6 —
; 7 — ; 8 — ; 9 —
; 10 — ; 11 —

0,6

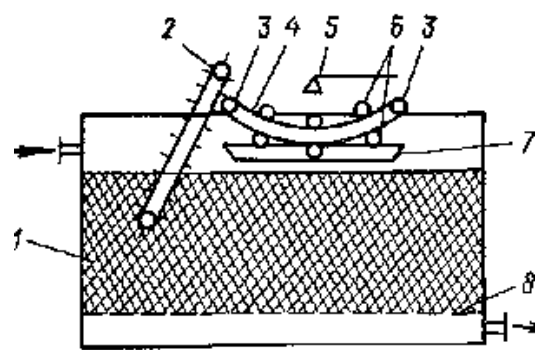
1 .

(, 1 2) ,

: ,
 , -
 .
 .
 .
 ()
 , .
 .
 2...3 , .
 , -
 5...12 / , 12...48
 (-
). 7...20 / (-
 40...80 /), — 10...20 / (-
 30...60 /).
 ,
 1...2 / ³, — 1,5...3 / ³.
 5...10 / Al₂(SO)₃ 0,2...0,3 /
 0,9...1,3 (0,009...0,13).
 (-
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 (), ,
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 ,
 (0,01...0,03 / ³).
 ,
 0,6...2 / .
 ,
 2...5 , 0,3...2
 « » (. 11.25)

= 6...9.



. 11.25. :
 1 — ; 2 — ; 3 — ; 4 — ; 5 — -
 ; 6 — ; 7 — ; 8 —

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 ,
 .
 ,
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 ,
 ,
 ,

$$v_0 = \frac{V - V_0}{V}; \quad a = \frac{6(1 - v_0)r}{d},$$
 v_0 — ; V — , 3 ; V_0 — , 3 ; a — , $^2/ ^3$; d — , ; r — .
 .
 ,
 ,
 ,

$$-\frac{\partial C}{\partial x} = bC - a \dots ; \quad \frac{\partial \dots}{\partial t} = -w \frac{\partial C}{\partial x} ,$$
— ; — ; b , — .
 ; \dots —
 ; w — .
 :

$$\frac{\partial^2 C}{\partial x \partial t} + a w \frac{\partial C}{\partial x} + b \frac{\partial C}{\partial t} = 0 . \quad (11.8)$$
(11.8)
 ,
 .
 .
 .
 t .
 , . . .
 .

$$(H) \qquad t \; . \qquad t \approx t \; .$$

$$t \quad t$$

$$t \; = \frac{1}{k} \frac{b}{a} \bigg(x - \frac{x_0}{b} \bigg); \qquad t \; = \frac{H \; - H_0}{H \; F_{(A)}} \frac{b}{a} x,$$

$$\begin{array}{l} k \; x_0 \text{ --- } , \qquad , \qquad ; H_0 \\ \text{---} \qquad ; F_{(A)} \text{---} , \qquad . \end{array}$$

$$H=\int\limits_0^x i\,dx=i_0\int\limits_0^x \left(\frac{\mathsf{v}}{\mathsf{v}_0-\Delta\mathsf{v}}\right)^3dx;)$$

$$i_0=\frac{0,188\mathbb{E}^2\sim(1-\mathsf{v}_0)^2}{d^2\mathsf{v}_0^3}\;;\qquad i=i_0\bigg(\frac{\mathsf{v}_0}{\mathsf{v}_0-\Delta\mathsf{v}}\bigg)^3,$$

$$\begin{array}{l} i_0 \text{ ---} \\ ; i \text{ ---} \qquad \qquad \qquad - \\ \qquad \qquad \qquad ; \Delta\mathsf{v} \text{ ---} \qquad \qquad \qquad , \qquad \qquad \qquad - \end{array}$$

$$S \; (\quad ^2)$$

$$S=\frac{Q}{t\,w_p-3,6n\,u\,t_1-n\,w_p\,t_2}\;,$$

$$\begin{array}{l} t \text{ ---} \qquad \qquad \qquad , \; ; w_p \text{ ---} \qquad \qquad \qquad , \; / \; ; \\ n \text{ ---} \qquad \qquad \qquad ; u \text{ ---} \qquad \qquad \qquad , \; / (\quad ^2); t_1 \text{ ---} \qquad \qquad \qquad - \\ \qquad \qquad \qquad , \; ; t_2 \text{ ---} \qquad \qquad \qquad - \\ , \; ; t_2=0,33 \; . \end{array}$$

$$\qquad \qquad \qquad \ll \qquad \qquad \qquad \gg$$

$$t \; = k \frac{EV}{m \; - m} \; ,$$

$$(\quad ^3/ \;)$$

$$Q_p=\frac{Q(m \; - m \;)}{\ldots}+\frac{2V}{t},$$

$$\begin{array}{l} k=0,85 \text{ ---} \qquad \qquad \qquad , \qquad \qquad \qquad ; \quad - \qquad \qquad \qquad - \\ \qquad \qquad \qquad , \quad / \; ^3; V \text{ ---} \qquad \qquad \qquad , \quad ^3; m \; , \end{array}$$

m — , / ; ... —
 , / ³.

12.

12.1.

0,001...0,1 ,
 0,1...10 , 10 .
 10 ,
 ; ,
 , .

, ,
 (-
)
 .
 :
 ;
 ;
 ;
 , ,
 $I_2(S_4)_3$ $FeCl_3$ 1:1 1:2 ,
 , , .

: ($SiO_2 \cdot y H_2O$) .

0,4 1,5 / ; — 2...3 / .

,
 ,

, .

, ,

, , .

().

10...17 %.

10^{-2} 10...12 .

1...2 .

, ,

.

(. 12.1)

.

20...100 . $S = \frac{Q}{v_o}$.

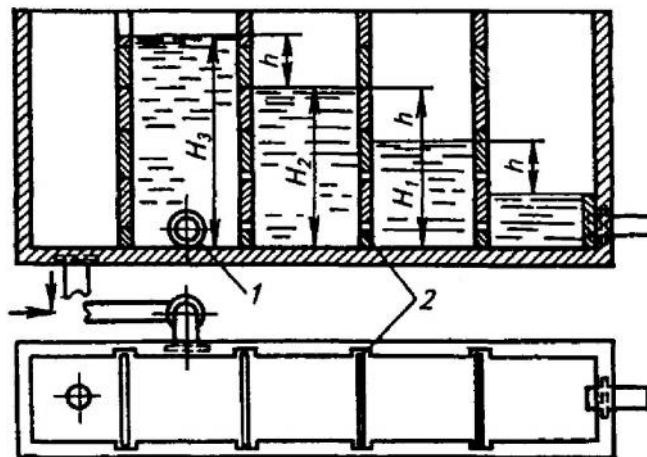
$$v_o = 1 \text{ / ,}$$

$$v_o = 0,6 \text{ / .}$$

$$H_0 = 0,4...0,5 \text{ .} \quad -$$

$$h = < \frac{v_o^2}{2g},$$

< —



. 12.1. :

1 — ; 2 —

$$H_0 \quad \text{---} h,$$

(. 12.2) -

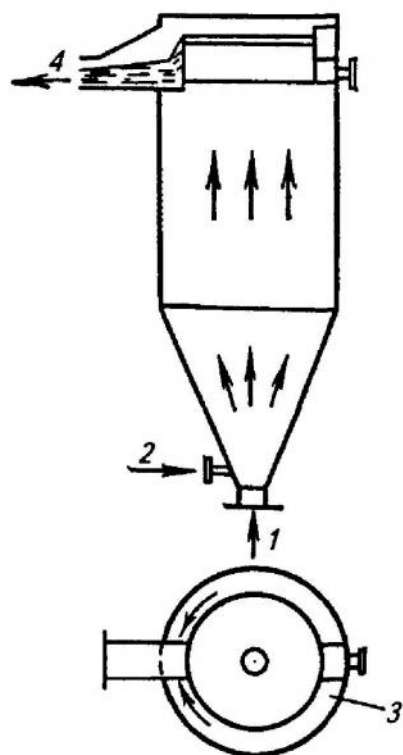
$$1 \text{ / ,} \quad 25 \text{ / .}$$

$$t = 1,5...2 \text{ .}$$

$$Q (\text{ }^3/) \quad v ,$$

:

$$D = \sqrt{\frac{4Q}{f v}} .$$



. 12.2. :
1 — ; 2 — ; 3 — ; 4 —

$$h_k = \frac{(D - d)}{2\sin\frac{\{ }{2}},$$

d — ; $\{$ — .

$$V_k = \frac{f}{3} h_k \left[\left(\frac{D}{2} \right)^2 + \left(\frac{d}{2} \right)^2 + \frac{D}{2} + \frac{d}{2} \right].$$

:

$$V = Qt \text{ .}$$

$$h = \frac{V - V}{F}.$$

:

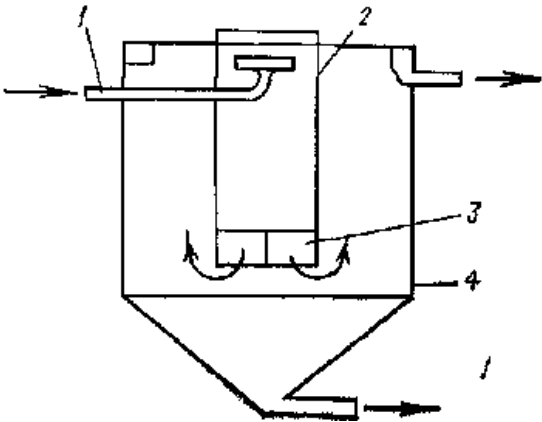
$$H = h + h \text{ .}$$

0,8...1 / 2 . -

, -
 , , ,

(. 12.3) ,

2...3 / . -



. 12.3. :
 1 — ; 2 — ; 3 — ; 4 —

$t = 15...20$, -
 $t = 1$. $v = 2...3$ / . = 3,6...4

n . , -

$$S = \frac{q_{\max} t}{n \cdot H} ; \qquad d = \sqrt{\frac{4S}{f}} .$$

0,2 $d_{.x}$ 0,5 -

$$d_c = 1,13(q'_{\max}/\mu \cdot v_c)^{1/2} ,$$

q'_{\max} — , ³/ ; μ - -

(0,908).

$$V_{oc} = q_{max} t_{oc} / n . .$$

$$= . . + 0,5.$$

$$D = 1,13[(V_{oc} + V . .) / H_{oc}]^{1/2}.$$

0,7...1,2 / .

70°.

4...5 / ,

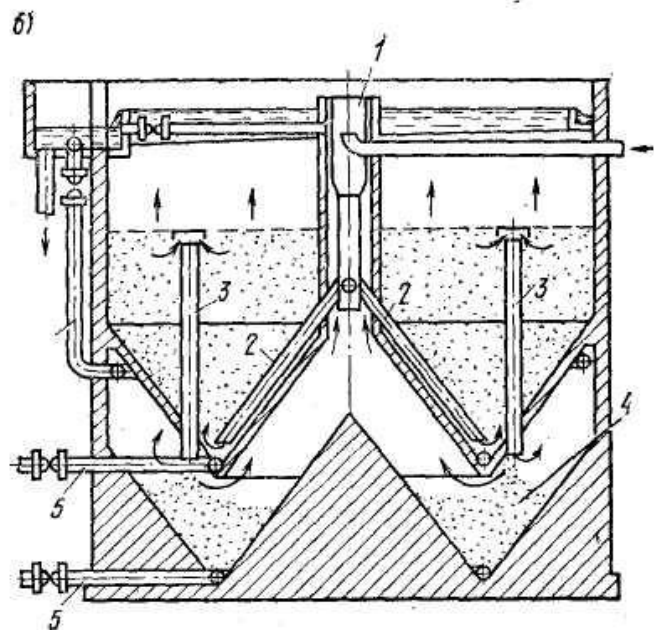
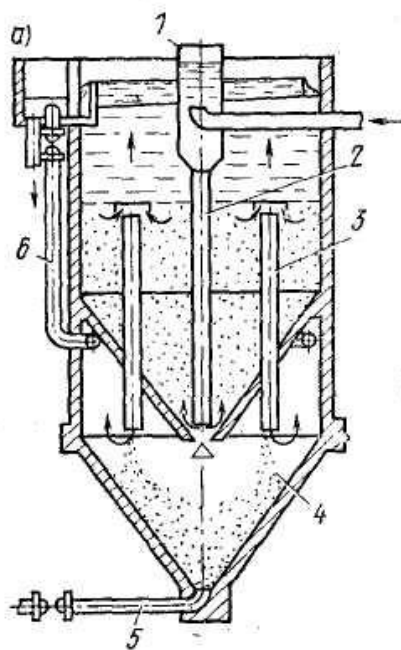
6...10 .

20...30 , ,

0,15...0,2 / .

4 / ,

(. 12.4).



. 12.4.

1 —

; 2 —

; 3 —

; 4 —

; 5, 6 —

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 (15) ,
 150².
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 ,
 400 / $v = 0,8...1$ / ,
 400...1000 / — $v = 1...1,1$ / , 1000...2500 / — $v = 1,1...1,2$ / .
 ,
 v ,
 (1
 / 20 °)
 ,
 Q ,³/ ,
 $Q = Q [1 + (-) /]$,
 Q — ,³/ ; —
 , /³.
 S_o ,²,
 $S = S_{\text{.}} + S_{\text{.}} = Q [1 + (-) /] [k + (1 - k)] / v$,
 $S_{\text{o.}} S_{\text{o.y}}$ — ,²; k_p . —
 , :
 $k_p = 1 - v (-) /$;
 — , 1,15...1,2.
 $V_{\text{.}}$ (, -
 0,5...0,7)
 $V_{\text{.}} Q t (C - C) / C$,

t — , 3...6 .

12.2. .

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0,01 / , , -

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, 15...30

, 100...200 .

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$G/G = 0,01...0,1$. -

$G/G = 1,3 Y^*(fp - 1)Q_1/C Q$,

G — , ; G — , ; Y^* —

, $^3/$; f — -

; $f = 0,5...0,8$; p — , -

； Q_1 — , , $^3/$ ； Q — , $^3/$ ；
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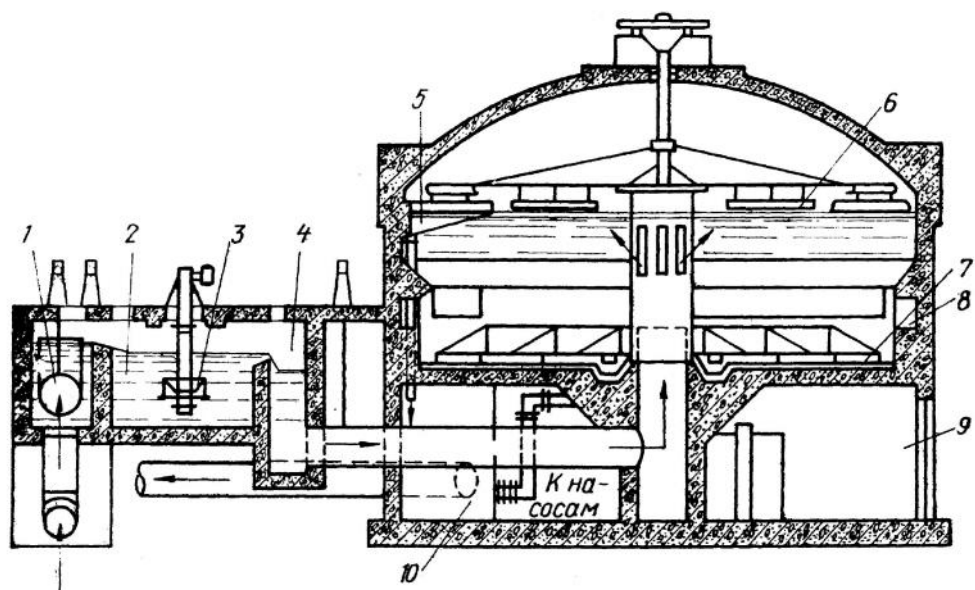
(. 12.5) ， -

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. 12.5.

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1 — ; 2 — ; 3 — ; 4 — ; 5 —
 — ; 6 — ; 7, - ; 8 — -
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(250 /) -

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1...2 (. 12.5),

(0,02...0,03)

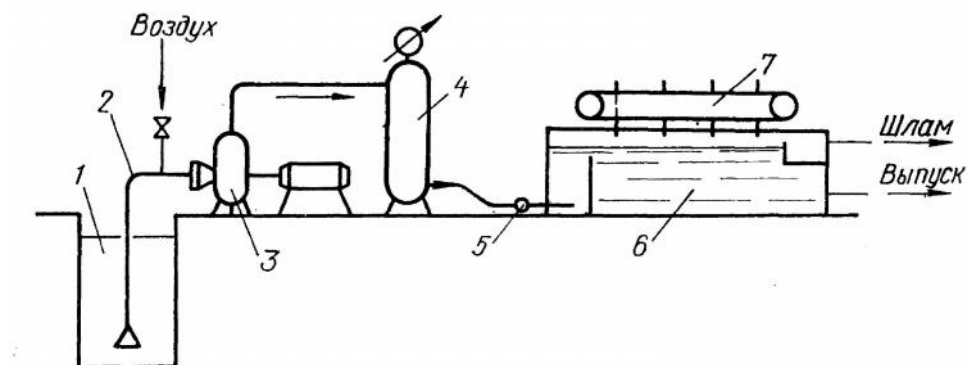
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20 , 1 ² 200 /cy .

(. 12.6), -

4...5 / .



. 12.6. :

1 – ; 2 – ; 3 – ; 4 – ; 5 –
 – ; 6 – ; 7 –

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 , () -

3...5 % 0,3...0,5 -

$$W = A \exp[16 \frac{3}{K T P_2^2} \ln^2(p_1/p_2)],$$

— ; — ;
 K — ; — ; p_1 p_2 —

$$= (2 + 3 \cos - \cos^2) / 4,$$

— . —

W :

$$J = k\, W\,,$$

k — .

—

$$W\,=\,[n^{4/3}\,(R+r)^3-n^{4/3}\,R^3]/V=C\,[(1-2/R)^3-1],$$

n — R V ; r — ; —

:

$$=n\,(4/3\,R^3/V),\quad R=2\,/(P_1-P_2).$$

N

$$N=\frac{4\cdot10^{-5}v'}{\epsilon\,d_c^{1,5}}\cdot\left[1-\left(\frac{v}{v}\right)^{0,75}\right]^2,$$

v' — , / ;

v — , —

, / ; v — , / ; $d_{\rm c}$ — , ; —

, ²/c.

:

$$v\,=\frac{1}{9}\frac{g\,R^2}{\epsilon};$$

:

$$v\,=\frac{1}{9}\frac{...gR^2}{9\sim+3C\,R},$$

— ; — ; μ — —

.

$$y\,=\frac{v\,t_1}{H_1}(1-e^{-r\,C\,v\,t}),$$

t_1 — ; $t=t_1+t_2$; t_2 —

; H_1 — ; —

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85...95 %.

(1...3).

100 ³/

1...1,5 ,

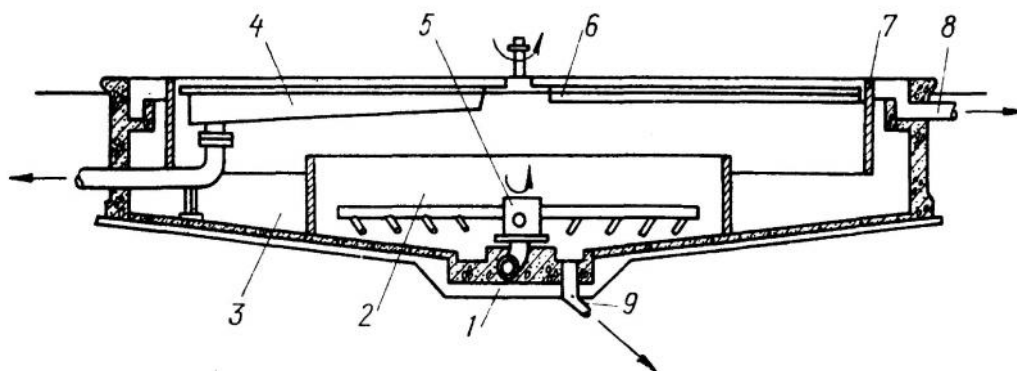
100 ³/

(. 12.7)

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1,5 ,

5 15 .



. 12.7.

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D

$$D = (4 Q / v) .$$

$v = 10,8 / ,$

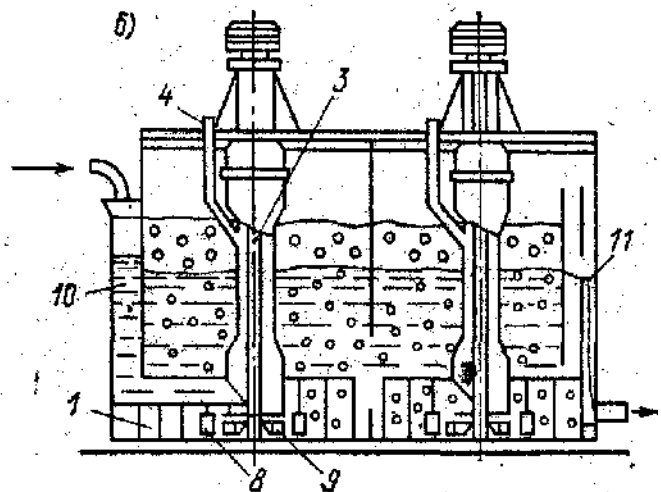
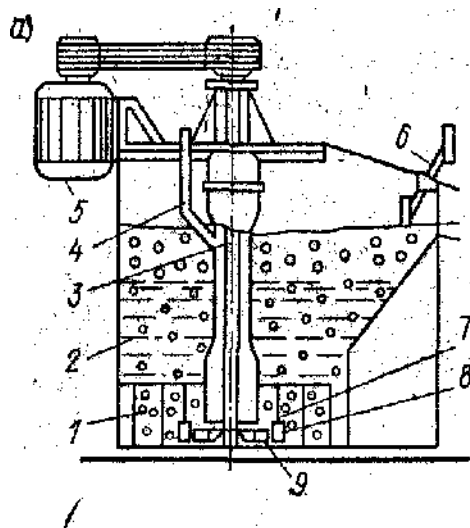
5...7 .

D

$$D=\sqrt{\frac{4Q}{f\,v_o}+D^2}\,.$$

$$v_o=4,7\text{ / }.$$

. 2...4 ,
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 (20...35),
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 (2...3 /) , -
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 « » (. 12.8), 6,3³, -
 12³/ . , 30...40 .
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. 12.8.

— ; — ; 1 — ; 2 — ;
 3 — ; 4 — ; 5 — ; 6 — ; 7 —
 ; 8 — ; 9 — ; 10, 11 —

α ,

d .

10...15 / ,

— 0,6 .

15...20 .

$= 0,35$.

$b = 6 d$.

$$S = b^2 = 36 d^2 .$$

$$V = h F = 36 h d^2 ,$$

h —

, :

$$h = H / ,$$

($= 0,67$), / 3 .

$$H_c = \left\{ \frac{v_o^2 \chi}{2g}, \right.$$

v_o — , / ; — , 0,2...0,3.

$$n = 60 \ v_o / (\ d).$$

Q ,

3 ,

$$m = \frac{Q \ t}{24 \cdot 60 \ V (1 - r) } ,$$

t — , .

$$N (\quad)$$

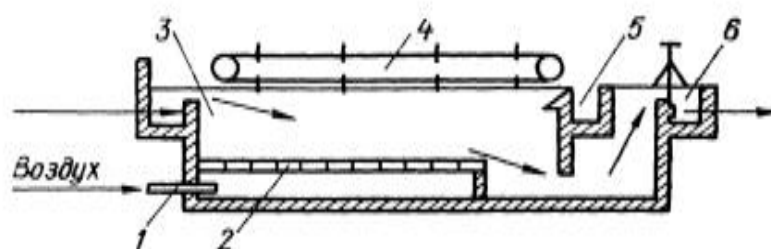
$$N = q \quad H / (102 \quad) ,$$

q — , / ; — ., 0,2...0,3.

(. 12.9)

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. 12.9.

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1 — ; 2 — ; 3 — ; 4 — ; 5 — ; 6 —

-

, , , . 4...20 , 0,1...0,2 , 20...30 ,

-

1,5...2 .

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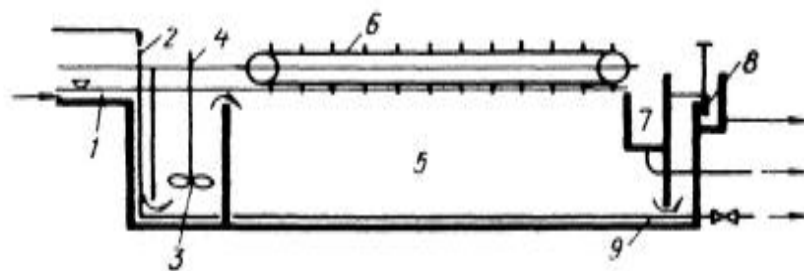
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(. 12.10)



. 12.10.

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1 – ; 2 – ; 3 – ; 4 – ;
 5 – ; 6 – ; 7 – ; 8 –
 ; 9 –

12.3.

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$$k_p = C / C \quad \text{const,}$$

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, / ³.

$$k_p \quad ,$$

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. 12.11.

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3 4

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6, *G* - 7.

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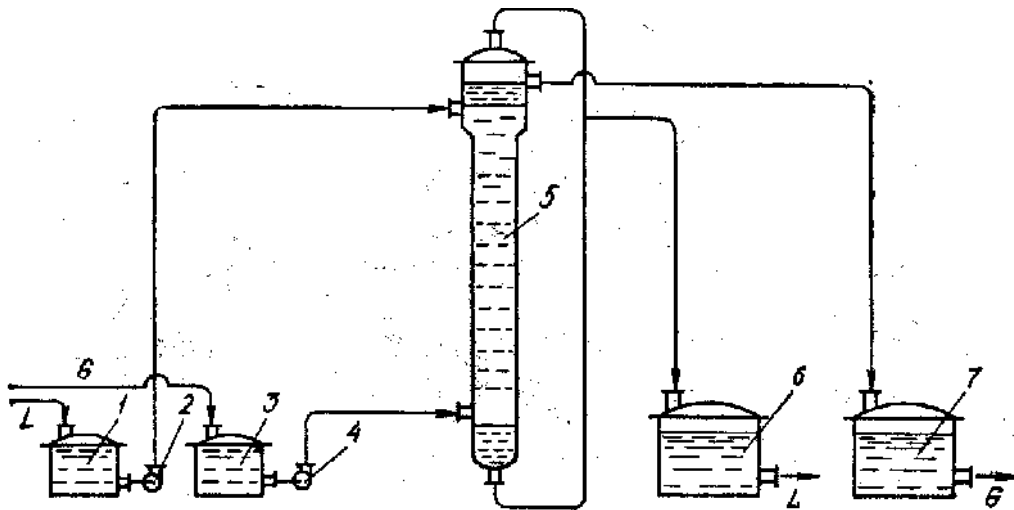
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. 12.11.

$$= \frac{1}{(1 + bk)^n},$$

—
, / ³; — ; b —
, ³ / ³, :

$$b = \frac{V}{nQ};$$

V — , ³; Q —
, , ³.

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\rangle ,
$$>$$

$$= (1 - bk) .$$

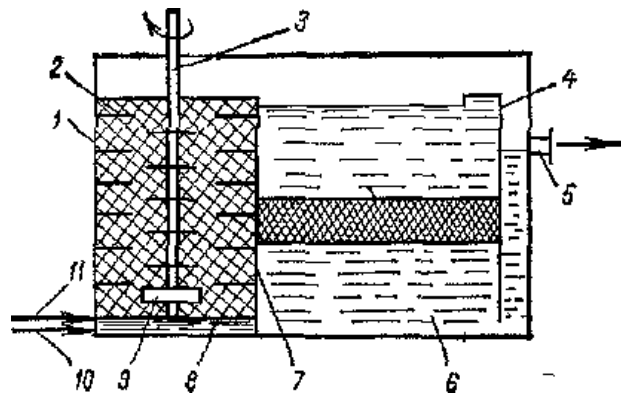
$$b = \frac{C - C}{k C}.$$

1)

2)

3)

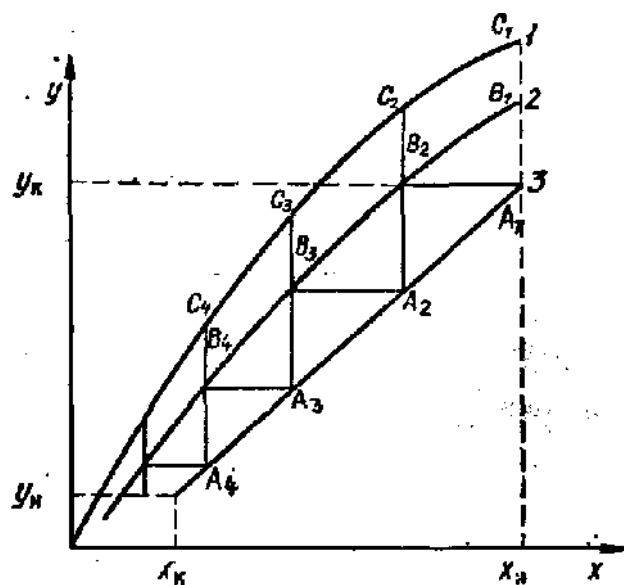
4)



12.12.

1 — ; 2 — ; 3 — ;
 4 — ; 5 — ; 6 — ; 7 —
 ; 8 — ; 9 —
 ; 10 — ; 11 — ,

L G -
 G/L
 $F + S = R +$,
 F, R -
 () ; S , -
 G L , o
 (12.13).



. 12.13.

$$V = V_0 = \text{const} \quad V = V_p = \text{const} \quad -$$

$$V x - V = V x - V_0 y .$$

$$y = \frac{V}{V_0} x + y - \frac{V}{V_0} x$$

$$= + ,$$

$$V, V_0, V, V_p \text{ — } , , ; , \text{ — } -$$

$$; , \text{ — } -$$

$$; = V/V_0 = \text{tg} \text{ — } ;$$

$$= - (V/V_0) \text{ — } , .$$

$$v = \frac{y - y}{y^* - y}; \quad v = \frac{x - x}{x - x^*},$$

$$^*, ^* \text{ — } , \text{ —}$$

$$= n/n . , -$$

$\text{Re} = 62,9 Ga^{0,82} \left(\frac{\text{Re}^2}{We} \right)^{0,74} \left(\frac{\sim}{\sim} \right)^{0,03} \left(\frac{\Delta_{...}}{...} \right)^{0,13};$
 $\text{Re} = 2,85 Ga^{0,3} \left(\frac{\text{Re}^2}{We} \right)^{0,15} \left(\frac{\sim}{\sim} \right)^{0,04} \left(\frac{\Delta_{...}}{...} \right)^{0,08} \left(\frac{D}{d} \right)^{0,92},$
 $\text{Re} = \rho n_0 d^2 / \mu \text{ —}; Ga = \frac{2}{3} d^3 g / \mu^2 \text{ —}, We =$
 $\frac{c n_0^2 d}{\mu} \text{ —}; \mu, \mu_c \text{ —}$
 $\text{ —}, \text{ —}; \text{ —}, \text{ —}^3; \text{ —} = \text{ —} \text{ —}$
 $\text{ —}, \text{ —}^3; d \text{ —}, \text{ —}; D \text{ —}$
 $\text{ —}, \text{ —}; n_0 \text{ —}, \text{ —}^{-1}; \text{ —},$
 $/ \text{ —}.$

$$\text{Re} = \frac{..._c n_0 d^2}{\sim_c} = 3,38 \cdot 10^{-2} ... 2 \cdot 10^5;$$

$$Ga = \frac{..._c d^3 g}{\sim_c^2} = 1,74 \cdot 10^5 ... 1,24 \cdot 10^{11};$$

$$\frac{\text{Re}^2}{We} = \frac{..._c d \uparrow}{\sim_c^2} = 2,45 ... 1,18 \cdot 10^7;$$

$$/ \text{ }_c = 0,02 ... 0,594; \mu / \mu_c = 0,005 ... 2,46; D/d = 1,72 ... 4,0.$$

(—⁻¹) —

$$n_0 = 45,4 \left\{ \frac{V \Delta_{...}^{0,5}}{...^{1,38} \sim^{22} d^{3,56} [1 - (D/d)^4 h]} \right\}^{0,36},$$

$V \text{ —}, \text{ —}^3; D \text{ —}, \text{ —}; h \text{ —}$
 $\text{ —}, \text{ —}.$

$$d = 0,333 \frac{\uparrow^{0,6}}{...^{0,2} (P/V)^{0,4}} \left(\frac{n_0 d \sim}{\uparrow} \right)^{0,2} \left(\frac{\sim}{\sim} \right)^{0,29},$$

$/V \text{ —},$
 $\text{ —}.$

$$S_c = 0,016 n_0 d \left(\frac{\tilde{c}}{D_c} \right)^{-0,5},$$

D —

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$$\begin{array}{ccccccc} & \cdot & & & & & \\ & \vdots & & & & & \\ & \cdot & , & & , & & - \end{array}$$

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$$H$$
$$N \quad h \quad :$$

$$H = N h .$$

• —

:

$$N_y = \frac{K_{yf} S}{G},$$

[illegible]
$$x - (12.13) \quad 1 \quad * = f(x) -$$

$$3 \quad = A x + \quad , \quad 2 \quad -$$

•

$$\frac{A_1 C_1}{B_1 C_1} = \frac{A_2 C_2}{B_2 C_2} = \dots = \frac{A_n C_n}{B_n C_n} = e^{N_y}$$

$$B_1, \dots, B_n$$
$$x, x \quad y, y \quad N \quad .$$

0,2 .

 $0,25 \dots 0,60$,

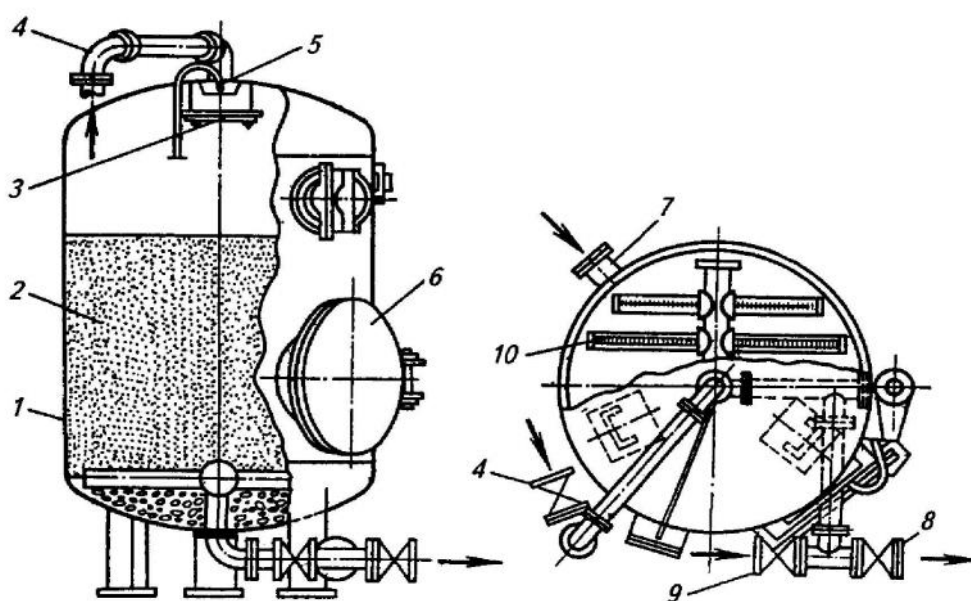
0,40...0,60 ,

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12.4.

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(. 12.14),



1 — ; 2 — ; 3 — ; 4 —
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1...6 / ; — 1,5...5 .

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$t_{\text{с}}$

$t_{\text{с}} = k_{\text{с}} H -$,

$k_{\text{с}}$ — , / ; —

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$k_{\text{с}} = / (w)$,

a — , / ³ (-

); w — , / ;

— , / ³,

$= \Delta t$,

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Δt ,

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M ,

$M = (H - h) S a$,

h — , ; S — ²; —

, / ³.

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, . . (. II.41).

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$m a + Q = Q$ „
 m — , ; $a -$, / ; Q — -
 , 3 ; C —
 , / 3 .

m

$$= K \ C \ ,$$

:

$$m = \frac{Q(C - C)}{K \ C} ,$$

K — .

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$$C_1 = \frac{QC}{Q + K \ m} .$$

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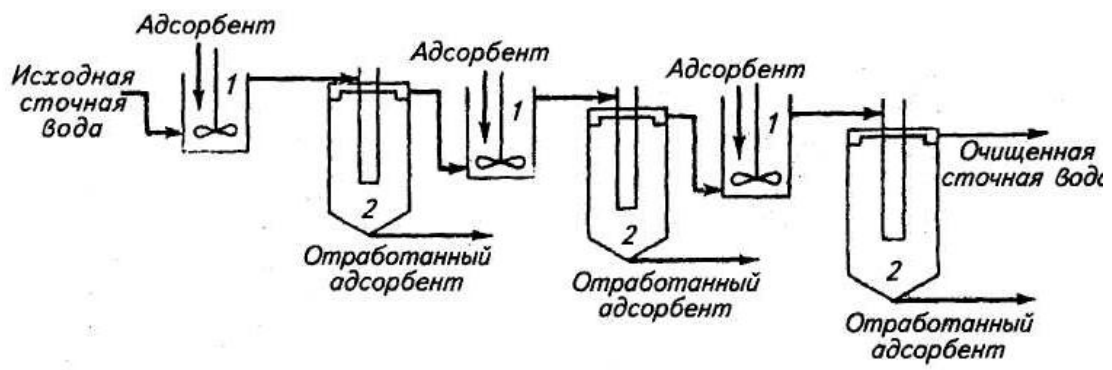
m

(. 12.15), ,

$$C_2 = \frac{Q}{Q + K \ m_2} C_1 = C \left(\frac{Q}{Q + K \ m_2} \right)^2 ,$$

2 — II- , / 3 ; m_2 — , -

, .



. 12.15.

1 — ; 2 —

3...5

n

n

$$C_n = C \left(\frac{Q}{Q + K m_n} \right)^n.$$

$m_n,$

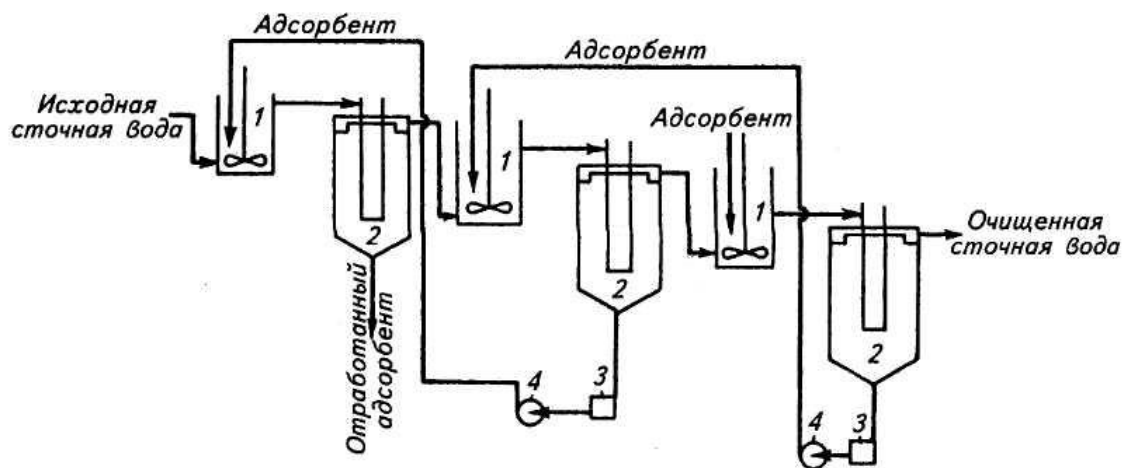
$$m_n = \frac{Q(\sqrt[n]{C / C_n} - 1)}{K}.$$

$$m = n m_n.$$

(. 12.16)

n

$$C_n = C \frac{K m/Q - 1}{(K m/Q)^{n+1} - 1}.$$



. 12.16.

1 — ; 2 — ; 3 — ; 4 —

$$r m^{n+1} - s m - x = 0,$$

$$r = (K / Q)^{n+1}; s = K C / (Q C_n); x = / C_n - 1.$$

(0,25...0,3) (40)

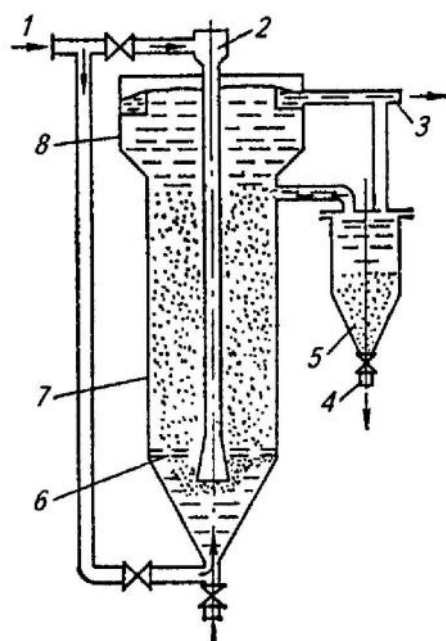
7...15

$$^3/(\ ^2.), \quad \frac{H}{H_0} \quad 1,5.$$

$$v = 1 - \frac{V}{V},$$

V — , ; $V_{\text{с}}$ — -

(. 12.17), 4 , -
1,5...2



. 12.17 43. :

1 — ; 2 — ; 3 — ; 4 —
: 5 — ; 6 — ; 7 — ; 8 —

30...60°. -

5...10 10 , -

0,25...1

0,5...0,75 . 2,5...2,7 .

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1,5...1,6. 5...20 %-

, .

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$$Nu' = 0,81 Re^{0,50} (Pr')^{0,33} \frac{1}{v}, \quad (5 < Re < 50);$$

$$Nu' = 0,60 \operatorname{Re}^{0,57} (\operatorname{Pr}')^{0,33} \frac{1}{\nu}, \quad (50 < \operatorname{Re} < 2000),$$

$$\text{Re} = \frac{v}{\epsilon} d; (0,6 < \text{Pr} < 2000); (0,43 < v < 0,75), v \text{ —}$$

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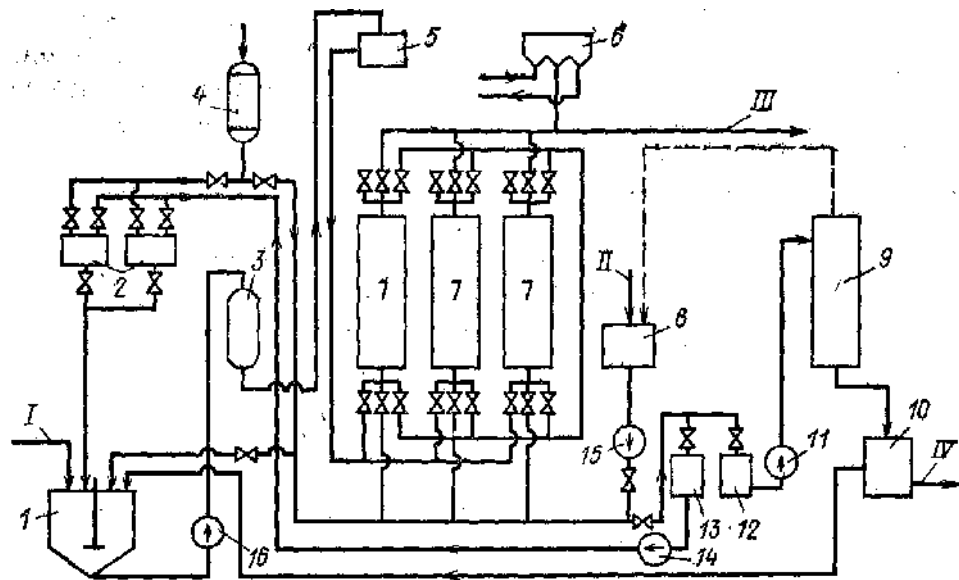
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1 3

1 3

1,2...2

12.18



12.18 44.

