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## NOMENCLATURE

a	inside radius of the storage tank (m)
c <sub>p</sub>	heat capacity of the storage fluid (Kcal/Kg.°C)
d	inlet diameter of the storage tank (m)
D	inner diameter of the storage tank (m)
E <sub>a</sub>	total energy stored in the storage fluid (Kcal)
E <sub>c</sub>	extracted energy (Kcal)
f(z)	initial temperature profile of the storage tank fluid (°C)
g(t)	inlet temperature of the storage tank fluid (°C)
Gr <sub>D</sub>	Grashof number based on tank diameter, $(g\beta^2/\mu^2)D^3\Delta T$
h	wall-to-water heat transfer coefficient (Kcal/m <sup>2</sup> .hr.°C)
k	thermal conductivity of storage tank fluid (Kcal/m.hr.°C)
L	length of storage tank (m)
q(θ)	function of θ defined by equation (12)
Q	volumetric flow rate (l/min)
r	radial distance from the central axis of the storage tank (m)
Re <sub>d</sub>	Reynolds number based on inlet pipe diameter, $\rho v_m d/\mu$
s	complex variable used in Laplace transformation
t	time (min)
T <sub>h</sub>	the highest temperature of the storage fluid (°C)
T <sub>l</sub>	the lowest temperature of the storage fluid (°C)
T <sub>o</sub>	temperature of storage fluid (°C)
T <sub>w</sub>	temperature of the tank wall (°C)

$\Delta T$	temperature difference between the storage fluid and the tank wall ( $^{\circ}\text{C}$ )
$V$	volume of the storage tank (l)
$v_m$	average velocity of the storage fluid (m/sec)
$v_z$	z-component of the velocity (m/sec)
$\alpha$	thermal diffusivity of storage fluid, $k/c_p$ ( $\text{m}^2/\text{hr}$ )
$\Gamma$	$2hL/a\rho c_p v_m$
$\epsilon$	extraction efficiency of the storage tank
$\eta$	$z/L$ , dimensionless axial distance
$\theta$	$t/\tau$ , dimensionless time
$\Theta$	$(T - T_1)/\Delta T$ , dimensionless fluid temperature
$\Theta_w$	$(T_w - T_1)/\Delta T$ , dimensionless wall temperature
$\mu$	viscosity of storage fluid (Kg/m.hr)
$\rho$	density of storage fluid ( $\text{Kg}/\text{m}^3$ )
$\sigma$	variance
$\tau$	$V/Q$ , mean residence time of the fluid in the storage tank (hr)
$\wedge$	Laplace transform
*	dimensionless quantity

APPENDIX I

EXPERIMENTAL DATA

Table 9.1

## Experimental Data

Tank Size: L = 1.524 m., D = 0.152 m.

Flow Rate = 2.30 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
0	93	93	92	92	91	91	90	90	91	93	90
0.50	91	91	91	91	91	91	89	89	90	40	90
1.00	50	91	91	91	91	91	90	88	90	35	90
1.50	35	90	91	91	90	90	89	88	90	33	90
2.00	34	44	90	90	90	90	89	88	90	33	90
2.50	34	44	90	90	90	90	89	88	90	33	90
3.00	33	35	46	90	90	90	89	88	90	33	90
3.50	33	33	37	74	90	90	89	88	90	33	90
4.00	33	33	35	44	89	89	89	87	89	32	90
4.50	33	33	34	37	62	89	89	89	89	32	90
5.00	33	33	33	35	41	88	88	89	89	32	90
5.50	33	33	33	34	37	56	88	87	89	32	89
6.00	33	33	33	34	34	41	70	87	89	32	89
6.50	33	33	33	34	34	36	46	86	88	32	89
7.00	33	33	33	34	34	36	40	66	88	32	89

