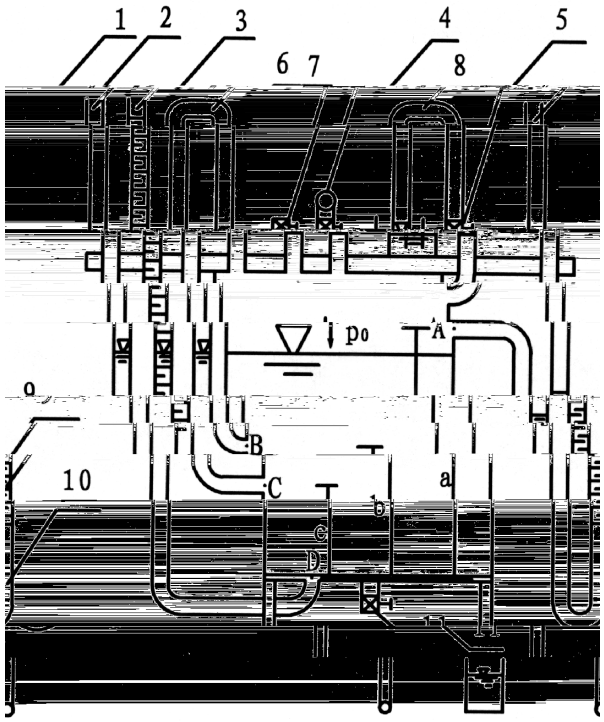
2023 6

1.



1.	2.	3.	4.
5. U	6.	7.	8.
9.	10.	11.	

:

(1) (2)

(2) ∇_B ∇_C ∇_D B C D

, ∇_B ∇_C ∇_D Z_B Z_C Z_D

(3)

2.

(1)

(2)

(3)

3.

(1)

U

(2) , 0.1cm

(3)

(4)

(5) =150cm 55cm

1.

800ml

2.

A B $5^{\#}$U

20cm

1~2cm

3. 1 2 5

4.

5.

(a)

(b)

(c)

(d)

6.

5(a) (c)

1.

——

(1)

(2)

(1)

(2)

(1) C D

(2) p_0 4

2 3

(3)

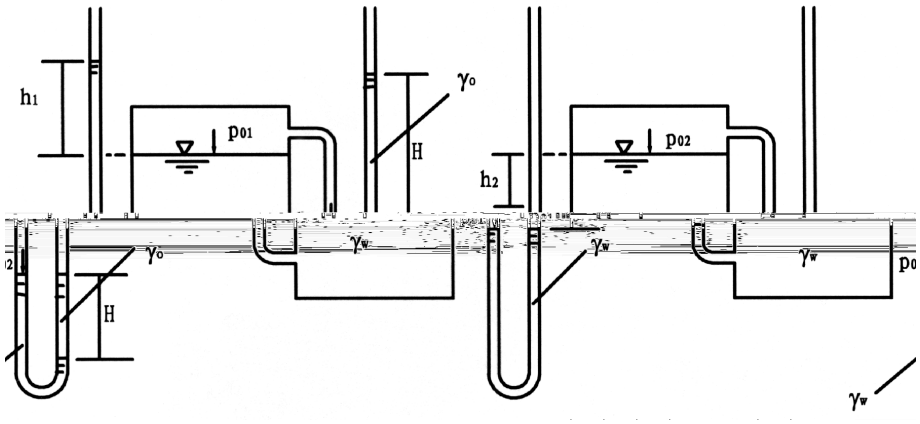
(4)

6 11

4 2

U

2.



(1)

(2)

Z ——
p —— (,)
p_0 ——
γ ——
h ——
( )U S_0

(3)

( ) S_0

3.

(1)

, 1 2 4 5

3

(2)

C D 2

C C C (p_C/γ) C

D C (Z_C) C

(Z_C+p_C/γ)

(3)

1 2 3

(4)

4

$p_0>0$

$p_0<0$ 4

(5)

C D

C D

(6)

C C C

C

(7)

2cm

a. C 1 2 5

b. 5 U

c. 4 4

4 b

c a 1 2

(8)

∇_h,

∇_h h $=\nabla_0-\nabla_h$

(9)

U

(10)

p_0=0

γ

γ

(11)

C

1 C

C

(12)

4

4 4

(13)

80 1-12

4 2

h ( )

h 4

4.