I, II —

; III, IV —

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; 9 —

; 10 —

; 11, 14, 15, 16 —

; 12 —

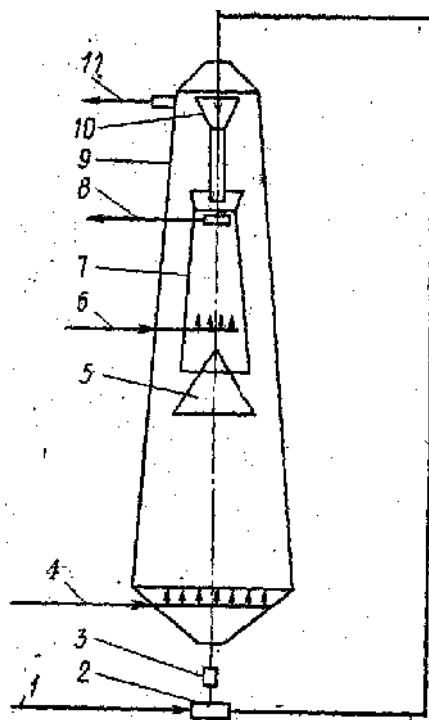
2

4...4,5.

16

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 3 ; $2^{3/2}$ (2^2).
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 35...40 °
 12, 11
 9
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 8...10 %-
 4. , 13 14
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- (. 12.14) (. 12.19).



. 12.19.

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(12.17).

$$S = Q/w \quad .$$

$$- \quad - \quad , \quad - / :$$

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t , , , ,

$$M = M \cdot t .$$

$$V_1, \quad ^3,$$

$$V_1 = M \quad / \ldots \quad ,$$

$$\quad , \quad / \quad ^3 .$$

$$\quad , \quad H_1, \quad ,$$

$$H_1 = V_1 / S \quad .$$

$$H_2/H_1 = 1,5, \quad 2, \quad ,$$

$$H_2 = 1,5 \cdot V_1 / S \quad .$$

$$D \quad ,$$

$$n = \frac{4 S}{f D^2} .$$

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$$75 \ldots 100 \quad \%$$

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12.5.

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. 12.20.

2, 3, 4,

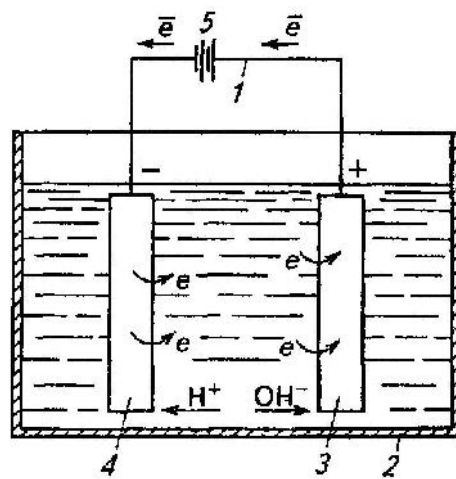
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0,3...7,5 0,5...8 / .

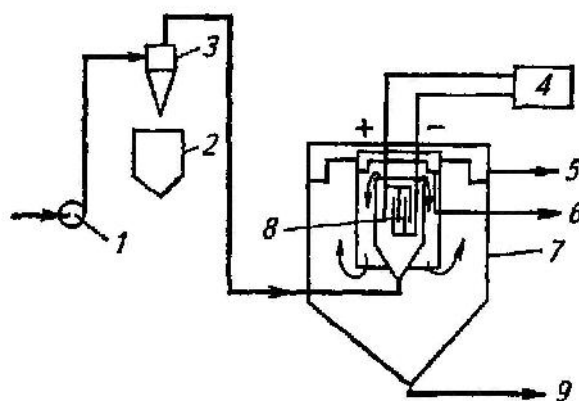
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10...18 .

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0,4...0,5 · .


$$\vdots$$

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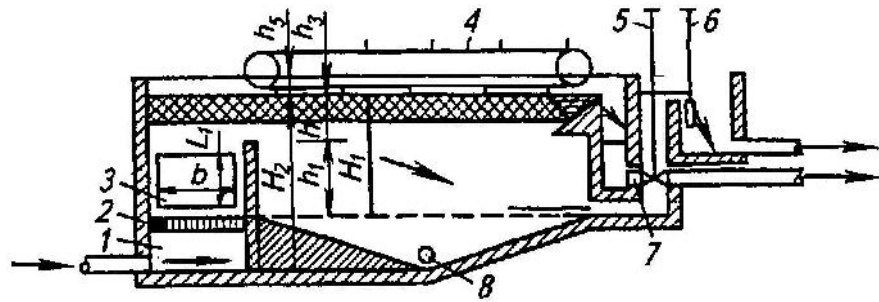
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10...15 ³/ -
 — (. 12.22) .



. 12.22 48. :

1 — ; 2 — - ; 3 — ; 4 —
 ; 5 — ; 6 — ; 7 —
 ; 8 —

-
 V_y , V -
 V , ³ , ,

$$V = V + V .$$

-
 . , (. II.48) -

Q : $Q < 90$ ³/ , $B =$

2 , $Q = 90...180$ ³/ , $= 2,5...3$.

n , ,

$$n = (B - 2 a_1 + a_2) / (+ a_2),$$

a_1 — , 100 ; 2

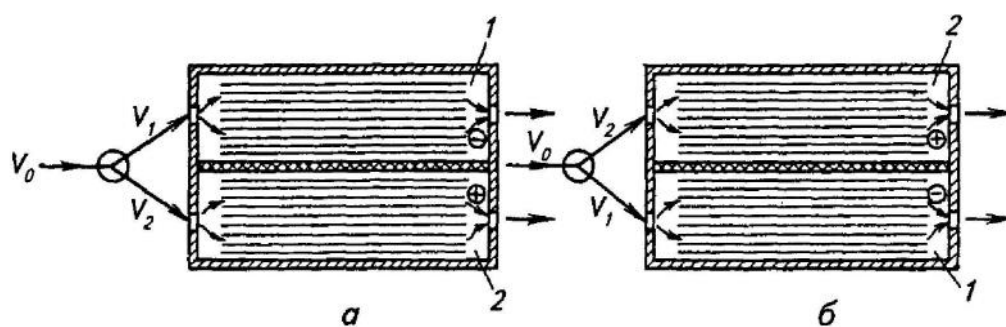
— , 15...20 ; δ — ,

6...10 .

f , ² ,

$$f = f . / (n - 1),$$

f_{\cdot} — \cdot^2 ,
 $f_{\cdot} = E Q/i$,
— \cdot^3 ; Q —
 $^3/$; i — \cdot^2 .
 f $h = 1...1,5$, $l = f/h$,
 $L = l + 2a_1$.
 \cdot^3 , :
 $V = B H L$,
 H — , , :
 $H = h_1 + h_2 + h_3$,
 h_1 — , $1...1,5$; h_2 — ,
 $0,3...0,5$; h_3 — , $0,4...0,5$.
 $V = Q t$,
 t — ,
 $0,3...0,75$.
 L H V
.
,
:
 $m = k$,
 m — , 1^3 , ; k —
, $0,5...0,95$ (); —
, $/(\cdot)$, $\text{Fe}^{2+}, \text{Fe}^{3+}, \text{Al}^{3+}$ $1,042; 0,695$ $0,336$.
,
 $= M \cdot 1000 / (m / Q)$,
— , :
 $M = \dots k f u n$,
— , \cdot^3 ; k —
, $0,8...0,9$; Q_{cy} — , $^3/$.



. 12.23.

— 1, 2 ; — 1, 2 ; V — ; V_1, V_2 — ,

— 1 2.

1 2.

1,

(. 12.23,),

1. —

2, ,

(. 12.23,).

0,8 /

+1,23 ,

+0,4 .

FeO·Fe₂O₃.

373

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-

$V = Q\,t\,,$
 Q — $\quad\quad\quad,$ $^3/$; t — $\quad\quad\quad,$.

$$I = \frac{qC_0B_TQ}{t},$$
 q — $\quad\quad\quad,$
 $\quad\quad\quad$; C_0 — $\quad\quad\quad$ -
 $\quad\quad\quad$; B_T — $\quad\quad\quad$ — $\quad\quad\quad,$
 $\quad\quad\quad$.

$$S = \frac{V}{2d}$$
 d — $\quad\quad\quad,$.

B_T ($\quad\quad\quad$), $\quad\quad\quad,$ -
 $\quad\quad\quad$ ($\quad\quad\quad$).

$$S = \frac{I}{j},$$
 I — $\quad\quad\quad,$; j — $\quad\quad\quad,$ $/$ 2 .
 $\quad\quad\quad,$ $\quad\quad\quad,$ -

$\quad\quad\quad,$

$$S\,=\frac{m_{\scriptscriptstyle\sim}}{K_m}\ln\!\left(\frac{C}{}\right),$$

$m_{\pi^-} = 139.57$ MeV; $K_m = 1.18$ MeV

$\frac{D}{u}$, $\frac{D}{u} = 0.15$; $\frac{D}{u} = 0.15$; $\frac{D}{u} = 0.15$

$D = 0.15$; $D = 0.15$

$\frac{D}{u}$

$\frac{D}{u}$

$\frac{D}{u}$

$W = 1.18$ MeV ($W = 1.18$ MeV)

$W = 1.18$ MeV

$W = 1.18$ MeV

$W = 1.18$ MeV

$$W = \frac{Q}{U}$$

$Q = 1.18$ MeV; $U = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$(Q = 1.18, U = 1.18)$

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$Q = 1.18$ MeV

$(Q = 1.18, U = 1.18)$

$$U = E_{\pi^-} + E_{K_m} + y_{\pi^-} + y_{K_m} + \Delta E_{\pi^-} + \Delta U_{\pi^-} + \Delta U_{K_m} + \Delta U_1 + \Delta U_2,$$

$E_{\pi^-} = E_{K_m} = 1.18$ MeV; $y_{\pi^-} = y_{K_m} = 1.18$ MeV

$y_{\pi^-} = 1.18$ MeV; $\Delta E_{\pi^-} = 1.18$ MeV

$\Delta U_{\pi^-} = 1.18$ MeV; $\Delta U_{K_m} = 1.18$ MeV

$\Delta U_1, \Delta U_2 = 1.18$ MeV

$\Delta U_1, \Delta U_2 = 1.18$ MeV

U .

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E , , . -

: U U .

U ,

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$U = IR$,

I — (), ; R —

$R = \dots[u\ s^2/(Sn)]$,

— * -

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S — , ²; — .

, , -

$U = j \cdot l$,

j — , / ²; — , ; l — -

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(. 12.24) -

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(«+»), , -

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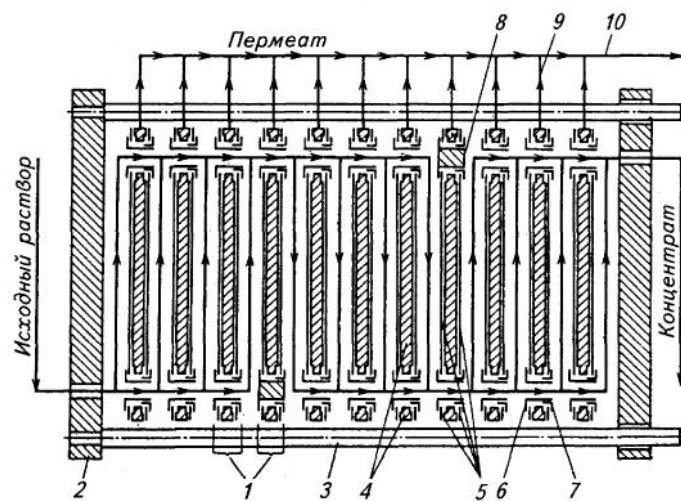
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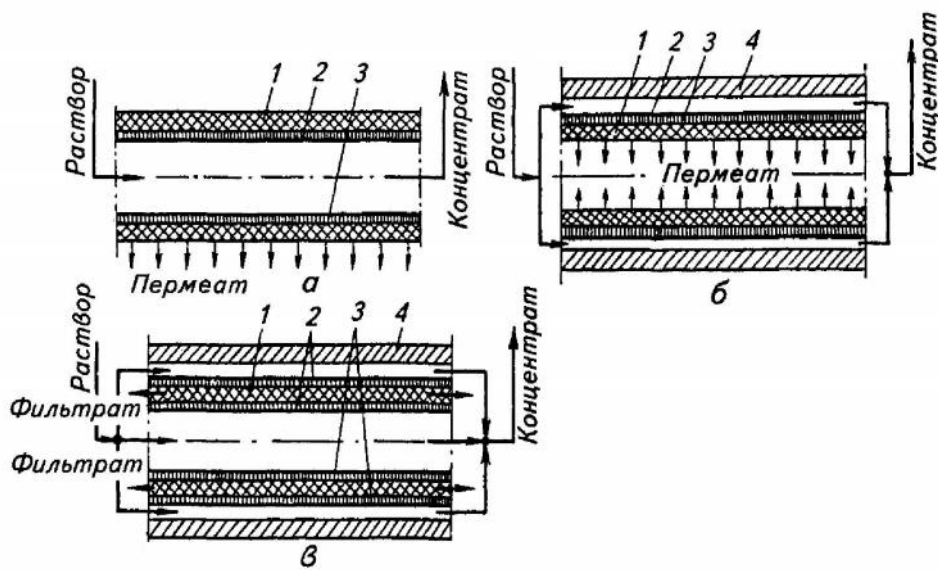
. 12.25.



. 12.25 51.

1 - ; 2 - ; 3 - ; 4 - ; 5 -
 ; 6 - ; 7 - ; 8 - ; 9 - ; 10 -
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(. 12.26).



. 12.26.

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 - ; 1 - ; 2 - ; 3 - ; 4 -

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$2/3$).

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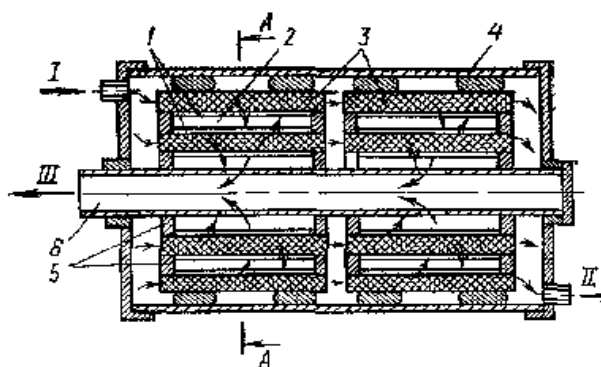
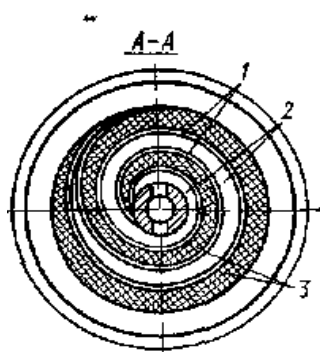
(. 12.26,)

(. 12.26,)

(. 12.26,)

(60...200 $2/3$).

. 12.27.



. 12.27.

I —

; II —

; III —

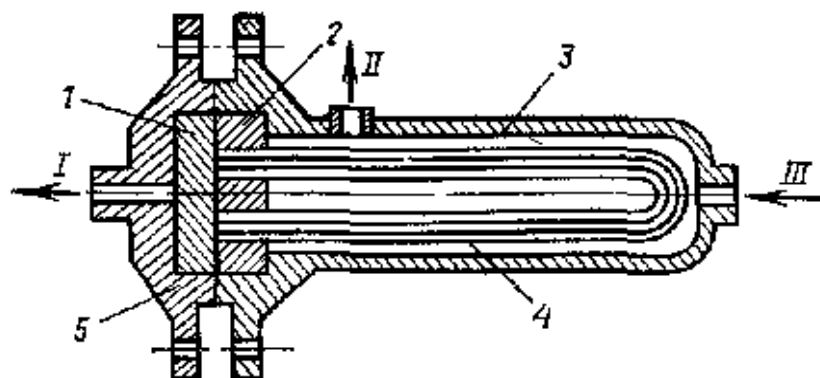
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 (300...800 ²/₃), ;
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 - 20...30 .
²/₃ . -
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 (. 12.28).
 U- 1,5...2,0 -
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 U-
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. 12.28.

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x_0 x (—

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G ,

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(. . , ,

) G

$i-i$

x

:

$$G = f(x, Q),$$

Q —

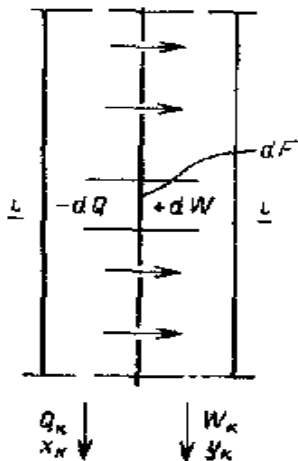
$i > i$;

$$G = -\frac{dQ}{dF} = \frac{dW}{dF},$$

$$dF \text{ --- } i-i; dQ = -dW \text{ --- } -$$

$$dS; W \text{ --- } (\quad)$$

$$i-i.$$



. 12.29.

$$dS = -\frac{dQ}{G} = -\frac{dQ}{f(xQ)}. \tag{12.1}$$

$$(\quad)$$

$$\frac{dQ}{Q} = \frac{dx}{y-x}, \tag{12.2}$$

$$y = g(x,Q) - .$$

$$dQ \quad (12.2), \tag{12.1} \quad S$$

$$x_0 \quad x \quad :$$

$$S = Q_0 x_0 \int_{x_0}^x \left(-\frac{1}{G_0 x} - \frac{c}{G_0^2} \ln \frac{G_0 - cx}{x} \right) dx = \frac{Q_0 x_0}{G_0} \left[-\frac{c}{G_0^2} \ln \frac{(G_0 - cx)x_0}{(G_0 - cx_0)x} + \frac{1}{x_0} - \frac{1}{x} \right].$$

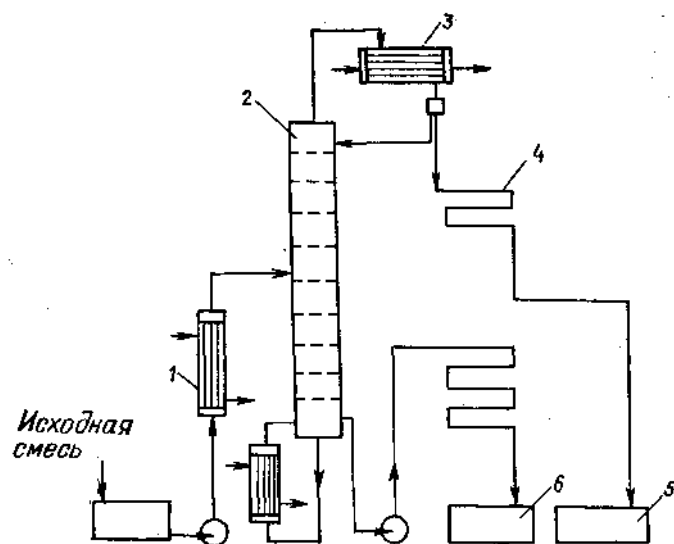
-

$$Q_0, \ x_0, \ x_k \quad c \quad G_0.$$

$$G_0 \quad 1,1 \cdot 10^{-3}, \ 1,67 \cdot 10^{-3}, \ 2,78 \cdot 10^{-3}$$

$$4,17 \cdot 10^{-3} \quad / (\quad^2 \quad). \quad c \quad G \approx G_0 - cx.$$

Δp 5...7 -
 0,3...0,8 -
 (-
) Δp . Δp -
 (Δp_k)
 (Δp):
 $\Delta p = \Delta p + \Delta p + \Delta p$.
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 () 10...60% .
 12.7. .
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 (. 12.30), -
 2, - 3, 4,
 1, 5 6. -
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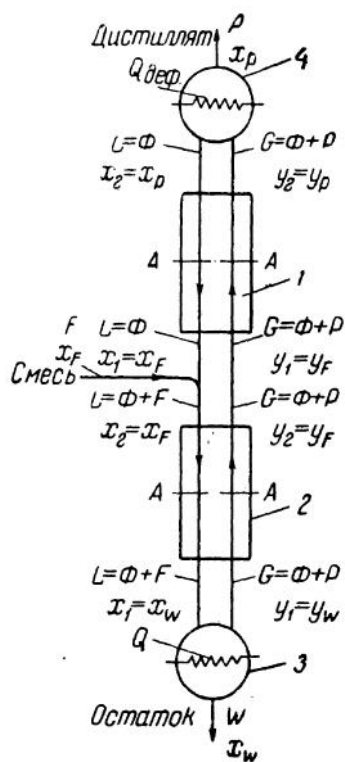
. 12.30.

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 G_F , () F ,
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() . 12.31 :

$$G y + L x_2 = G y_2 + L x; \quad y = y_2 - \frac{L}{G}(x_2 - x). \quad (12.3)$$



. 12.31. :

1 — ; 2 — ; 3 — ; 4 —

) :

$$G y_1 + L x = G y + L x_1; \quad y = y_1 - \frac{L}{G} (x - x_1). \quad (12.4)$$

G

$$, G = + .$$

$$/ = R$$

$$= PR,$$

$$G = PR + = (R + I), . .$$

$$(R + 1)$$

$$L = = PR,$$

$$(y_2 = _2 = _p).$$

$$L, G, y_2 \quad x_2$$

$$(12.3), -$$

:

$$y = x_p - \frac{P}{R+1} (x_p - x), \quad y = \frac{x_p}{R+1} + \frac{R}{R+1} x. \quad (12.5)$$

$$- \quad (\quad . 12.32).$$

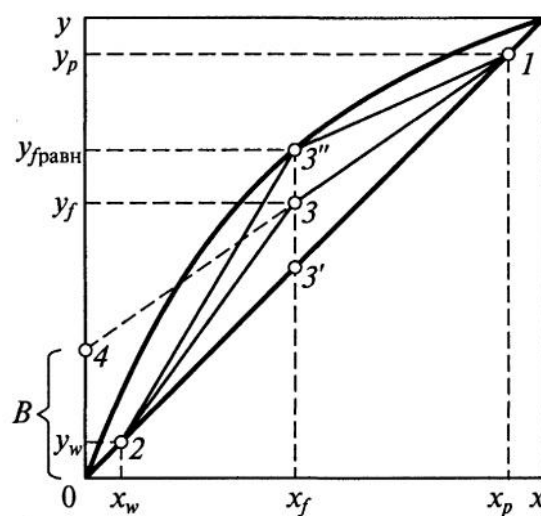
$$I,$$

$$(\quad = \quad = \quad _p),$$

$$tg \, \gamma = R/(R+1);$$

$$4$$

$$B = x_p/(R+1).$$



$$. 12.32.$$

$$L \quad -$$

$$F. \quad F/P = f, \quad -$$

:

$$L = \quad + F = P(R + f).$$

:

$$y_1 = x_1 = x_w.$$

$$L, G, y_1 \quad 1 \quad (12.4), \quad :$$

$$y = x_w + \frac{R + f}{R + 1}(x - x_w), \quad y = \frac{R + f}{R + 1}x - \frac{f - 1}{R - 1}x_w. \quad (12.6)$$

,

-

$$\quad , \quad 2 \quad w \quad (\quad 1 = y_1 = \quad w). \quad 3 \quad -$$

-

$$(12.5) \quad (12.6):$$

$$\frac{x_p}{R + 1} + \frac{R}{R + 1}x = \frac{R + f}{R + 1}x - \frac{f - 1}{R + 1}x_w,$$

$$x_p = f \, x - (f - 1)x_w.$$

$$\quad , \quad f = F/P, \quad , \quad = \, F, \quad .$$

.

$$3 \quad (\quad . \quad . 12.32) \quad -$$

$$F.$$

$$R,$$

$$P.$$

$$3''$$

$$R_{\min}.$$

$$R_{\min} < R < \infty.$$

$$R_{\min}.$$

$$R_{\min} = \frac{y_P - y_F^*}{y_F^* - x_F} = \frac{x_P - y_F^*}{y_F^* - x_F}. \quad (12.7)$$

$$R > R_{\min}, \quad R/R_{\min} = \quad , \quad -$$

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$$(\quad 1, 1$$

$$10) \quad , \quad -$$

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R , -

R (12.7) -

$R_{min.}$,
1,1...5,0,

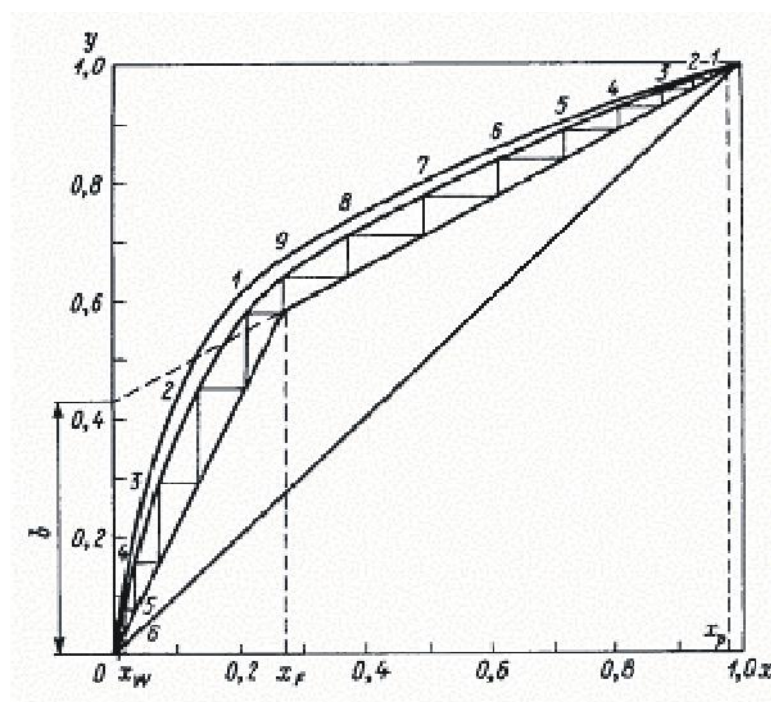
(. 12.33). , -

$P - x_F,$

N , -

$F - x_W, -$

N



. 12.33 59.

$R,$

R ,

$$R = f[(R+1)N],$$

R $N.$

().

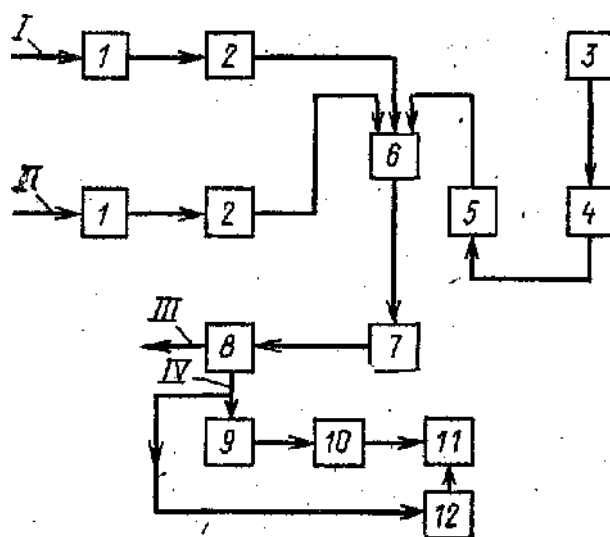
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 w_p ,
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 $v :$
 $v_p = k w$,
 k - ,
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13.

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 6,5...8,5. , 6,5
 8,5.
 : $2SO_4$,
 N , 1, .
 HNO_2 , O_4 , $2S_3$, H_2S ,
 HF , $2rO_4$, : CH_3COOH ,
 $6_2(NO_2)_3$, H_2_3 , $6_4()_2$.
 :
) ;
) (, , -
 $Ca(OH)_2$, Na_2CO_3 , $NaOH$, NH_3OH);
) [, 3 ,
 $CaCO_3 \cdot MgCO_3$, $MgCO_3$, MgO , 3 (96...99 %)];
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(. 13.1).



. 13.1.

I, II —

; III, IV —

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; 10 —

; 11 —

; 12 —

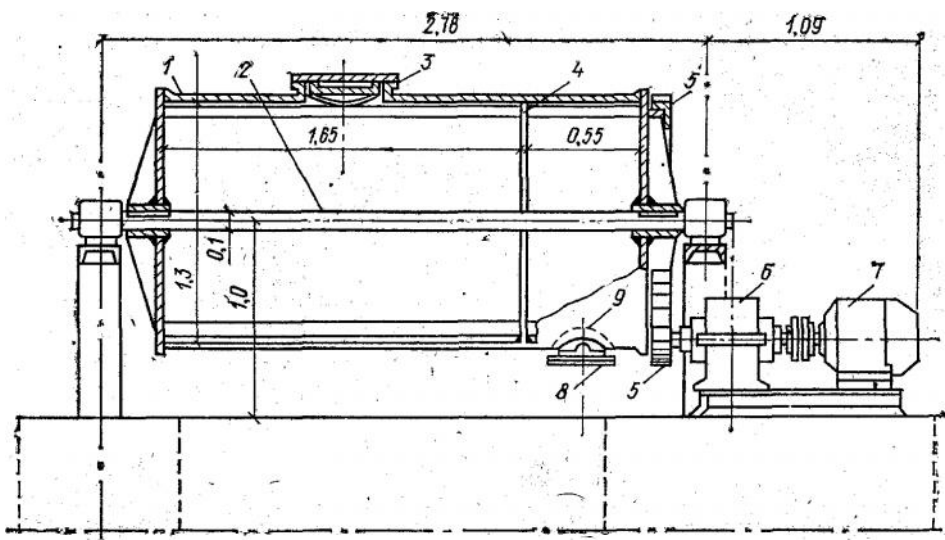
5 %-

5...10

(60...70 %)

10...100 (30...40 %). -

1300 23...25 -1. 12...15



13.2. :
 1 — ; 2 — ; 3 — ; 4 — ; 5 — ; 6 —
 — ; 7 — ; 8 — ; 9 —

Q (3 /) (/):
 394

$$G=k_3\frac{100}{B}QaC,$$

，

：

$$G=k_3\frac{100}{B}Q(aC+b_1C_1+b_2C_2+...+b_nC_n),$$

k — ； — ，%； a —

， / ； — ， / ³； ₁， ₂，.._n，

n — ， / ³； $b_1, b_2, .., b_n$ — ， / 。

， ， 1 ³

， ， -

$$M=\frac{100-B}{B}(x_1+x_2)+x_3+(y_1-y_2-2),$$

B — ，%； x_1, x_2 —

，

， ； 3 — ， ； y_1, y_2 — -

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V_{oc} , %,, 1 ³ ，

$$V=\frac{100M}{100-w},$$

w — ，%。

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1,5 /

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， 5 / ；

10 。 ， -

HCl HNO₃ 1...1,5 ， H₂SO₄ — 1,5...2 。

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 1,5 / .
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$$H = k d^n (3 + \lg b) \sqrt{w}, \quad (13.1)$$
 k — ; d — , ; b — , - ./ ; w — , 4...8 / .
 n (13.1) 1,47. -
 k .
 S , 2 , -
 $S = q / w$,
 q — , $^3 /$; w — , / .
 , / ():
 $M = a C Q / 1000$,
 — ; C — , / 3 ; Q
 — , $^3 /$.
 (100 %-)
 ,
 (, = 1,5).
 , -
 .

$$t = \frac{H S \dots}{M k},$$

q — , $^3/$; ... —
 (, ... = 2800 / 3 , — 3000
 / 3 , — 2700 / 3); — , / ; k — ,

·
 - ()

$$L = wt.$$

:

$$t = \frac{6k_1 d^{1,2}}{\sqrt{w}} (3 + \lg C),$$

k_1 — , (-
 $k_1 = 1,87$, — 3,96); d — , ; — -
 , - ./ .

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 , C₂, S₂, NO₂ ,
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13.2.

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$$G = 100dQ/z,$$

,³,

$$V = Q d/k \text{ ,}$$

d —

, /³; Q — ,³; z —

-

,%; k — , /³.

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$$V = Q d/(k - n),$$

n —

, $n = 2 \dots 6$.

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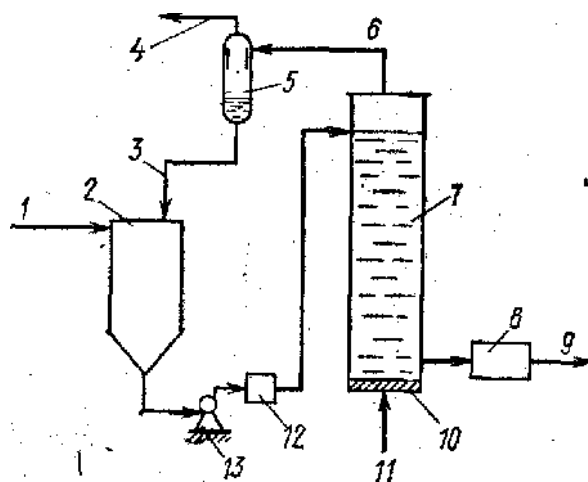
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. 13.3.

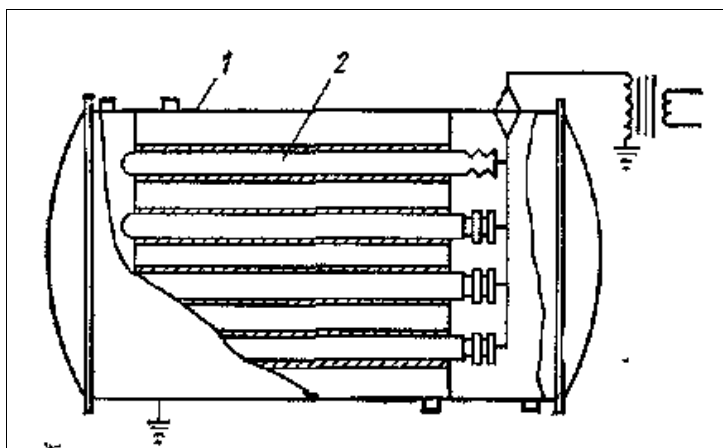
1 — ; 2 — ; 3, 4, 6 —
; 5 — ; 7 —
; 8 — ; 9 — ; 10 —
; 11 — ; 12 — ; 13 —

0,1

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0,4 / .

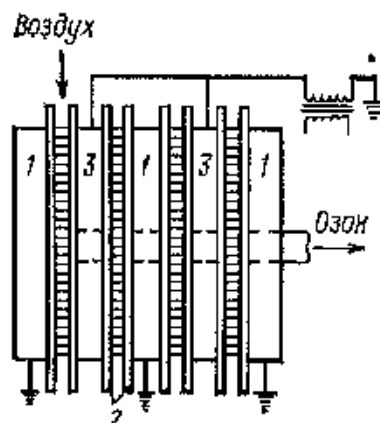
. 13.4,



. 13.4.

1 — ; 2 —

. 13.5.



. 13.5.

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+ 2 3.

$$P\left(\frac{1}{q}\right)=P/q$$

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40...100

60...100 ,

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76...91 20...26³/(².).

$$y=1-(1-0,1_{-1})^s;$$

$$s=-(0,113-0,0017\cdot t)\frac{Hf}{0,25-Q/S},$$

1 —

, ; t —

,^o ; f —

,⁻¹; Q —

,³/ ; S —

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,²,

S

$S = Qd/(C^{\cdot})$,
 $d = \dots, /^3;$; —
 $\dots, /^3;$ —
 $\dots, ^3/(^2)$.

$S :$

$$n = S / S .$$

$0,4$, — $0,5$.
 V

$$V = k \cdot Q t ,$$

$k = \dots$ —
 $, k = 1,1; t = \dots, .$

$$D = d \cdot Q/1000.$$

$n = k D / q$,
 $k = \dots, 1,05\dots1,1; q = \dots$
 $\dots, /$.

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 $\dots, -$

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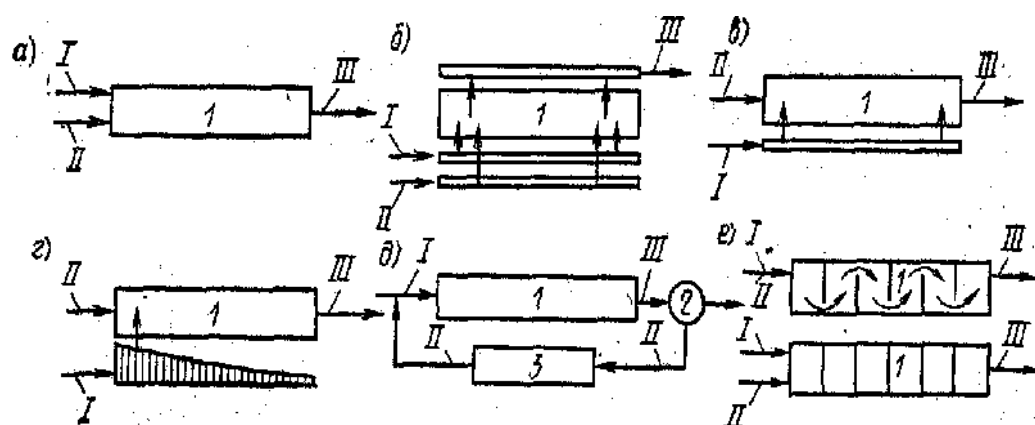
$\dots, \dots, \dots, \dots),$

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 (, CO₂,
 2O).
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 , FeS₄
 H₂SO₄, 80...90 %
 (25...50 1³).
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 (5...10 /
).
 30...100 /²
 1...3 / . 100 %-
 (200 /³) 0,2 1 -
 - . 80 %
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 : ⁻, ²⁻ (), H₂, H⁺ (-
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(. 14.1).



. 14.1.

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$$q_x = \frac{rQ}{2l} \frac{(1/r + 1)^2 - 1}{\sqrt{x[(1/r + 1)^2 - 1]/l + 1}},$$
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 , $^3/$; l — , ; —
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$$D, \quad ^3/ \quad ^3,$$

$$1 \quad ^3 \quad , \quad , \quad 1 \quad ^3 \quad ,$$

$$D=\frac{z(L \quad -L_t)}{k_1k_2n_1n_2(C_p-C)},$$

$$z \text{ --- } , \quad 1 \quad ; L_t \quad L \text{ --- } ; k_1 \text{ --- } ,$$

$$\begin{aligned} & (\quad) \\ & , \\ & ; k_2 \text{ --- } , \quad ; \quad 1 \text{ --- } , \\ & \quad ; n_2 \text{ --- } , \end{aligned}$$

$$\begin{aligned} t &= 20 \text{ }^\circ \quad ; C_p \text{ --- } \\ & \quad , \quad / \quad ; \quad \text{ --- } \\ & \quad , \end{aligned}$$

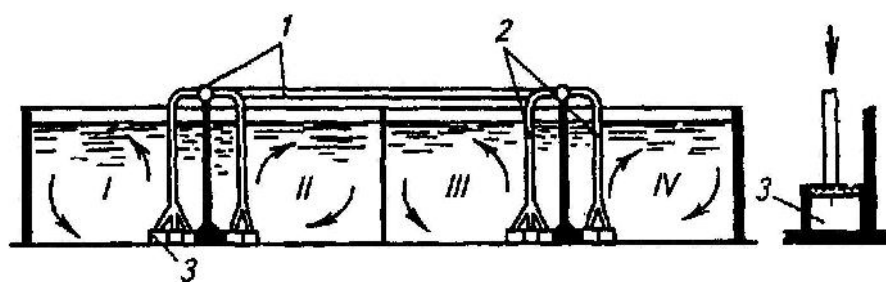
$$, \quad / \quad .$$

$$\begin{aligned} & (\quad . 14.2) \quad (\\ &). \end{aligned}$$

$$\begin{aligned} & (\quad) \\ & (\quad) \end{aligned}$$

$$0,5; 1 \quad ^3 \quad , \quad 80, 230 \quad 1860 \quad / \quad .$$

500 / . (. 14.3)
4,5; 6 9 ,
6 .



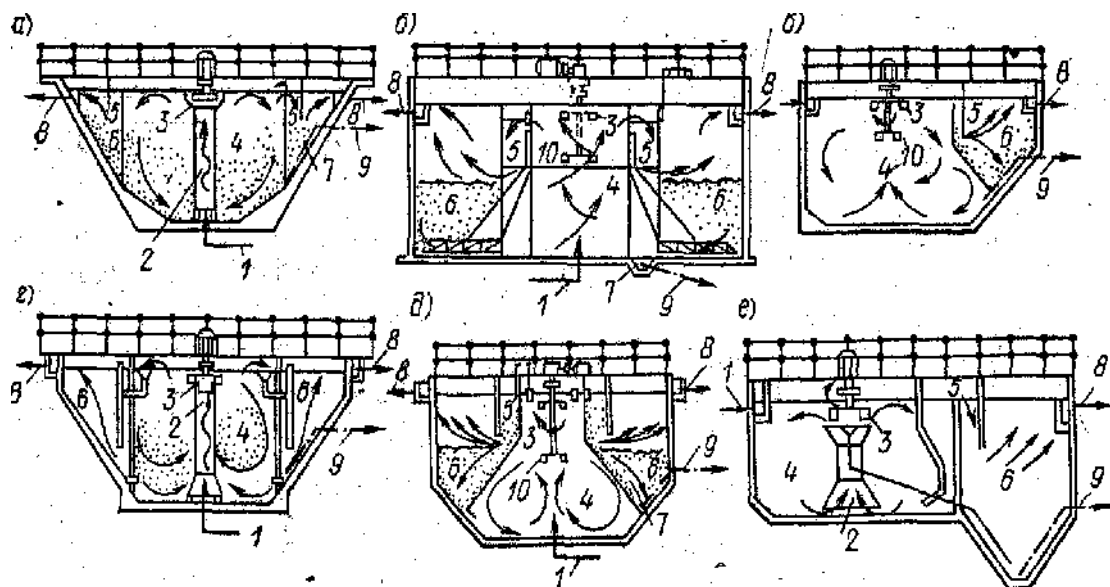
. 14.3.
1 — ; 2 — ; 3 — ; I-IV —

50 % 5 , 6
, 2, 3, 4, 36...84 6 .