Table 9.1

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
7.50	33	33	33	33	34	34	37	45	88	32	89
8.00	33	33	33	33	34	34	36	39	88	32	89
8.50	33	33	33	33	34	34	35	37	86	32	89
9.00	33	33	33	33	34	34	35	35	56	32	89
9.50	33	33	33	33	34	34	35	35	49	32	88
10.00	33	33	33	33	34	34	35	35	44	32	88
10.50	33	33	33	33	34	34	35	35	41	32	88
11.00	33	33	33	33	34	34	35	35	39	32	88
11.50	33	33	33	33	34	34	35	35	38	32	86
12.00	33	33	33	33	34	34	35	35	37	32	86
12.50	33	33	33	33	34	34	35	35	36	32	71
13.00	33	33	33	33	34	34	35	35	35	32	61
13.50	33	33	33	33	34	34	35	35	35	32	51
14.00	33	33	33	33	34	34	35	35	35	32	49
15.00	33	33	33	33	34	34	35	35	35	32	45
16.00	33	33	33	33	34	34	35	35	35	32	43
17.00	33	33	33	33	34	34	35	35	35	32	40
18.00	33	33	33	33	34	34	35	35	35	32	38
19.00	33	33	33	33	34	34	35	35	35	32	37

Table 9.1  
(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
20.00	33	33	33	33	34	34	35	35	35	32	36
21.00	33	33	33	33	34	34	35	35	35	32	35



Table 9.2

## Experimental Data

Tank Size: L = 1.524 m., D = 0.152 m.

Flow Rate = 4.45 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
0	97	97	96	96	96	95	95	94	95	97	94
0.50	53	95	95	95	95	95	94	94	94	40	94
1.00	39	74	94	94	95	95	95	93	94	36	94
1.50	37	39	68	94	95	95	95	93	94	36	94
2.00	36	37	42	75	94	94	94	93	94	35	94
2.50	36	37	37	43	69	93	93	93	94	35	94
3.00	36	36	36	38	44	73	93	93	94	35	94
3.50	36	36	36	37	38	44	80	92	93	35	94
4.00	36	36	36	37	37	39	45	80	93	35	93
4.50	36	36	36	37	37	37	40	76	48	35	93
5.00	36	36	36	37	37	37	40	40	48	35	93
5.25	36	36	36	37	37	36	37	39	44	35	93
5.50	36	36	36	37	37	36	37	38	41	35	93
6.00	36	36	36	37	37	36	37	37	38	35	91
6.25	36	36	36	37	37	36	37	37	38	35	68



Table 9.3

## Experiment Data

Tank Size:  $L = 1.524$  m.,  $D = 0.152$  m.

Flow Rate = 6.43 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>o</sub> °C
0	96	96	96	95	95	95	94	94	94	96	94
0.50	42	91	94	94	94	94	93	92	93	37	94
1.00	39	45	69	94	94	94	93	92	93	35	94
1.50	36	38	41	52	91	93	93	91	93	34	93
2.00	36	38	36	40	46	73	92	91	93	34	93
2.50	36	38	36	37	38	44	59	90	92	34	93
3.00	36	38	36	37	38	38	41	50	82	34	92
3.50	36	38	36	37	38	36	37	43	48	34	92
4.00	36	38	36	37	38	36	36	37	38	34	89
4.25	36	38	36	37	38	36	36	37	37	34	52
4.50	36	38	36	37	38	36	35	36	37	34	48
4.75	36	38	36	37	38	36	35	36	36	34	46
5.00	36	38	36	37	38	36	35	36	36	34	42
5.25	36	38	36	37	38	36	35	36	36	34	39
5.50	36	38	36	37	38	36	35	35	35	34	38

Table 9.3

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
5.75	36	38	36	37	38	36	35	35	35	34	37
6.00	34	35	34	35	35	34	35	35	35	34	36
7.00	34	35	34	35	35	34	35	35	35	34	35

Table 9.4

## Experimental Data

Tank Size: L = 1.524 m., D = 0.152 m.

Flow Rate = 8.82 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
0	97	97	97	96	96	96	95	95	95	97	94
0.25	51	97	97	96	96	96	95	95	95	41	94
0.50	44	56	97	96	96	96	95	95	95	37	94
0.75	42	43	51	96	96	96	95	95	95	37	94
1.00	39	40	42	50	96	96	95	95	95	37	94
1.25	39	40	40	46	60	96	95	95	95	36	94
1.50	38	39	39	42	47	69	92	95	95	36	94
1.75	38	38	39	42	47	47	80	92	95	36	94
2.00	37	38	39	42	45	47	68	88	93	36	94
2.25	37	38	39	41	44	46	46	58	90	36	93
2.50	36	37	38	41	43	45	45	46	59	36	93
2.75	36	37	38	40	42	43	43	45	44	36	78
3.00	35	37	38	40	41	40	40	42	42	36	51
3.25	35	36	38	39	40	39	39	40	41	36	45
3.50	35	36	37	39	39	39	39	39	38	36	44



Table 10.1

## Experimental Data

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.