(1)

σ γ *d* *h*

(t=20) σ=7.28dyn/mm γ=0.98dyn/mm^3 θ
cosθ=1.0

(h d mm)

10mm

σ

θ *h*

(2) *δ* *H*

p_0=0 (H+δ)

H 0.8cm 20cm

, *δ* 1 2

H

d 0.8cm D 20cm

δ / H 0.0032

ε

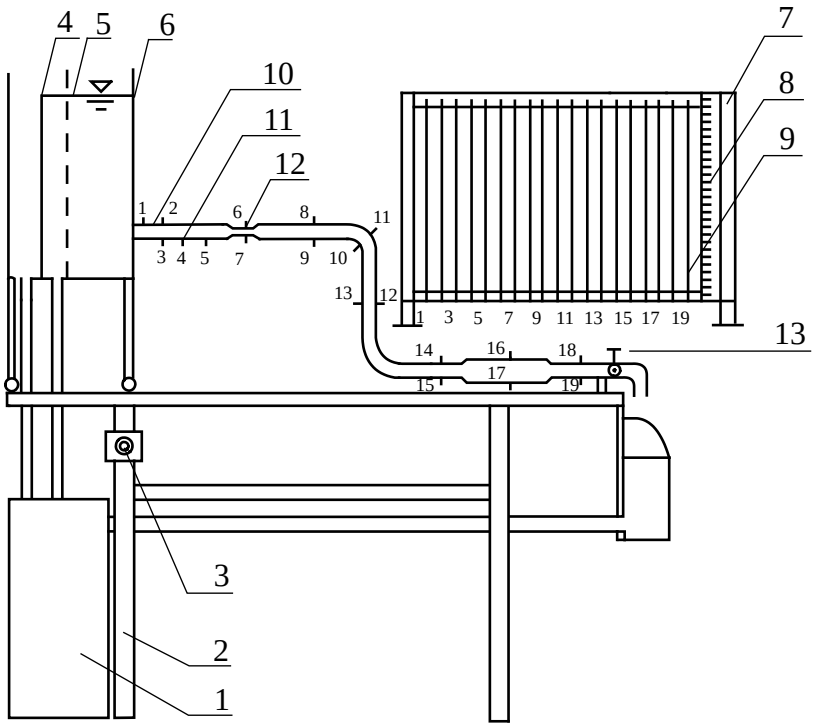
D/d≤10 D/d≤7

ε≤0.01

:

CAI

1.



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

[ ] :

(1) ,

(2) ,

2.

(1)

(2)

(3)

3.

(1) ,

(2) ,

,

(3) , ,

(4) ,

,

(5) , , ,

(6) 220V 50HZ, 100W
(7) 0 300ml/s, 0 200ml/s
(8) 150cm 55cm

1. , , ,
,
,
2. 220V , ,
, , , ,
,
3. , , ,
,
4. , , ,
, , ,
, , ,

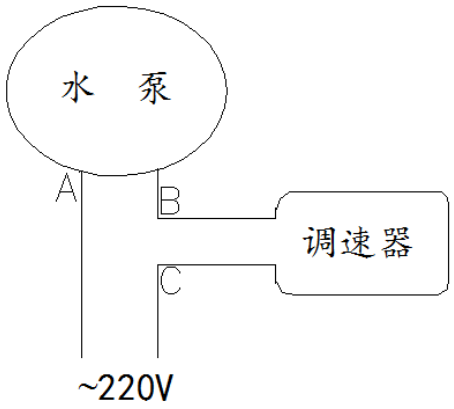
5. ,

6.
(1) , ,
; , , ,
, ,
(2)
a. , ,

b. ,
c. , , ,
; , , ,

d. , , : 220V ,
B C , , A B 220V , , ;
, , ; ,
6A, ; ,
, , ,

-



e. , ,
, 5 10 , ,
, ;

f. , , ,
502 ,

1.
, ?