. 14.4.

15...20 %.

I



. 14.4.

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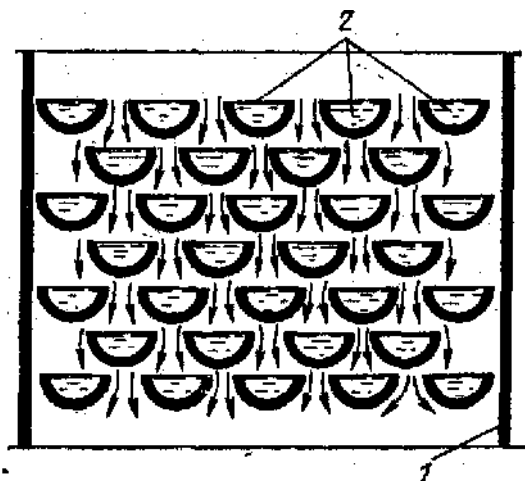
; 10 —

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(. 14.5) .

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(. 14.5)



14.5. :

1 — ; 2 —

(5 30 /) 5 1,5 / (³).

(,),

t , , - ,

$$t = \frac{V}{Q} = \frac{L - L_t}{\dots a(1-s)} = \frac{L - L_t}{r}, \quad (14.1)$$

V — ; Q — , ; s — -

, ; ρ — , 1 -

1 ; $\approx 2 \dots 5$ / ³ — () (-

) .

r [³ / ()]

() . (14.1) -

$$r = \dots a(1-s) = .$$

$$V=\frac{Q}{L-L_t},$$

$$Q=\frac{1}{\rho}\frac{dL}{dt},$$

$$\rho=\frac{1}{L-L_t},$$

$$\dots=\dots_{\max}\frac{L_tC_o}{L_tC_o+K_lC_o+K_oL_t}\left(\frac{1}{1+\{a\}}\right),$$

$$\max_{\theta} \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \tag{85}$$

$$O = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt},$$

$$, \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \quad 0,625; K_l = \frac{1}{L-L_t} \frac{dL}{dt}, \quad -$$

$$, \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt},$$

$$33; \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \quad , \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt},$$

$$0,07; \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt},$$

$$, \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \quad -$$

$$: \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \quad , \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \quad ,$$

$$, \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \quad , \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt}, \quad -$$

$$.$$

$$- \quad t, \quad ,$$

$$t=\frac{1+\{a\}}{\dots_{\max}C_o a(1-s)}\left[(C_o+K_o)(L-L_t)+2,3K_lC_o\lg\frac{L}{L_t}\right]K_p,$$

$$K_p = \frac{1}{L-L_t} \frac{dL}{dt}, \quad , \quad \frac{1}{L-L_t} \frac{dL}{dt} = \frac{1}{L-L_t} \frac{dL}{dt},$$

$$1,5 \quad L_t < 15 \quad / \quad 1,25 \quad L_t = 30 \quad / \quad .$$

$$L/ > 30.$$

$$L/B < 30 \quad 5...6.$$

$$8...12 \quad , \quad 20 \quad .$$

$$q, \quad / \quad 1 \quad , \quad :$$

$$q=\frac{24(L-L_t)}{a(1-s)t}.$$

$$V \quad Qt - (\quad Q - \quad -$$

$$t \quad).$$

$$D \left(\frac{3}{3} \right) \quad (\quad -$$

$$(\quad -$$

$$_t) \quad .$$

(
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)
$$\frac{dM}{V} = K_c \left(\frac{S}{V} \right) (c^* - c) dt, \quad (14.2)$$

 dM —
 dt ; K_c — ; S — (—
); c —
; c^* — .

S Q ,
 , H (—
) :

$$S = K_a Q - H, \quad (14.3)$$

K_a — , S .

$$S \quad (14.3) \quad (14.2), \quad \frac{dM}{V} = d, \quad \frac{dc}{dt} = \frac{K_c K_a Q - H(c^* - c)}{V}. \quad (14.4)$$

$$\frac{(c^* - c)}{c^*} = d \quad , \quad c^* \approx 10 \quad / \quad ,$$

20 ° $c = 2 \quad / \quad d \quad 0,8.$
0,2...1,0,

.

$$d \quad (14.4)$$

$$\frac{dc}{dt} = \frac{K Q - H d}{V},$$

$K = K_c K c^*$.

dL/d . -

$$dL/dt = K Q - H d/V ;$$

$$\int_L^{L_t} dL = (K Q - H d/V) \int_0^t dt ;$$

$$|L - L_t| = K Q - d H t / V .$$

$$Q = V(L - L_t)/(K H t d) = Q(L - L_t)/(K H d);$$

$$Q / Q = (L - L_t)/(K H d),$$

$$Q = V / t.$$

K

6...7 2/ 4

15...18 2/ 4

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6...8 / ,

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90...95 %.

(. 14.6)

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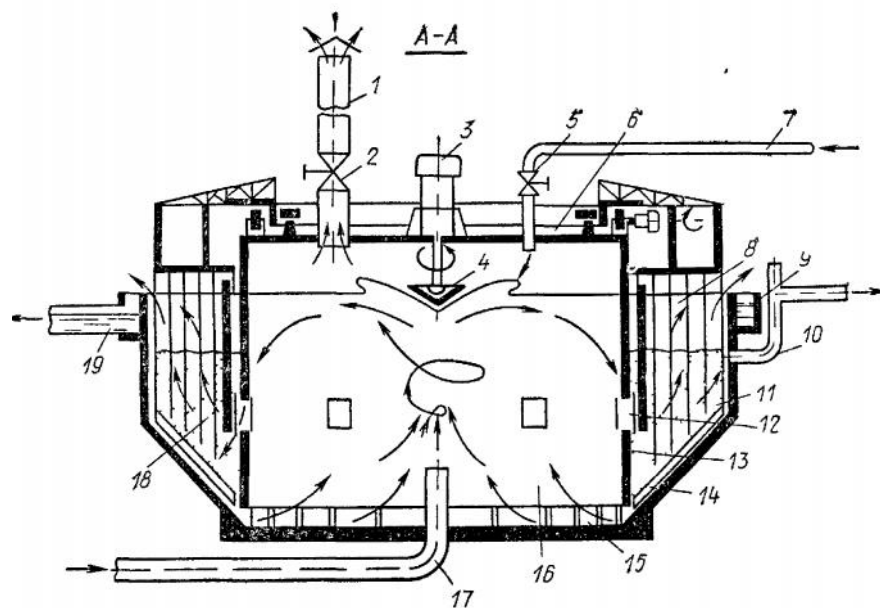
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.14.6. :

- 1 — ; 2, 5 — ;
 3 — ; 4 — ; 6 — ;
 7 — ; 8 — ; 9 — -
 ; 10 — ; 11 — ; 12 — -
 ; 13 — ; 14
 — ; 15 — ; 16 — ; 17
 - ; 18 — ; 19 - -

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:

$$t = \frac{L - L_t}{\dots a(1-s)k}.$$

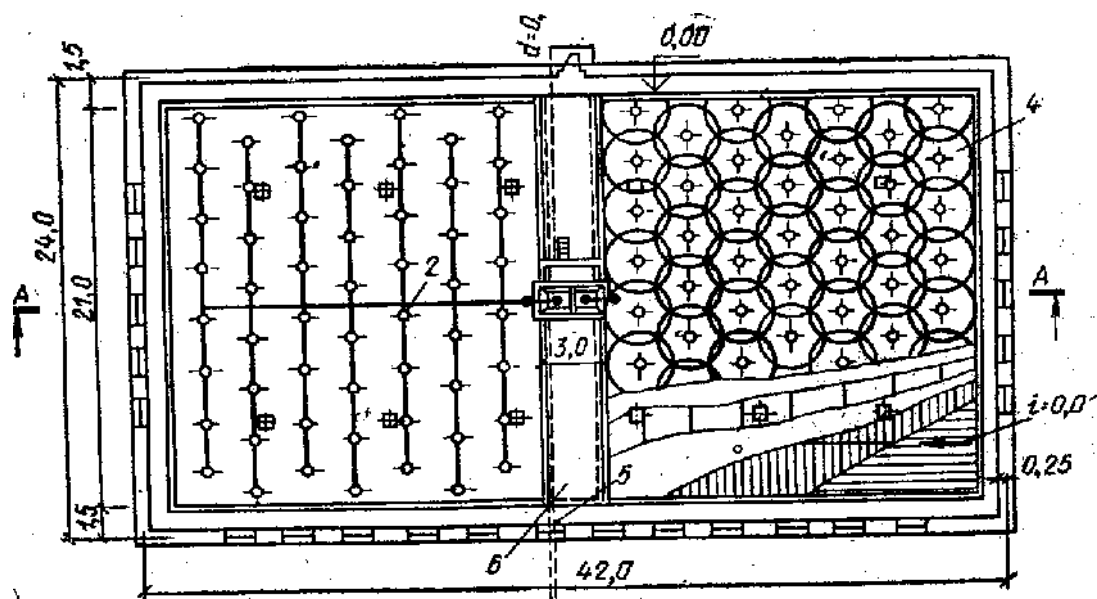
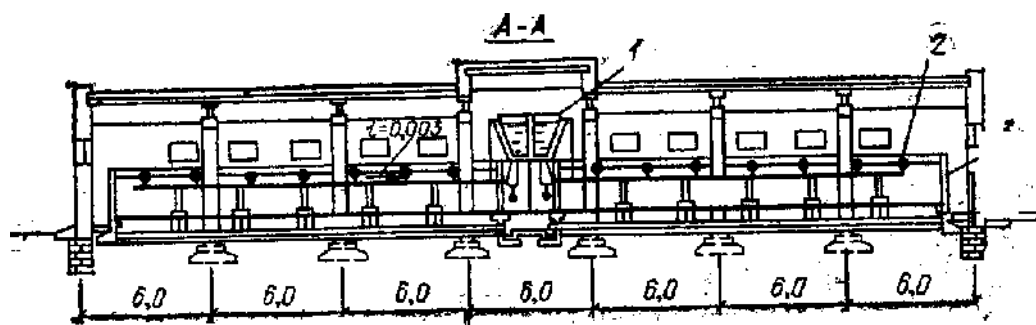
k :

, /	1	2	3	5	8	10	15
k	1,8	1,3	1	0,7	0,5	0,4	0,3

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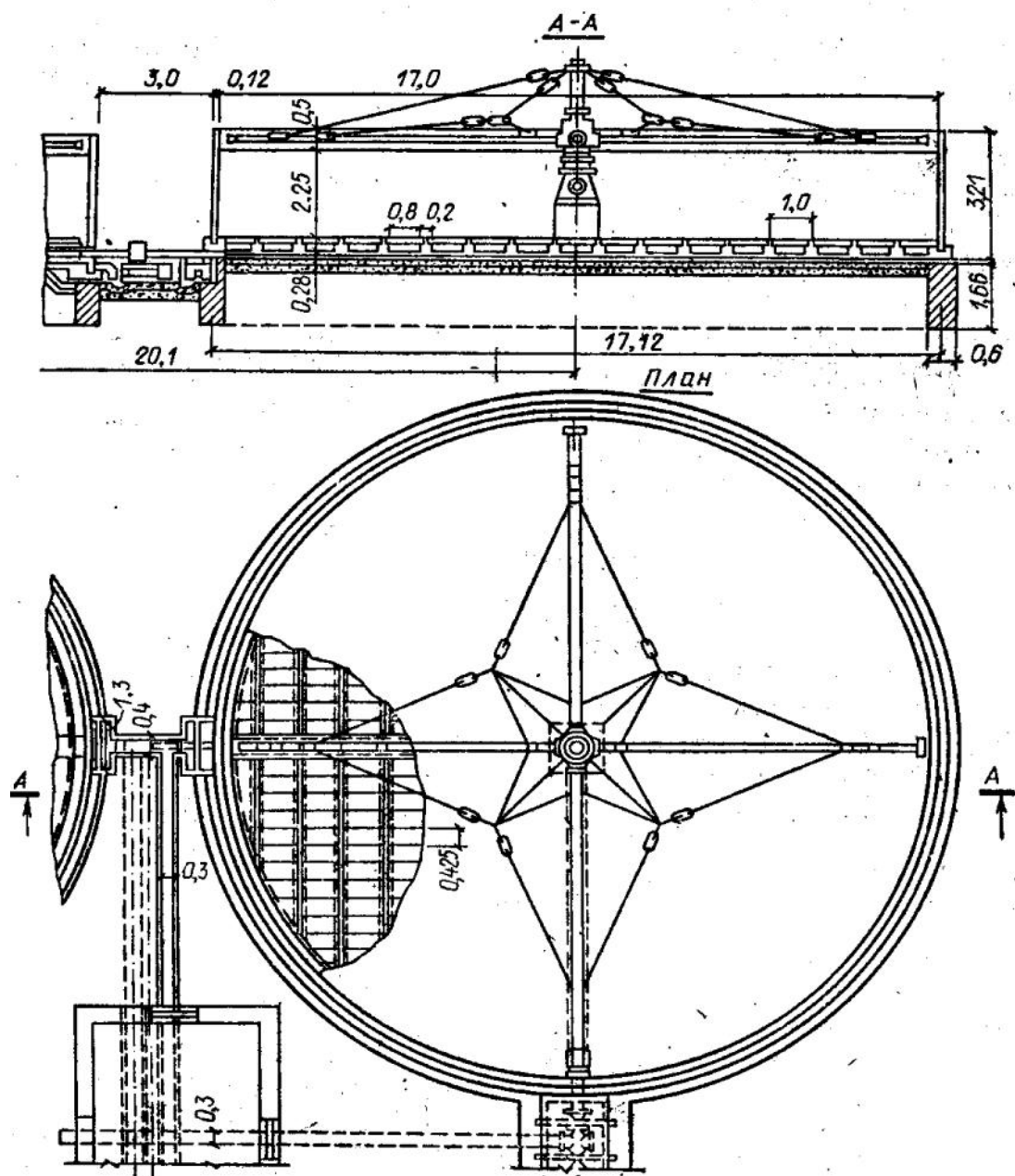
$a k$, , 8...10 /

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 70...100 . , -
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 0,9...9 $^3/(^2)$ (. 14.7), -
 9...40 $^3/(^2)$ (. 14.8) .



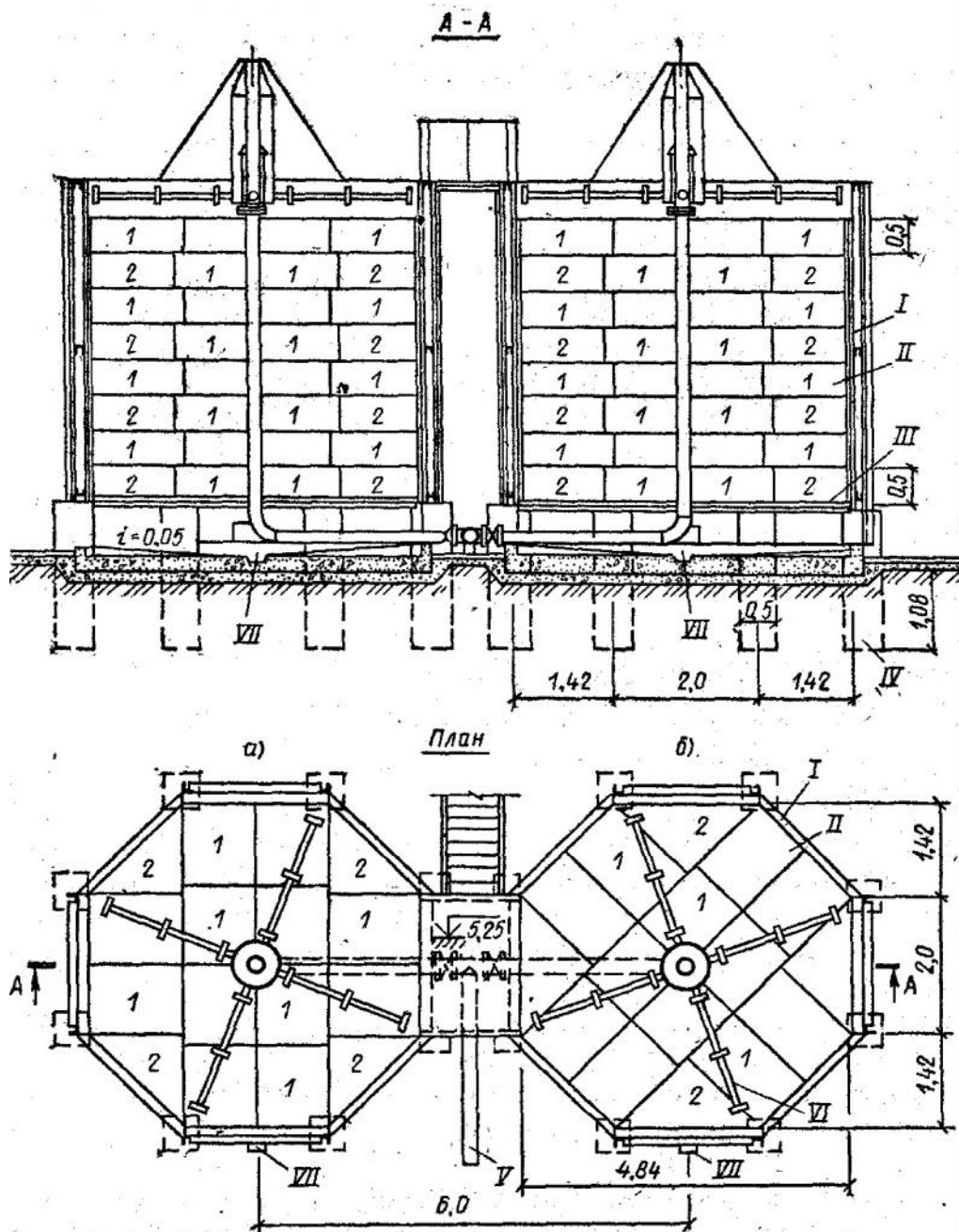
. 14.7.

1 — ; 2 — ; 3 — ; 4 —
; 5 — ; 6 —



. 14.8.

(. 14.9)



. 14.9.

1400 ³/ :

I —

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; VII —

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(. 14.10)

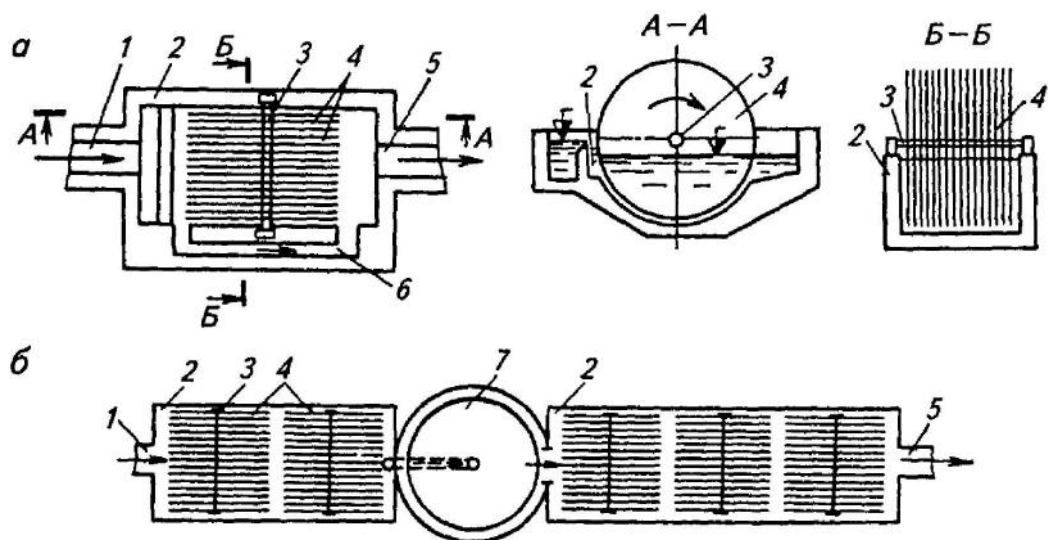
1/3...1/2 -

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) 10...20 .
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. 14.10. :
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 70 , 3
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$$\Phi = 10 \frac{k}{q} \frac{H}{^{0,4}},$$

$$k_T \text{ --- } .$$

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-

$$\cdot$$

$$,$$

$$D_L(d^2L/dy^2)=r_L,$$

$$D_L \text{ --- } (< (10^{-5} \ldots 10^{-6}) \text{ } ^2/ \text{ }); \text{ --- } , \text{ -}$$

$$; r_L = \mathrm{d}L / \mathrm{d}t \text{ --- } -$$

.

.

$$V$$

$$1 \text{ } ^3$$

$$V \text{ } =(L \text{ } -L_t)/ \text{ } .$$

$$L \text{ } / L_t = K; \hspace{10em} K \hspace{10em} -$$

,

-
-

$$:$$

$$q[\text{ } ^3/(\text{ } ^2. \text{ })].$$

$$H(\text{ })$$

$$,$$

-

$$1 \text{ } ^2$$

.

$$; \hspace{10em} , \hspace{10em} 7 \hspace{10em} 100 \hspace{10em} 1 \text{ } ^2$$

-

$$\mathbf{I}$$

14.2.

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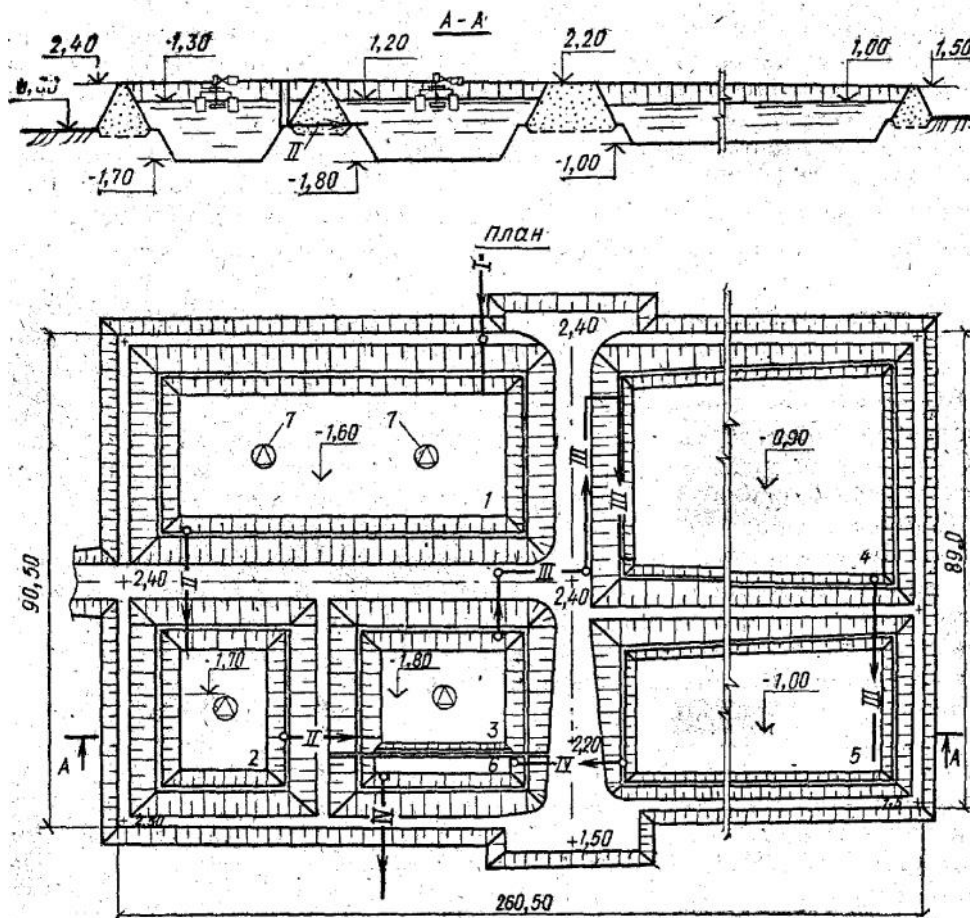
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 0,5...25 25...700, 1400...10000
 17000...80000, 100000...280000 ^{3/} .
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(. 14.11)

150...400 / .



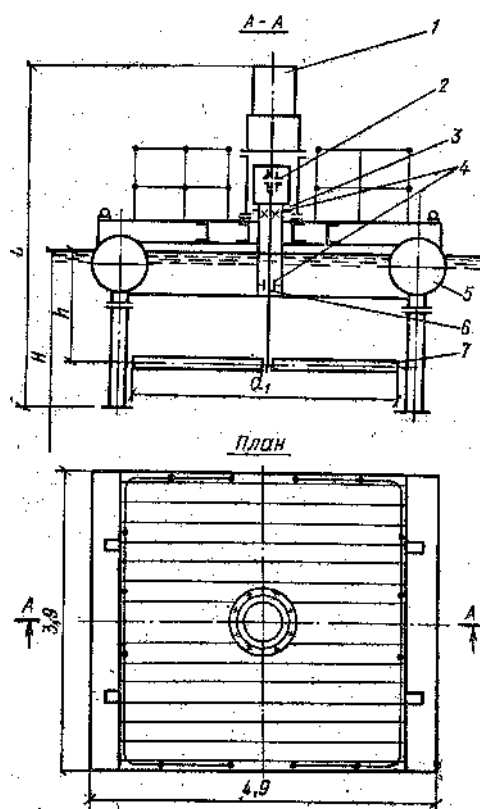
. 14.11.

: I — , I ; II — , II
 III ; III — ; IV — ,
 ; 1, 2, 3 — I, II III ; 4, 5
 — I II ; 6 — -
 ; 7 —

: 3 1 .
 1...3 , 4 5
 , = 400 /
 4, = 250 / — 3, = 150 / — 2.
 , 15 / , 5...6 / .

1 : 2 1 : 3

(5)
 4,5...11,2 $2/(^2)$, 80...95 %.
 (. 14.12),



. 14.12.

1 – ; 2 – ; 3 – ; 4 – ; 5 – ; 6 – ; 7 –

$k \longrightarrow$, $k = (5 \dots 7) < k_1$; $V \longrightarrow$
 $\qquad \qquad \qquad ; q \longrightarrow$.
 N ,
 $\qquad \qquad \qquad L_n$;

$$N = \frac{\lg \frac{L_n}{L}}{\lg S},$$
 $L \longrightarrow$.
 $D, \quad {}^3 \quad 1 \quad {}^3$, i - -

$$D = \frac{z(L_{i-1} - L_i) + b - b_0}{k k_3 n_1 n_2 (a - b)},$$
 $z \longrightarrow$, $1, 8 \dots 2 \quad / \quad 1$; $L_{i-1} \longrightarrow$
 $\qquad \qquad \qquad i$ - ; $L_i \longrightarrow$,
 $\qquad \qquad \qquad ; b \longrightarrow$ i - ($2 \dots 3 \quad / \quad$,
 $\qquad \qquad \qquad$); $b_0 \longrightarrow$, i - ; k
 \longrightarrow , o ; $k_3 \longrightarrow$,
 h , : $k_3 = h^{0,67}$; ${}_1 \longrightarrow$,
 $\qquad \qquad \qquad ; \quad {}_2 \longrightarrow$, ($n_2 = 0,9$);
 \longrightarrow .
 $\qquad \qquad \qquad$,
 $\qquad \qquad \qquad$.
 m

$$m = \frac{[z(L_{i-1} - L_i) + b - b_0]q}{k n_1 n_2 (a - b)},$$
 $q \longrightarrow$;
 $k = 0,57 n^2 D^{3,5} (H + h)^{0,7} b^{0,2} n^{0,25}$;
 $n \longrightarrow$; $D \longrightarrow$; \longrightarrow -
 $\qquad \qquad \qquad ; h \longrightarrow$; $b \longrightarrow$; \longrightarrow .
 $\qquad \qquad \qquad (\qquad \qquad)$
 $V = Q t$,

V — , 3 ; Q — ,
 $^3/$; t — , ,

$$t = \frac{-}{24aR};$$

, — -
 , / ; — (), -
 0,02...0,06 / ; R — -

(), 1 1 (R_{15}
 15°); T R :

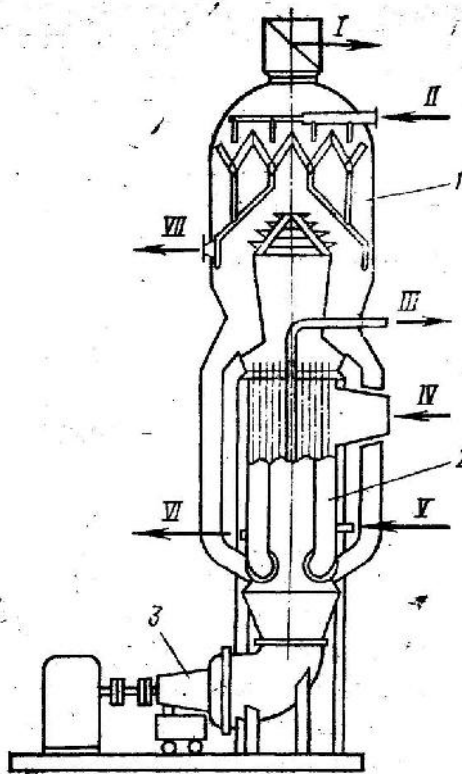
$$R = R_{15}(T/15).$$

15.

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15.1.

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. 15.1.

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I – ; II – ; III – ; IV – ; V –
 ; VI – ; VII – ; 1 – ; 2 –
 ; 3 –

- :
 -

$$G = G + W; \quad (15.1)$$

-

$$G x = G x, \quad (15.2)$$

G, G - (/); x, x -

,

1 ; W - , / .

(15.1) (15.2)

():

$$G = \frac{G x}{x}; \quad W = G - G = G \left(1 - \frac{x}{x} \right),$$

$$x = \frac{Gx}{G-W}.$$

:

- :

$$Di + Gi;$$

- :

$$Gi + Di + Wi + Q + Q.$$

$$G = G + W,$$

-

:

$$Di + (G + W)i = Gi + Di + Wi + Q + Q,$$

$$D - , / ; i, i -$$

$$(/); i, i, i -$$

-

$$(/); Q -$$

-

$$x x (/); Q - (/).$$

$$Q$$

,

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$$(-$$

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$$Q = D(i - i) = G(i - i) + W(i - i) + Q + Q. \quad (15.3)$$

$$(15.3)$$

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$$D (/) . \quad (15.3)$$

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$$Q$$

$$Q$$

.

$$D = \frac{Q}{i - i} = \frac{G(i - i)}{i - i} + \frac{W(i - i)}{i - i} + \frac{Q + Q}{i - i}.$$

$$(15.3)$$

$$D$$

$$Q,$$

,

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$$()$$

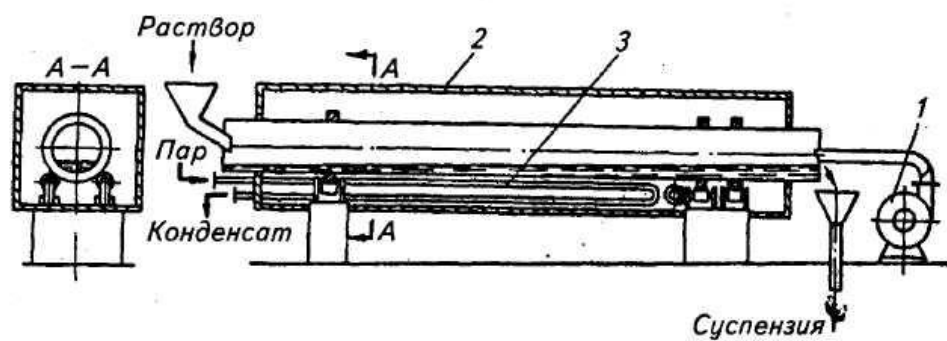
-

:

$$S = \frac{Q}{K_t \Delta t} = \frac{Q(i - i)}{K_t \Delta t},$$

$K_t -$; $\Delta t -$.
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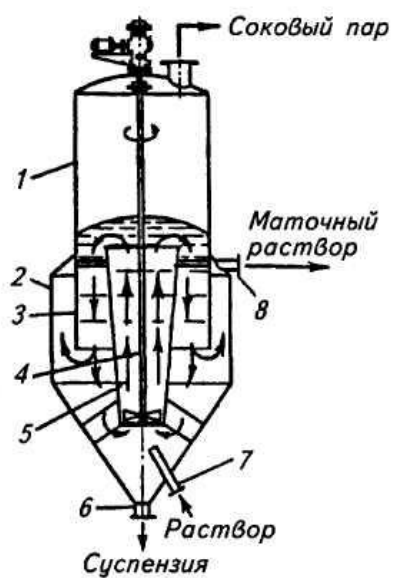
. 15.2.



. 15.2.

1 — ; 2 — ; 3 —

. 15.3.



. 15.3.

1 — ; 2 — ; 3 — ; 4 —
; 5 — ; 6, 7 — ; 8 —

:

$$G = G + L + W;$$

:

$$G = G + L\lambda,$$

$$G, G - L -$$

$$, /; W -$$

$$, /;$$

$$-$$

$$, .; \lambda -$$

.

$$L = [G (-) + W] / (\lambda -).$$

$$W = 0 :$$

$$L = G (-) / (\lambda -).$$

-

$$(=)$$

$$L = W / (\lambda -).$$

$$G - t + L q + W - t = G - t + L - L t_L + W - t + Q ,$$

$$W -$$

$$, /; c, c, c, c, c_L -$$

$$,$$

$$,$$

$$, / (\cdot); q -$$

$$, /$$

$$; t, t, t_L, t, t -$$

$$,$$

$$,$$

$$; Q -$$

$$, / .$$

$$W = \frac{G (c t - c t) + L (q - c_L t_L + c t) - Q}{c t - c t} .$$

-

$$G - t + L q + D i = G - t + L - L t_L + D i + W i_W + Q ,$$

$$D -$$

$$, /; i, i, i_W -$$

$$, -$$

$$, / (\cdot).$$

:

$$D=\frac{G\left(c\,t^{\ast}-c\,t\right)+L\left(c_Lt_l-q^{\ast}-c\,t\right)+W\left(i_w-c\,t\right)+Q}{i^{\ast}-i}.$$

,

q

15.2.

,

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8400 / (2000 /).

,

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“ ”

150...375°

2...28

,

$q=3,2$,

$q-$

, /

. 15.4

$$G_{\perp}=G-Wa\;,$$

$$a=1/V(\tau^3)$$

$$V=V_{\tau},\quad \tau=3/V$$

$$Q(\tau)$$

$$Q=3.55\,q\,\eta;\quad \eta=(\tau^3-1)/\tau^3,$$

$$q=\tau^3/\eta$$

$$q=q_0\,\eta.$$

$$300^\circ,$$

•

« »

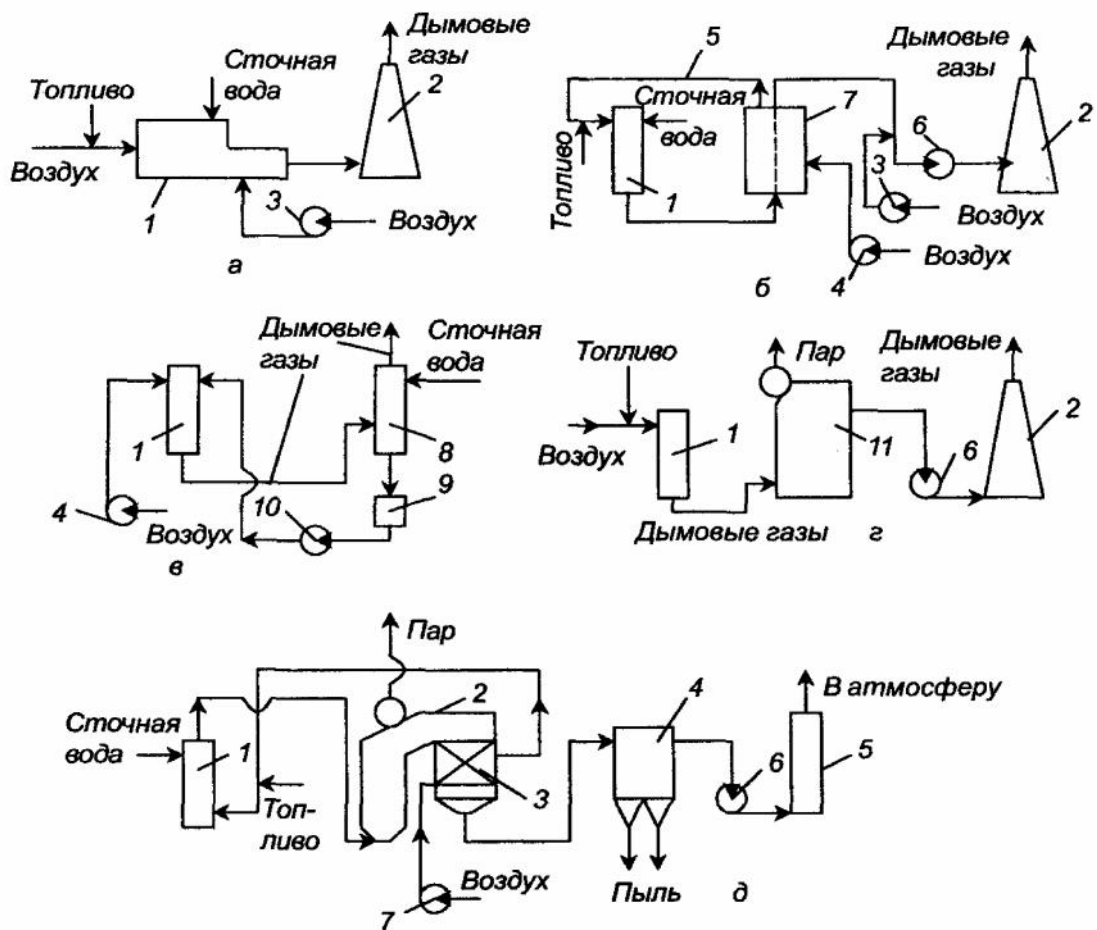
900...1000 °)

300 1

20...30 %

90 /()

15.5, .



. 15.5.

— ; — ; — ; 1 — ; 2 — ; 3 — ; 4 — ; 5 — ; 6 — ; 7 — ; 8 — ; 9 — ; 10 — ; 11 — ; — ; 1 — ; 2 — ; 3 — ; 4 — ; 5 — ; 6 — ; 7 —

(CaO, MgO, BaO, K₂O, Na₂O).

SO₂, SO₃, P₂O₅, HCl, Cl₂

90 %.

16.1.

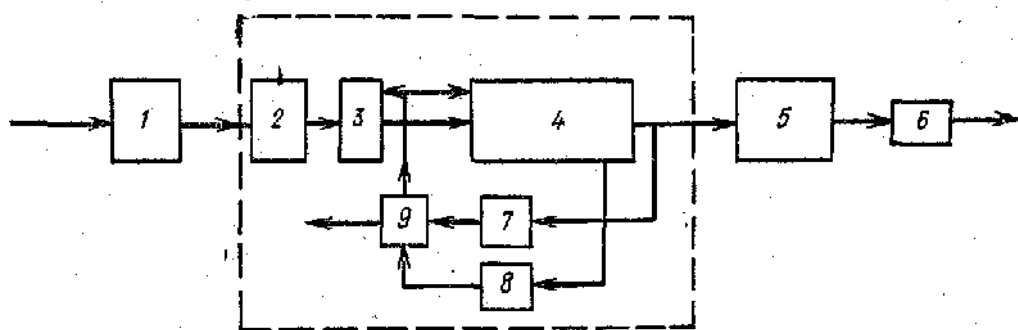
1)

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2)

(. 16.1)

10, 17 25 . ³/ .



. 16.1.

1 —

; 2 —

; 3 —

; 4 —

; 5 —

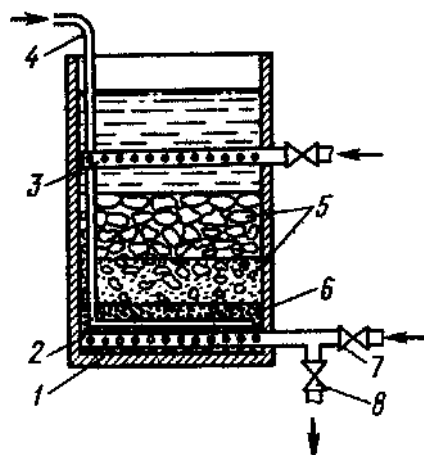
; 6 —

; 7 —

; 8 —

; 9 —

15 / — 6...8 / , -
6...8 3...5 / . -
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-
:
8,5 / ; 1...2 -
 d 1,5 ; $d = (2...4)d$ -
; 0,5...1 ; 0,6... 0,9 ;
40 / .
20...40 / 86...90 % -
4,4...7,7 / ³ , 15...34 .
1,6 1,5...2 .
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(. 16.2).



. 16.2. - ():

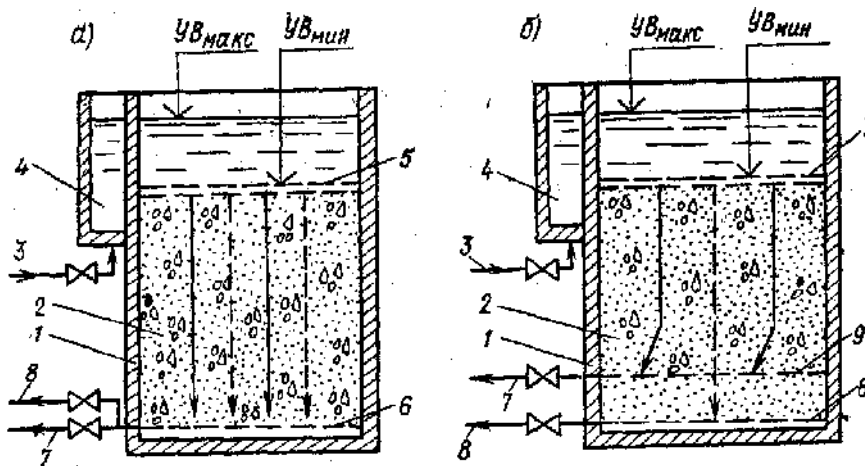
1 — ; 2 — ; 3 —
 — ; 4 —
 ; 5 — ; 6 — ; 7 — ; 8 — -
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 40...60 , , 0,8...1,0 . -
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 20 / -
 10 / 20 .
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3 . 10...12 / . -
 : I — 1,5...2 -
 18... 20 / (· ²); II — -
 10...12 18...20 / (· ²) 3...3,5 / (· ²); III -
 — 6...8 6...7 / (· ²). -

()

. 16.3.