Flow Rate = 2.30 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>1</sub> °C	T <sub>o</sub> °C
0	92	92	93	91	92	91	92	92	92	92	91
1.00	91	91	92	91	92	91	92	92	92	52	91
2.00	40	90	91	91	92	91	92	92	92	36	91
3.00	33	63	91	90	90	89	90	91	91	33	91
4.00	32	36	90	89	90	89	90	91	91	33	91
5.00	32	33	43	90	89	89	90	91	91	32	90
6.00	32	32	34	62	89	89	90	90	90	33	90
7.00	32	32	34	38	88	89	90	90	90	33	90
8.00	32	32	33	34	49	88	89	90	90	33	90
9.00	32	32	33	34	37	72	89	90	90	33	90
10.00	32	32	33	34	34	41	88	90	90	33	90
11.00	32	32	33	33	33	35	52	89	89	33	90
12.00	32	32	33	33	33	33	39	57	89	33	90
13.00	32	32	33	33	33	33	36	40	88	33	90
14.00	32	32	33	33	33	33	34	35	52	33	90

Table 10.1

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>11</sub> °C	T <sub>o</sub> °C
15.00	32	32	33	33	33	33	33	34	48	33	89
16.00	32	32	33	33	33	33	33	34	39	33	89
17.00	32	32	33	33	33	33	33	33	36	33	89
18.00	32	32	33	33	33	33	33	33	35	33	89
19.00	33	33	34	34	34	34	34	34	34	33	88
20.00	33	33	34	34	33	33	34	34	34	33	87
20.50	33	33	34	34	33	33	34	34	34	33	85
21.00	33	33	34	34	33	33	34	34	34	33	78
21.50	33	33	34	34	33	33	34	34	34	33	65
22.00	33	33	34	34	33	33	34	34	34	33	56
22.50	33	33	34	33	33	33	34	34	34	33	50
23.00	33	33	34	33	33	33	34	34	34	33	46
23.50	33	33	34	33	33	33	34	34	34	33	44
24.00	33	33	34	33	33	33	34	34	34	33	42
25.00	33	33	34	33	33	33	34	34	34	33	40
26.00	33	33	34	33	33	33	34	34	34	33	39
27.00	33	33	34	33	33	33	34	34	34	33	38
28.00	33	33	34	33	33	33	34	34	34	33	36
29.00	33	33	34	33	33	33	34	34	34	33	34



Table 10.2

## Experimental Data

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.

Flow Rate = 4.45 l./min.

Time t min.	Temperature										
	$T_1$ °C	$T_2$ °C	$T_3$ °C	$T_4$ °C	$T_5$ °C	$T_6$ °C	$T_7$ °C	$T_8$ °C	$T_9$ °C	$T_{10}$ °C	$T_{11}$ °C
0	96	96	96	95	95	95	96	96	95	95	94
1.00	50	94	95	95	95	95	95	95	95	41	94
2.00	36	42	94	95	95	95	95	95	95	35	94
3.00	36	36	43	92	95	95	95	95	95	34	93
4.00	34	35	38	43	91	94	94	94	94	34	93
5.00	35	35	35	36	41	85	93	93	93	34	93
6.00	35	35	35	35	36	40	76	93	93	34	93
7.00	35	35	35	35	34	36	41	86	92	34	93
8.00	35	35	35	35	34	35	37	45	82	34	93
9.00	35	35	35	35	34	35	36	35	65	34	92
10.00	35	35	35	35	34	35	35	35	41	34	92
10.50	35	35	35	35	34	35	35	35	35	34	83
11.00	35	35	35	35	34	35	35	35	35	34	60
11.50	35	35	35	35	34	35	35	35	35	34	49
12.00	35	35	35	35	34	35	35	35	35	34	46

Table 10.2

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
12.50	35	35	35	35	34	35	35	35	35	34	42
13.00	35	35	35	35	34	35	35	35	35	34	40
14.00	35	35	35	35	34	35	35	35	35	34	38
14.50	35	35	35	35	34	35	35	35	35	34	36
15.00	35	35	35	35	34	35	35	35	35	34	35

Table 10.3

## Experimental Data

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.