:

(1) :
;

(2) : ,
,
, ,
;

(3) : a ; b) ; c ; d
; e ; f ;

(4) : a ; b ,
, , ,
, , ,
, ; c
,
, ,
, ,

2.
n (1) (i)
i=2,3,…,n

α_1 α_2 α_3 α_n 1, , ,

, v ,

3.

,

(1)

, 19 19

(2) ,

, , 9 9 h_9

$h_9 = Z_9 + \frac{p_9}{\gamma}$, 8 h_8, $h = Z_8 + \frac{p_8}{\gamma} + \frac{v^2}{g}$,

h_8 h_9 $\Delta h_{8\text{-}9}$, , ,

, h , $\Delta h_{8\text{-}9}$

, ,

(3) ,

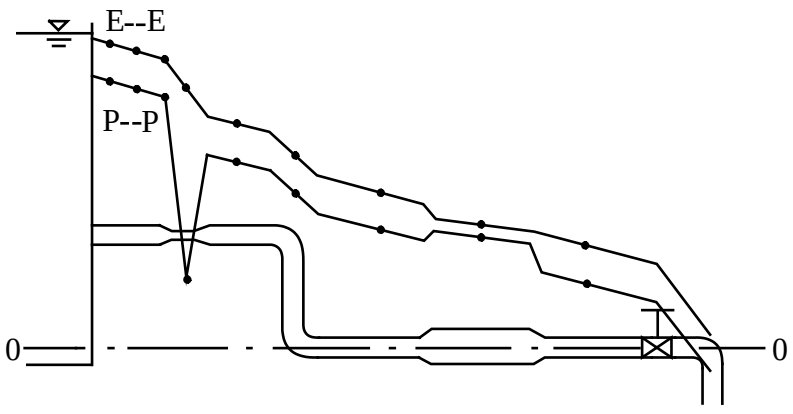
2 3 , ,

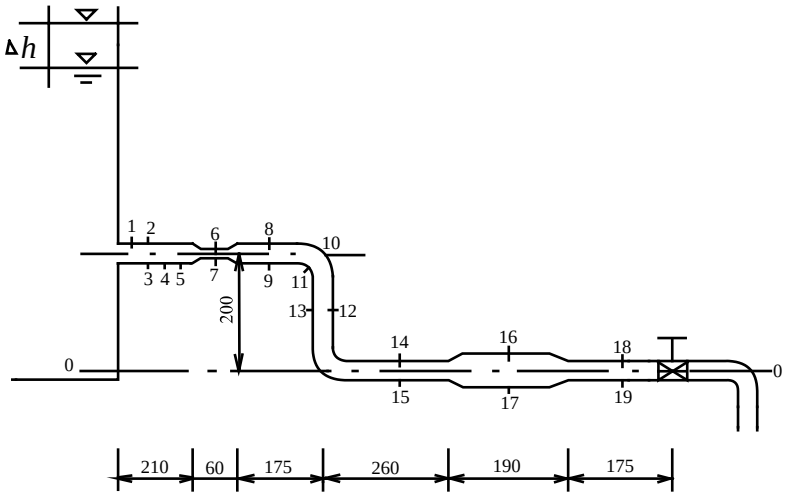
,

(4)

, ,

$1^{\#}$, :





1 6 8 12 14 16 18 ,

, , , ,

, , ,

$\Delta h_{1\text{-}6}$

$\Delta h_{6\text{-}8}$, $\Delta h_{6\text{-}8} >> \Delta h_{1\text{-}6}$, 6 8 , 1 6 ,

$\Delta h_{14\text{-}16}$ $\Delta h_{16\text{-}18}$,

, ,

, ,

(5)

2 4 5 7 9 13 17 19 , ,

,

2 4 5 ,

, , , , ,

5 7 , 5 7, ,

, 5 7 , 7

9 , ,

, , 15 17

17 19 9 15 9

, , 15 , 9 , ,

9 ,

4.