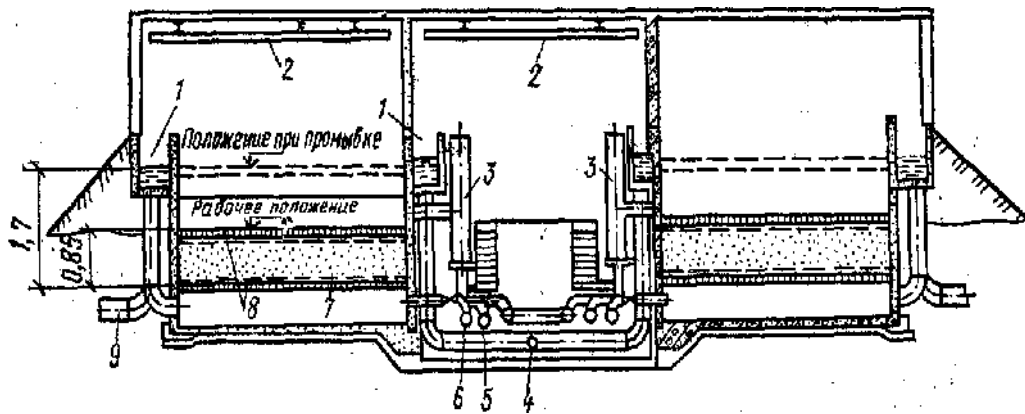
. 16.3 84.

— -3; — -4; 1 — ; 2 — ; 3 — ;
 4 — ; 5 — ; 6 — ; 7 — -
 ; 8 — ; 9 —

(-3) (-4) -

-3 -4 1,5
50° ().

(. 16.4).



. 16.4.

1 — ; 2 — - ; 3 — ; 4 —
— ; 5 — ; 6 — -
; 7 — ; 8 —
; 9 —

().

92...93 %,

50...60 % 15...35 / .

— 4...6 ; 35...40
/ ³, 15 %, 850 , -
.
:
10 / ,
12 / ; -
50...60 , 17...36 . 1,3 ; -
8,8...17 / ³, 6,8...9,6 / ³.

$S, \text{ }^2,$
 $S = (Q + Q) / (24w - n w t),$
 Q_p — , ³/ (-
 Q_p -
); Q — ,
, ³/ [-
 $Q = 0,025 Q_p (= 1) \quad Q = 0,05 Q_p (n = 2); n$ —
; t —
. , ; w_p — , / ,

$w = w \frac{N - m}{N};$
 N — ; m — , ($N > 20$
 $m = 3; \quad N < 20 \quad m = 2); w$ — , . . .
, / .
 N , -
,
 $N = 0,5\sqrt{S} .$

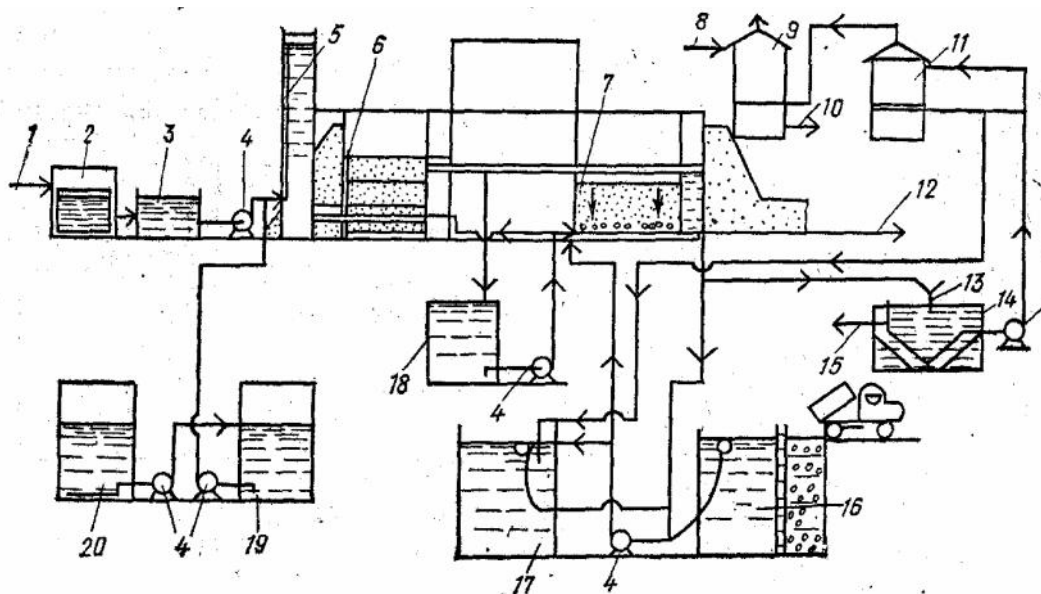
16.2.

— ,
NH₄—N 500...700 - ./ . -
90...97 %.

90 %

16 / .

(. 16.5)



. 16.5.

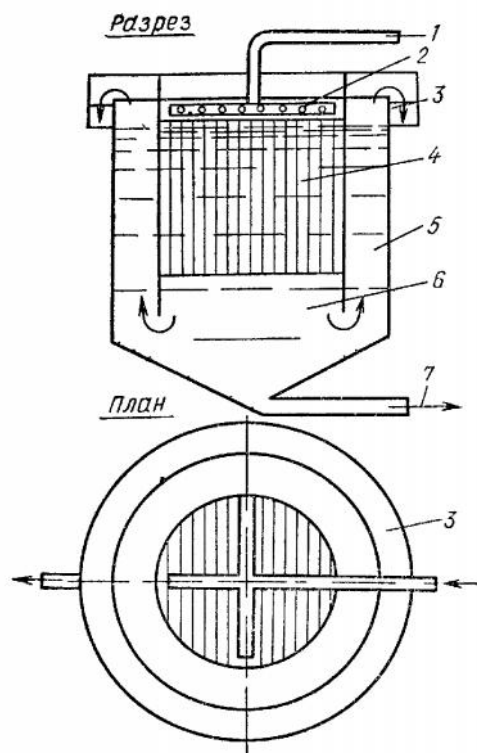
- 1 — ; 2 — ; 3 — ;
 4 — ; 5 — ; 6, 7 — ; 8 —
 ; 9, 11 — -
 ; 10, 11 — ; 12 — -
 ; 13 — ; 14 — ; 15
 — ; 17 — -
 : 18 — ; 19 — ; 20 —

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2 ,

5...7 .

. 2 / ,
 2 .
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 (,
 , —) ,
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 ,
 10...20
 « — » . 5 %
 .
 -3, -3, .
16.3.
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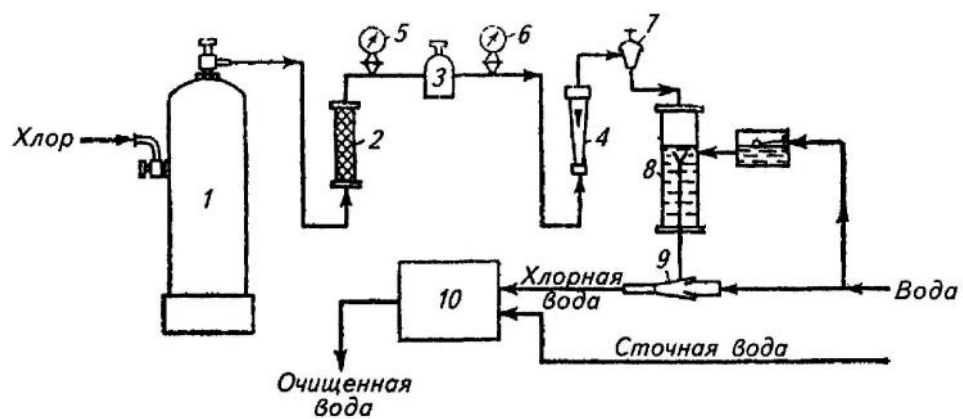
16.6. :
 1 — ; 2 — ; 3 — ; 4 — -
 ; 5 — ; 6 — ; 7 —

, 500 / ,
 , 500...1000 / , -
 I , -
 350...500 / , II ,
 .
 2...3 .

16.4.

()

(,), -
(99,9 %). -
, , .
, , -
, 1000 1 , 1,5 / -
30 1 / 60 .
:
) — 10 / ³;
) -
- (-
70 %) — 5 / ³;
) — 3 / ³.
-
.
-
.
— .
1,5...3,5 / (-
); 0,3...0,5 / . -
, . -
-
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. 16.7.



. 16.7.

:

1 – ; 2 – ; 3 – ; 4 – ; 5, 6 – ; 7 –
; 8 – ; 9 – ; 10 –

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(. 16.8).

10...20 / .

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1 20 °

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22 ,

7,6 9,2 — 15 .

-

25 ° .

5

1

-

0,2...0,5 / .

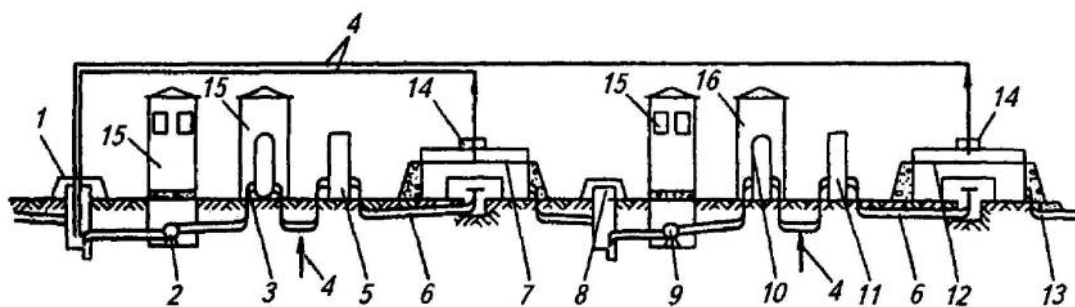
-

,

.

20

4...4,5 .



. 16.8.

$$\vdots$$

1, 8 – ; 2, 9 – ; 3, 10 – ; 4 –
; 5, 11 – ; 6 – ; 7, 12 –
; 13 – ; 14 – ; 15 –
; 16 –

99,8 %.

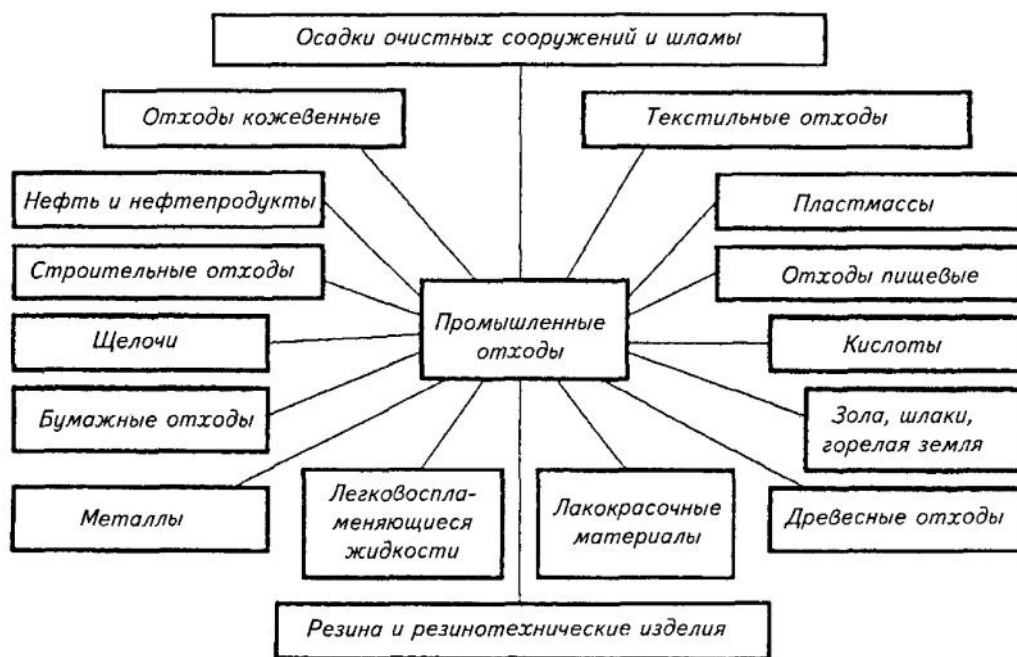
60

16.5.

16. ?
17. ?
18. .
19. -
20. ?
21. ?
22. ?
23. ?
24. ?
25. ?
26. ?
27. ?
28. .
29. ?
30. ?
31. -
32. .
33. .
34. ()
35. ?
36. ?
37. ?

17.

(. 17.1).



. 17.1.

(, , , , .).

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() , 20 ,

10 , 3...4 ,

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— — — (, . .)

(. 17.2) :

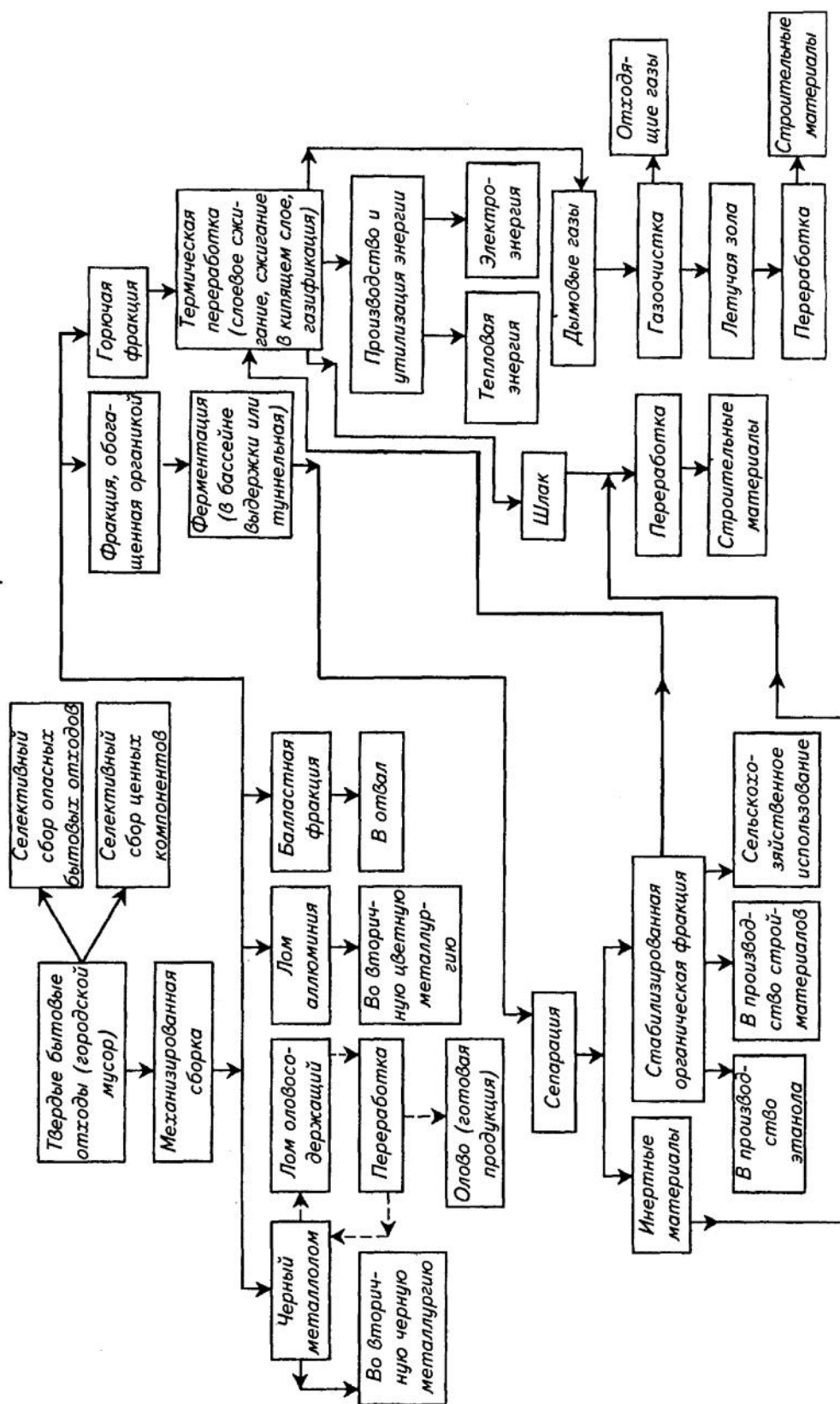
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. 17.2.

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 .
 (43 %) (57 %).
 462
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1 % .

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, .

CO₂, H₂ , NH₃, a -

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, , -

. , -

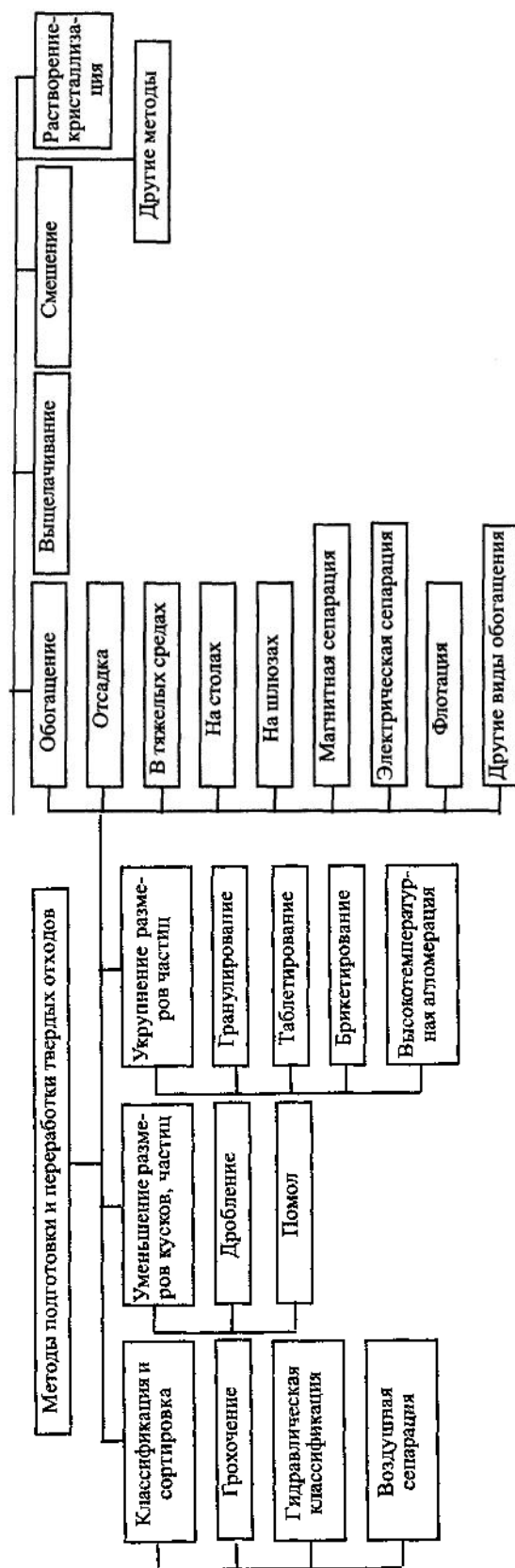
. 100³ 98 % 70 %

() V

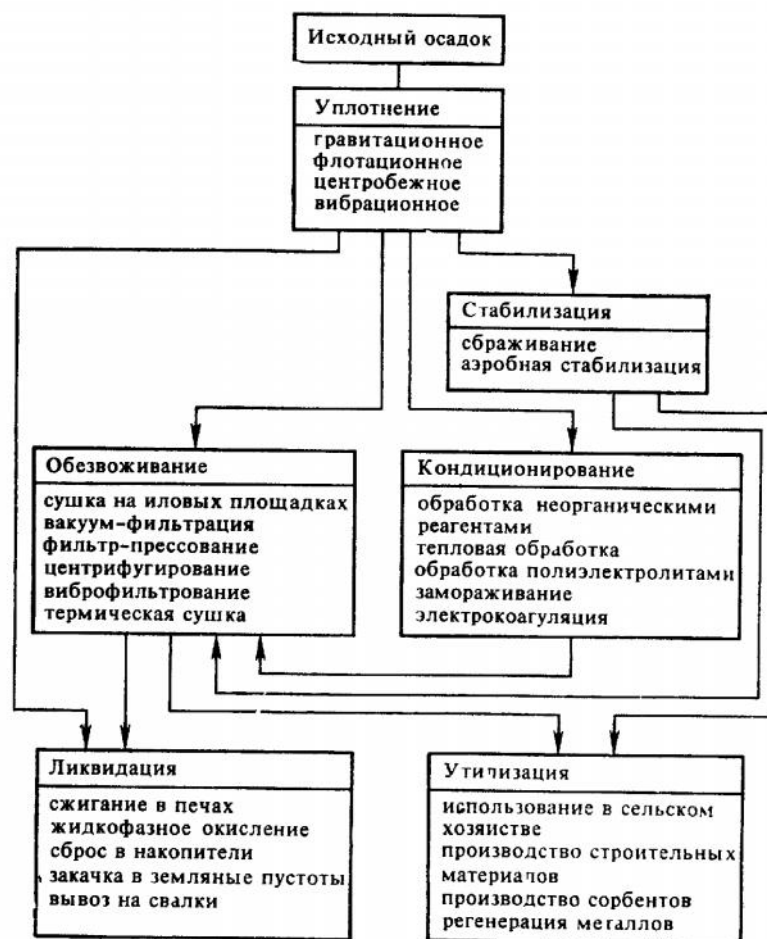
$$V = 100 \frac{100 - 98}{100 - 70} = 6,7^3.$$

10 -

.



. 17.3.



. 18.1.

18.1.

- 1) ;
- 2) , 10 %;
- 3) ;

10 60 %.

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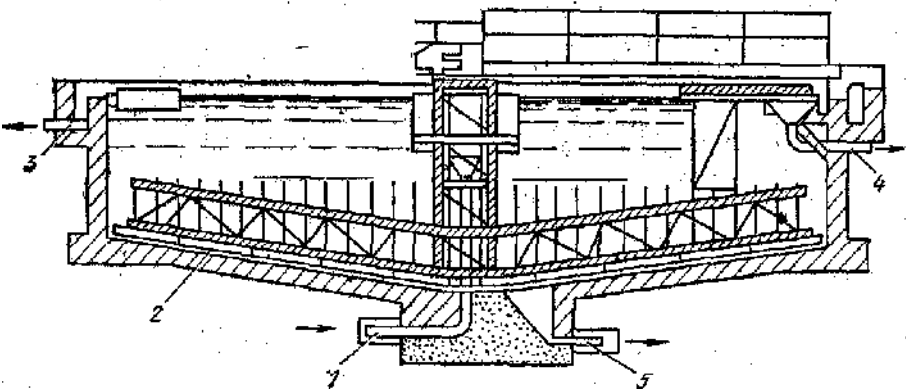
4...24 -

85...97 %.

(. 18.2).

(2...4 /)

(9...14 .)



. 18.2.

1 — ; 2 — ; 3 — ; 4, 5

97 % (99,5...99,7 %, -
).

(. 18.2),

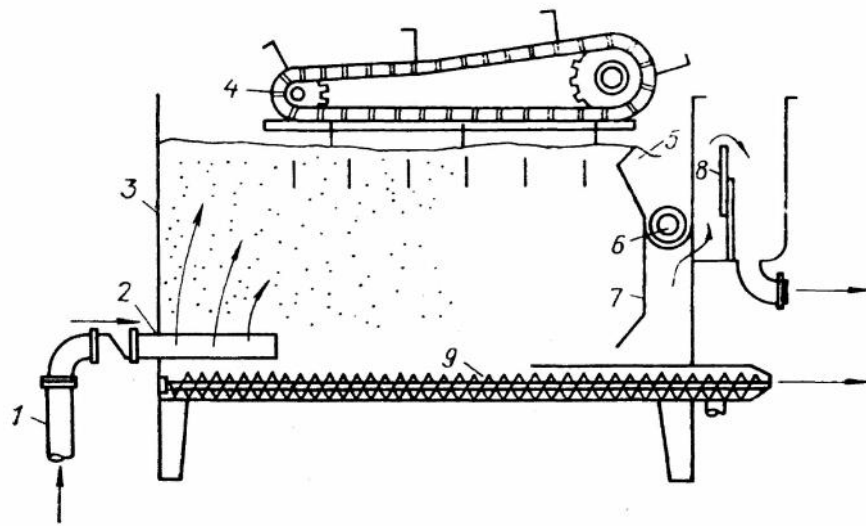
6- 93,6

97,5 %.

0,4

10...15

(. 18.3).



. 18.3.

1 –

; 2 –

; 3 –

; 4 –

; 5 –

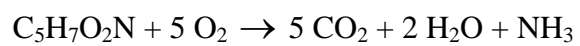
; 6 –

; 7 –

; 8 –

; 9 –

,
 .
 .
 ,
 ,
 92 %.
18.3. C
 .
 — ()
 60...70 %
 1 %
 .
 ,
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 (,
 .).
 ()
 .
 — ,
 ,
 20 °
 8...11 , 1
 0,7 . 4200 ³/ .
 ;
 « » (
 NH₃):



-

(,

) ; -

: 7 25 . 20...50 %

1 ³/ 1 ³ — -

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(

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(2...6).

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30...35 °
52...55 °

).

()

(

)

(—

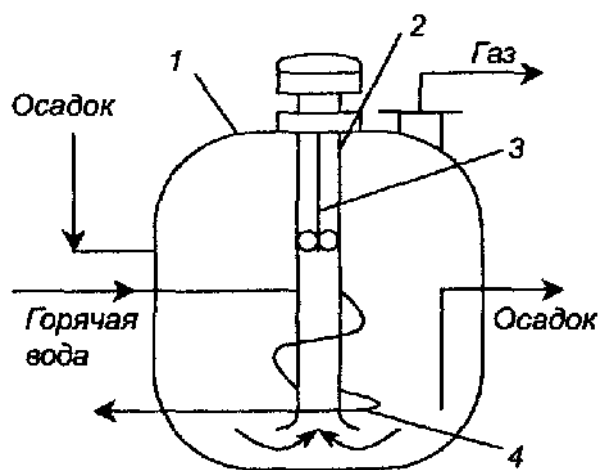
).

(. 18.4)

30...40 ° (

)

(0,2...0,46).



. 18.4.

:

1 — ; 2 — ; 3 — ; 4 -

V ($\text{ }^3/\text{ }^3$) -

$$V = M/(D/100),$$

D — , % -

; D

.

1000...8000 ^3 . -

:

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(60).

18.4.

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. 40 % -

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 (25...50 %), ;
 — ;
 — .
 .
 0,05...0,4 % .
 , 40...50 %.
 ,
 30...40 %.
 .
 150...200 ° 0,5...2 .
 40 %
 .
 92...94 % 20...30 %
 .
 ,
 - (65...70 %) -
 .
 , ;
 .

40...70 %.

;

;

();

200 ° 50 %; 70 %

250...300 ° .

96 %

. 18.5

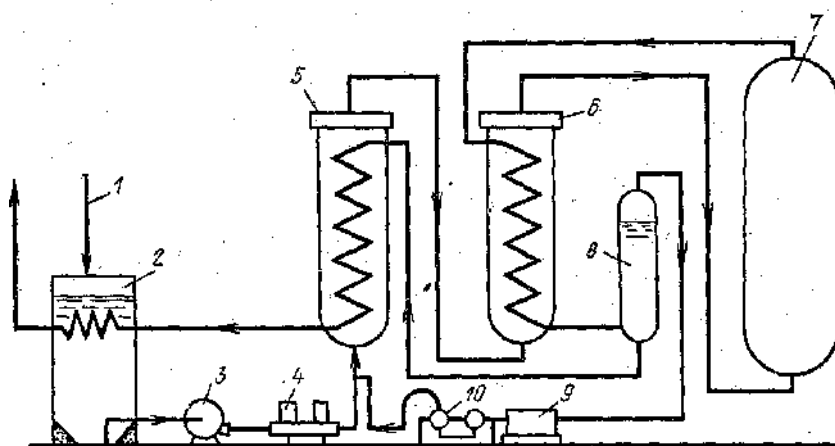
1

45...50 ° . 3, 4 -

5, 6 7. -

240 ° .

8 6.



. 18.5.

:

1 —

; 2 —

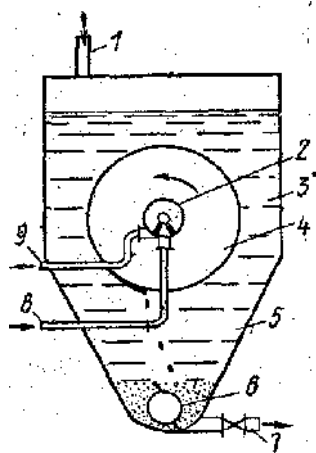
; 3 —

; 4 —

$$r = \frac{2 p S^2}{\sim m} b \text{ ,}$$

$p -$ (), $S -$; $\mu -$; $m -$, $b = t/V^2 -$, $(t -)$; $V -$

. 18.6.



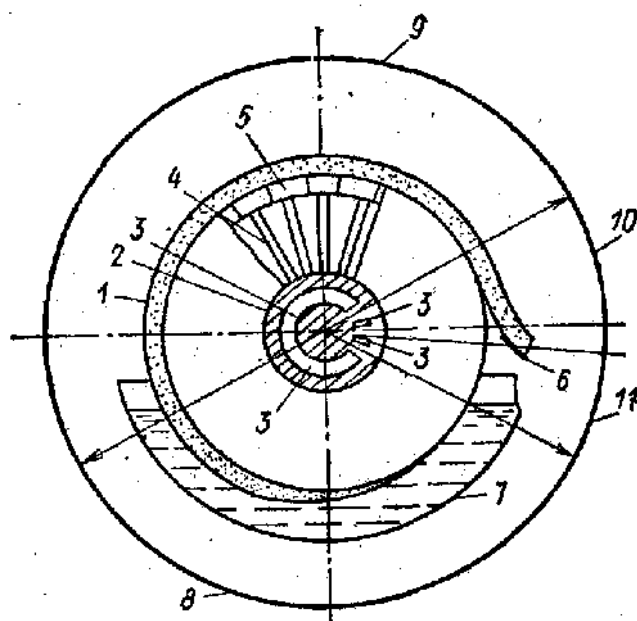
. 18.6.

1 — ; 2 — ; 3 — ; 4 —
 — : 5 — ; 6 — ; 7 —
 ; 8 — ; 9 —

80 %,

— 90 %, — 98 %, — 60...70 %

(. 18.7).



. 18.7.

1 — ; 2 — ; 3 — ; 4 — ; 5 — ; 6 — ; 7 — ; 8 — ; 9 — ; 10 —

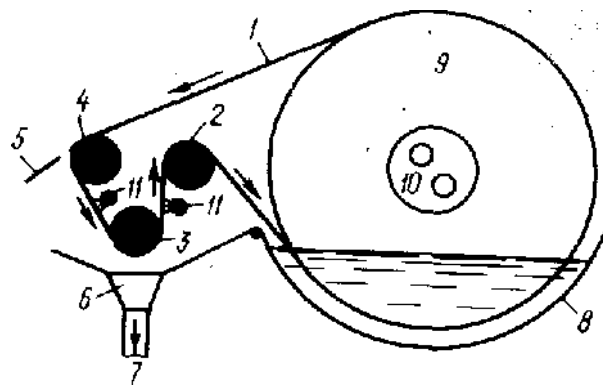
16...32

8...24

(. 18.8)

9, (35...40 %)

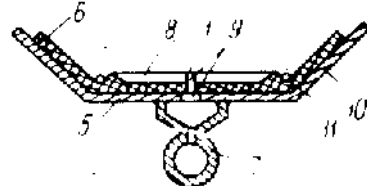
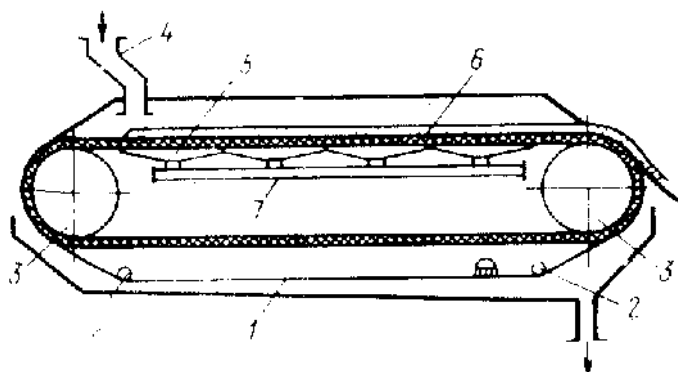
8



. 18.8.

- 1 - ; 2 - ; 3 - ; 4 - ; 5 - ; 6 - ; 7 - ; 8 - ; 9 - ; 10 - ; 11 -

,
 10. -
 ,
 .
 8 .
 , , -
 , .
 1 4, 3 2.
 4
 5. , -
 4. 4
 3^2 ,
 11. 3^2 ,
 . -
 -
 .
 , (1...3),
 -
 1,2...2 .
 -
 - 60...200 /(2^{\cdot}) 25...35 %;
 46,7...60 ; 3,5...5 $^{-1}$.
 ,
 - .
 - 9...100 2
 -
 .
 , .
 , -
 .
 12,
 9 102 2 .
 -



. 18.9.

- 1 - ; 2 - ; 3 - ; 4 -
; 5 - ; 6 - ; 7 -
; 8 - ; 9 - ;
10 - ; 11 -

9.

6

1

11.

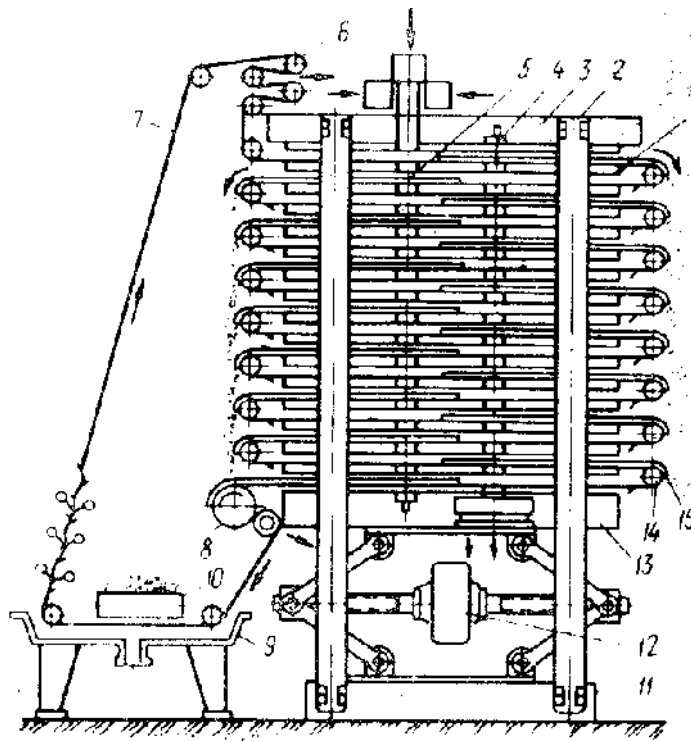
9.

10,

1,6...10

2.

,
 .
 .
 -
 .
 -
 ,
 .
 -
 ,
 ()
 -
 $L = \frac{(100-w)H}{20t}$,
 w - , %; ρ - , /³; H :- , ; t -
 , .
 -
)
 2,5...50². - (. 18.10)
 1,
 2. 45
 13
 12. - 50...70
 (. . 18.10)
 8,
 13.
 9. 4.



. 18.10.

- 1 - ; 2 - ; 3 - ; 4 - ; 5 - -
 ; 6 - ; 7 - ; 8 -
 ; 9 - ; 10 - ; 11 - ; 12 - -
 ; 13 - ; 14 - ; 15 -

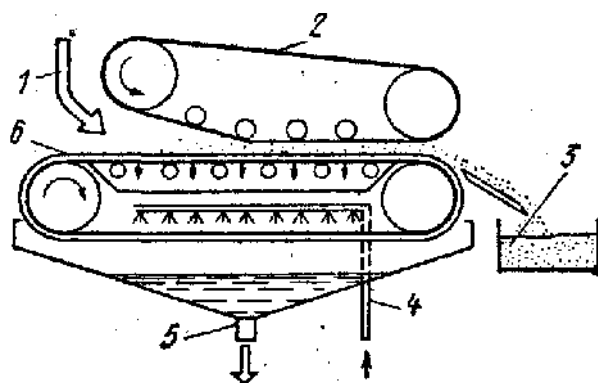
15 10.

9,

. 18.11.

4.

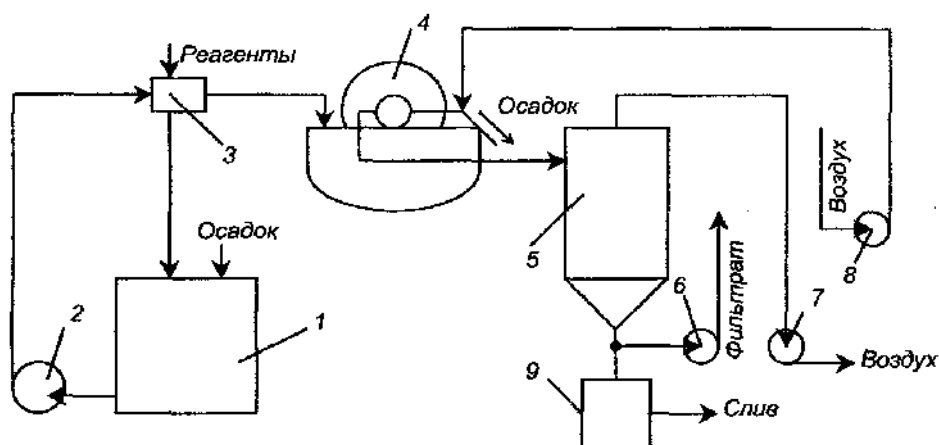
5.



18.11.

1 — ; 2 — ; 3 — ; 4 —
; 5 — ; 6 —

18.12



18.12.

1 — ; 2, 6 — ; 3 — ; 4 — ; 5 — ; 7 — ; 8 —
; 9 —

V

V

$$\Delta p = \text{const}$$

l ;

$$= V / V;$$

R ;

r

R

$(r = R / l);$

$S:$

$$t=\frac{R}{\Delta P}.\frac{V}{S}+\frac{rx}{2\Delta p}.\left(\frac{V}{S}\right)^2.$$

$$\frac{V}{V}=\frac{1}{x}\quad \frac{V}{S}=\frac{l}{x},$$

$$t=\frac{R}{\Delta p\,x}l+\frac{r}{2\Delta p\,x}l^2.$$

$\tau:$

$$V=S\frac{l}{x}.$$

() ():

$$t=t_{\scriptscriptstyle{1}}+t_{\scriptscriptstyle{2}},$$

$t=$

.

$$V\sim k\,t^{\,\,0,5}.$$

:

$$V=\frac{V}{t_{\scriptscriptstyle{1}}+t_{\scriptscriptstyle{2}}}=\frac{k\,t^{0,5}}{t_{\scriptscriptstyle{1}}+t_{\scriptscriptstyle{2}}}.$$

:

$$\frac{dV}{dt}=\frac{(t_{\scriptscriptstyle{1}}+t_{\scriptscriptstyle{2}})k\,0,5t^{-0,5}-k\,t^{0,5}}{(t_{\scriptscriptstyle{1}}+t_{\scriptscriptstyle{2}})^2}=0. \tag{18.1}$$

$$, \tag{18.1}$$

$$(t_{\scriptscriptstyle{1}}+t_{\scriptscriptstyle{2}})k\,0,5\,t^{-0,5}-k\,t^{0,5}=0,$$

$$k\neq 0\quad 0,5\,t^{-0,5}\neq 0,\quad t_{\scriptscriptstyle{1}}-t_{\scriptscriptstyle{2}}=0,\quad \ldots$$

$$t_{\scriptscriptstyle{1}}=t_{\scriptscriptstyle{2}}.$$

$$V=\frac{V}{t}24$$

$$V_{\scriptscriptstyle{z}}=V_z=V\,\frac{24}{t}=V\,\frac{24}{t_{\scriptscriptstyle{1}}+t_{\scriptscriptstyle{2}}}.$$

:

$$N=\frac{V}{V}\;.$$

.

$$V\qquad\qquad\qquad\Delta p\qquad\qquad\qquad S\;,\qquad\qquad\qquad$$

,

$$l,$$

$$=V/V:$$

$$S\;=\frac{V}{l}=\frac{Vx}{l}\;.$$

$$\Delta p=\text{const:}$$

$$t\;=\frac{R}{\Delta p\,x}l+\frac{r}{2\,\Delta p\,x}l^2\,.$$

$$B:$$

$$v=\frac{L}{t}=\frac{S}{t}\,,$$

$$L\;-\qquad\qquad\qquad.$$

$$V\;:$$

$$S\;=\frac{V\;(R\;+R\;)}{\Delta p}.\frac{\sim}{\sim}\;,$$

$$\mu\;,\mu\;- \qquad\qquad\qquad.$$

$$\tau:$$

$$S\;=L\;=v\;t\;\;,$$

$$L\;- \qquad\qquad\qquad.$$

:

$$D\;=\frac{L}{f}=\frac{L\;+L\;+L}{f}=\frac{S\;+S\;+S}{f}=\frac{S}{f},$$

$$L\;- \qquad\qquad\qquad;S\;- \qquad\qquad\qquad.$$

$$(\;\;/\;)\qquad\qquad\qquad D\;:$$

$$n=\frac{60v}{f\,D}\,.$$

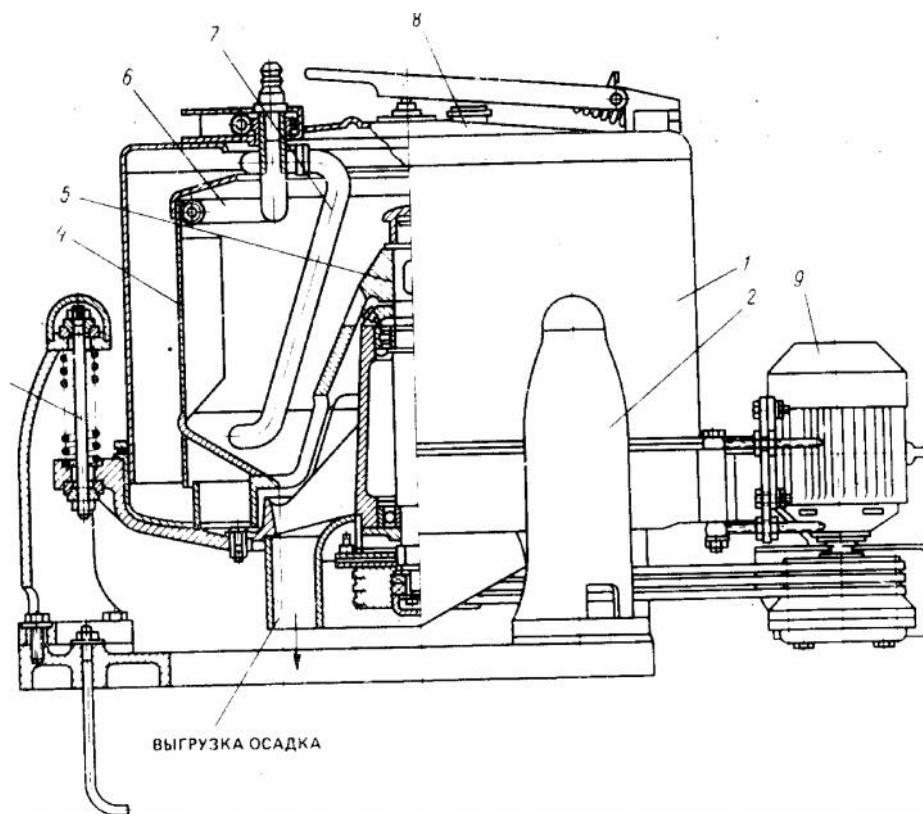
.