Flow Rate = 6.43 l./min.

Time t min.	Temperature											
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C	
0	97	97	98	97	97	96	97	97	97	97	97	95
1.00	42	82	96	95	96	95	96	96	96	96	38	95
2.00	37	40	47	94	95	94	96	96	96	96	35	95
3.00	36	37	38	41	65	94	95	95	95	95	35	95
4.00	35	36	36	36	39	43	91	95	95	95	35	94
5.00	35	36	36	35	35	37	42	68	90	90	35	94
6.00	35	36	36	35	35	35	38	41	64	64	35	93
6.50	35	36	36	35	35	35	38	37	39	39	35	84
7.00	35	37	36	35	35	35	36	36	37	37	35	59
7.50	35	36	36	35	35	35	36	36	36	36	35	48
8.00	35	36	36	35	35	35	36	36	36	36	35	44
8.50	35	36	36	35	35	35	36	36	36	36	35	41
9.00	35	36	36	35	35	35	36	36	36	36	35	40
10.00	35	36	36	35	35	35	36	36	36	36	35	37
11.00	35	36	36	35	35	35	36	36	36	36	35	36

Table 10.4

## Experimental Data

Tank Size: L = 1.524 m., D = 0.203 m.

Flow Rate = 8.82 l./min.

Time t min.	Temperature											
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C	
0	99	99	98	97	97	97	97	97	97	97	98	96
1.00	41	45	76	95	97	97	97	97	96	37	37	96
2.00	38	39	40	51	95	94	96	96	96	35	35	95
3.00	37	37	37	37	42	44	95	95	96	35	35	95
3.50	37	37	37	36	37	38	45	48	94	35	35	94
4.00	36	37	36	36	36	37	40	43	51	35	35	91
4.50	36	37	36	36	36	37	37	38	42	35	35	89
5.00	36	37	36	36	36	37	37	37	37	35	35	50
5.50	36	37	36	36	36	36	36	37	36	35	35	44
6.00	36	37	36	36	36	36	36	37	36	35	35	43
7.00	36	37	36	36	36	36	36	36	36	35	35	40
8.00	36	37	36	36	36	36	36	36	36	35	35	38
9.00	36	37	36	36	36	36	36	36	36	35	35	37
10.00	36	37	36	36	36	36	36	36	36	35	35	36

Table 11.1

## Experimental Data

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Flow Rate = 2.30 l./min.

Time t min.	Temperature										
	$T_1$ °C	$T_2$ °C	$T_3$ °C	$T_4$ °C	$T_5$ °C	$T_6$ °C	$T_7$ °C	$T_8$ °C	$T_9$ °C	$T_{10}$ °C	$T_o$ °C
0	95	96	94	94	94	93	93	94	94	94	94
1.00	94	96	93	94	94	92	93	93	93	33	94
2.00	58	96	93	94	94	92	93	93	93	33	94
3.00	41	96	93	94	94	92	93	93	93	33	94
4.00	36	95	93	94	94	92	93	93	93	33	94
5.00	36	68	93	94	94	92	93	93	93	33	94
6.00	35	56	92	94	94	92	93	93	93	33	94
7.00	35	42	92	94	94	92	93	93	93	33	94
8.00	34	38	91	94	94	92	92	93	93	33	94
9.00	34	35	57	94	94	92	92	93	93	33	94
10.00	34	35	39	94	94	92	92	93	93	33	94
11.00	34	35	35	93	94	92	92	93	93	33	94
12.00	34	35	35	65	94	92	92	93	93	34	94
13.00	35	35	35	43	93	93	92	92	92	34	94
14.00	35	35	35	39	91	93	92	92	92	34	94