(1) , ,

,

(2) E E

, :

a) , ,

;

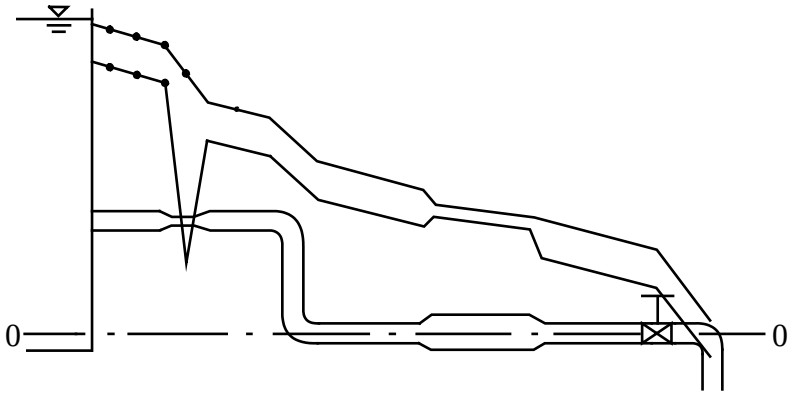
b) 3mm ,

, E-E P-P , E E
P P , ,)
a) , , 1 6 8
, ,
, ,
10 11 ,
(3) P P
, , (2) b)

(2) (3) , , ,

(4)
, , ,
,
, 7 , 7
7 , , 9,
, 9 9 , 9
, , , ,

(5)
P P , J_p E E
, J , J 0 , ,
, 5 7, , ,
, J_p 0 7 9, , , , J_P 0
E_1 E_2 $h_{и1\text{-}2}$, $h_{и1\text{-}2}$, , $h_{и1\text{-}2}$ 0, E_2 E_1,
E E E E , J ,
, ,



, ,

, , ,
10 11 , 9 10 11 13 ,

, ,

:

$$Z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} - \frac{w_1^2 r_1^2}{2g} = Z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} - \frac{w_2^2 r_2^2}{2g} + h_w$$

(7) 2 3 10 11
$1^{\#}$,

2 3 , 0.7cm, H_p 37.1cm

0.1mm , , 10 11
, 7.3cm,

,

, , , ,
, 10 11

(8) 7

:

(a) ; (b) ; (c) ; (d)

(a) (b) (c) , (c)
, 90°
, , 0 0, , p/γ
Z , 7 (d)

Δh , 7

1 2 3 , cm
1 2 α_2 α_3 1

Z_1 Δh (1)

$h_{w1\text{-}2}$

$$h_{w1-2} = (\lambda \frac{l_{1.2}}{d_2} + \zeta_e + \zeta_s) \frac{v_3^2}{2g} = \zeta_{c1.2} \frac{v_3^2}{2g}$$

$\zeta_{c1.2}$ 1 2 , ζ_e ζ_s

$$\frac{v_2^2}{2g} = (\frac{d_3}{d_2})^4 \frac{v_3^2}{2g}$$

(1)

(2)

1 3 ,

$$Z_1 + \Delta h = Z_3 + \frac{\upsilon_3^2}{2g} + \zeta_{c1.3} \qquad (3)$$

$\zeta_{c1.3}$

$$= (Z_1 \quad Z_3 \quad \Delta h) / (1 \quad \zeta_{c1.3}), \qquad (2)$$

(4)

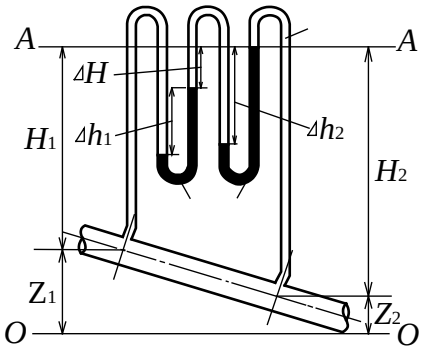
$(Z_2 \quad p_2/\gamma) \quad \Delta h$, $\partial (Z_2 \quad p_2/\gamma) / \partial (\Delta h)$