—

,

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$$\qquad\qquad\qquad, \qquad\qquad\qquad 10...20\qquad\qquad\qquad,$$



. 18.13.

:

1 - ; 2 - ; 3 - ; 4 - ; 5 - ; 6 - -

; 7 - ; 8 - ; 9 -

1

2

3.

4,

,

5.

6,

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7.

8,

9.

. 11.21).

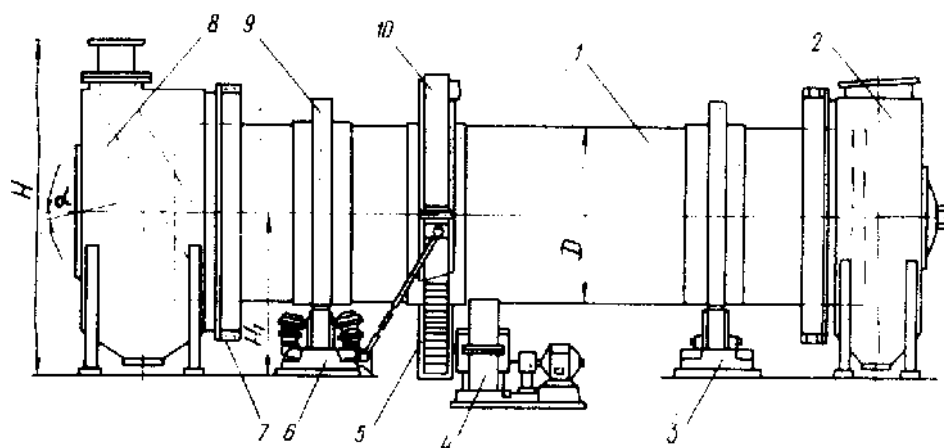
(.

...), , (-
), , .
 , -

1...3,5

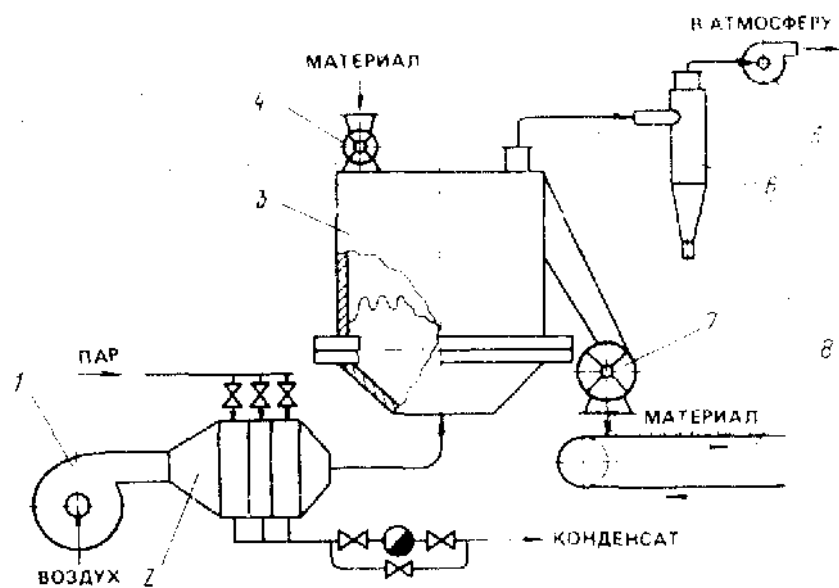
4...27 , 0,3...15 / .
 30...40 %

1 (. 18.14), 9,
 3 4 5,



. 18.14.

1 - ; 2 - ; 3 - ; 4 - ; 5 - ; 6 -
 ; 7 - ; 8 - , 9 - ; 10 -



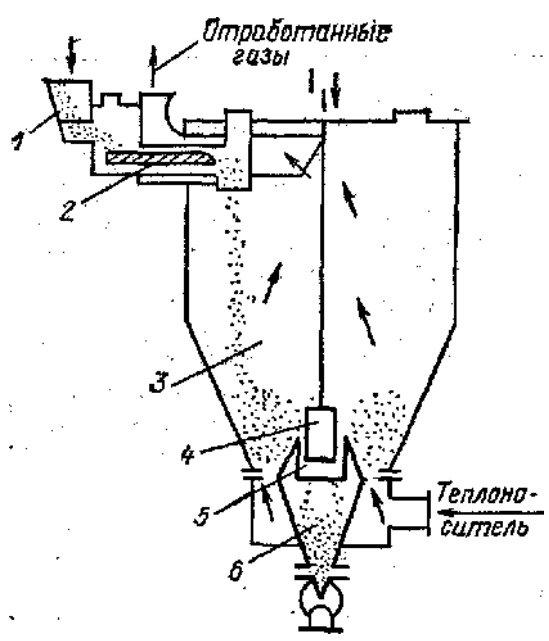
. 18.15.

1 - ; 2 - ; 3 - ; 4 - ; 5 - ; 6 - ;
7 - ; 8 -

0,003... 0,005 (300...500 .).

0,1 5 .

. 18.16



. 18.16.

1 — ; 2 — ; 3 — ; 4 — ; 5 — ;
6 —

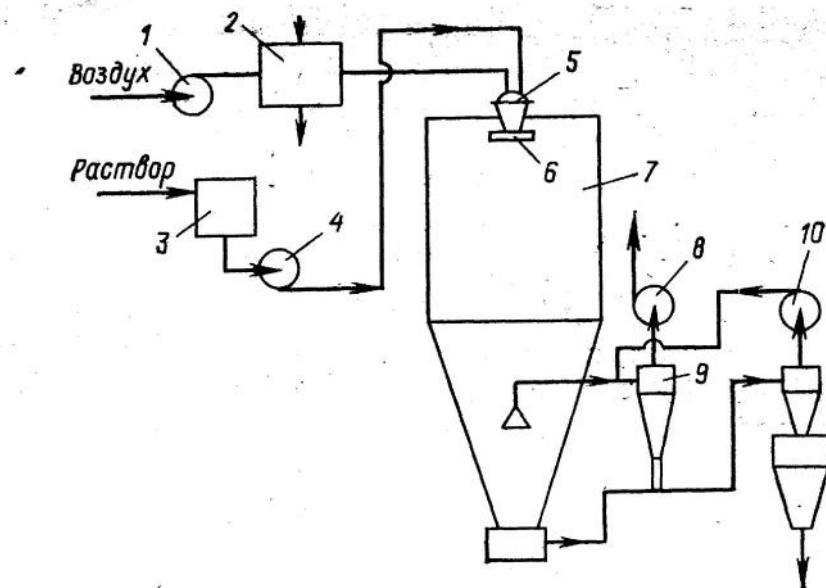
60...70 ° .

(4...5) -

1200 ° .

15...30 ,

. 18.17.



. 18.17.

1 – ; 2 – ; 3 – ; 4 – ; 5 – ; 6 –
; 7 – ; 8, 10 – ; 9 –

vx 1 - 2 -
7. , -

6. 8,

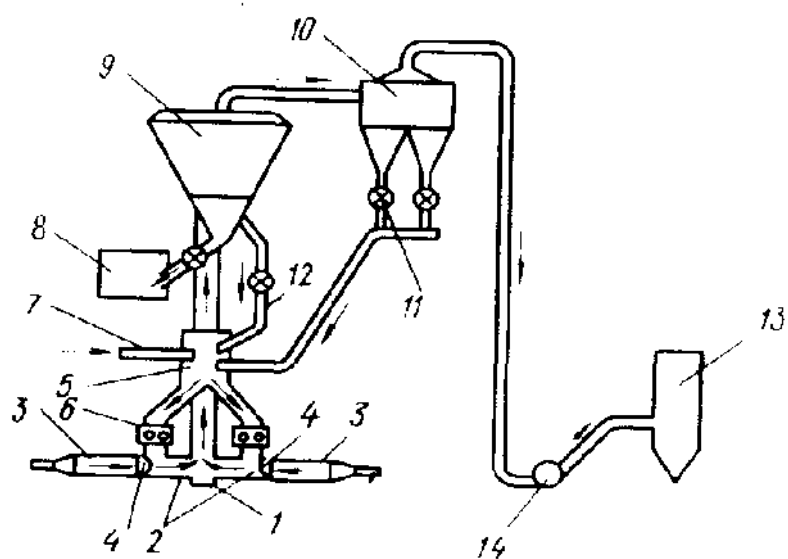
9,

1 3 10...12

$$A = \frac{W}{V t},$$

W - , ; V - , ³; t - ,

. 18.18



. 18.18.

1 - ; 2 - ; 3 - ; 4 - ; 5 - -
; 6 - ; 7 - ; 8 - ; 9 - -
; 10 - ; 11 - ; 12 -
; 13 - ; 14 -

5,

6,

2,

3.

1.

1

- 9,

.

10 14 -

23.

11 . ,

.

-

3...5 / .

, -

.

-

.

:

$$G_1 = G_2 + W,$$

$G_1, G_2 -$ () , / ; $W -$,
 , / .

:

$$G_1(100 - c_1)/100 = G_2(100 - c_2)/100,$$

1, 2 - (),

%.

$$G_2 = G_1 \frac{100 - c_1}{100 - c_2}.$$

$$G_1 - G_2,$$

$$W = G_1 - G_2;$$

$$W = G_1 \frac{c_1 - c_2}{100 - c_2}.$$

,

:

$$L x_1 + W = L x_2 ,$$

$$L\,x_1 - \qquad \qquad \qquad ; \, L\,x_2 - \qquad \qquad \qquad ; \, \, \, _1, \, _2 - \qquad - \\ \qquad \qquad \qquad , \qquad \qquad \qquad /(\qquad \qquad \qquad - \qquad) ; L - \qquad - \\ \qquad \qquad \qquad , \qquad \qquad \qquad ./ \, .$$

$$L=W/(x_2-x_1)\,.$$

$$1 \qquad \qquad \qquad :$$

$$l=L/W=1/(x_2-x_1)$$

$$- \qquad \qquad \qquad .$$

$$\qquad \qquad \qquad :$$

$$t_{\Sigma}=t_1+t_2\,.$$

$$\tau_1:$$

$$t_1=\frac{W}{S_pS\,\Delta p}=\frac{W}{S\,\,S\,\Delta x}\,,$$

$$\beta\,,\beta\,-$$

$$;\,S\,-$$

$$:$$

$$\Delta p\,\,=\frac{\Delta p\,\,-\Delta p}{\ln\frac{\Delta p}{\Delta p}}\,,$$

$$\Delta p\,=(p\,\,-p)\,;\,\Delta p\,=(p\,\,-p)\,-$$

$$;\,\,p\,\,,p\,-$$

$$,\qquad \qquad \qquad .\,\,;\,$$

$$\Delta x\,\,=\frac{\Delta x\,\,-\Delta x}{\ln\frac{\Delta x}{\Delta x}}\,,$$

$$\Delta\,\,=(\,\,-\,)\,;\,\Delta\,\,=(\,\,-\,)\,-$$

$$;\qquad \qquad \qquad ,\qquad \qquad \qquad -$$

$$,\qquad \qquad \qquad /(\,$$

$$.\qquad \qquad \qquad).$$

$$:$$

$$t_2=\frac{G}{K\,S}\ln\frac{c\,\,-c}{c\,\,-c}\,,$$

G – ; K – ; c – ; c – .

, :

$$S_1 = \frac{W}{S_p p_{t_1}} = \frac{W}{S_x \Delta x_{t_1}} .$$

, :

$$S_2 = \frac{G}{K t_2} \ln \frac{c_{-c}}{c - c} .$$

,

:

$$S_{\Sigma} = S_1 + S_2 .$$

18.7.

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. - 16800...21000 / ,

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16800...21000 / ， -

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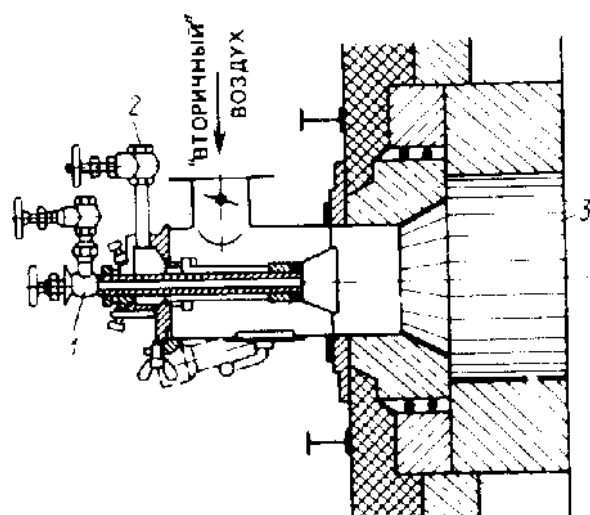
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() . ，

" " ，

(， ， .) .



. 18.19.

1 -

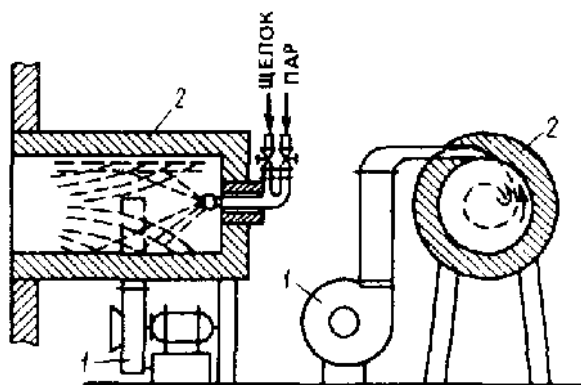
; 2 -

; 3 -

1

2.

0,7

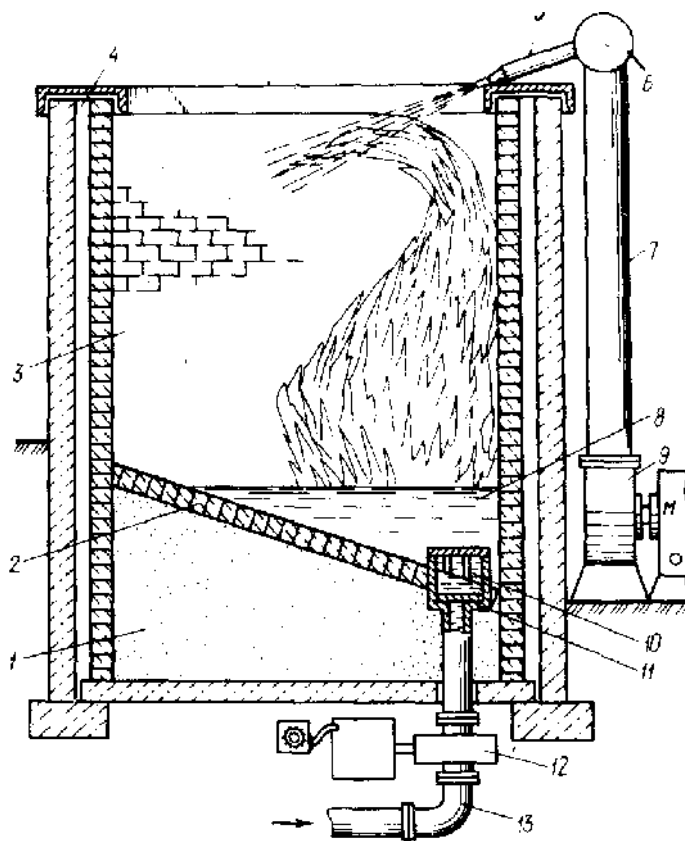


. 18.20.

1 - ; 2 -

C

(. 18.21).

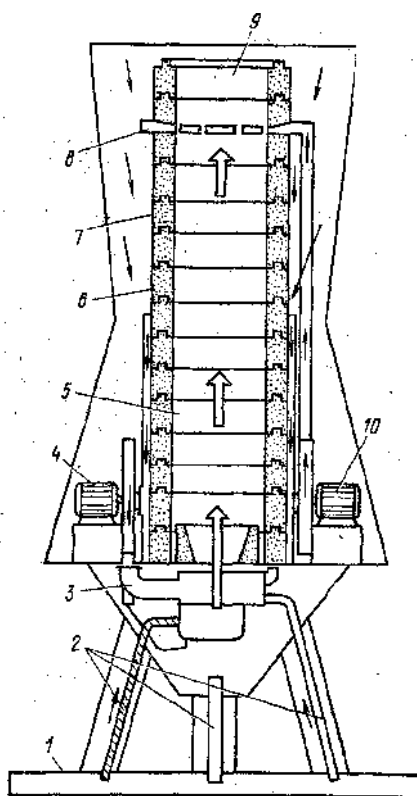


. 18.21.

- 1 - ; 2 - ; 3 - ; 4 -
 ; 5 - ; 6 - ; 7 - ; 8 - ; 9 -
 ; 10 - ; 11 - ; 12 - ; 13 -

3 , ,
4 . 2 , -
, 1. -
11, -
10. 12 13 . -
9 7 6, -
5. -
, -
, -
(, . .) -
9; -
, -

(. 18.22).



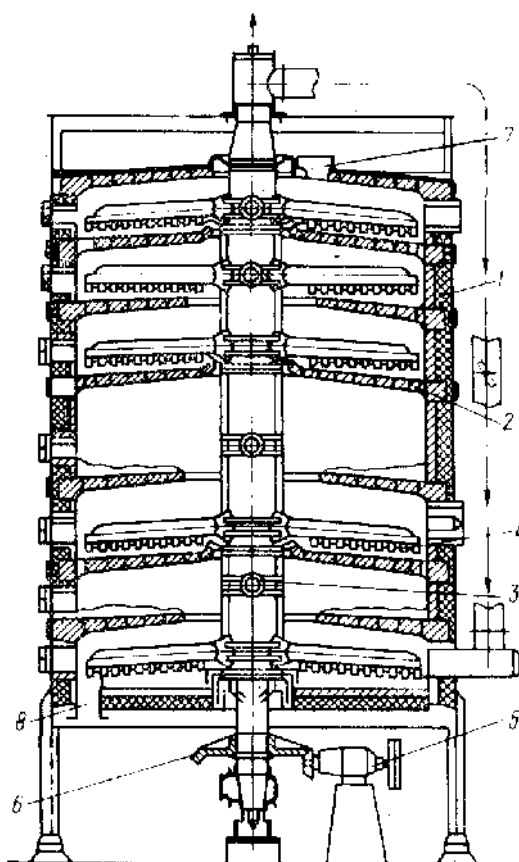
. 18.22.

1 — ; 2 — ; 3 — ; 4 — ; 5 —
 ; 6 — ; 7 — ; 8 —
 ; 9 — ; 10 —

900...1700 ° .

6 ^{3/} ,

(. 18.23)

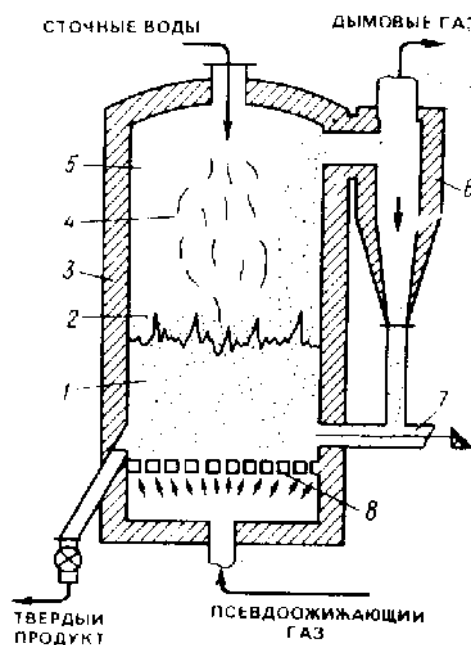


. 18.23.

1 - ; 2 - ; 3 - ; 4 - ; 5 -
 ; 6 - ; 7 - ; 8 -

1,
 2.
 3
 4.
 5
 6.
 8,
 9...300 /

. 18.24.



. 18.24.

:

1 - ; 2 - ; 3 - ; 4 - -
 ; 5 - ; 6 - ; 7 - -
 ; 8 -

3,
 8

2.

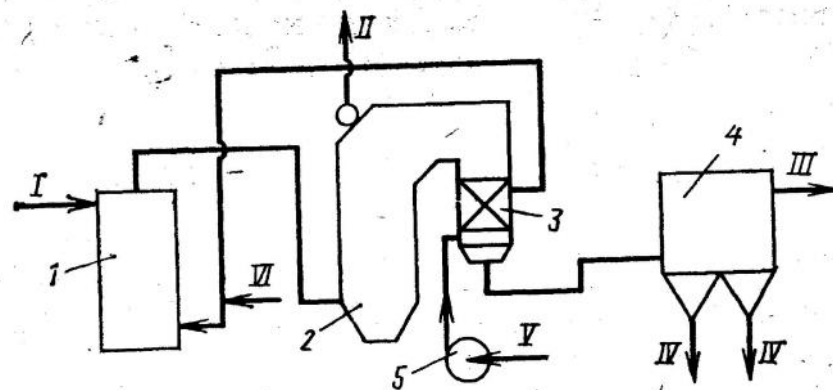
5. ,

30 , -

6.

7.

. 18.25.



. 18.25.

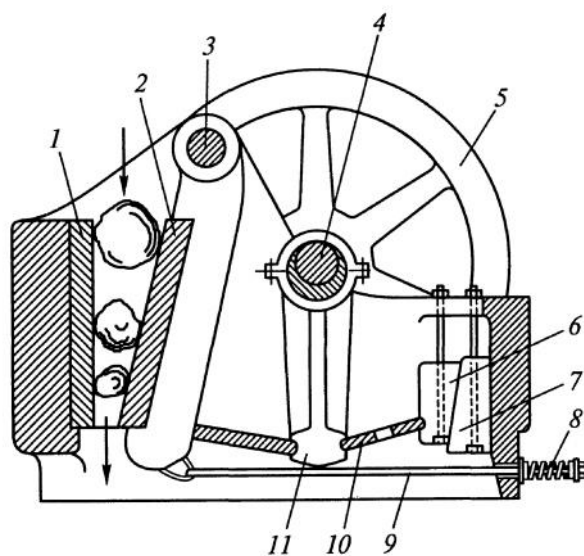
I - ; II - ; III - ; IV - ; V - ; VI - ; 1 - ; 2 - -
 ; 3 - ; 4 - ; 5 -

, , (, -
 , , .) 60 %
 10 %.
19.

19.1.
 , ,
 , , , -
 , , , (. .
 17.3).
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 . -
 (. 19.1).
 19.1

	,	-	<i>i</i> -
:	1500-300	300-100	2-6
-	300-100	50-10	5-10
-	50-10	10-2	10-50

() 1500×2100 .



. 19.1. :

1, 2 – ; 3 – ; 4 – ; 5 – ; 6, 7 – ;
8 – ; 9 – ; 10 – ; 11 –

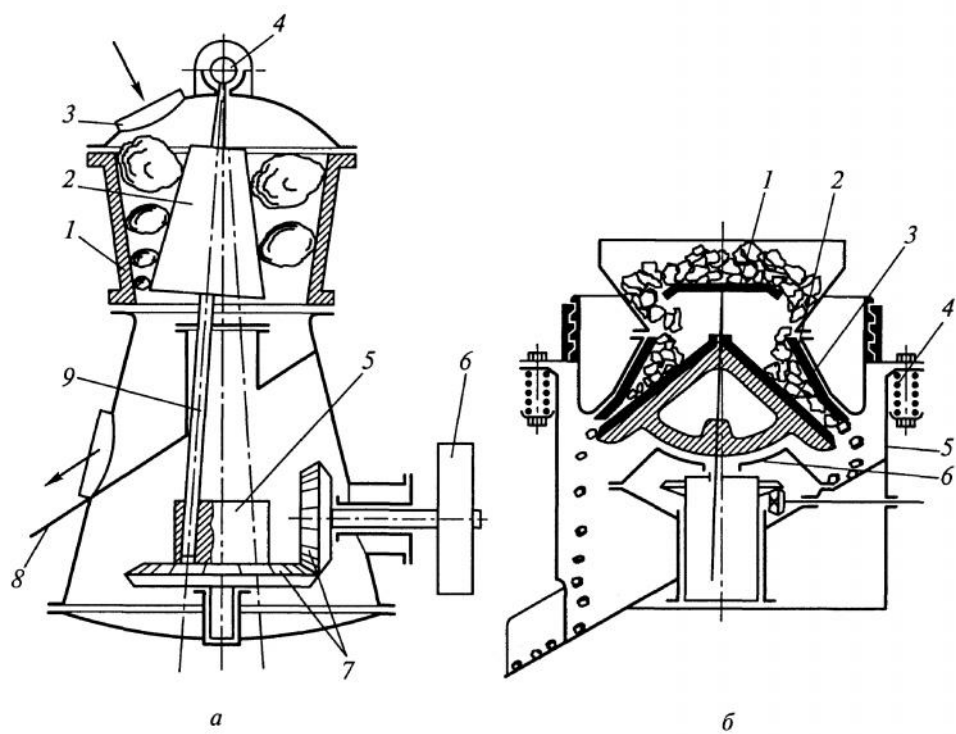
(. 19.2) ,

() . -

2000 .

(7...10) (3...5)

(4500 /), , -



. 19.2.

:

— : 1 — ; 2 — -
; 3 — ; 4 — ; 5 — ; 6 — ; 7 —
; 8 — ; 9 — ; -
: 1 — ; 2 — ; 3 — ; 4 — ; 5 — ; 6 — -

(. 19.3)

.

, -

1 100 .

0,5 / 4...6 / ,

1500 250 / .

,

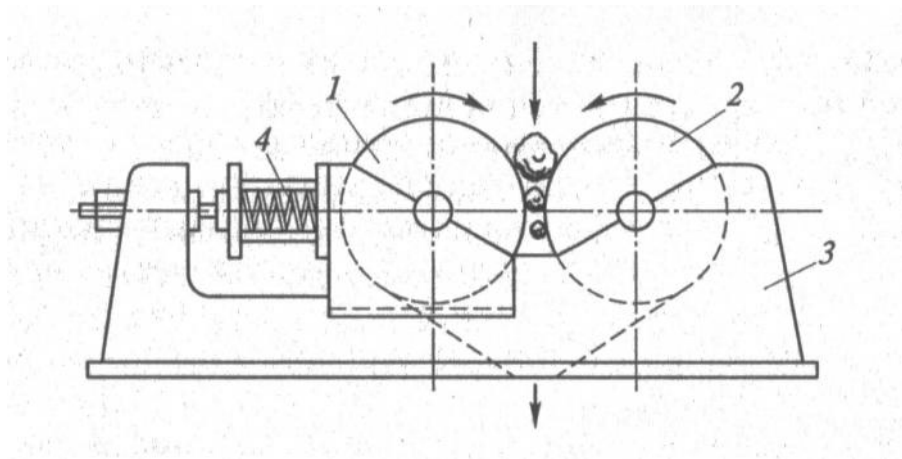
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. 19.3.

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1, 2 –

; 3 –

; 4 –

(. 19.4)

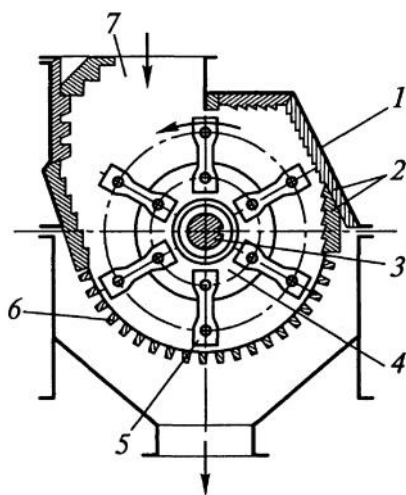
-

800...1000

⁻¹

(, , ,

.).



. 19.4.

:

1 –

; 2 –

; 3 –

; 4 –

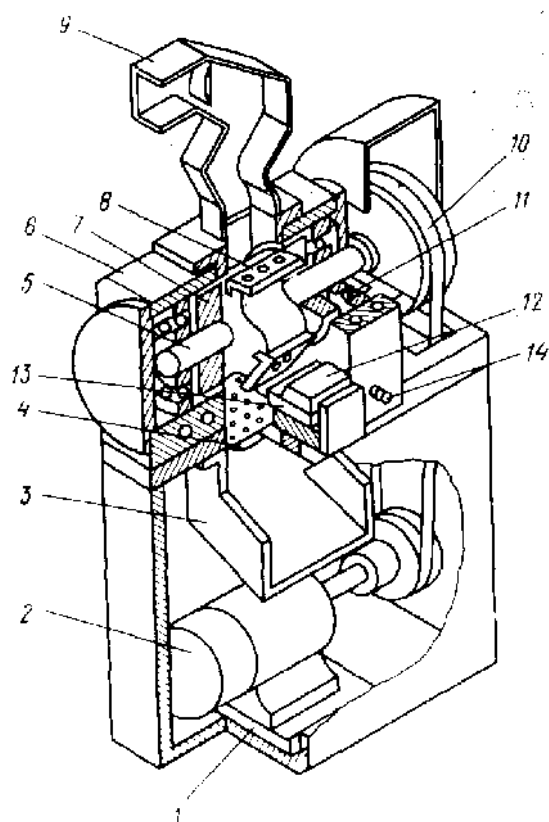
; 5 –

; 6 –

; 7 –

2 ,

10...15 / .



. 19.5.

- 1 - ; 2 - ; 3 - ; 4 - ; 5 -
 ; 6 - ; 7 - ; 8 - ; 9 - ; 10 - -
 ; 11 - ; 12 - ; 13 - ; 14 -

:

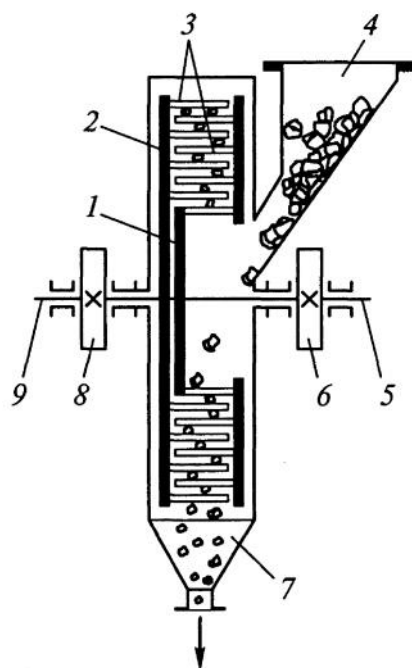
1200...1450 , 55...70 / ,
800...1000 , 400...500 / .

(. 19.6)

(1500)

3000 ⁻¹.

()



. 19.6.

:

1, 2 – ; 3 – - ; 4 – ; 5, 9 – ; 6, 8 – ; 7 – -

$$x=0,6b\sqrt[3]{W_i},$$

$$b-\qquad\qquad\qquad,\qquad;W_i-\qquad\qquad\qquad,\qquad\qquad\qquad/.$$

$$n_0=30\sqrt{g(tg\mathfrak{r}_1+tg\mathfrak{r}_2)/2l},$$

$$\alpha_1\qquad\qquad\qquad-(\alpha_1\approx17^{\circ});\alpha_2-\qquad\qquad\qquad-\\(\qquad\qquad\qquad)(\alpha_2=9^{\circ}30');l-\qquad\qquad\qquad,\qquad.$$

$$Q=40k_fk\ D^2tg\mathfrak{v}(e\cos50^{\circ}+b_0),$$

$$k_f-\qquad\qquad\qquad(k_f=0,9\dots1,2);\ k\quad-\qquad\qquad\qquad\\,\ (k\quad=0,89\dots1,1);D-\qquad\qquad\qquad-\\,\ ;\ \varepsilon-\qquad\qquad\qquad;\ e-\qquad\qquad\qquad\\;\ b_0-\qquad\qquad\qquad,\quad.$$

$$x=k\sqrt{W_i}tg^2\mathfrak{v}(2e\cos50^{\circ}+b_0)^2,$$

$$k=4\dots4,2.$$

$$Q\qquad\qquad\qquad-$$

$$S=Lb\qquad\qquad\qquad v=\pi\,D\,n/60:$$

$$Q=3600\,\mu\,(L\,b)v,$$

$$\mu\approx0,25-\qquad\qquad\qquad.$$

$$v=1,6\dots3,2\quad/.$$

$$x_{\max}=1,5\,b.$$

$$Q=2,5\ v_o\ D\,L,$$

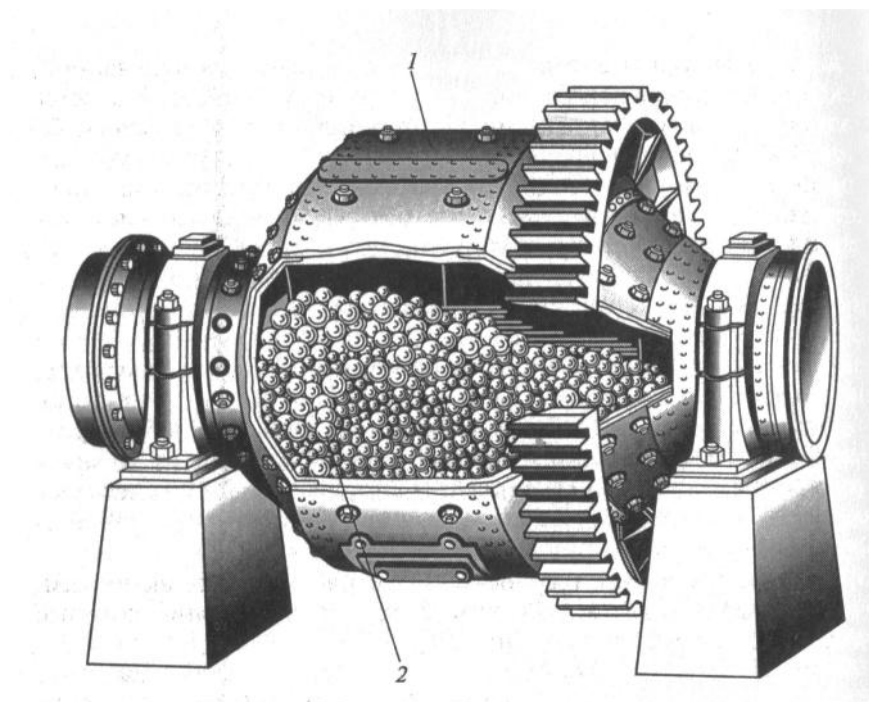
$$v_o-\qquad\qquad\qquad,\quad/;\ D-\qquad\qquad\qquad,\quad;L-\qquad\qquad\qquad,\quad.$$

$$Q=3,3\ v_o\ D\,L.$$

$$(\qquad\qquad\qquad),\qquad\qquad\qquad,\qquad\qquad\qquad,$$

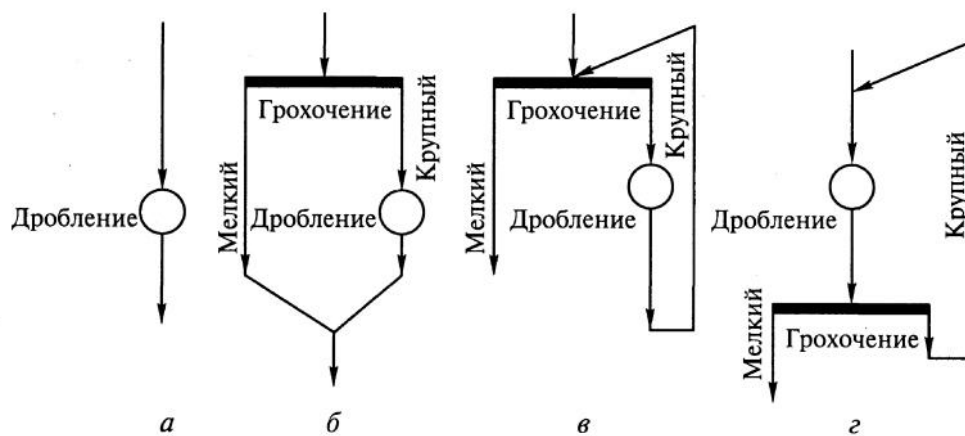
$$-\qquad\qquad\qquad-\qquad\qquad\qquad.$$

() (, -
 ,) .
 (. 19.7)



. 19.7. :
 1 – ; 2 -

75...80 %



. 19.8.

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25...50

⁻¹,

2...4 .

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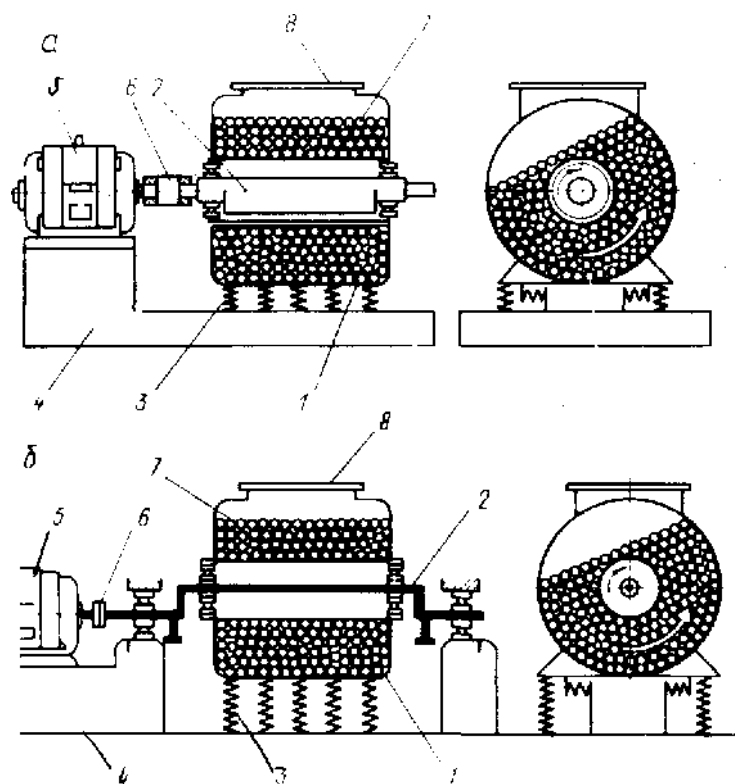
,

,

300 / .

$$\frac{1800 \times 800}{10 \dots 15}^{-1}, \quad \frac{3,6}{43} / .$$

1...2 1...5 .


$$\vdots$$

— ; - ; 1 — ; 2 - ; 3 - ; 4 - ; 5 — -
; 6 - ; 7 - () ; 8 —

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 (, .),
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 1 % ,
 15...20
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 196° ,
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 ,
 .

$$Q(\text{ / })$$

$$Q = q_1 V / (\beta - \beta_0), \tag{19.1}$$

$$Q_1(\text{ / })$$

$$Q_1 = Q(\beta - \beta_0) / 100,$$

$$q_1 - , \text{ / (} ^3 \text{)};$$

$$\beta - \beta_0 -$$

$$, \text{ \%}.$$

$$q, \text{ / (} ^3 \text{)},$$

$$q = Q / V, \tag{19.2}$$

$$V - , ^3.$$

$$q_1 \quad (19.1)$$

$$(19.2) \quad -$$

:

$$q_1 = Q_1/V.$$

,

,

$$\varphi = G / \rho \quad V = (0,26/\psi^2)^{1,18/\psi},$$

$$G - , ; \rho = 4,9 / ^3 -$$

$$; V - , ^3; \psi -$$

.

:

$$G = (\pi D^2/4)L \varphi \rho ,$$

$$D - , ; L - , .$$

$$() -$$

:

$$D = 6 d^{0,5} \lg d ,$$

$$d - , ; d -$$

,

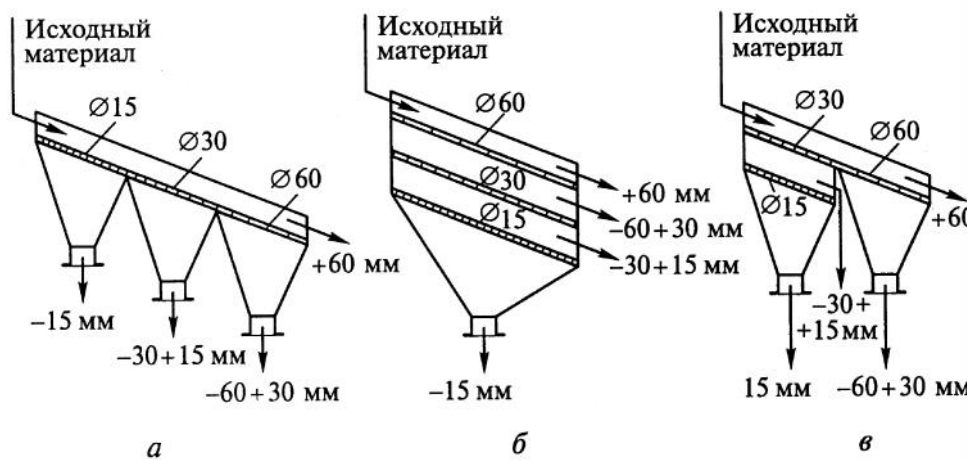
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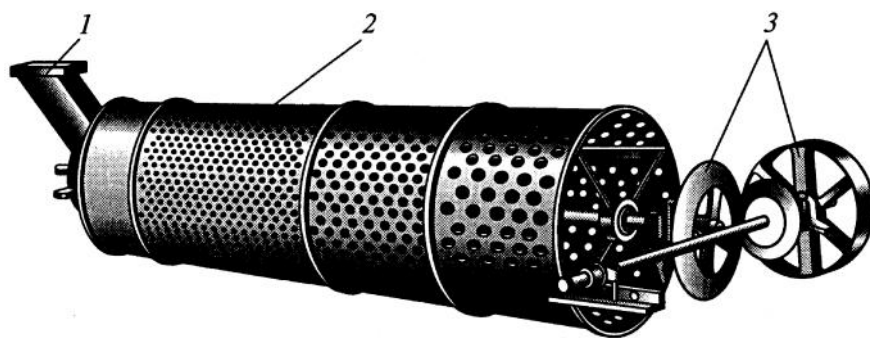
, (. 19.10).



. 19.10.

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,
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 .
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 200
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 , . .
 , 25...50 %, - 75 %.
 .
 .
 , () 25
 .
 (45...50) -
 , -
 , -
 60 %.
 , -
 , -
 , (90...95 %) .
 -
 300 / .
 .
 , , -
 .
 15...50 ⁻¹ 25 0,5 ,
 , . -
 .
 (. 19.11) -
 , .
 -
 .
 , , , .



. 19.11.

:

1 – ; 2 – ; 3 –

20 %

100 / .

2500 × 1500 ,

± 250 , -

85...90 %

2000 / .