Table 11.1

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>i</sub> °C	T <sub>o</sub> °C
15.00	35	36	35	38	60	93	93	92	92	34	94
16.00	35	36	35	37	43	93	93	92	92	34	94
17.00	35	36	35	37	39	86	93	92	92	34	94
18.00	35	36	35	37	37	51	92	92	92	34	94
19.00	35	36	35	36	37	43	91	92	93	34	94
20.00	35	36	35	36	36	41	66	92	93	34	94
21.00	35	36	35	36	36	38	47	90	93	34	94
22.00	35	36	35	36	36	38	41	54	92	34	94
23.00	35	36	35	36	36	38	39	42	92	34	94
24.00	35	36	35	36	36	37	38	39	91	34	94
25.00	35	36	35	36	36	37	37	38	84	34	94
26.00	35	36	35	36	36	36	36	37	72	34	94
27.00	35	36	35	36	36	36	36	36	60	34	94
28.00	35	36	35	36	36	36	36	36	54	34	94
29.00	35	36	35	36	36	36	36	36	45	34	94
30.00	35	36	35	36	36	36	36	36	41	34	94
32.00	35	36	35	36	36	36	36	36	38	34	94
34.00	35	36	35	36	36	36	36	36	37	34	94
36.00	35	36	35	36	36	36	36	36	37	34	94



Table 11.2

## Experimental Data

Tank Size:  $L = 1.524 \text{ m.}$ ,  $D = 0.305$ Flow Rate =  $4.45 \text{ l./min.}$ 

Time t min.	Temperature											
	$T_1$ °C	$T_2$ °C	$T_3$ °C	$T_4$ °C	$T_5$ °C	$T_6$ °C	$T_7$ °C	$T_8$ °C	$T_9$ °C	$T_{10}$ °C	$T_{11}$ °C	
0	97	97	97	97	97	97	97	97	97	97	97	96
1.00	73	97	97	96	96	97	94	95	95	34	34	96
2.00	46	97	95	96	96	95	94	95	95	34	34	95
3.00	39	71	94	95	96	94	94	94	94	34	34	95
4.00	37	41	93	95	96	92	94	93	94	34	34	95
5.00	37	37	50	95	95	91	94	93	94	34	34	95
6.00	36	36	36	65	95	91	93	93	94	34	34	95
7.00	36	36	35	50	95	91	93	93	94	34	34	95
8.00	36	36	35	40	93	91	93	93	94	34	34	95
9.00	36	36	35	36	48	91	94	93	93	34	34	95
10.00	36	36	35	36	40	66	94	93	93	34	34	95
11.00	36	36	35	36	38	42	92	93	93	34	34	95
12.00	36	36	35	35	37	38	47	93	93	34	34	95
13.00	36	36	35	35	36	36	40	91	93	34	34	95
14.00	36	36	35	35	36	36	38	54	93	34	34	95
15.00	36	36	36	36	36	36	38	43	92	35	35	95





Table 11.3

## Experimental Data

Tank Size: L = 1.524 m., D = 0.305 m.

Flow Rate = 6.43 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
0	97	97	96	96	96	94	95	95	95	93	95
1.00	57	96	95	95	95	94	95	95	95	33	95
2.00	43	58	95	95	96	94	94	95	95	33	95
3.00	39	40	88	95	95	94	94	94	94	33	94
4.00	38	38	41	94	95	93	94	94	94	33	94
5.00	37	37	37	45	94	93	93	94	94	33	94
6.00	37	37	35	38	54	92	93	94	94	34	94
7.00	36	37	35	36	39	62	93	94	94	34	94
8.00	36	36	35	36	37	39	61	93	94	34	94
9.00	36	36	35	36	37	37	40	93	94	34	94
10.00	36	36	35	35	35	35	38	52	93	34	94
11.00	36	36	35	35	35	35	37	43	93	34	94
12.00	36	36	35	35	35	35	36	39	93	34	94
13.00	36	36	35	35	35	35	36	38	51	34	94
14.00	36	36	35	35	35	35	36	37	39	34	84
15.00	36	36	35	35	35	35	36	37	38	34	55

Table 11.3

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>o</sub> °C
16.00	36	36	35	35	35	35	36	36	36	34	43
17.00	36	36	35	35	35	35	36	36	36	34	40
18.00	36	36	35	35	35	35	36	36	36	34	39
19.00	36	36	35	35	35	35	36	36	36	34	38
20.00	36	36	35	35	35	35	36	36	36	34	37
21.00	36	36	35	35	35	35	36	36	36	34	36
22.00	36	36	35	35	35	35	36	36	36	34	36
23.00	36	36	35	35	35	35	36	36	36	34	35

Table 11.4

## Experimental Data

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Flow Rate = 8.82 l./min.