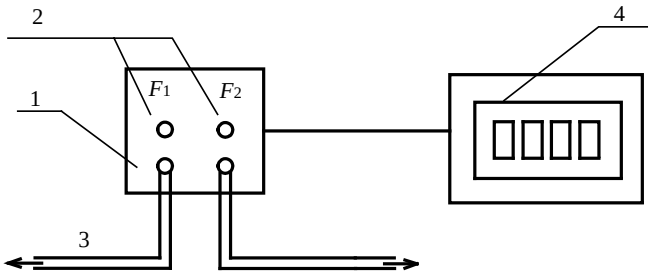
(5)

$1-[(d_3/d_2)^4 \quad \zeta_{c1.2}] / (1 \quad \zeta_{c1.3}) \quad 0$, 2 $Z \quad p/\gamma \quad \Delta h$,

,

$d_3/d_2 \quad 1.37/1$, $Z_1 \quad 50$, $Z_3 \quad 10$, $\Delta h \quad 0$, $(Z_2 \quad p_2 / \gamma)$





1. 2.

3. 4.

2.

(1)

;

(2) ;

(3)

3.

(1) , 11 ,

;

(2) ,

± 1mm;

(3) ,

, , ;

(4) U ,

;

(5) 6 8 , ;

(6) : 220V, 50HZ; 450W;

(7) 250ml/s, 11 ;

(8) : 0.8kg/cm^2, 1.4kg/cm^2;

(9) : =150cm 55cm

1. , ,
, ;
, ;

2. , 220V , ,
, , ,
, , ;

3. , ,
, ,
;

4.

(1) ,
,

, 3/5, ,
, , ,

(2) F_1
F_1

5. ,

6.

(1)

a. , , ;

b. ;

c. , , ;

d. , , ;

e. , , ;

f. , ,
, ; ,
, ;

g. , ,

(2)

a. , ;

b. ,

, 5 10 ;

c. ,

, , 502 ,

;

d. , , ,

;

e. ,

1.

,

,

,

,

;

;

, , ;

, , , ,

, , , ,

,

,

,

, ,

±1 mm , 150cm

55cm , ,

,

,

, ,

, ,

,

2.

, ,

, ,

,

$$\upsilon = C\sqrt{RJ} \qquad (1)$$

(Chezy) , , : υ ;

R , R $\frac{A}{P}$, J , J $\frac{h_f}{L}$; C ,

a.

$$\frac{1}{\sqrt{\lambda}} = -2lg(\frac{k_s}{3.7d} + \frac{2.51}{Re\sqrt{\lambda}})$$

b. $S \cdot J$

$$\lambda = \frac{1.325}{[ln(k_s / 3.7d + 5.74 / Re^{0.9})]^2}$$

c. *Barr*

$$\frac{1}{\sqrt{\lambda}} = -2lg(\frac{k_s}{3.7d} + \frac{5.1286}{Re^{0.89}})$$

c $\frac{k_s}{d}$, *b* λ *Re*

k_s / d, k_s

(2)

Re λ , ,

, *Re* λ

,

λ π *g* ^{5} $_f$ 8 *Q*

d *Q* , *Q* 2% , λ 4% , *d* 2% , λ 10% *Q* , *d* , , $\varepsilon < 1\%$, ,

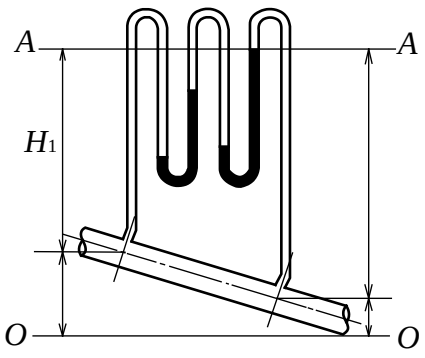
, ,

,

(3) *m*

(lgh_f $lg\upsilon$) *m* 1.0 1.8, h_f $\upsilon^{1.0\ 1.8}$,

m 1.0



(4) ? ,

?