()

()

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(),

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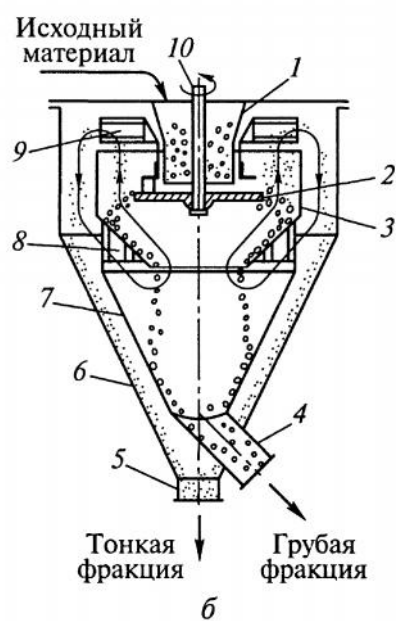
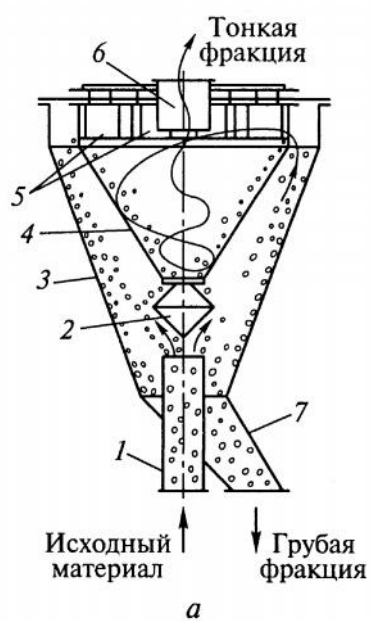
()

()

(. 19.12,)

()

. 19.12, .



. 19.12.

— : 1, 6, 7 — ; 2 — ; 3 — ; 4 —
 ; 5 — ; — : 1, 4, 5 — ; 2 — ;
 3, 7 — ; 6 — ; 8 — ; 9 — ; 10 -

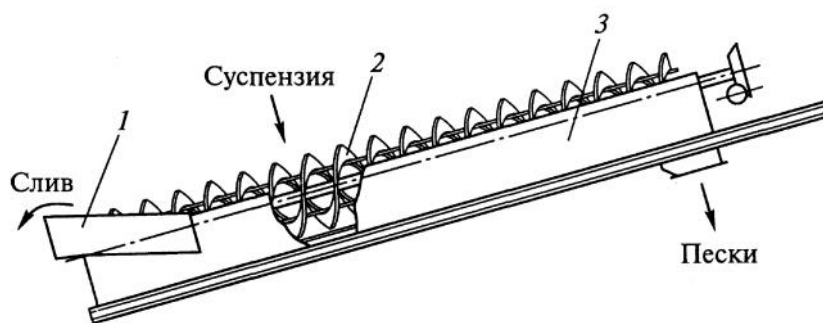
10 / .

100 .

65...80 %.

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 (,),
 () , () ().
 ,
 ,
 10...15°
 ,
 ,
 ,
 3×8,5 ,
 0,59...0,074
 33...10 1 / . 85...95
 %.

(. 19.13)
 ().



. 19.13.

:

1 – ; 2 – ; 3 –

,
 300...1000
 6...190 25...465 , - 1100
 18500 .

, . -
 .
 , . -
 1,0...2,5 . -
 , - ,
 , .
 -
 (), -
 , ,
 .
 10...500 .
 1 20
 600 / .
 1000 1500 150 ^{3/} , - 55
 / .
 . -
 $Q (\text{ } ^3/ \text{ })$
 $q_0, \text{ } ^3/ (\text{ } ^2. \text{ })$, $S (\text{ } ^2)$:
 $Q = q_0 S .$
 $Q (\text{ } / \text{ })$:
 $Q = 600 \rho \gamma n (R^3 \cdot h^3)^{0,5} \operatorname{tg} 2\alpha$,
 $\rho -$, ³; $\gamma -$, $\gamma = 0,2...0,4$; n
 $-$; $R -$, ; $h -$, ;
 $\alpha -$, .
 $Q (\text{ } ^3/ \text{ })$,
 :
 $Q = 160 S \text{ } v$,
 $S -$ (, ²; $v = 0,5...0,6 \text{ } / -$
 .
 -
 $Q (\text{ } ^3/ \text{ })$ -

$$B_1(\text{ / })$$

$$\mu(\text{ / }) -$$

:

$$Q=B_1/(\mu\rho)\,,$$

$$\rho - \quad , \quad / \,^3.$$

:

$$S=Q/v\,,$$

$$v - \quad , \quad /.$$

$$H_V(\text{ / }):$$

$$V=Q/H_V,$$

$$H_V \quad \quad \quad (\quad \quad) \quad \quad \quad H_V=$$

2000...4500.

$$- \quad \quad \quad (\text{ }^3/ \text{ }) \quad \quad \quad :$$

$$Q=9,5\cdot10^3\,k_D\,k_\alpha\,d\,\,d\,\sqrt{g\,p}\,,$$

$$k_D\quad k_\alpha\quad:$$

$$k_D=0,8+\frac{1,2}{1+10D};$$

$$k_r=0,79+\frac{0,044}{0,0379+tg\,r/2},$$

$$D - \quad , \quad ; \, \alpha - \quad , \quad ; \, d - \quad -$$

$$\quad , \quad ; \, d - \quad , \quad ; \, p - \quad -$$

$$,\quad \quad .$$

$$\quad . \quad \quad \quad -$$

$$(\quad \quad , \quad \quad) \quad \quad -$$

$$\quad \quad \quad -$$

$$,$$

$$.$$

$$,\quad \quad \quad -$$

$$\quad . \quad \quad , \quad \quad \quad -$$

$$-$$

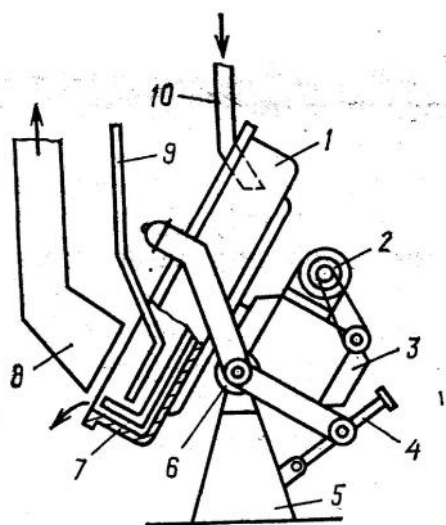
$$.$$

$$.$$

$$(\quad \quad) \quad \quad , \quad \quad , \quad \quad -$$

: ,
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 (. 19.14)

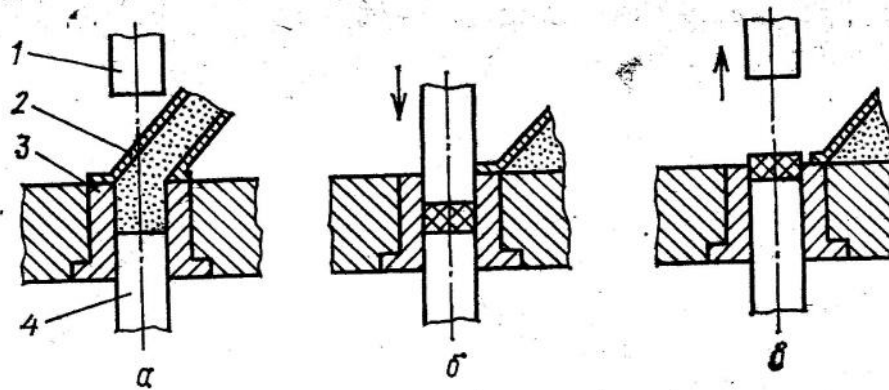
1...6 , 0,6 .



. 19.14.

1 – ; 2 – ; 3 – ; 4 – ; 5 – ;
 6 – ; 7 – ; 8 – ; 9 – ; 10 –

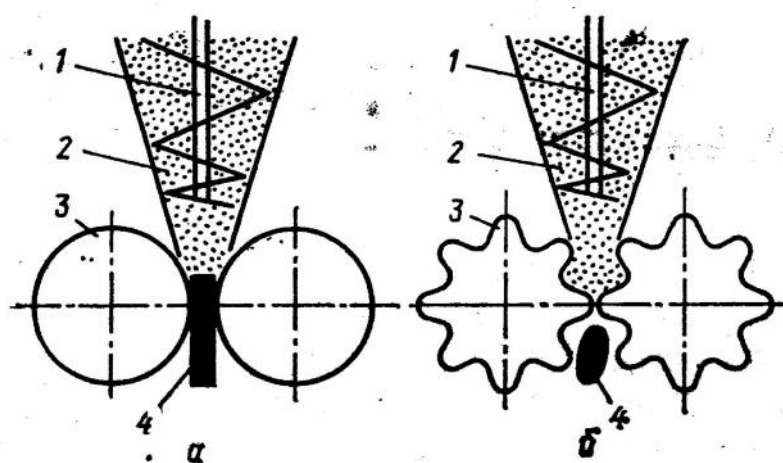
(. 19.15).



. 19.15.

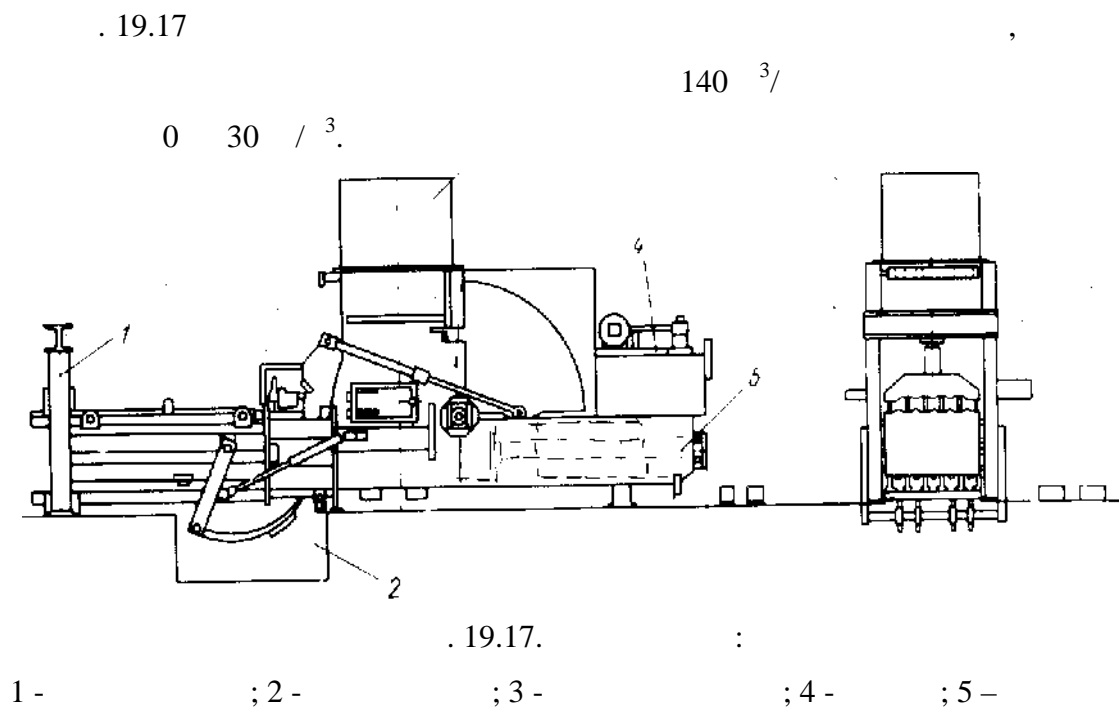
— ; — ; — : 1 —
; 2 — ; 3 — ; 4 —

(. 19.16).



. 19.16.

() () :
1 — ; 2 — ; 3 — ; 4 — ()



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 .
 $Q(/)$ $D()$:
 $Q = K D^2,$
 $K -$,

q :

$$D = \sqrt{\frac{Q}{0,785q}},$$

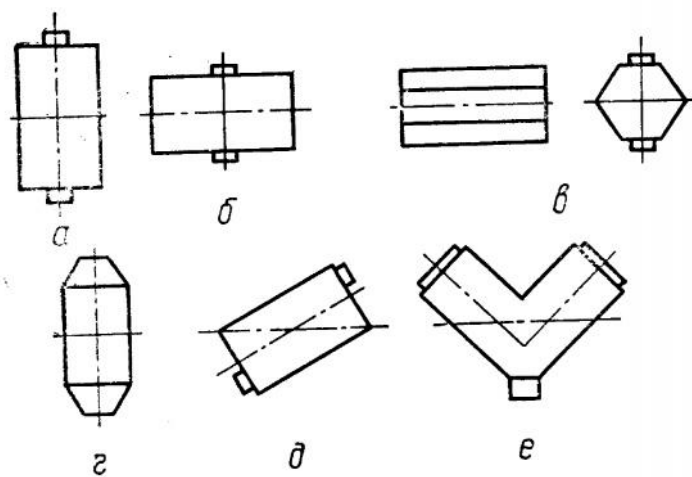
$q = (0,77...0,91) / (^2)$.
 $Q(/)$:
 $Q = 188,4 \cdot 10^3 \psi \rho \ b \ n \ L \ D,$
 $\psi = 0,5...0,6;$ $\rho -$, $/ ^3;$ $b -$
 , $;$ $n -$, $^{-1};$ $L -$, $;$ $D -$
 , .

:
 $Q = 60 \cdot 10^{-6} S b \dots m n,$
 $S -$, $^2;$ $b -$, $;$ $\rho -$
 , $/ ^3;$ $m -$ (); $n -$.
 (/) :
 $Q = 6 \cdot 10^{-5} g \ m \ n ,$
 $g -$, $;$ $m -$; $n -$.

K_c .

i

(. 19.18).



. 19.18.

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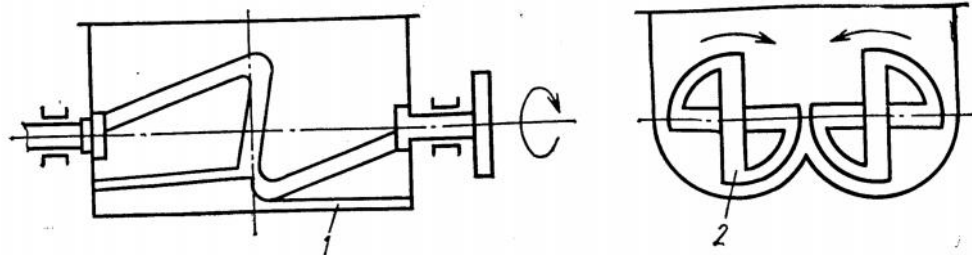
; —

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$$V - \frac{1}{2} \left(\frac{1}{\rho} \frac{d\rho}{dt} \right)^2, \quad \frac{1}{\rho} \frac{d\rho}{dt} = \frac{1}{\rho} \frac{d\rho}{dt}, \quad \frac{1}{\rho} \frac{d\rho}{dt} = \frac{1}{\rho} \frac{d\rho}{dt}, \quad \frac{1}{\rho} \frac{d\rho}{dt} = \frac{1}{\rho} \frac{d\rho}{dt},$$

$$n = (1500 \dots 2000) \sqrt{\frac{d}{R_{\max}}},$$
$$P = \frac{G}{102} R_0 \check{S} \sin \{ ,$$

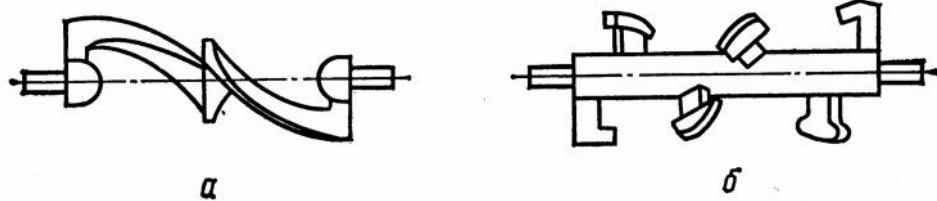
.



19.19.

1 – ; 2 –

19.20,) - (19.20,) ,



19.20.

($\frac{3}{4}$):

$$Q = V \frac{60S}{f} i \{ ,$$

ω - , / ; i - ; φ -

($\varphi = 0,3 \dots 0,5$); V -

, ³

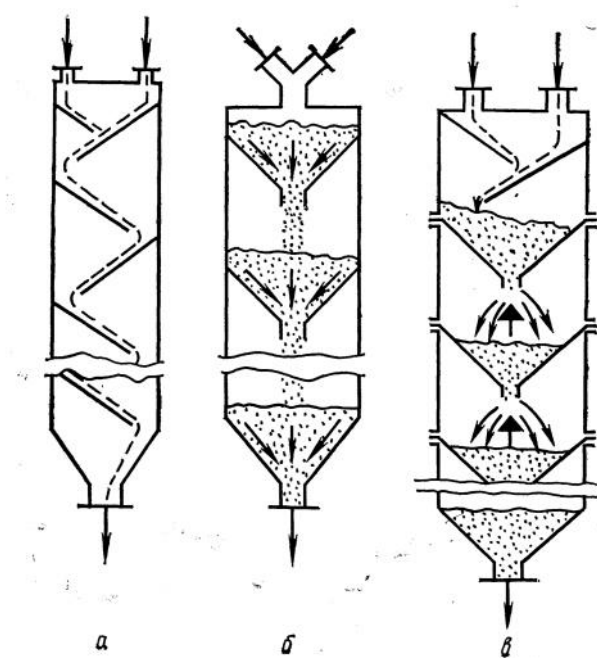
$$V = \frac{f}{4} (D^2 - d^2) (s - u),$$

D - , ; d - , ; s - ,

; δ - , .

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 . -
 . -
 » , 0,8...1,8 .
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 : ,
 .
 0,45 ³ , 3...4 , 6...9 ³/ , -
 75 .
 .
 . -
 . -
 , , , .
 . -
 (ρ = 300...500 / ³) -
 $K_c = 1,5...2 \%$.
 .
 18 / , 5 , 0,8.
 . , -
 , — .
 . -

(. 19.21)



. 19.21.

$$(\quad, \quad, \quad).$$

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 $(4^\circ).$

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19.2.

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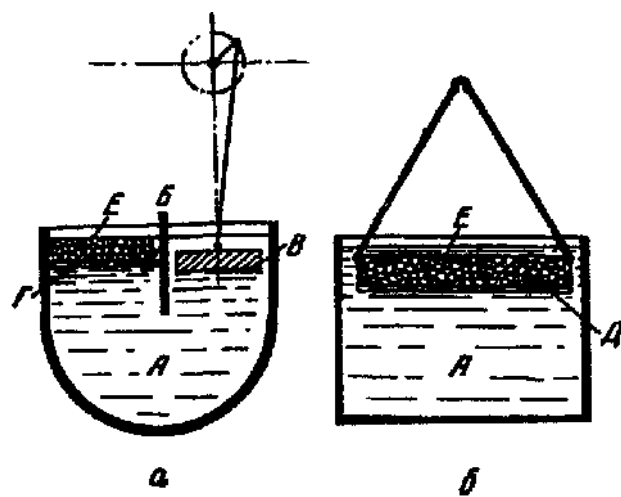
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100...0,5;

– 50...0,25).



. 19.22.

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 , 5...15 / (²) 600
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 ,
 12...30 220...280 -1. , -
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 ~ 2 -
 100 / .
 , , (1
 / ³).
 1 / ³ .
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 (),
 PbS (7,5), Fe₃O₄ (4,2), BaSO₄ (4), (6,5...6,8)
 15...18 % .

,
 , 60 % ~ 40 .
 25 %, 3,0...3,5 / ³.

-
 (0,1 / ³)
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 . - ,
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 ,
 .
 (/)

:
 $Q = 3600 \rho \ B H \nu$,
 ρ – , / ³; B –
 , ; H – , ; ν –
 , / .

$t \tau ()$
 f f :
 $t = \ln \frac{f}{f - f} \cdot \frac{1}{k}$,

$k = (0,01...0,05)^{-1}$ – ,

n $L ()$,
 :

$$n = \frac{250}{\sqrt[5]{d_{\max}}}; \quad L = \frac{18}{\sqrt[4]{d_{\max}}},$$

d_{\max} – , 5 %.

(/)

:

$$Q=\frac{1}{\chi D^{0,5}h^{1,5}v_{\text{u}}},$$

γ - , ; D - , ; h - -

($h = 1,2...1,5$), ; $v = 0,3...0,5$ / -

; δ - , / ³.

. (/) -

:

$$Q=qS,$$

q - ,

/(²); S - , ².

• , -

, (,

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100,

40 () 6,7 (,

), - 0,40...1,82 (, ,), -

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0,37 (, , .). -

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• -

, (120...150) , -

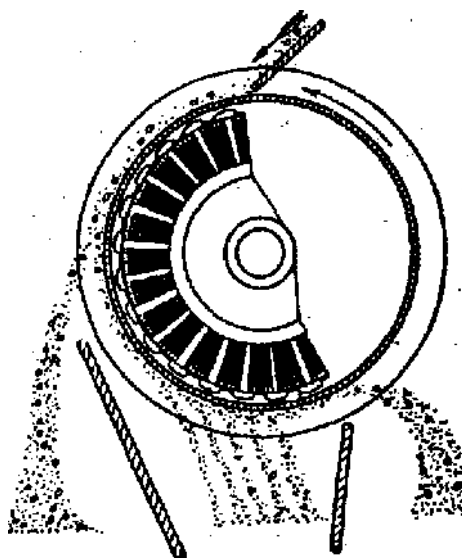
, •

(6...8) ,

() • -

,

(. 19.23).



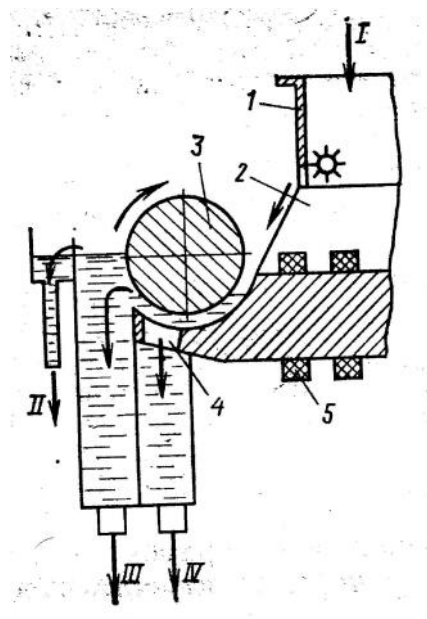
. 19.23.

().

60 / 1

(. 19.24)

(, ,)



. 19.24.

:

I – ; II – ; III – ; IV – ; 1 – ; 2 –
 – ; 3 – ; 4 – ; 5 –

5 ,
 (,).

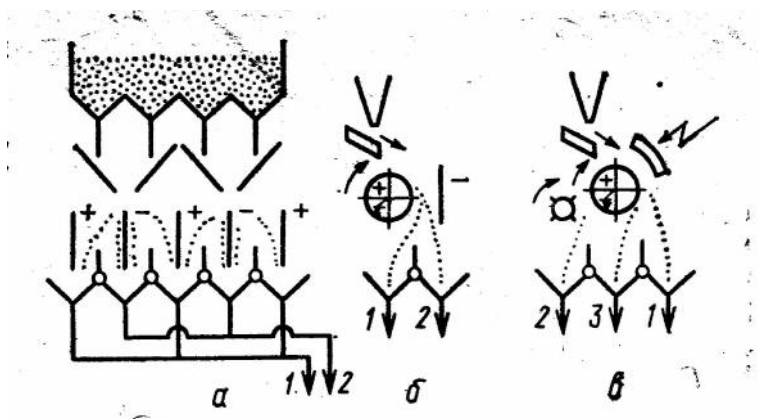
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()

(. 19.25).



. 19.25.

1 -

; 2 -

; 3 -

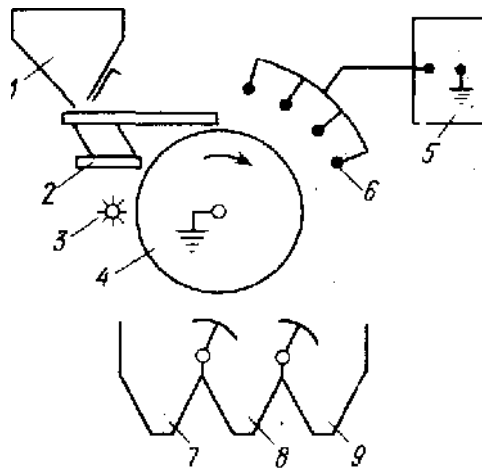
20 / ,

500

-1

20...50 .

. 19.26



. 19.26.

1 – ; 2 – ; 3 – ; 4 – ();
5 – ; 6 – ; 7, 8, 9 –

, , - 4, -
6. -

8.

7.

3, -

500 / ³

8000 / .

F

B

H :

$$F = \mu_0 \chi H_{\text{grad}} H,$$

$$B = \mu \mu_0 H = \mu_0 (\chi + 1) H,$$

$(H_{\text{grad}} H) -$, $^2/ ^3$; $\mu_0 = 1,26 \cdot 10^{-6}$ / -
 (); $\mu -$.
 -
 1 :
 $Q = q n L$,
 $q -$, $/(\cdot)$; $n -$,
 ; $L -$, .
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 . -
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 () -
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 (). -
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 , (-
) (). -
 . -
 $4,2 / ^3$, $2,6 / ^3$
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 () (). -
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(. . 12.8) -

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- ,
25...35 % , 0,3...0,5 , -
10...200 / , 50...1000 / ,
10...10000 / .

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19.3.

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(. . 18.23). , -

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(. 19.27)

1,

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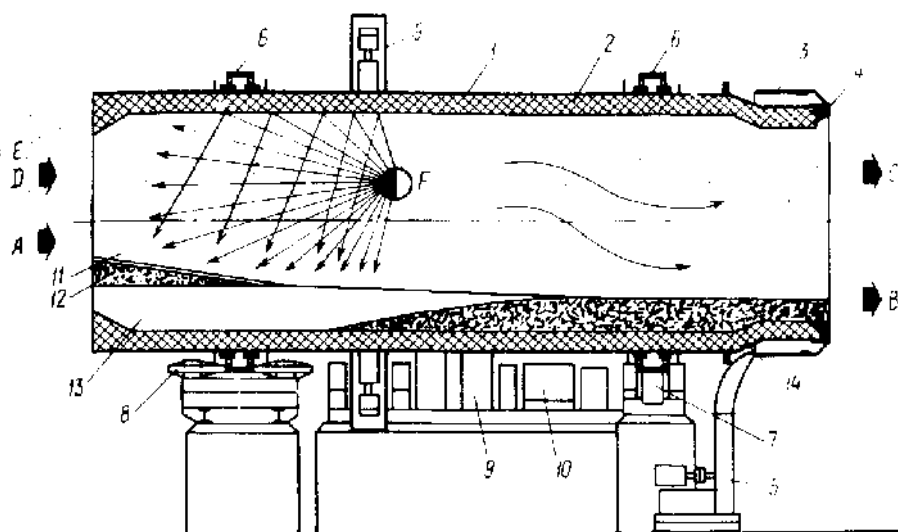
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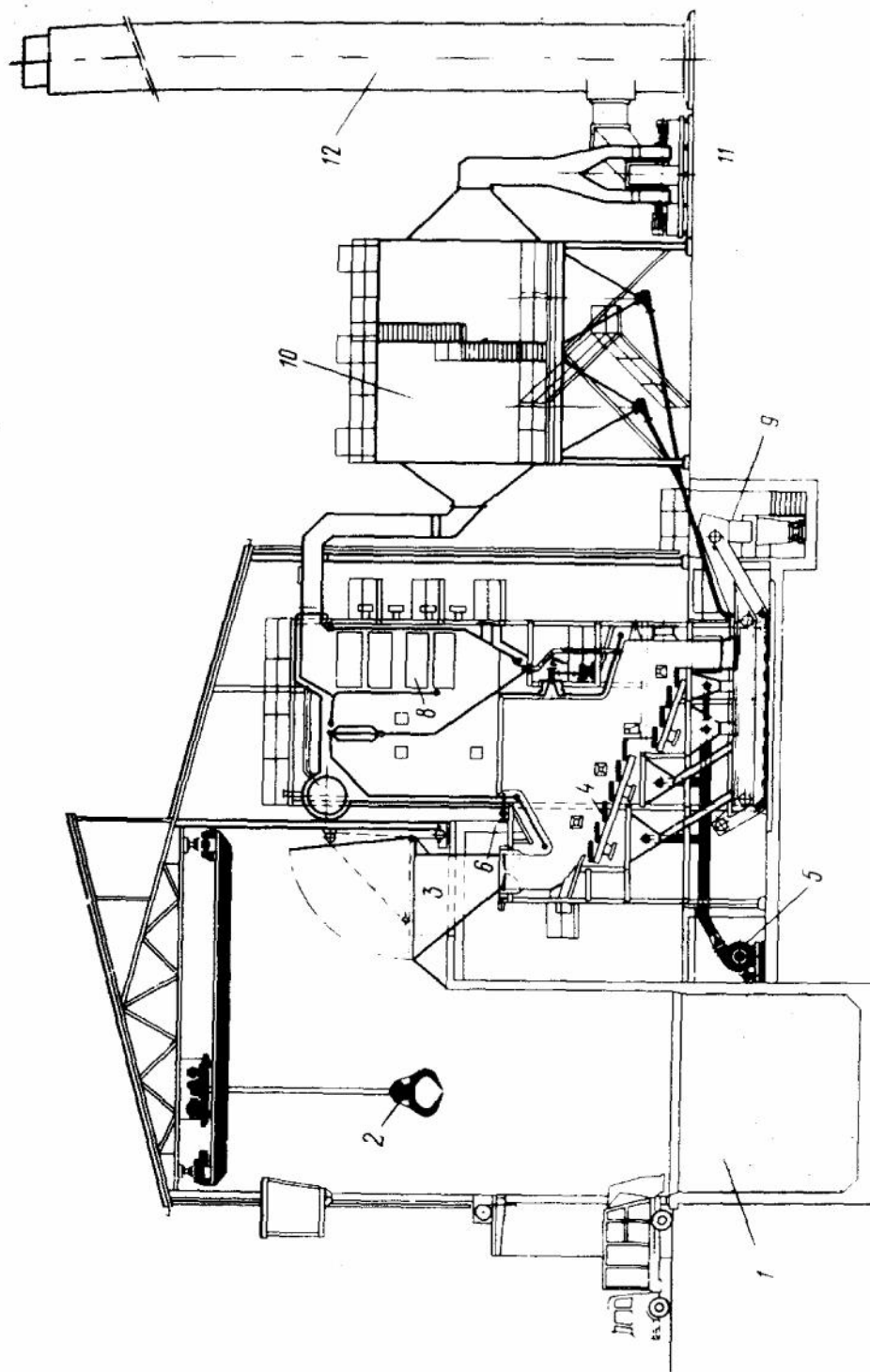
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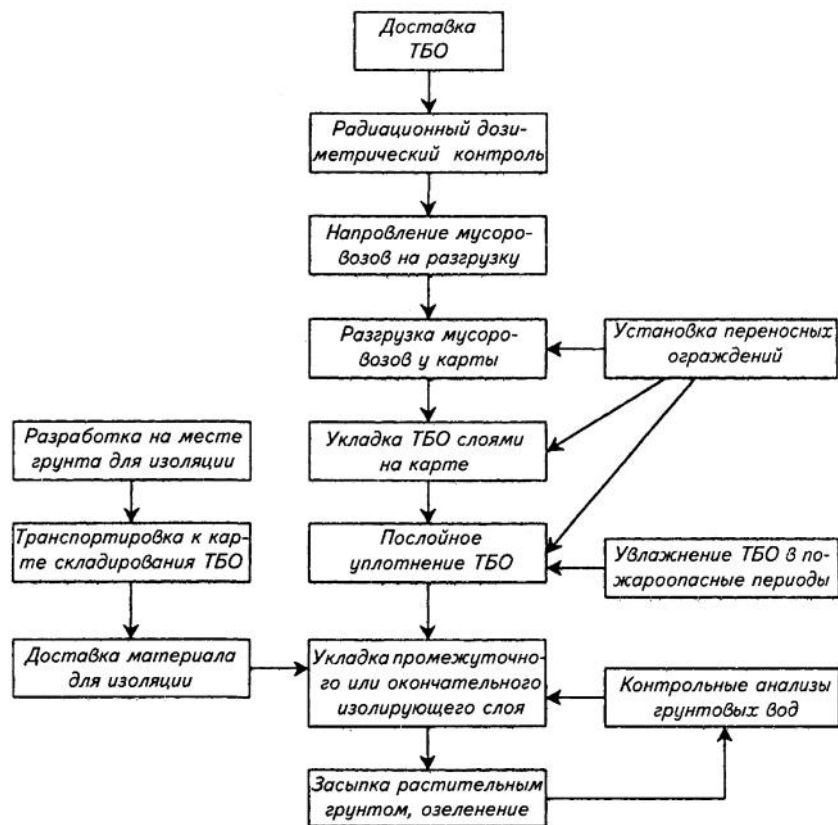
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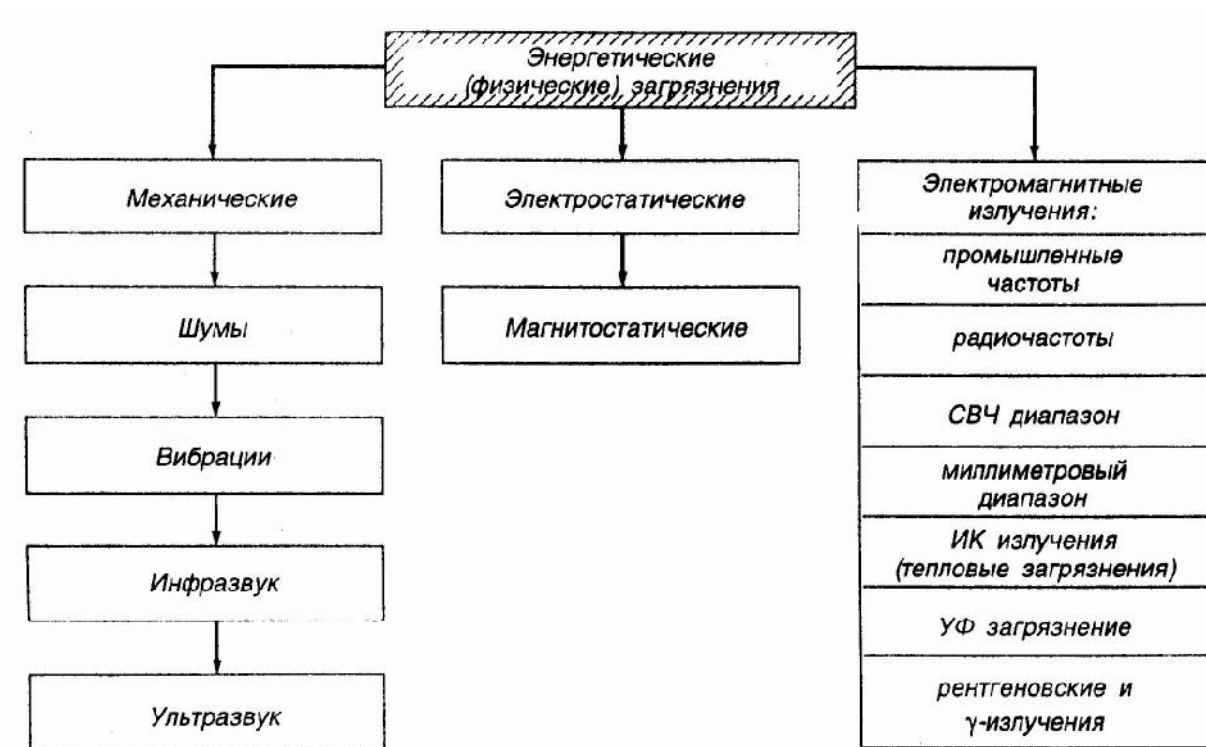
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. 22.1.

22.1.

$$L$$

$$L_{\text{tot}}=L+\sum_{i=1}^n\Delta_i\,,$$

$$L_{\text{tot}}=\sum_{i=1}^n\Delta_i-$$

$$L_J$$

$$L_J=10\lg\frac{J}{J_0},$$

$$J=J_0-$$

$$J_0=10^{-12}\text{ W/m}^2) \quad L$$

$$L_J=L+10\lg\frac{\cdots_0c_0}{\cdots c}=L+\Delta L\,,$$

$$\rho_0c_0=410\text{ kg/m}^3-$$

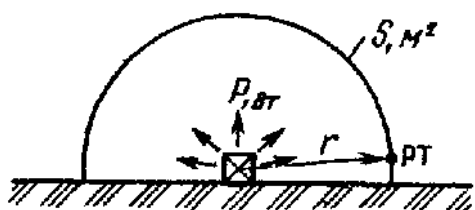
$$(\lambda=293\text{ nm}=1034\text{ nm});\rho=10^{-3}\text{ kg/m}^3;\Delta L_{\text{a}}=10^{-3}\text{ m};$$

$$L_J=L. \tag{22.1}$$

$$\Delta L_{\text{a}}=10^{-3}\text{ m} \tag{22.1}.$$

$$(\text{Fig. 22.2}),$$

$$J=\frac{\Phi\tilde{S}}{S\,k}. \tag{22.2}$$



. 22.2.

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 - ; S — ,
 , 2 . $S = \Omega r^2$, Ω — ,
 4 , 2π —
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 (22.2)
 J_0 ,
 :

$$L = L_p + 10 \lg \tilde{S} - 10 \lg \Omega - 20 \lg r - \Delta L_p , \quad (22.3)$$
 L_p - () ,
 ΔL_p - .
 (22.3) () 6 -
 ,
 (50) L_p .
 ,
 $\Delta L_p = S \cdot r / 1000$, -
 (. 22.1):

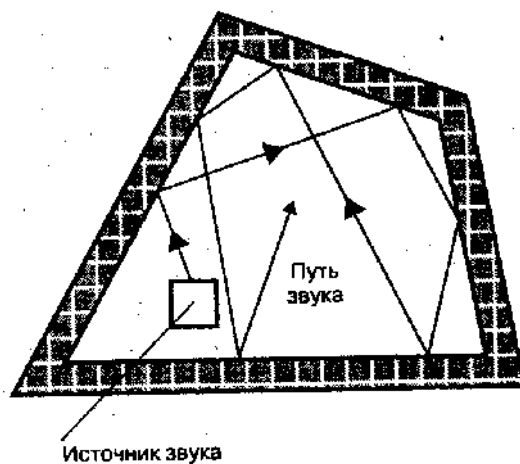
22.1

-	63	125	250	500	1000	2000	4000	8000
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$$L_i = L.$$

(. 22.3)

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. 22.3.

$$L = L_p + 10 \lg \left(\frac{t \check{S}}{\Omega r^2} + \frac{4E}{B} \right),$$

- , (. 22.4); -
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(= 1), -
; r - , ; B -
, ²;

$$B = \frac{\bar{r} S}{1 - \bar{r}};$$

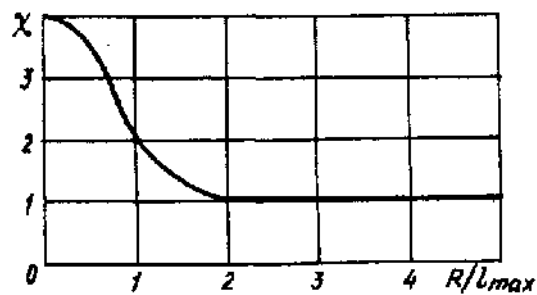
\bar{r} - :

$$\bar{r} = \sum_{i=1}^n r_i S_i / S;$$

S - , ²; r_i -

()

S_i , ².



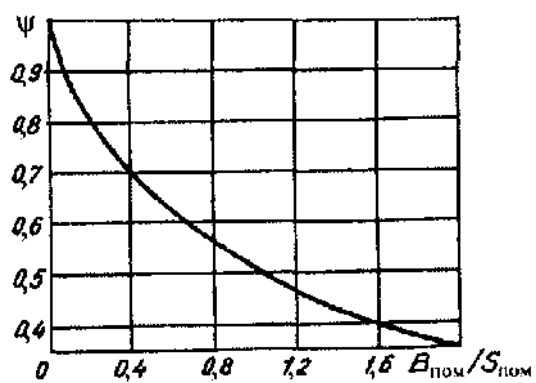
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$$L_p = L + 10 \lg S - u, \quad ,$$

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$$J = \frac{\Phi}{\Omega r^2} + \frac{4\Phi}{A}(1 - \overline{r}),$$
 r — () ; A -

$$L_J = L_\Phi + 10\lg\left(\frac{1}{\Omega r^2} + \frac{4(1 - \overline{r})}{A}\right) \quad ,$$
(22.5)

$A = \overline{r} \quad S$.
 (22.5) :

22.2.



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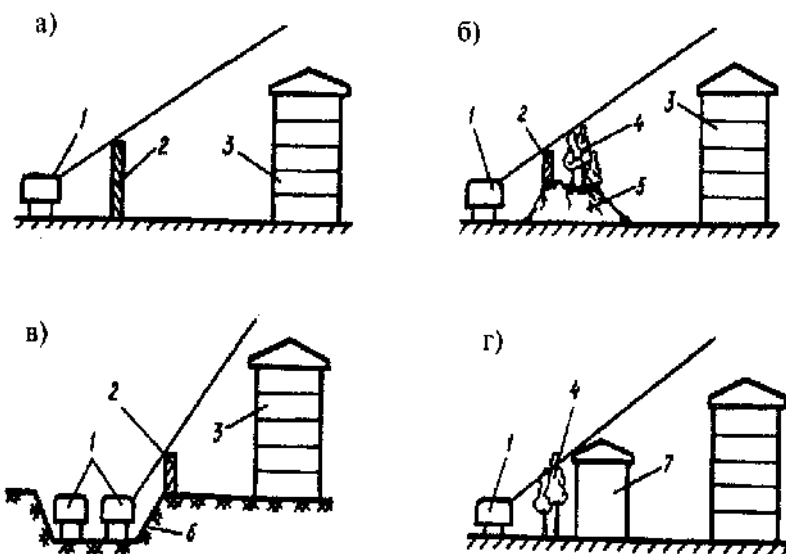
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(. 22.7).

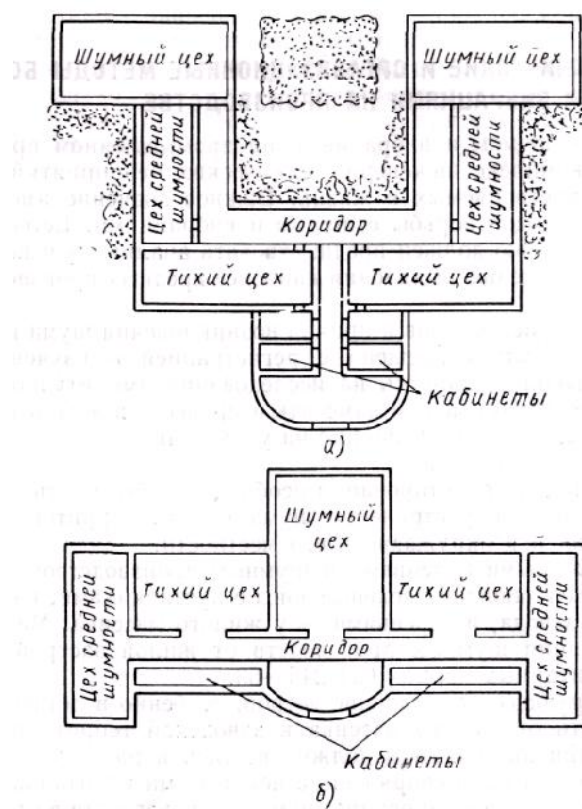


. 22.7.