Time $t$ min.	Temperature										
	$T_1$ °C	$T_2$ °C	$T_3$ °C	$T_4$ °C	$T_5$ °C	$T_6$ °C	$T_7$ °C	$T_8$ °C	$T_9$ °C	$T_{10}$ °C	$T_o$ °C
0	97	98	97	96	97	97	96	96	96	96	96
1.00	57	97	96	95	96	95	94	95	95	33	95
2.00	42	42	87	94	96	94	93	95	95	33	95
3.00	38	42	43	93	95	94	93	94	94	33	95
4.00	37	37	36	42	94	94	93	94	94	33	94
5.00	36	37	35	37	44	87	92	93	94	33	94
6.00	36	36	35	35	38	41	61	93	94	33	94
7.00	36	36	35	35	35	37	40	93	94	33	94
8.00	36	36	35	35	35	35	37	46	93	33	94
9.00	36	36	35	35	35	35	36	39	93	33	94
10.00	36	36	35	35	35	35	36	37	45	33	79
11.00	36	36	35	35	35	35	36	36	38	33	51
12.00	36	36	35	35	35	35	36	36	36	34	45
13.00	36	36	35	35	35	35	36	36	36	34	42
14.00	36	36	35	35	35	35	36	36	36	34	41
15.00	36	36	35	35	35	35	36	36	36	34	41

Table 11.4

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
16.00	36	36	35	35	35	35	36	36	36	34	39
17.00	36	36	35	35	35	35	36	36	36	34	38
18.00	36	36	35	35	35	35	36	36	36	34	37
19.00	36	36	35	35	35	35	36	36	36	34	36
20.00	36	36	35	35	35	35	36	36	36	34	35

Table 12.1

## Experimental Data

Tank Size:  $L = 1.524$  m.,  $D = 0.356$  m.

Flow Rate = 2.30 l./min.

Time t min.	Temperature											
	$T_1$ °C	$T_2$ °C	$T_3$ °C	$T_4$ °C	$T_5$ °C	$T_6$ °C	$T_7$ °C	$T_8$ °C	$T_9$ °C	$T_{10}$ °C	$T_o$ °C	
0	96	96	96	96	96	96	96	96	96	96	96	96
1.00	95	96	96	96	96	96	96	96	96	52	96	96
2.00	95	96	96	96	96	96	96	96	96	40	96	96
3.00	95	96	96	96	96	96	96	96	96	37	96	96
4.00	70	96	96	96	96	96	96	96	96	35	96	96
5.00	43	96	96	96	96	96	96	96	96	35	96	96
6.00	38	96	96	96	96	96	96	96	96	35	96	96
7.00	37	92	96	96	96	96	96	96	96	35	95	95
8.00	37	62	96	96	96	96	96	96	96	35	95	95
9.00	36	46	95	95	96	96	96	96	96	35	95	95
10.00	36	39	93	95	95	95	95	95	95	35	95	95
11.00	36	38	93	94	95	95	95	95	95	35	95	95
12.00	35	37	92	94	94	94	94	94	94	35	95	95
13.00	35	36	64	94	94	94	94	94	94	35	95	95
14.00	35	36	58	94	94	93	94	94	94	35	95	95
15.00	35	36	43	94	94	93	94	94	94	35	95	95

Table 12.1

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
16.00	35	36	39	94	94	93	94	94	95	35	95
17.00	35	36	37	93	93	93	94	94	95	35	95
18.00	35	36	36	85	91	93	94	94	95	35	95
19.00	35	36	36	66	91	93	94	94	95	35	95
20.00	35	36	36	47	91	93	94	94	95	35	95
21.00	35	36	36	42	91	93	94	94	95	35	95
22.00	35	36	36	39	84	93	94	94	95	35	95
23.00	35	36	36	38	66	94	94	94	95	35	95
24.00	35	36	36	38	49	94	94	94	95	35	95
25.00	35	36	36	37	42	93	94	94	95	35	95
26.00	35	36	36	37	39	91	93	94	95	35	95
27.00	35	36	36	37	38	77	93	94	94	35	95
28.00	35	36	36	37	38	58	93	94	94	35	95
29.00	35	36	36	37	37	46	94	94	94	35	95
30.00	35	36	36	37	37	42	92	93	94	35	95
31.00	35	36	36	37	37	41	81	93	94	35	95
32.00	35	36	36	36	37	40	63	93	93	35	95
33.00	35	36	36	36	36	39	51	93	93	35	95
34.00	35	36	36	36	36	38	45	91	93	35	95