A *A*

:

0 0 , 1 1 2 2 , ,

υ_1 υ_2, $\sum h_j$ 0,

$$h_{f1-2} = (Z_1 + \frac{p_1}{\gamma}) - (Z_2 + \frac{p_2}{\gamma})$$

$$\frac{p_1}{\gamma} = \frac{p_2}{\gamma} - H_2 + 13.6\Delta h_2 - \Delta h_2 + \Delta H + 13.6\Delta h_1 - \Delta h_1 - \Delta H + H_1$$

$$= \frac{p_2}{\gamma} - H_2 + 12.6\Delta h_2 + 12.6\Delta h_1 + H_1$$

$$h_{f1-2} = (Z_1 + H_1) - (Z_2 + H_2) + 12.6\Delta h_2 + 12.6\Delta h_1$$

=12.6 Δh_1 Δh_2

,

(5) , ,

, , ?

0.2mm, (20) 0.01cm^2/s,

300cm/s, *D* (20 100)cm, *Re* 6 10^5 3 10^6, $\frac{k_s}{d}$

0.0002 0.001, ,

, *Re* 10^6 9 10^6, (5 9)m/s

(1 9)mm, (2 3)m,

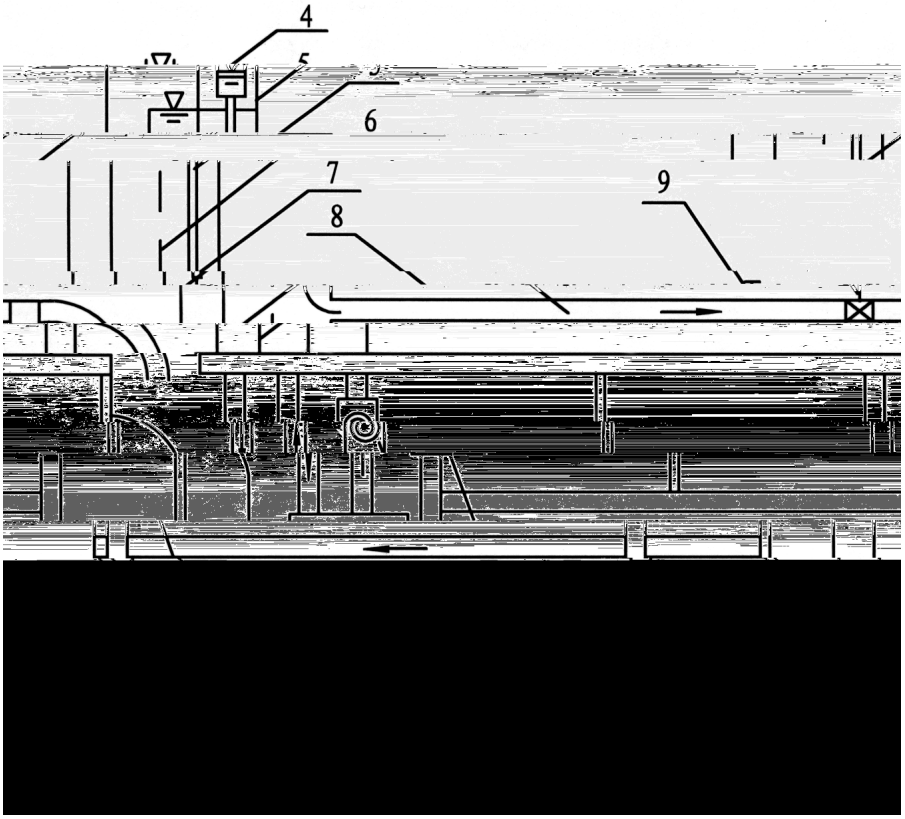
(5 10)m/s , *Re* 10^7,

:

, , CAI

, ,

1.



1. 2. 3. 4.

5. 6. 7. 8.

9.

[ ]

, 4 ,

, 3~5

5 8, ,

2.

,

3.