1 - ; 2 - ; 3 - ; 4 -
; 5 - ; 6 - ; 7 -

); - 5...15 ; - 3...8 ;
- 25...30 ; - 15...20 .

2...4 () 20...25 ().

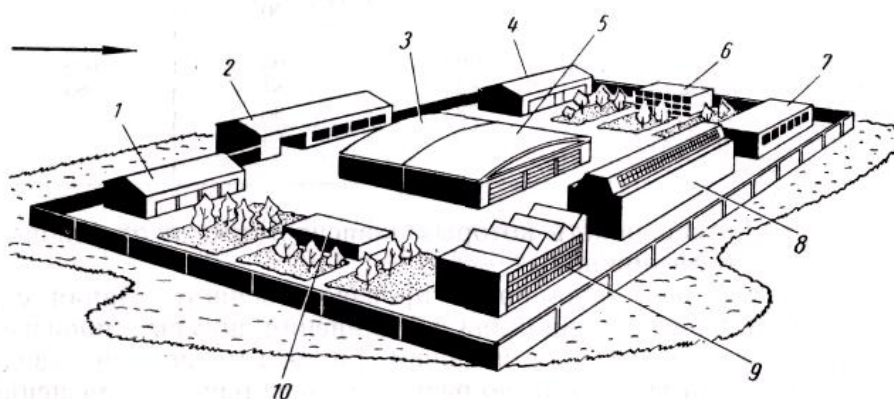


. 22.8.

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. 22.9.

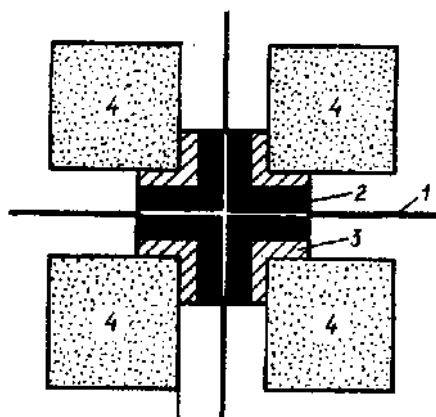


. 22.9.

1 — ; 2 — , ; 3 —
 (80...85); 4 — ; 5 — (70...80); 6 —
 120 ; 7 — (110); 8 — (100); 9 —
 (100); 10 — (100)

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(. 22.10).



. 22.10.

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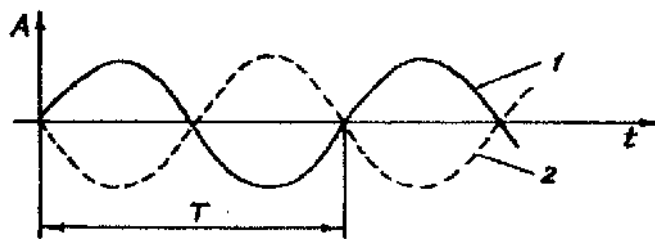
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. 22.11.

(1 2)

$$A = \sqrt{A_1^2 + A_2^2 - 2A_1A_2 \cos \{ ,$$

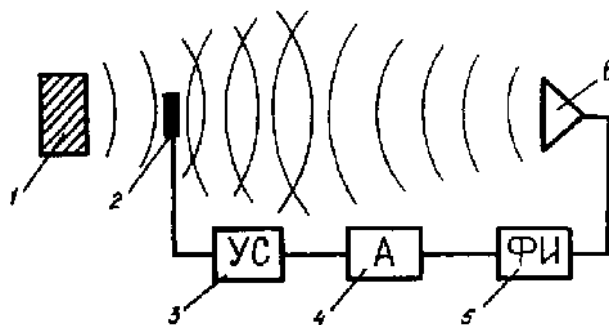
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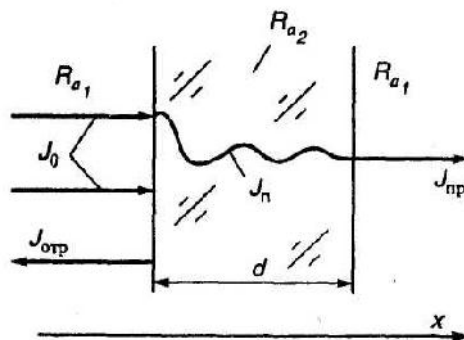
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(. 22.13).



. 22.13.

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(R_1, R_2) .

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$(\quad) J$,

J_0 :

$$r = \frac{J}{J_0}.$$

J

J_0

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$$S = \frac{J}{J_0}.$$

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J , :

$$\dagger = \frac{J}{J_0},$$

$$J_{-}=J_0-(J_{+}+J_{-}).$$

$$\dagger = \frac{J_0-(J_{+}+J_{-})}{J_0}=1-(s+r).$$

,

:

$$r = \frac{J_0-(J_{+}+J_{-})}{J_0}=1-(s+\dagger).$$

,

:

$$+_{-}+_{+}=1.$$

$$R_{-},R_{+},$$

-

:

$$\dagger = 1-\left|\frac{R_{-}-R_{+}}{R_{-}+R_{+}}\right|^2.$$

$$R_{+}\gg R_{-},\quad \text{---}.$$

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$$A = A_0 \exp(-t x)$$

$$J = J_0 \exp(-2t x),$$

$$\left(\begin{array}{cc} -1 & -1 \end{array} \right).$$

$$> 0,3.$$

$$h$$

6 %

0,8,

100 :

$$h = \frac{28,5}{\sqrt{r}}; \quad (22.6)$$

$$h = \frac{2,6 \cdot 10^3}{r}, \quad (22.7)$$

$r =$

$$r > 10^4 \quad \cdot / \quad ^4 \quad (22.7), \quad r < 10^4 \quad \cdot / \quad ^4 \quad \text{—} \quad (22.6).$$

$f_1:$

$$f_1 = \frac{c}{5,28h}, \quad (22.8)$$

$$/ \quad ; \quad h —$$

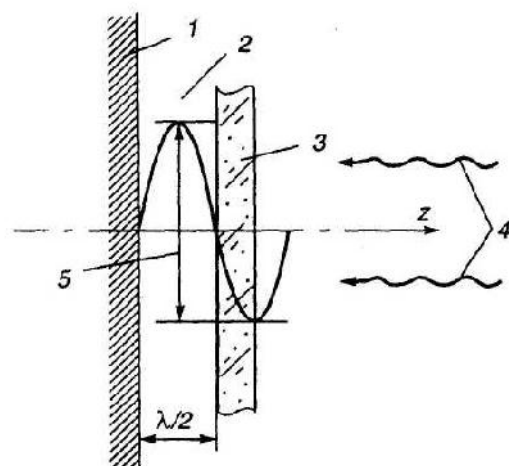
f_1 ; f_1 -

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(22.6) — (22.8).

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22.14).



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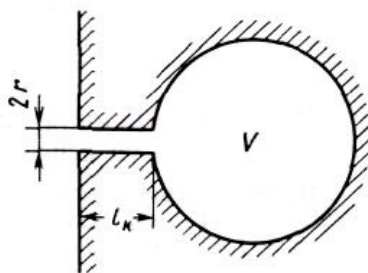
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(. 22.15).



. 22.15.

$$f_0 = \frac{5,4 \cdot 10^3}{\sqrt{\frac{l_k V}{S}}}, \quad (22.9)$$

V — 3 ; S — 2 ; l — ;

$$l = l + 1,57 r.$$

l — ; r —

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, (22.9).

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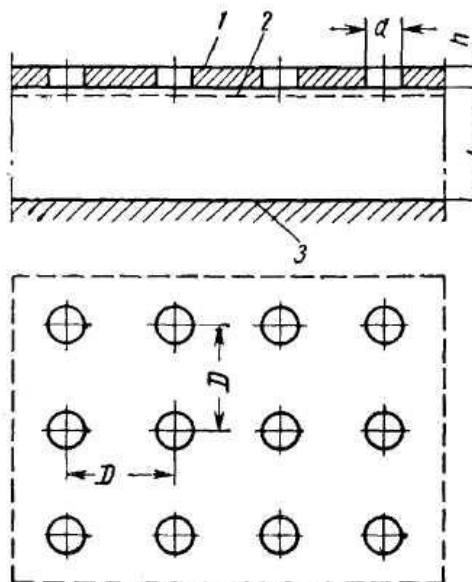
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$$= \frac{1}{6,28} \left(\frac{\quad}{f_0} \right)^2.$$

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. 22.16.

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$$\Gamma_0 = \frac{4R \cos_{\theta}}{(\overline{R} \cos_{\theta} + 1)^2 + [\dots c m \cos_{\theta} - \operatorname{ctg}(k L \cos_{\theta})]^2},$$

k — $(k = \frac{\check{S}}{c})$; L — ;

$$\overline{R} = \frac{R}{\dots c}.$$

$$R = r_1 \frac{S}{S_1};$$

r_1 — , , ; S — , ; S_1 — - .

$$\overline{m} = \frac{m}{\dots c}.$$

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 d

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$$\overline{m} = \dots \left[D \left(1,13 \frac{D}{d} - 1,21 \right) + 1,27 h \left(\frac{D}{d} \right)^2 \right],$$

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$$r = \int_0^{f/2} r_{\pi} \sin 2_{\pi} d_{\pi} ,$$

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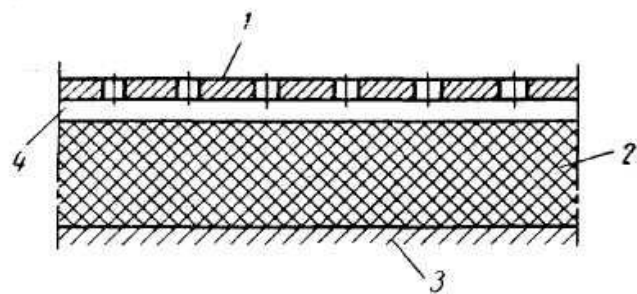
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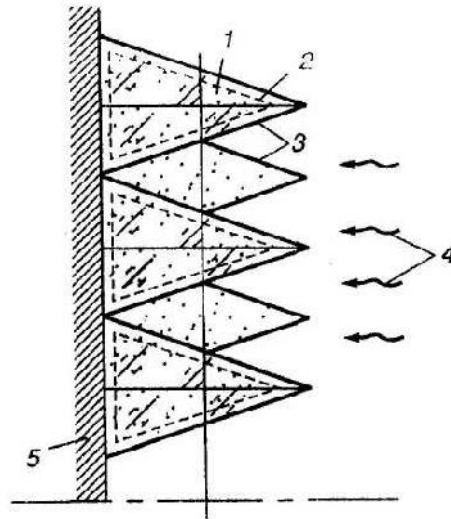
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. 22.17.

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(. 22.18).

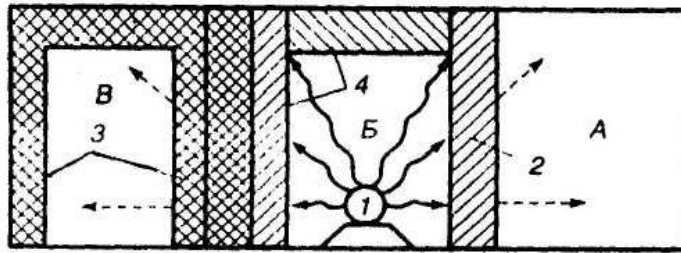


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\bar{w}_0

$$\bar{J} = \bar{w}_0 c,$$

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$$\frac{w_0}{c} = \frac{4f \bar{J}}{c}$$

$$\overline{J} = \frac{\overline{w_0 c}}{4f}.$$

$$= 4$$

$$d\bar{J} = \frac{\bar{w}_0 c}{4f} d\Omega.$$

$$d\Omega = \sin\epsilon \, d\epsilon \, d\zeta \, .$$

$$\Phi = \frac{\overline{w_0 c}}{4f} \int_0^{2f} \int_0^{f/2} \cos \epsilon \sin \epsilon \, d\epsilon \, d\zeta.$$

$$\Phi = \frac{\overline{w_0} c}{4} = \frac{J}{4},$$

$$\frac{-}{w_0} = \frac{4\Phi}{c} = \frac{J}{c}. \quad (22.10)$$

(22.10)

$$\Phi = \Phi \quad r = \frac{\overline{r_{w_0 c}}}{4}.$$

$$\Phi_{,\Sigma} = \frac{A w_0 c}{4}, \quad (22.11)$$

$$A = \sum_{i=1}^n (r_i S_i); \quad S_i —$$

($\epsilon = 1$):

$$\Phi = \Phi_{\Sigma},$$

Φ —

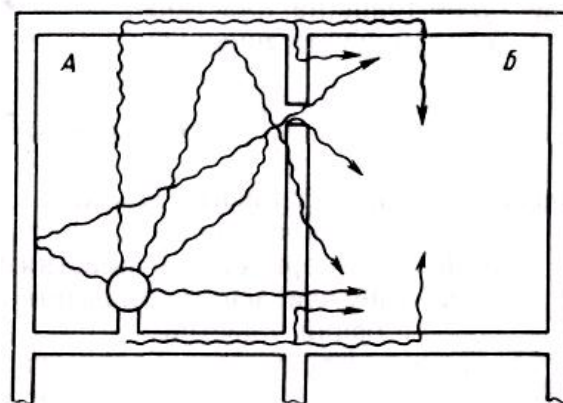
(22.11)

$$\Phi = \frac{\overline{w_0} c A}{4}.$$

$$\overline{w_0} = \frac{4\Phi}{Ac}. \quad (22.12)$$

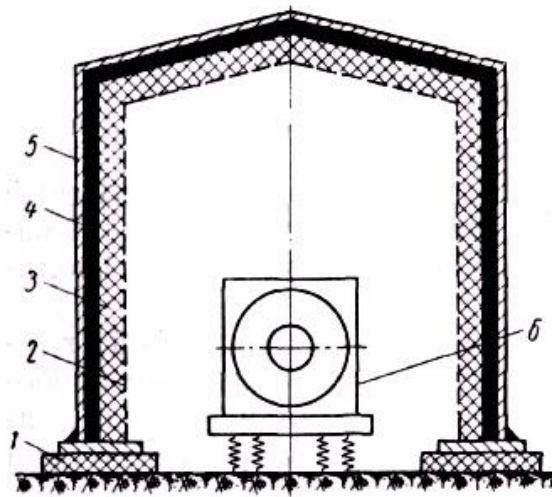
(22.12)

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. 22.20.

8...10



. 22.21.

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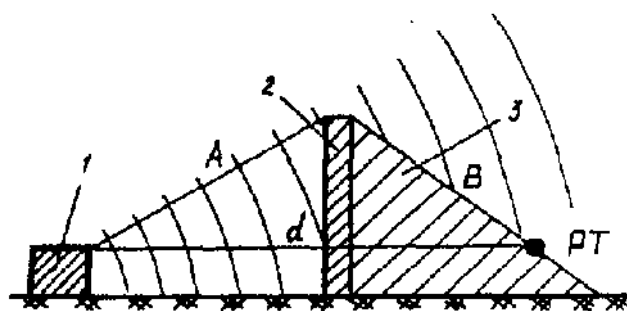
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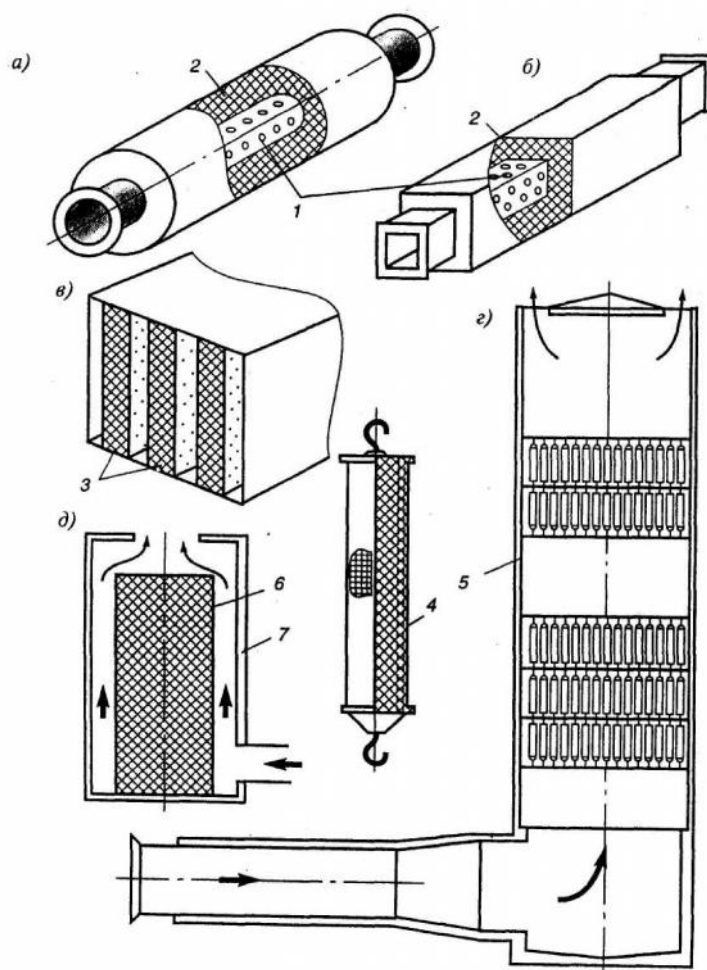
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. 22.23.



. 22.23.

(. 22.23, ,)

1

2 -

500...600 .

L :

$\Delta L \cong l r \Pi / \Delta S$,

l — ; — ; Π —

; ΔS —

20

500 150 3000 -

0,6 12 .

(. 22.23,).

3,

200 600

50 100 .

25...30 .

5 4 (.

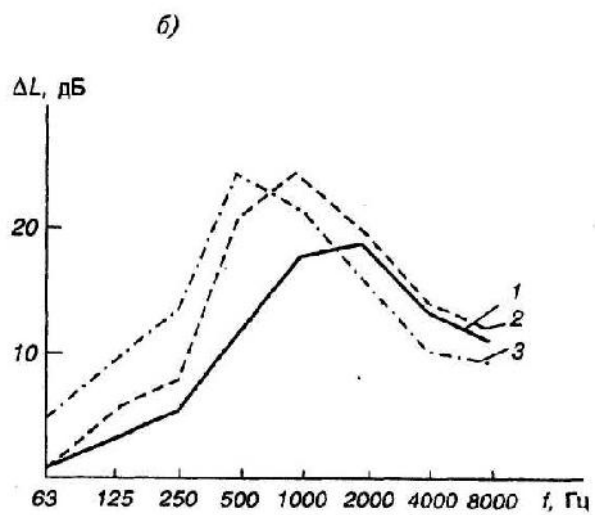
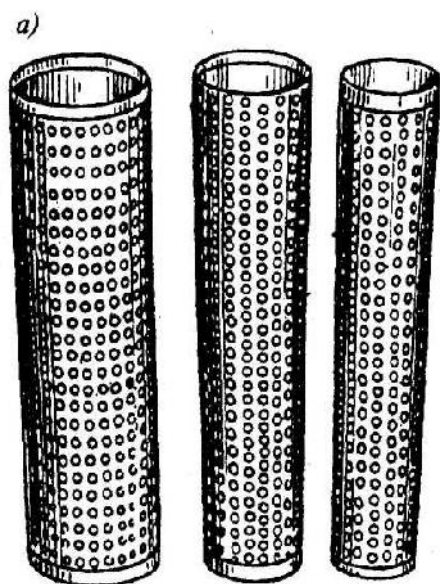
22.23,)(0,2 1),

22.23,)

6(1,5...2 , 6...8),

7.

. 22.24, .



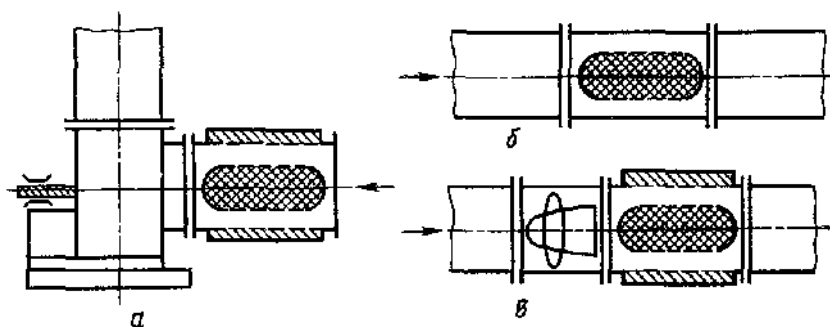
. 22.24.

140 (1), 250 (2) 560 (3)

L

. 22.24, . L

. 22.25.



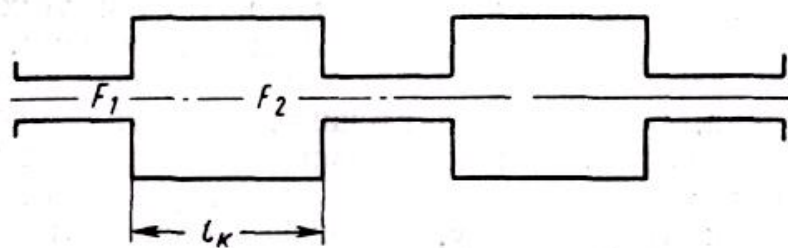
. 22.25.

() ; -

р.

« »,

(. 22.26)



. 22.26.

F_1 –

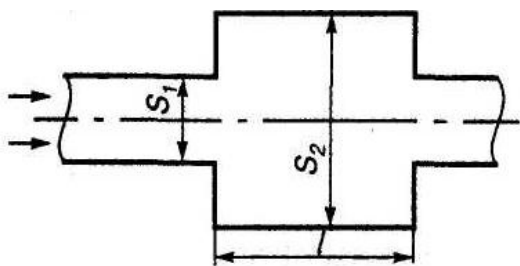
; F_2 –

; l –

l .

()

(. 22.27).



. 22.27.

S_2 -

S_1

$$l = (\pi/4)n \quad (n = 1, 3, 5 \dots).$$

(. 22.28)

f ,

:

$$f = \frac{\tilde{S}}{2f} \sqrt{\frac{K}{V}},$$

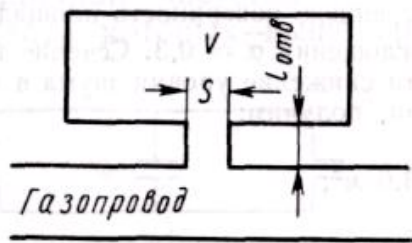
$$K = S_0(l + 0,8) —$$

(); d —

; l —

; S_0 —

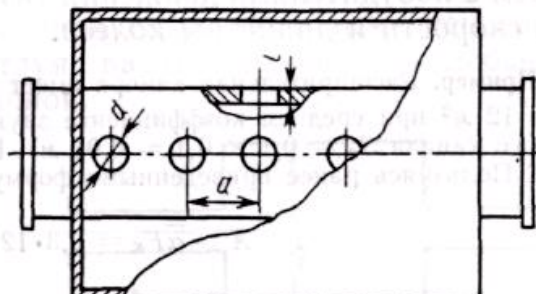
; V —



. 22.28.

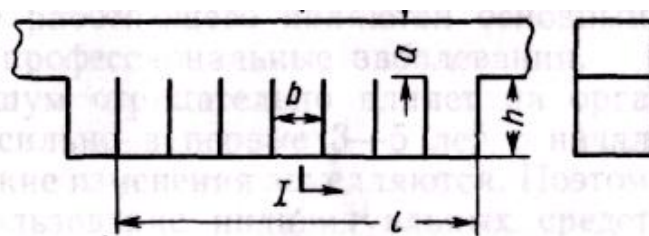
$$\sqrt{KV/2S}, \quad S$$

(. 22.29).



. 22.29.

. 22.30



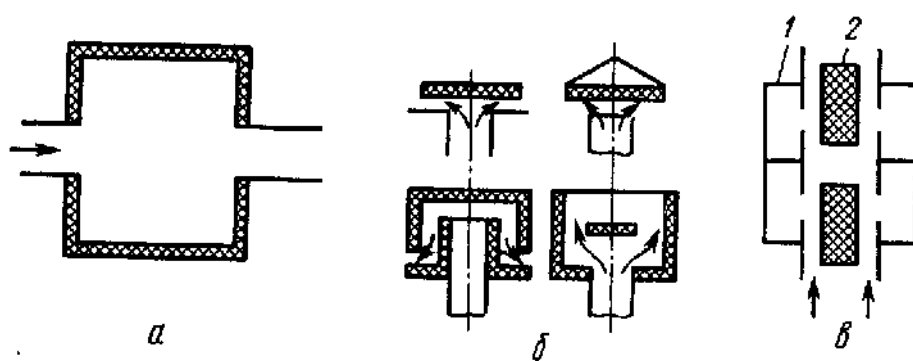
. 22.30.

l — ; b — ; a — ; h —

$$f_0 = \frac{c}{4h_1} = \frac{c}{\quad},$$

h_1 — (); $h_1 = h + 0,4d$ (d —); —

(. 22.31).



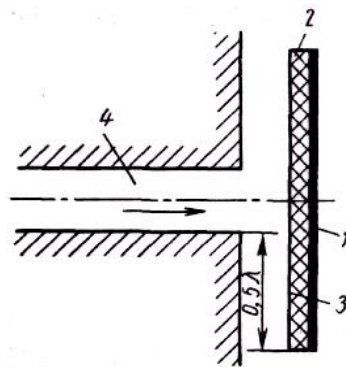
. 22.31.

:

; - ; -
; 1 - ; 2 -

$$f \geq \frac{c_n}{4} \}$$

(. 22.32)



. 22.32.

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1 – ; 2 – ; 3 –
; 4 -

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40 .

22.3.

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()

$$\Delta L = 10 \lg(A_2 / A_1),$$

$$A_1 = \sum_{i=1}^n r_{i1} S_{i1},$$

$$A_2 = \sum_{i=1}^m r_{i2} S_{i2};$$

1 2 -

, ²; r_{i1} r_{i2} -

i -

; S_{i1} S_{i2} - i -

2.

. 22.4

r

		63	125	250	500	1000	2000	4000	8000
-	20	0,02	0,03	0,17	0,68	0,98	0,86	0,45	0,20
	—	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
-	50	0,1	0,25	0,7	0,98	1,0	1,0	1,0	0,95
-	50	0,02	0,15	0,46	0,82	0,92	0,93	0,93	0,93

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 r -

$w_0 = \frac{\Phi_0 \check{S}}{\Omega r^2 c},$

(22.13)

Φ_0 — ; — , —
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$$A = \sum_{i=1}^{i=n} r_i S_i,$$

S_i — i - ,
 Φ , (—
),

$$w_0 = \frac{4\Phi}{cA}. \tag{22.14}$$

, .

$$w_{0(t)} = w_{01} e^{-\frac{cAt}{4V}}, \tag{22.15}$$

w_{01} —
 ; V — ; t — ; — .

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 10^6 ,
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60 .

$$\frac{w_{01}}{w_0} = 10^6. \tag{2.15}$$

$$T = \frac{4V}{cA} 2,3 \lg \frac{w_0}{w_t}$$

$$T = \frac{4V}{340A} 2,3 \cdot 6 = 0,162 \frac{V}{A}. \tag{22.16}$$

$$(22.16).$$

$$1...3$$

$$3$$

$$T = \frac{0,162 V}{S \ln \frac{1}{(1-\bar{r})}}, \tag{22.17}$$

$$V - \quad ; S - \quad ; \bar{r} -$$

$$(22.16), (22.17),$$

$$A = 0,35V^{2/3} \qquad A = 17 \lg V.$$

$$V - \quad ^3.$$

$$(22.13).$$

$$(22.14).$$

$$J_n = \frac{\Phi}{\Omega r^2}; \tag{22.18}$$

$$J = \frac{4\Phi}{A};$$

$$J = \frac{4\Phi(1-\bar{r})}{A}. \quad (22.19)$$

$$(22.18) \quad (22.19).$$

r

$$L_J(r) = 10 \lg \frac{\Phi}{\Phi_0} + 10 \lg \left(\frac{1}{\Omega r^2} + \frac{4}{\Pi} \right), \quad (22.20)$$

$$\Pi = B$$

$$(22.20),$$

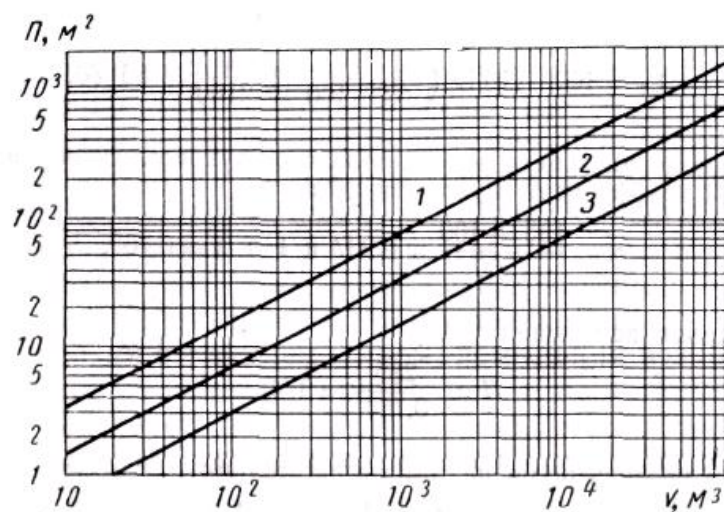
Φ

Ω ,

Π ,

r

$$(\text{ . 22.33}),$$



. 22.33.

1 –

; 2 –

; 3 –

$$\frac{p_1-p_2}{\sphericalangle}=i\check{S}\,m\,,$$

$$i\,-\hspace{1.5cm};\hspace{1.5cm}-\hspace{1.5cm};\hspace{1.5cm}m\,-\hspace{1.5cm}-$$

$$Z$$

$$Z=i\check{S}\,m.$$

$$,$$

$$,$$

$$^{\cdot}:$$

$$J=\sphericalangle^2\ldots c.$$

$$,\hspace{1.5cm}=\sphericalangle\ldots c$$

$$J=\frac{p^2}{\ldots c}.\tag{22.21}$$

$$\text{---}$$

$$\cdot$$

$$\cdot$$

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$$:$$

$$\frac{p_1}{p_2}=1+\frac{i\check{S}\,m}{\ldots c}.\tag{22.22}$$

$$(22.21)\hspace{10cm}(22.22)$$

$$:$$

$$\left(\frac{p_1}{p_2}\right)^2=\left(1+\frac{i\check{S}\,m}{\ldots c}\right)^2,$$

$$,$$

$$2\lg\frac{p_1}{p_2}=2\lg\left(1+\frac{\check{S}\,m}{\ldots c}\right).\tag{22.23}$$

$$,$$

$$\text{---}$$

$$\cdot$$

$$-$$

$$(22.23)$$

$$\mathfrak{o}\mathfrak{L}\mathfrak{Y}$$

$$10\lg\left(\frac{p_1}{p_2}\right)^2=10\lg\left(\sqrt{1+\left(\frac{\check{S}\,m\cos\{\}}{\ldots c}\right)^2}\right)^2.$$

,

$$10\lg\left(\frac{p_1}{p_2}\right)^2=10\lg\left(\frac{\check{S}\,m\cos\{\}}{\ldots c}\right)^2.$$

d ,

$$20\lg\frac{p_1}{p_2}=20\lg\frac{\check{S}\,\ldots d\cos\{\}}{\ldots c}.$$
(22.25)

$$(22.25) \quad ,$$

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$$p_{\{\}}=p_0\cos\{.$$

$$0 \qquad \qquad \qquad ;$$

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$$, \qquad \qquad \qquad (22.25),$$

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$$, \qquad \qquad \qquad (\quad=90^{\circ}; \cos\quad=$$

$$0) \qquad \qquad \qquad \ll \qquad \qquad \qquad \gg.$$

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R

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$$R=20\lg Q+20\lg f-54,$$
(22.26)

$$Q\text{---}\quad 1\quad^2 \qquad \qquad \qquad ; f\text{---}\quad .$$

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。

$$p_1=\sqrt{\frac{4\Phi...c}{A}};$$

Φ —

$$A=r_1S_1+r_2S_2+...+r_nS_n,$$

$$A=\sum_{i=1}^nr_iS_i.$$

A_1 ,
— 2.
，
，
1，
2
2
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2.
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.

$$p_2^2=\frac{p_1^2S}{A_2}.$$

$$p_2^2=\frac{p_1^2S^\dagger}{A_2}.$$

$$10\lg\frac{p_1^2}{p_0^2}=10\lg\frac{p_2^2}{p_0^2}+10\lg\frac{A_2}{S^\dagger}.$$

$$20\lg p_1/p_0-L_1, \quad 20\lg p_2/p_0-L_2, \quad R=10\lg 1/$$

$$R=L_1-L_2+10\lg\frac{S}{A_2}. \tag{22.27}$$

(22.27).

(22.27) :

$L_1 - L_2 = R + 10 \lg \frac{A_2}{S}.$ (22.28)

(22.26) (22.28), , $Q \cdot 10^{-2}$,

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$L_1 - L_2 = (20 \lg Q + 20 \lg f - 54) + 10 \lg \frac{A_2}{S}.$

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$\frac{w_0 S \ddagger}{A} = \frac{4 \Phi_1}{A c} ,$

$\Phi_1 = \frac{w_0 c S \ddagger}{4} ,$

$\Phi_1 \text{ — } ; \text{ — } .$

-

(22.14)

$w_{01} = \frac{4 \Phi_1}{A c} .$

Φ_1

-

$R,$

:

$w_{01} = \frac{w_0 \sum_{i=1}^n S_i 10^{-\frac{R}{10}}}{A} .$

$$L_1 \text{ --- } , \quad , \quad , \quad , \quad w_0 = J ,$$

$$L_1 = 10\lg \frac{w_0}{w_{0\ddagger}} = 10\lg \frac{J_0}{J_{0\ddagger}} ,$$

$$J_{0\ddagger} \text{ --- } .$$

$$10\lg \frac{J_1}{J_{on}} = 10\lg \frac{\sum S_i 10^{\frac{L_1-R}{10}}}{A} . \tag{22.29}$$

$$L_2 = 10\lg \sum_{i=1}^n S_i 10^{\frac{L_1-R}{10}} - 10\lg \frac{A}{A_0} , \tag{22.30}$$

$$L_2 = 10\lg \frac{J_1}{J_{on}} ,$$

$$S_i \text{ --- } , \quad R \text{ --- } ; \quad 0 \text{ --- } , \quad (10 \lg 0 = 0). \tag{22.30}$$

$$L_2 = 10\lg \sum_{i=1}^n S_i 10^{\frac{L_1-R}{10}} - 10\lg \left| 0,164 \frac{V}{T} \right| , \tag{22.31}$$

$$V \text{ --- } ; \quad \text{ --- } . \tag{22.30} \quad \tag{22.31},$$

$$L \quad (L > L). \tag{22.28}, \quad : \quad L \text{ --- } L = R + 10\lg \frac{A}{S} = R + 10\lg \frac{r S}{S} .$$

$$L - L = R + 10\lg r .$$

L -

:

$$\Delta L \cong L-L_{\text{н}}+5,$$

L — ; L — -

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L L .

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:

$$\Delta L \cong 10\lg \frac{1}{\ddagger}+10\lg \frac{S}{\sum r S_i}+\Delta S \cong S_{\text{н}}+\Delta S,$$

S — (. 22.5).

22.5

S

-, ,								
	63	125	250	500	1000	2000	4000	8000
$l<1$	-	1	2	5	6	8	9	10
$l>2$	1	2	4	8	12	16	20	22

S , . 22.5, -

30...50 20 / ³,
50...80 100 / ³.

L -

, -

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• :

1. [L] .

2. ,

, . 1. ΔL_{Φ}

$$\Delta L_{\Phi}=L_{\Phi}-[L]-20\lg r-\Delta L_a-10\lg \Omega,$$

$$L_\Phi \text{ --- } \qquad \qquad \qquad ; \quad [L] \text{ --- } \qquad \qquad \qquad ;$$

$$r \text{ --- } \qquad \qquad \qquad ; \quad L_a \text{ --- } \qquad \qquad \qquad -$$

$$3. \qquad \qquad \qquad .$$

$$4. \qquad \qquad \qquad .$$

$$\qquad \qquad \qquad . \qquad \qquad \qquad ($$

$$\qquad \qquad \qquad)$$

$$\qquad \qquad \qquad (\qquad \qquad \qquad).$$

$$\qquad ,$$

$$\qquad .$$

$$\qquad , \qquad \qquad L_w,$$

$$\qquad \qquad \qquad L ,$$

$$L , \qquad \qquad \qquad L . \qquad \qquad \qquad -$$

$$\qquad \qquad \qquad :$$

$$\qquad)$$

$$L_\Phi - \Delta L \text{ --- } \Delta L = [L],$$

$$[L] \text{ --- } \qquad \qquad \qquad ;$$

$$\qquad)$$

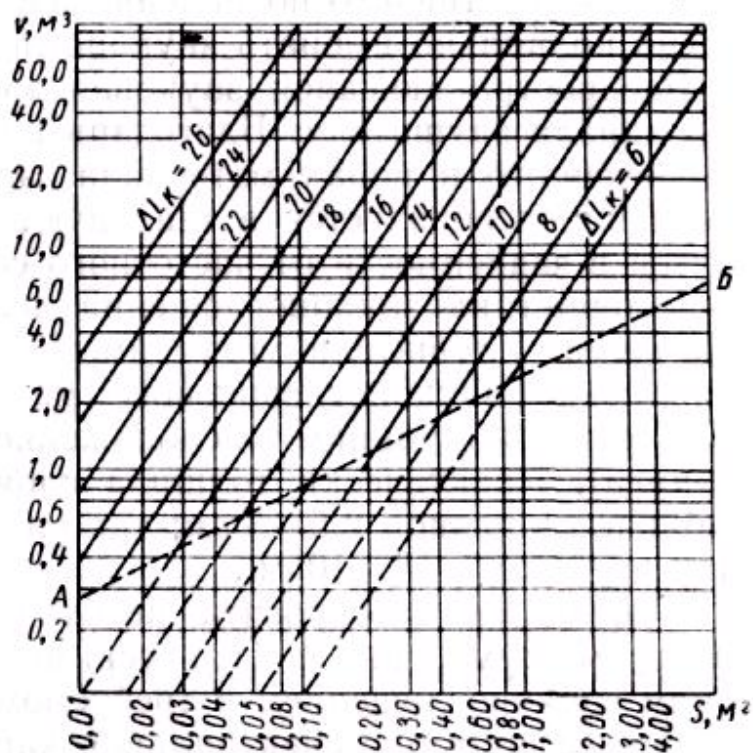
$$L_\Phi - \Delta L \text{ --- } \Delta L_n = [L] \quad (\qquad \qquad \qquad);$$

$$L_\Phi - \Delta L \text{ --- } \Delta L_n = [L] - 10 \qquad (\qquad \qquad \qquad).$$

$$L = L - L$$

$$- [L] \qquad \qquad \qquad (\quad . \quad . 22.34, \qquad \qquad \qquad).$$

$$(\qquad \qquad) \qquad \qquad \qquad ,$$



. 22.34.

:

V –

; S –

; L –

–

–

–

$$d = \frac{4S}{\Pi},$$

S —

; Π —

.

$$L = 4,4 \frac{F(r)l}{d}, \quad ,$$

l — d –

, ; $F(r)$ – ,

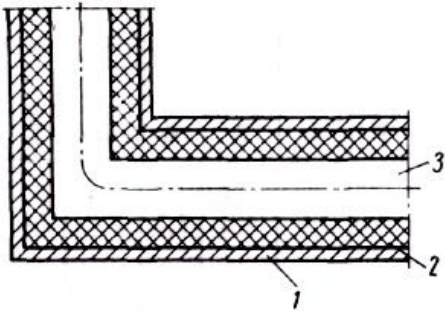
r (. 22.6).

$F(r)$

r	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8
$F(r)$	0,1	0,2	0,35	0,5	0,65	0,9	1,2	1,6

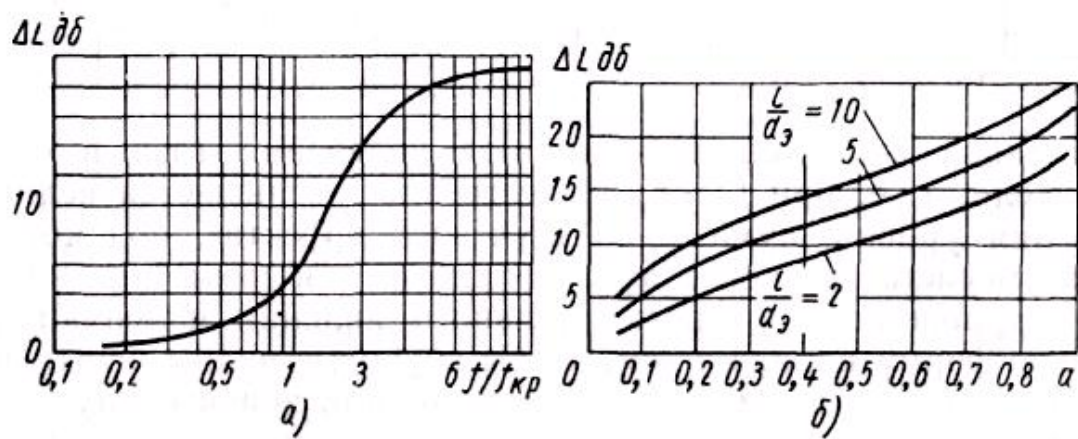
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 ,
 :
 $l = nd$
 l — ; — ; d —
 .
 ,
 (.

22.35).



. 22.35.
 1 – ; 2 – ; 3 ⊥
 (= 0,8) 90° -
 . 22.36. -

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 .
 10 .



. 22.36.

90 () 180 ()

180°

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. 22.36, ,

-

l

d .

L

S

$$\Delta L = 1,1 \frac{f(r) \Pi l}{S}, \quad (22.32)$$

$f()$ —

,

; Π —

-

; l —

; S —

.

$$1,1 f() S^{-1}$$

.

$$\Delta L = 4,4 \frac{f(r) l}{d}, \quad (22.33)$$

d —

.

$$\Delta L = 2,2 \frac{f(r) l}{a},$$

—

.

22.7

$f()$

-

:

$f()$

	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
$f()$	0,1	0,2	0,35	0,5	0,65	0,9	1,2	1,6	2,0	4,0

(22.32) (22.33) , , -
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$w_0 = \frac{4 \Phi_1}{cA},$

(22.34)

Φ_1 — . Φ_2

$S :$
 $\Phi_2 = \frac{w_0 c S}{4} .$

(22.35)

(22.34) (22.35),

$$\Phi_2 = \frac{\Phi_1 S}{A} ,$$

L , ,

$$\Delta L = 10 \lg \frac{\Phi_1}{\Phi_2} = 10 \lg \frac{A}{S}$$

$$\Delta L = 10 \lg \left(\frac{\sum_{i=1}^n a_i S_i}{S} \right), \tag{22.36}$$

i — i - ; S_i — i -
 2 .

L , , -
 L , -
 L ,

, :
 $L - \Delta L - \Delta L = [L]$.