Table 12.1

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>0</sub> °C
35.00	35	36	36	36	36	37	43	91	93	35	95
36.00	35	36	36	36	36	37	41	79	92	35	95
37.00	35	36	36	36	36	37	39	62	92	35	95
38.00	35	36	36	36	36	36	39	50	92	35	94
39.00	35	36	36	36	36	36	38	43	91	35	94
40.00	35	36	36	36	36	36	38	39	79	35	94
41.00	35	36	36	36	36	36	38	38	64	35	94
42.00	35	36	36	36	36	36	37	38	53	35	94
43.00	35	36	36	36	36	36	37	38	46	35	94
44.00	35	36	36	36	36	36	37	37	44	35	94
45.00	35	36	36	36	36	36	37	37	41	35	93
46.00	35	36	36	36	36	36	36	37	40	35	93
47.00	35	36	36	36	36	36	36	36	39	35	93
48.00	35	36	36	36	36	36	36	36	38	35	92
49.00	35	36	36	36	36	36	36	36	37	35	92
50.00	35	36	36	36	36	36	36	36	37	35	91
51.00	35	36	36	35	35	36	36	36	36	35	91
52.00	35	35	35	35	35	36	36	36	36	35	91
53.00	35	35	35	35	35	35	35	36	36	35	88





Table 12.2

## Experimental Data

Tank Size: L = 1.524 m., D = 0.356 m.

Flow Rate = 4.45 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>1</sub> °C	T <sub>o</sub> °C
0	94	94	94	95	93	94	94	94	93	94	93
1.00	93	93	94	94	92	93	93	93	93	44	93
2.00	93	93	94	94	92	93	93	93	93	38	93
3.00	44	92	93	94	91	92	93	93	92	35	93
4.00	40	91	93	93	91	92	93	93	92	35	92
5.00	38	56	93	93	91	92	93	93	92	35	92
6.00	37	42	90	93	91	92	93	93	92	35	92
7.00	36	38	90	93	91	92	92	92	92	35	92
8.00	34	37	51	93	91	92	92	92	92	35	92
9.00	34	36	40	92	91	92	92	92	92	35	92
10.00	34	36	36	84	91	92	92	92	92	35	92
11.00	34	35	35	52	89	92	92	92	92	35	92
12.00	34	35	35	43	89	92	92	92	92	35	92
13.00	34	35	35	40	66	92	92	92	92	35	92
14.00	34	35	35	38	44	92	92	92	92	35	92
15.00	34	35	35	36	38	81	92	92	92	35	92

Table 12.2

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
16.00	34	35	35	36	37	54	93	92	92	35	92
17.00	34	35	35	36	36	44	92	92	92	35	92
18.00	34	35	35	36	35	41	68	92	92	35	92
19.00	34	35	35	36	35	38	48	91	92	35	92
20.00	34	35	35	36	35	37	43	91	92	35	92
21.00	35	35	35	36	35	36	41	67	91	35	92
22.00	35	35	35	36	35	36	39	51	91	35	92
23.00	35	35	35	36	35	36	38	42	91	35	91
24.00	35	35	35	36	35	36	37	38	64	35	91
25.00	35	35	35	36	35	36	36	37	53	35	90
26.00	35	35	35	36	35	36	36	37	42	35	85
27.00	35	35	35	36	35	36	36	36	39	35	83
28.00	35	35	35	36	35	36	36	36	38	35	68
29.00	35	35	35	36	35	36	36	36	37	35	57
30.00	35	35	35	36	35	36	36	36	36	35	49
31.00	35	35	35	36	35	36	36	36	36	35	46
32.00	35	35	35	36	35	36	36	36	36	35	43
33.00	35	35	35	36	35	36	36	36	36	35	42
34.00	35	35	35	36	35	36	36	36	36	35	42