(1) ;

(2) , ,
3 5 ;

(3) , ,
;

(4) : 220V 50HZ; : 100W;

(5) 2000 2300, 3000 5000;

(6) : 0 300ml/s, 0 200ml/s;

(7) : =150cm 55cm

1. , , ;
;
, ;

2. 220V , ,
, , , ,
;

3. , , ,
, ;

4. ( ) , 700ml ,
, , , 10 20ml ,
, ;

5. , , , ,
, ;

6.

(1)

a. , ;

b. ;

c. , , ;

d. ;

e. , ,

(2)

a. , , ,
5 10 ;

b. , , ,

; , , ,

;

c. , ;

d. , , :

220V , B C , , A B (220V),

, ; , , ;

, , (6A,) :

, ,

1.

, , ,

, , ,

,

; , ,

, , ; ,

, , ,

,

2.

$$Re = \frac{\upsilon d}{\nu} = \frac{4Q}{\pi d \nu} = KQ$$

$$K = \frac{4}{\pi d \nu} \qquad (1)$$

:

υ —— ;

ν —— ;

d —— ;

Q ——

, d

ν , $\frac{\upsilon_c d}{\nu}$, Re_c ,

$$Re_c = \frac{\upsilon_c d}{\nu} \qquad (2)$$

, , ,

$\mathrm{Re}_c, \mathrm{Re}_c = \frac{\upsilon_c d}{\nu}$; , $Re_c, Re_c = \frac{\upsilon_c d}{\nu}$

, ,

Re_c , ,

Re_c 2320 $Re<Re_c=2320$,

; $Re>Re_c=2320$,

3.

(1)

, , , ,

, , ,

, ,

, ,

(2) ,

a.

, , , ,

, ( ) , ,

, , 2000 2300

2320,

, ,

,

, 2000 2300 , ,

2000 ,

b.

, , , , , ,

, , ,

, 3000 5000 , , ,

, 12000, 20000,

40000 , , ,

4.

(1) ,

1883 , —— ,

$\upsilon_c^{'}$,$\upsilon_c^{'}$ ν d ,

$$\upsilon_c^{'} = f(\nu, d) \qquad (3)$$

, $\upsilon_c^{'}$

, ,

$(\upsilon d / \nu)$,

(3)

$$\upsilon^{'} = K\nu^{\alpha_1} d^{\alpha_2} \qquad (4)$$

K

(4)

$$[LT^{-1}] = [L^2T^{-1}]^{\alpha_1}[L]^{\alpha_2} \qquad (5)$$

,

L: $2\alpha_1+\alpha_2=1$

T: $-\alpha_1= -1$

$\alpha_1 = 1$, $\alpha_2 = -1$

, (4),

, ( ) ,

, , , ,

, ,

, ,

, , ,

, , , ,

→ → → ,

(4)

$= ma = \rho W \frac{d\upsilon}{dt}$, W L

, $[W]=[L]^3$; $\frac{d\upsilon}{dt}$, $[\frac{d\upsilon}{dt}] = \frac{[\upsilon]}{[t]}$

$$[\rho][W][\frac{d\upsilon}{dt}] = [\rho][L]^3 \frac{[\upsilon]}{[t]}$$

$T = \mu\omega \frac{du}{dn}$, ω L , $[\omega]=[L]^2$, $\frac{du}{dn}$

L , $[\frac{du}{dn}] = \frac{[\upsilon]}{[L]}$

$$[\mu][L]^2 \frac{[\upsilon]}{[L]} = [\mu][L][\upsilon]$$

$$\frac{[\qquad]}{[\qquad]} = \frac{[\rho][L]^3 \frac{[\upsilon]}{[t]}}{[\mu][L][\upsilon]} = \frac{[\rho][L]^2}{[\mu][t]}$$

$$= \frac{[\rho][L][L]}{[\mu][t]} = \frac{[\upsilon][L]}{[\nu]}$$

, L d ,

R

,

(5)

a. , Re_c=1.0, $Re=DU/\nu$<1.0 , , , U

, D , ν

b. ( ), $Re=\upsilon R/\nu$ $R=$ $/P$, P ,

$R=d/4$, Re_c=800

:

, , CAI

, ,