$= 0,4$, . 22.34. -

$L = L - L - [L]$ ().

, -
 () . -

:

$$\Delta L = 10 \lg \left[1 + \frac{(m - m^{-1})^2}{4} \sin^2 k l \right], \tag{22.37}$$

$m = \frac{S_2}{S_1}$ — S_2 S_1 ; k —
 l —
 (22.37) .

(22.37).

. . -
 ()

5...7 , .

12...15

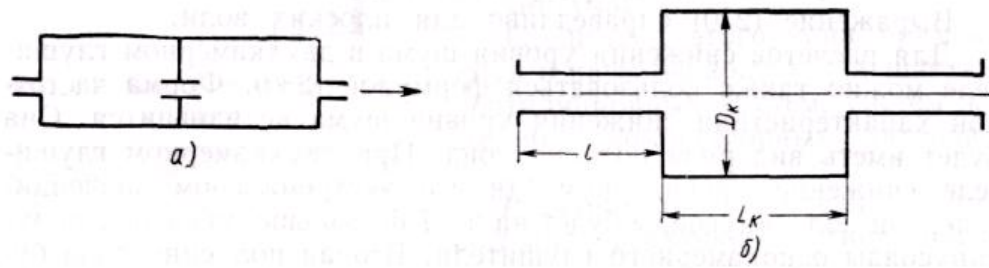
, 30 .

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22.37,)



. 22.37.

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()

$$f = \frac{c}{2l} \sqrt{\frac{S}{V}},$$

$$V = \frac{c^2 S}{4f^2 l f^2},$$

— / ; S — 2 ; l — ; f_p — .

$$L = \frac{V}{\frac{f}{4} D^2},$$

L D —

f_p .

(22.36).

$$f = \frac{1}{2f} \sqrt{\frac{k}{V}}, \quad (22.38)$$

$$k = \frac{S}{l + 0,8d} \quad ; \quad l_0 = \frac{S}{k} \quad ; \quad d = \frac{S}{k} - 0,8l_0 \quad ; \quad V = \frac{S}{k} - 0,8l_0 \quad .$$

$$\Delta L = 10 \lg \left[1 + \frac{\left(\frac{\sqrt{k_p V}}{2S} \right)}{\frac{f}{f_p} - \frac{f_p}{f}} \right] \quad , \quad (22.39)$$

$$\begin{aligned}
k_p &= \frac{1}{2} \left(\frac{1}{f} + \frac{1}{f_p} \right) ; \quad S = \frac{1}{2} \left(\frac{1}{f} - \frac{1}{f_p} \right) . \\
f &= \frac{1}{2} \left(\frac{1}{k_p} + \frac{1}{k_p} \right) , \quad (22.39) \quad f = f_p -
\end{aligned}$$

(22.26),

$V \quad k_p.$

(22.38).

$$k_p = \frac{nS}{l + 0,8\sqrt{S}},$$

$$f_p = \frac{1}{\pi} \int_0^\pi f(\theta) d\theta; S = \frac{1}{\pi} \int_0^\pi S(\theta) d\theta; l = \frac{1}{\pi} \int_0^\pi l(\theta) d\theta. \quad (22.38),$$

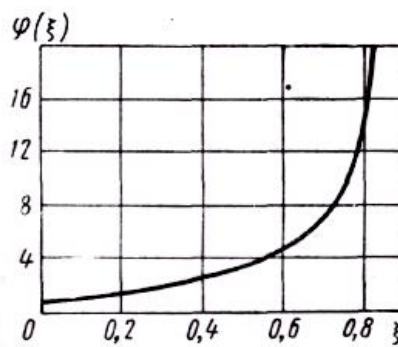
$$k_p = \frac{\frac{f d^2}{4} n}{l + \frac{f d}{4 \xi(\zeta)}};$$

d — , , ; —
; l — , , ; ()—
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$$: \zeta = \frac{d}{a} \text{ (—$$

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() .22.38.



. 22.38.

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$$\Delta L \text{ — -}$$

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$$\Delta L \text{ — -}$$

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$$\Delta L = -10 \lg(10^{-0,1 \Delta L^I} + 10^{-0,1 \Delta L^{II}} + 10^{-0,1 \Delta L^{III}}),$$

$$\Delta L^I \text{ — ,}$$

. 22.39,

$$_1 = a_1 + b_1 + d_1$$

$$f(\text{ . 22.39}); \Delta L^{II} \Delta L^{III} \text{ - -}$$

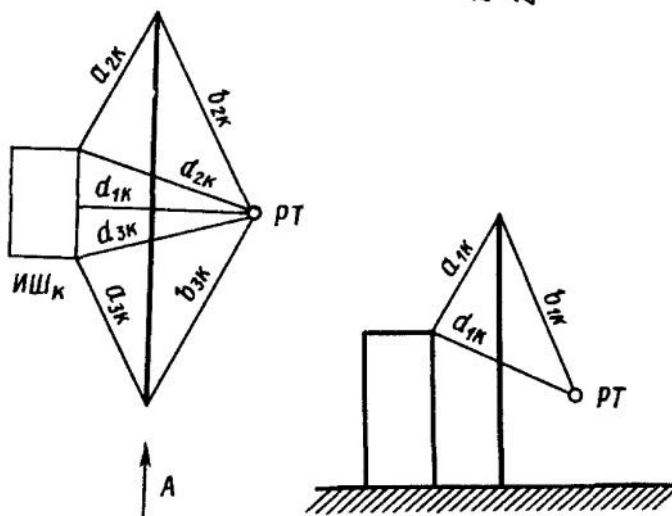
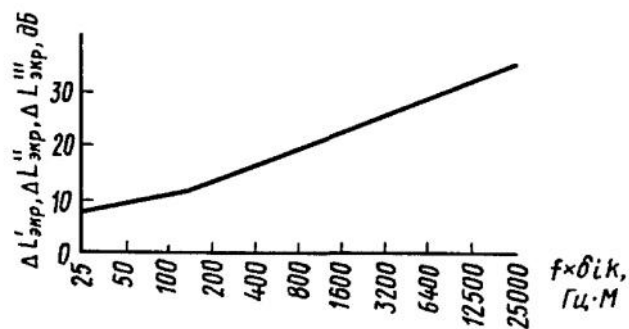
$$\text{ , . 22.39 } \delta_2 = _2 + b_2 + d_2 \quad \delta_3 = _3 + b_3 + d_3 \quad \delta_2 (_1,$$

2, 3 —

; b_1, b_2, b_3

; d_1, d_2, d_3 — -

).



. 22.39.

ΔL

$$\Delta L = 20 \lg N - 10 \lg n, \quad ,$$

$$N = 2u / \} ,$$

N -

; -

,

; $u =$

+ - d , ; } -

, .

$$\Delta L = 20 \lg \frac{1}{\beta} \left[X \sqrt{1 + \left(\frac{H}{X} \right)^2} + Y \sqrt{1 + \left(\frac{H}{Y} \right)^2} \right], \quad (22.40)$$

L — ; X —
 ; — ; Y — ;
 — .

(22.40) ,

L -

:

$$L = \frac{Y^2}{4}.$$

23.

23.1.

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1	2	3	4	5	6
-157	31,5; 63	119; 118	96	119 119	23
-148	8; 16	109; 110	85	108	23
-130	8;16	115; 116	85	121 121	36
-51	8; 16	107; 109	85	109	24
-53	8; 16	112; 110	84	111	27
	8; 16	114; 116	82	122	40
« -24»	8;16	115; 113	74	116	42
« -	2; 16	110; 108	87	106	19
»					
« -	8; 16	111; 113	74	102	28
255»					
	16	108	72	109	37
()	16; 31,5	91; 92	61	94	33
()	8; 16	115; 118	-	-	-
	8; 16; 31,5	93; 92	86	95	9
-	8; 16	101; 98	82	104	22

-					
-701	16; 31,5	111; 112	91	114	23
-75	- 31,5; 63	112; 109	96	115	19
	16; 31,5; 63	97;95	72	98	26
-100	16; 63	106;105	80	103	23
-663	31,5	112	89	110	21
3322	- 16; 31,5	106;100	84	100	16
« »	31,5	84	72	98	26
	16	94	87	98	11
-	8; 16	92; 93	74	98	24
-	4; 8	91	72	97	25
	4; 8	112; 109	80	112	32
	4; 8; 16; 31,5	104	76	110	34
-	16	110	83	112	29
	63; 125	98; 95	96	101	5
	4; 31,5	82; 84	67	90	23

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$$8 \cdot 10^{-6} \quad / \quad .$$

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$$f = n/60$$

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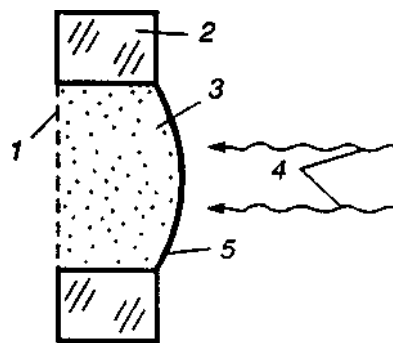
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(. 23.1).



. 23.1.

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$$f_0=\frac{1}{2f}\sqrt{\frac{c^2...}{mh}},$$

— ; — ; h — .

$$f>f_0$$

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23.2.

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$$F=m\check{S}^2l\, . \tag{24.1}$$

F ,
 :

$$\frac{d}{dt}(\dot{x}+i\check{S}x)-i\check{S}(\dot{x}+i\check{S}x)=\frac{1}{m}F(t)\, , \tag{24.2}$$

— ; — . (24.2) :

$$\frac{d\check{<}}{dt}-i\check{S}\check{<}=\frac{1}{m}F(t)\, , \tag{24.3}$$

$=x+i\check{<}x$.

(24.3), :

$$\check{<}=e^{i\check{S}t}\left\{\int_0^t\frac{1}{m}F(t)e^{-i\check{S}t}dt+\check{<}_0\right\}\, ,$$

$_0$ $t=0$. $x(t)$

, i . $F(t)$.

, () -

$F(t)$:

$$E=\frac{1}{2m}\left|\int_{-\infty}^{\infty}F(t)e^{-i\check{S}t}dt\right|^2\, .$$

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$F(t)$, .

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\overline{P} :

$$F_M = - M \, dv/dt,$$

$v =$.
 F_M , .
 , . . ,

$$F_G = Gx,$$

$G =$, / ; $x = x_1 - x_0 =$ -
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 , . .

, F_S -
 v :

$$F_Z = Zv,$$

$Z =$ () , · / .
 ,

Z , M - G .

$$\eta = \omega Z/G.$$

24.2.

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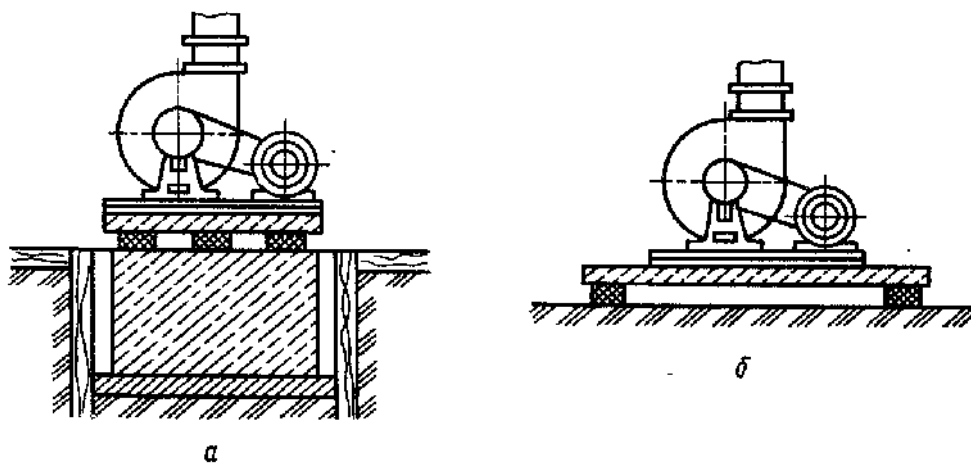
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(. 24.1).

~2



. 24.1.

2.02.05—87

$$= h \, \eta P ,$$

$h \, \eta$ —

$$A_{\max} = P_z / (b_z - m^2).$$

z —

2.02.05 - 87; m_{Σ} —

$$, b_z = c_z S, \quad S —$$

; c_z —

c_z

$$S \qquad 200 \text{ }^2$$

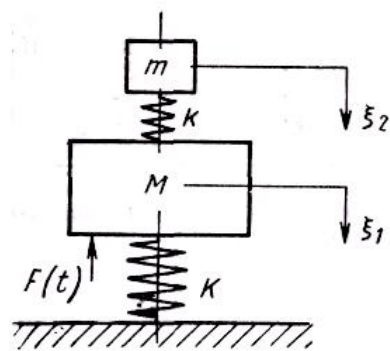
$$c_z = b_0 E (1 + \sqrt{S_0 / S}),$$

$$b_0 \text{ --- } , \quad ^{-1} (\qquad 1 \text{ --- } \qquad ; 1,2 \text{ --- } \\ ; 1,5 \text{ --- } \qquad) ; \text{ --- } \\ 1 \text{ }^2, \quad / \text{ }^2,$$

$$; S \text{ --- } \qquad , \text{ }^2; S_0 = 10$$

$$^2.$$

$$(\quad . 24.2).$$



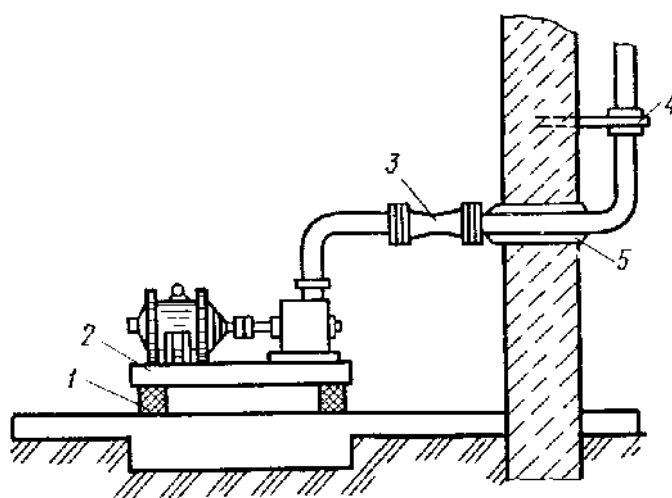
$$. 24.2.$$

$$M \quad m \qquad K$$

$$k$$

(. 24.3).

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. 24.3.

1 –

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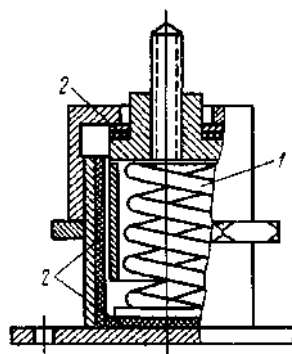
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(. 24.4),

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2,



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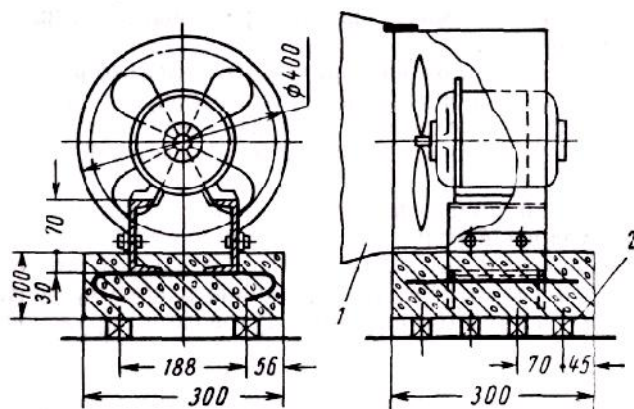
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. 24.5.



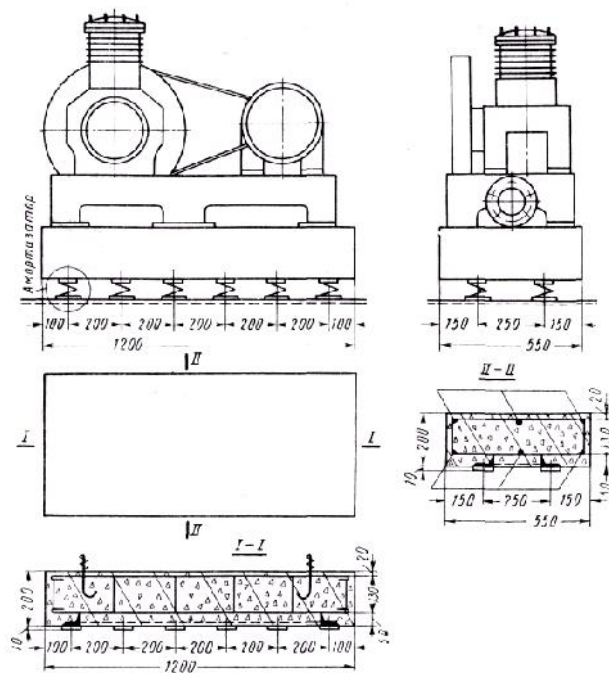
. 24.5.

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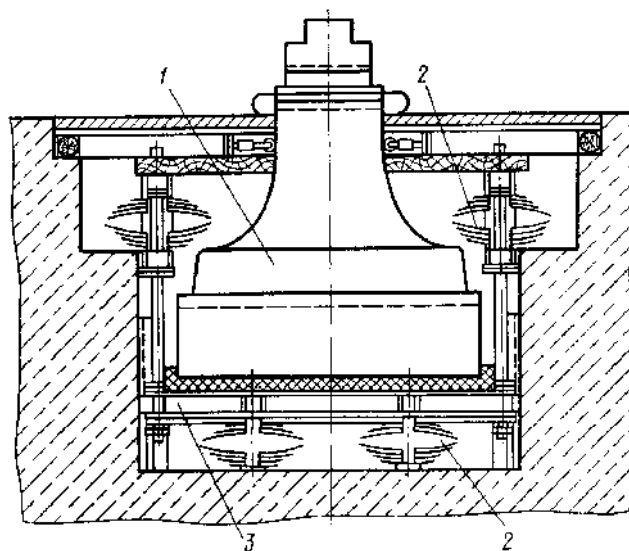
; 2 –

. 24.6



. 24.6.

(. 24.7).



. 24.7.

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$$=\frac{A_{F1}}{A_{F2}}=\frac{1}{r_x^2-1}, \quad \quad \quad _{\{x}}=\frac{A_{M1}}{A_{M2}}=\frac{1}{r_{\{x}^2-1}, \tag{24.6}$$

$A_{F1} \quad A_{M1} \text{ ---}$ -
, ; A_{F2} -
 $A_{M2} \text{ ---}$, -
; $\omega = \omega / \omega_0$, $\varphi = \omega_x / \omega_{0\varphi}$ --- -
 $\omega \qquad \qquad \omega_0 \quad \omega_{0\varphi} \qquad \qquad -$

f_0 -

ω

(24.6)

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$\eta = \omega \mu / b$, — ; μ — , b — .
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$\Delta L_{\epsilon} = 20 \lg(\eta_2/\eta_1)$,
 $\eta_2 = \eta_1$ — ($\eta = 10^{-3} \dots 10^{-4}$).

($10^4 \dots 10^5$ / 10^{-2}).
 , $10^4 \dots 10^5$ / 10^{-2} .
 , , .

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 , 10^3 / 10^{-2} .
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24.3.

I.

- 1) (Q) ;
- 2) f ;
- 3) P_z ;
- 4) ,
- 5)

II.

(az)

$\langle_{az} = \frac{P_z}{k_z - m\check{S}^2} \approx \left| \frac{P_z}{-m\check{S}^2} \right| = \frac{P_z}{m\check{S}^2} ,$ (24.7)

k_z — ; m — ;

k_z .

, . . $z > [z]$,

$Q = \frac{P_{az}g}{[\langle_{az}]\check{S}_0^2} ,$

g — .

f_z

k_z .

$$\begin{aligned} & \qquad \qquad \qquad , \qquad \qquad \qquad - \\ & \qquad \qquad \qquad \mathfrak{Z} \qquad \qquad \qquad - \\ & \qquad \qquad \qquad , \quad \cdot \quad \cdot \end{aligned}$$

$$\sim = \frac{P}{P_z}.$$

$$\mu \qquad \qquad \qquad f_{0z}$$

$$f$$

$$\sim = \frac{1}{\frac{f^2}{f_{0z}^2}-1} = \frac{1}{\mathfrak{E}_z^2-1},$$

$$\mathfrak{E}_z = \frac{f}{f_{0z}}.$$

$$z, \qquad \qquad \qquad -$$

$$z, \qquad \qquad \qquad z_{\min}, \quad \cdot \quad \cdot$$

$$\mathfrak{E}_z \geq \mathfrak{E}_{z\min}.$$

$$z\min$$

$$\mathfrak{E}_{z\min} = \sqrt{\frac{1}{\sim}+1} = \sqrt{\frac{P_z + [P]}{[P]}} = \sqrt{\frac{P_z}{[P]}+1}.$$

$$, \qquad \qquad \qquad ,$$

$$\mathfrak{E}_z \geq 3, \quad \cdot \cdot \cdot \sim \leq \frac{1}{8}.$$

$$, \qquad \qquad \qquad \mathfrak{Z}, \qquad \qquad \qquad \mu, \qquad \qquad \qquad -$$

$$f_{0z}, \qquad \qquad \qquad , \qquad \qquad \qquad :$$

$$f_{0z} = \frac{f}{\mathfrak{E}_z}, \tag{24.8}$$

$$k_z = \big(2f\ f_{0z}\big)^2 m,$$

$$\text{---} \qquad \qquad \qquad , \qquad \qquad \qquad (\qquad \qquad \qquad).$$

$$, \qquad \qquad \qquad , \qquad \qquad \qquad -$$

$$\cdot \qquad \qquad \qquad -$$

$$:$$

$$X\;=\;\frac{25}{f_{oz}^2}\;[\;\;\;].$$

$$f_{0z}=\frac{5}{\sqrt{X}}=5\sqrt{\frac{ES}{hQ}},\tag{24.9}$$

$$\begin{array}{l} \text{---} \hspace{10em} / \; ^2; \; S \text{---} \hspace{10em} ^2; \; h \\ \text{---} \hspace{10em} . \end{array} \tag{24.9}$$

$$X\;=\;\frac{h\uparrow}{E}=\frac{Q}{k_z}\;[\;\;\;],\tag{24.10}$$

$$\uparrow=\frac{Q}{S}\cdot\hspace{10em} / \; ^2. \tag{24.10}$$

$$\begin{array}{l} , \hspace{10em} . \\ . \hspace{10em} . \\ , \hspace{10em} : \end{array}$$

$$y=\frac{\check{S}r}{k}$$

$$y=d/f\; ,$$

$$d\text{---}\hspace{10em} .$$

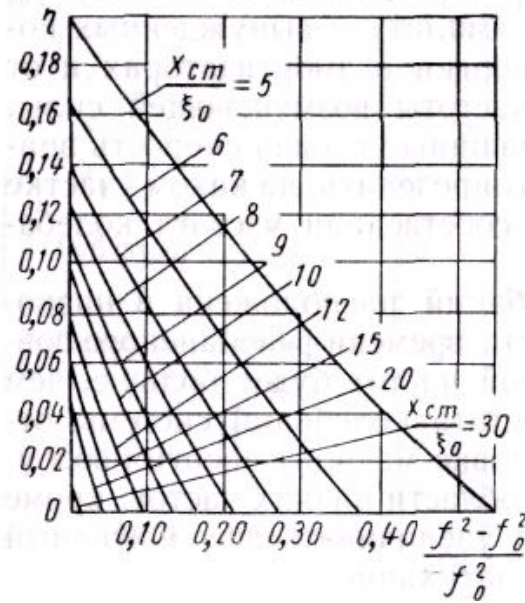
$$\begin{array}{l} - \\ , \hspace{10em} (i+1)\text{---} : \end{array}$$

$$d=\ln\frac{<_i}{<_{i+1}}.$$

$$\begin{array}{l} - \\ , \hspace{10em} . \\ , \hspace{10em} . \\ \text{zmax} \hspace{10em} , \end{array}$$

$$\kappa_{z\max} \leq \frac{Pz}{y k_z} = \frac{X}{y}.$$

. 24.8



. 24.8. $(f^2 - f_0^2)/f_0^2$

$$P = \kappa_{k_z},$$

k_z —

$$P_1 = \frac{P}{n} = \kappa_k \frac{K_z}{n} = \kappa_{k_{z1}},$$

k_{z1} —

k — , , ; — , -

$$v=\frac{D}{d}\; ,$$

D — .
3.

$$i_1=\frac{Gd}{8k_{z1}v^3}\cdot$$

4.

$$i=i_1+i_2\; ,$$

i_2 — , :

$$i_1> \qquad i_2=2,5$$

$$i_1<7 \qquad i_2=1,5.$$

5.

$$H_0=2\,D.$$

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1.

2. ,

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3. :

$$A=\sqrt{\frac{Q}{n\uparrow}}\; ,$$

Q — ; — :
 $2...4\quad / \quad ^2,$ $5\quad / \quad ^2.$

4.

$$\geq \frac{1}{4}.$$

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5.

$$_1 = -\frac{S_1}{8}.$$

6.

-

$$k_{z1} = \frac{E}{H_1} \frac{S_1}{H_1},$$

—

; S_1 —

-

7.

-

$$k_x = k_y = \frac{S_1 G}{H_1},$$

G —

.

8.

$$f_{0z} = \frac{1}{f} \sqrt{\frac{4S^2 g^2 E^2 n^2}{(8-s)^2 Q \dagger}}, \tag{24.11}$$

$$s = \frac{A}{H}$$

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(24.11)

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(24.8).

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0,5.

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$$, \qquad \mu < 0,5, \qquad H_1$$

$$, \qquad \qquad \qquad , \qquad \qquad \qquad ,$$

$$\begin{array}{l} \cdot \\ (\qquad \qquad \qquad), \\ \cdot \end{array} \qquad \begin{array}{l} - \\ - \\ - \end{array}$$

$$, \qquad \qquad \qquad \cdot \qquad \qquad \qquad -$$

$$_{01}, \qquad F_a \qquad \qquad \qquad 2 \qquad \qquad \qquad 0,$$

$$\dot{\zeta}_{01} = \frac{F_a}{i \left[\left(\frac{\check{S}_2}{\check{S}_0} \right)^2 - 1 \right] + y}. \qquad (24.12)$$

$$\begin{array}{l} , \\ 2 \cdot \\ , \end{array} \qquad \qquad \qquad (24.12), \qquad \qquad \qquad 2,$$

$$2 \qquad \qquad \qquad \cdot \qquad \qquad \qquad -$$

$$\begin{array}{l} (\cdot \cdot \cdot \qquad \qquad \qquad 2 = \cdot 0) \\ 20 \lg \frac{\dot{\zeta}_{01}}{\dot{\zeta}_{02}} = 20 \lg \frac{F_a y_2}{y_1 F_a} = 20 \lg \frac{y_2}{y_1} . \end{array}$$

$$\begin{array}{l} - \\ - \\ \cdot \end{array}$$

$$, \qquad \qquad \qquad 20 \lg \frac{\dot{\zeta}_{01}}{\dot{\zeta}_{02}} = 20 \lg \frac{p_1}{p_2} = \Delta L .$$

$$\begin{array}{l} , \qquad \qquad \qquad L \\ - \end{array}$$

$$\Delta L = 20\lg\left(\frac{\dot{\langle}_{01}}{\dot{\langle}_{02}}\right) = 20\lg\left(\frac{y_2}{y_1}\right) \quad . \tag{24.13}$$

$$\begin{aligned} \dot{\langle}_{01}, \quad 1 \text{ ---} \\ \qquad \qquad \qquad ; \quad \dot{\langle}_{02}, \quad 2 \text{ ---} \quad , \\ \cdot \\ (24.13) \qquad \qquad \qquad , \end{aligned}$$

$$\Delta L = 20\lg\left(\frac{y_1+y_2}{y_1}\right) \quad .$$

$$\begin{aligned} & , \\ y_2 = & y_3 \cdot a \cdot \{ (b) , \\ a = & \frac{E_n}{E} \end{aligned} \tag{24.14}$$

$$b = \frac{h_n}{h} ,$$

$$\begin{aligned} 3 \text{ ---} \qquad \qquad \qquad ; \quad n, \quad \text{---} \qquad \qquad \qquad - \\ \qquad \qquad \qquad ; \quad h \, , \, h \text{ ---} \qquad \qquad \qquad . \\ (24.14) \qquad \qquad \qquad , \qquad \qquad \qquad 2 \qquad \qquad \qquad , \qquad \qquad \qquad - \\ \qquad \qquad \qquad , \qquad \qquad \qquad 3 \qquad \qquad \qquad , \\ \qquad \qquad \qquad \cdot \\ \qquad \qquad \qquad b \qquad \qquad \qquad b = 3...5, \\ \qquad \qquad \qquad \cdot \\ \qquad \qquad \qquad 2...3 \end{aligned}$$

$$y_2 \approx y_3 \cdot \frac{E_n}{E} \left(\frac{h_n}{h}\right)^2 .$$

$$\begin{aligned} & , \\ & \cdot \\ & / \qquad 10^{-4} . \qquad \qquad \qquad , \end{aligned}$$

25.

25.1.

25.1.

25.1

-		-	
1	2	3	4
$\rightarrow \infty$		$\rightarrow 0$	
10^4	1-4.	30	
10^3	5. (- -)	300	
10^2	6. (- -)	3	
10	7. (- -)	30	
1	8. (-)	300	
0,1	9. (-)	3	
1	10. (-)	30	
1	11. (-)	300	
0,1 (100)		3000	
0,76	(-)	$4,3 \cdot 10^{14}$	
0,38		$7,5 \cdot 10^{14}$	
100	(-)	$3 \cdot 10^{16}$	

0,1		$3 \cdot 10^{19}$	
0,001	-	$3 \cdot 10^{21}$	
$\rightarrow 0$		$\rightarrow \infty$	

1...4 . 5...11 -
3...30 .
1 1 .
() 0...30 ()
 $3 \cdot 10^{15}$.
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0,76 0,38 .
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. 25.1 . - , -
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() . , -
() $r = /6$
/2 ; , -
. $(\overline{E}, \overline{B})$. -
. () $r = /6,$ -
 \overline{E} (/). 5...8 (. . IV.9)
(/).
:

$$E_{\Sigma}^2=\sum_{i=1}^NE_i^2,$$

i — i -
(). $r>/6$ -
. ,
— , 9...11 (.
. 25.1) (),
— /² (1 /²=0,1 /²=100 /²).

W_S^{Σ} N - :

$$W_S^{\Sigma}=\sum_{i=1}^NW_S^i,$$

W_S^i — i - о .

:

$$\sum_{i=1}^k\frac{E_i^2}{E_{0i}^2}+\sum_{i=1}^m\frac{W_S^l}{W_S^{0l}}\leq1,$$

E_{0i} — - i - о

- ; W_S^{0l} — -

l - - ; E_i , W_S^l —

; $i=1,2,...,k$; $l=1,2,...,m$.

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$$R=\}/2f\; ;$$

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$$R=d^2/2\} \; ,$$

d - , ;

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$$R=L_1L_2/2\} \; ,$$

L_1, L_2 - , .

$$E^2 = E_1^2 + E_2^2 + \dots + E_n^2,$$

E_1, E_2, \dots, E_n — ,

» , / .

$\Sigma \quad n$

9—11

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$$= \quad 1 + \quad 2 + \dots + \quad n$$

25.2.

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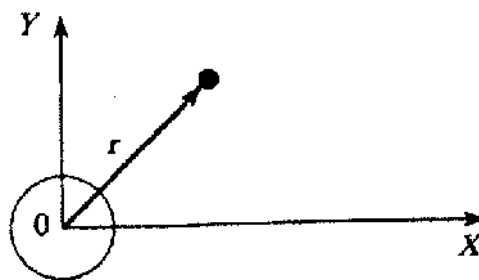
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. : U_0 ; , r_0 ; L ;
 r , (.25.1).



. 25.1.

, / :

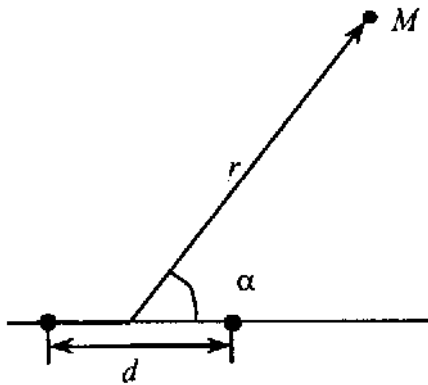
$$E(r) = \frac{U_0}{r \ln(L/r_0)} \quad r \ll L.$$

： ， ， I_0 ， ； L ， ；
 r ， (.25.1).

， / ：

$$H = \frac{I_0}{4f\,r} \cdot \frac{L}{\sqrt{(L/2)^2 + r^2}}.$$

： ，
 U_0 ， ； r_0 ， ；
 d ， ； r ， (.25.2).



.25.2. .

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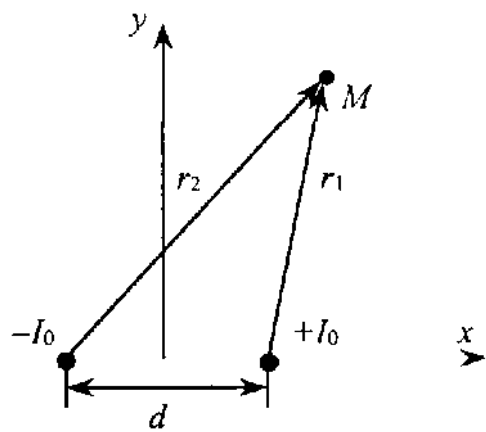
$$E_r = \frac{dU_0}{2r^2 \ln(d/r_0)} \cos \Gamma,$$

$$E_r = \frac{dU_0}{2r^2 \ln(d/r_0)} \sin \Gamma.$$

， / ：

$$E = \sqrt{E_r^2 + E_r^2} \quad r \gg d.$$

，
 I_0 ， ； d ， ；
 r_1, r_2 ， ； . (.25.3).



. 25.3.

, / , :

$$H_x = \frac{I_0 y}{2f} \left(\frac{1}{r_2^2} - \frac{1}{r_1^2} \right),$$

$$H_y = -\frac{I_0}{2f} \left(\frac{x+d/2}{r_2^2} - \frac{x-d/2}{r_1^2} \right).$$

, / :

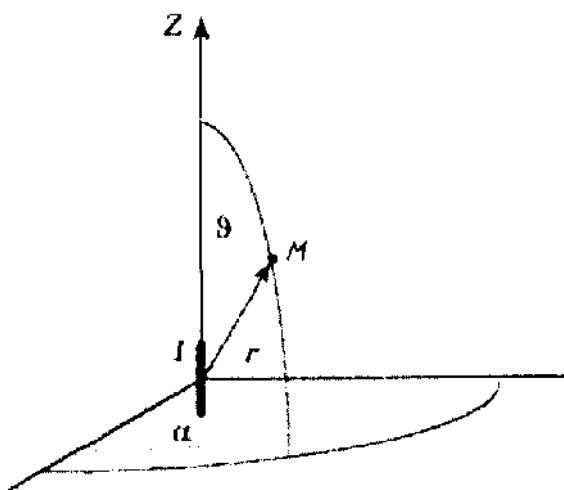
$$H = \sqrt{H_x^2 + H_y^2}.$$

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: I_0 , ; f , ; L , ;

r , ; Z

, (. 25.4).



. 25.4.

($r \ll \lambda$, $\theta \ll \pi$, $\alpha \ll \pi$):

$$E_r = \frac{I_0 L \cos [\sin \check{S} t]}{2f \check{S} v_0 r^3}, \quad / ;$$

$$E_{\perp} = \frac{I_0 L \sin [\sin \check{S} t]}{4f \check{S} v_0 r^3}, \quad / ;$$

$$H_r = \frac{I_0 L \sin [\cos \check{S} t]}{4f r^2}, \quad / .$$

($r \gg \lambda$):

$$E_r = 0; \quad E_{\perp} = \frac{k Z_0 I_0 L \sin [\sin(\check{S} t - kr)]}{4f r^2}; \quad H_r = \frac{k I_0 L \sin [\sin(\check{S} t - kr)]}{4f r^2},$$

Z_0 - $\frac{4\pi}{3} \times 10^{-7}$ Гс/А ; $k = 2\pi / \lambda$ - волновое число ; λ - длина волны ; $\lambda = \frac{c}{f}$.

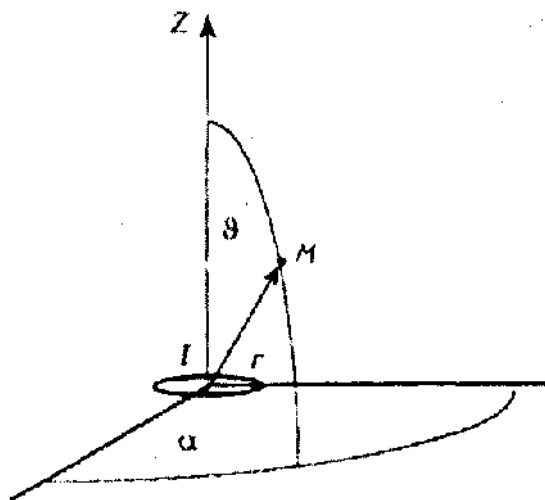
($r \gg \lambda$) . θ - угол наблюдения ;

I_0 - ток в антенне ; f - частота ; S - площадь ;

r - радиус ;

Z -

, (25.5).



25.5.

:

$$E_r = \frac{I_0 S \sim_0 \check{S} \sin [\cos \check{S} t]}{4f r^2}, \quad / .$$

$$H_{\perp} = \frac{I_0 S \cos [\cos \check{S} t]}{4f r^3}, \quad / ;$$

$$H_r=\frac{I_0S\cos[\cos\check{S}t]}{2fr^3},\quad /.$$

:

$$E_{\rm r}=\frac{k^2I_0SZ_0\sin[\cos(\check{S}t-kr)]}{4fr},\quad /;\quad H_{\rm l}=\frac{k^2I_0S\sin[\cos(\check{S}t-kr)]}{4fr},\quad /;$$

$$H_r=0.$$

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D ; r ,

; h_1, h_2 ,

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F a ,

, « » 180°:

$$F=2\sin\frac{2f\ h_1h_2}{\}r}.$$

$$E=\frac{\sqrt{30PD}}{r}F,\quad /.$$

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S :

$$H=E/377,\quad /;\quad S=E^2/377,\quad /{}^2.$$

25.3.

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25.2.

25.2

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1150	300	220	25
750	250	110	20
500	150	35	15
330	75	20	10

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	5	5...25	25...100	100
0,03...,0,3	10	10...75	75...480	480
0,3...3	20	20...150	150...960	960
3...30	175	175...400	400...2500	2500

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()	30-300	100 — 1000
()	300-3000	200 — 1000
(KB)	3-30	50 — 700
-	30-1000	25 — 800

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25.4.

$$=20\lg\quad.$$

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$r\gg\sqrt{d}/2$, r - ; - (« »), ,

. $r\ll\sqrt{d}/2$ « »,

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$$\begin{aligned} &= \frac{Z}{2} \frac{d}{\Delta} \dagger \quad \frac{d}{\Delta} \prec 0,1; \\ &= \frac{Z}{4\sqrt{2}} \frac{\Delta}{\dagger} \exp(d/\Delta) \quad \frac{d}{\Delta} \succ 0,1, \end{aligned}$$

Z - , ; -

. d - , ; $\Delta=1/\sqrt{\tilde{\gamma}_r\tilde{\gamma}_0\dagger f f}$ -

, ; μ_r - , $\mu_0=$

$1,257\cdot10^{-6}$ / ; - , / ; f - , .

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$$u=2f\sqrt{\frac{2}{\tilde{S}\sim\dagger}},$$

- , $=2f$, f - ; μ -

, $\mu=\mu_0=4\cdot10^{-7}$ / ;. $=-$, / ($^{-1}$. $^{-1}$).

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— , ; $R = \sqrt{3v/4f}$ —

, , $v = a \cdot b \cdot c$; a, b, c —

(25.1) (25.2) :

= ± , (25.3)

= 20 lg(0,21 · /R).

(25.3) , , ,

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$\lambda_1 = 8,7 \cdot d /$, ,

$\lambda_2 =$, — ,

(); $d -$; — .

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. 25.6.

25.6

	, , $d = 1$				
0,1	24	41	30	21	19
0,3	400	72	52	36	33
1,0	670	130	94	35	60
3,0	1100	230	160	110	100
10,0	1900	410	300	210	190
30,0	3000	720	520	360	330
100,0	6000	1300	940	650	600
300,0	7400	2400	1600	1100	1000
1000,0	12000	4100	3000	2100	1900

$$d_1(\quad)_1=\quad d_1,\quad.$$

$$\begin{array}{l} \vdots \\ f_{\quad,\min}=150\sqrt{\frac{1}{a^2}+\frac{1}{b^2}},\quad. \end{array}\tag{25.4}$$

$$\begin{array}{l} ,\quad\ldots\quad- \\ .\quad25.6. \\ 0,01\quad0,05 \end{array}$$

$$(25.3).\quad,\quad(25.4)$$

$$,\quad25.6$$

$$,\quad1\quad.$$

$$\begin{array}{l} ,\quad\ldots\quad- \\ 12.1.006-84. \end{array}$$

$$(\quad.)$$

$$S\quad(\quad)$$

$$\begin{array}{l} \vdots \\ S^{\quad}=20\lg\frac{J_{S0}}{J_{Sn}}, \end{array}$$

$$J_{S0},\,J_S\quad\text{---}$$

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25.7

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	1,0	0,8	0,6	0,5	0,4	0,3
16	1,868	2,29	3,1	3,79	4,92	6,97
20	2,21	2,77	3,8	4,68	6,1	8,68
30	3,4	4,37	6,12	7,6	9,59	14,27
50	5,03	6,54	9,21	11,47	15,1	21,59

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$K = \exp(-t L),$

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$$m = \frac{q_{1,2}}{q_{,2}},$$

$q_{1,2} = 1 - 2; q_{,2} = 2.$

$$\sim = \frac{T_1}{T} = \sqrt{\frac{m}{1 + \left(\frac{T_2}{T_1}\right)^4 + \left(\frac{T}{T_1}\right)^4}}.$$

$$= 1/m.$$

$$= 1 - = (m - 1)/m.$$

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26.2.

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$$N = N_0 e^{-\mu d}, \quad (27.2)$$
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		$\mu \cdot d$				
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	1,0	1,84	2,81	5,33	15,1 5,86	25,9
	4,0	1,53	2,01	2,96		8,08
	1,0	1,36	1,66	2,15	3,37	4,13
	4,0	1,27	1,55	2,17	4,64	7,64
	10,0	1,10	1,24	1,54	3,52	7,68

(27.1); $\mu \cdot d$ 10.

. (27.1) (27.2)
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	2		4	-		Fe	Ni	Pb
/ ³	1,0	1,67	1,67	0,92	2,4	7,86	8,9	11,3
’	9,3	13,0	10,0	8,3	11,0	6,5	6,6	9,4

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