Table 12.2

(Continued)



Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
35.00	35	35	35	36	35	36	36	36	36	35	40
36.00	35	35	35	36	35	36	36	36	36	35	39
37.00	35	35	35	36	35	36	36	36	36	35	38
38.00	35	35	35	36	35	36	36	36	36	35	37
39.00	35	35	35	36	35	36	36	36	36	35	36
40.00	35	35	35	36	35	36	36	36	36	35	35
41.00	35	35	35	36	35	36	35	36	36	35	34
42.00	35	35	35	36	35	36	35	36	36	35	34

Table 12.3

## Experimental Data

Tank Size: L = 1.524 m., D = 0.356 m.

Flow Rate = 6.43 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>i</sub> °C	T <sub>o</sub> °C
0	96	96	96	97	95	96	96	96	95	95	94
1.00	80	96	96	96	95	94	94	94	94	38	94
2.00	52	92	95	95	95	94	94	94	94	37	94
3.00	45	75	94	95	94	94	94	94	94	36	94
4.00	41	48	94	94	94	94	94	94	94	36	94
5.00	40	41	83	94	94	94	94	94	94	35	94
6.00	38	39	47	94	94	94	94	94	94	35	94
7.00	37	38	41	87	94	94	94	94	94	35	94
8.00	37	37	38	50	92	93	94	94	94	35	94
9.00	37	37	36	44	73	93	94	94	94	35	94
10.00	37	37	36	40	48	93	94	94	94	35	94
11.00	37	37	36	38	40	62	94	94	94	35	94
12.00	37	37	36	38	38	46	93	94	94	35	94
13.00	37	37	36	38	37	41	57	93	94	35	94
14.00	37	37	36	38	37	39	48	91	94	35	94



Table 12.4

## Experimental Data

Tank Size:  $L = 1.524$  m.,  $D = 0.356$  m.

Flow Rate = 8.82 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>i</sub> °C	T <sub>o</sub> °C
0	97	96	96	97	95	97	96	96	96	96	94
1.00	64	95	95	96	94	96	95	95	95	41	94
2.00	48	94	95	95	94	95	95	95	95	38	94
3.00	41	58	90	94	94	95	95	95	95	37	94
4.00	40	43	60	94	94	94	94	94	94	36	94
5.00	39	40	46	93	93	94	94	94	94	35	94
6.00	38	38	40	53	92	94	94	94	94	35	94
7.00	37	37	38	44	56	92	94	94	94	35	94
8.00	37	37	37	40	44	72	94	94	94	35	94
9.00	36	36	37	39	41	50	93	94	94	35	94
10.00	35	36	36	38	39	43	56	93	94	35	94
11.00	35	35	36	37	37	40	46	64	92	35	91
12.00	35	35	36	36	37	38	41	55	63	35	75
13.00	35	35	36	36	36	37	38	42	47	35	54
14.00	35	35	35	36	36	36	37	39	45	35	51
15.00	35	35	35	36	36	36	35	37	42	35	50

Table 12.4

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>1</sub> °C	T <sub>o</sub> °C
16.00	35	35	35	36	36	36	35	36	40	35	46
17.00	35	35	35	35	35	36	35	36	38	35	44
18.00	35	35	35	35	35	35	35	36	37	35	42
19.00	35	35	35	35	35	35	35	36	37	35	39
20.00	35	35	35	35	35	35	35	36	36	35	38
21.00	35	35	35	35	35	35	35	36	36	34	37
22.00	35	35	35	35	35	35	35	36	35	34	36
23.00	35	35	35	35	35	35	35	36	35	34	35
24.00	35	35	35	35	35	35	35	36	35	34	35
25.00	35	35	35	35	35	35	35	36	35	34	34







Table 13.1

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>o</sub> °C
36.00	-	-	-	-	-	-	-	-	-	35	51
37.00										35	50
39.00										35	49
40.00										35	48
41.00										35	47
42.00										35	46
43.00										35	45
44.00										35	43
45.00										35	42
46.00										35	39
47.00										35	39
48.00										35	39
49.00										35	38
50.00										35 3	38



















Table 14.1

Experimental Data for various  $\Delta T$

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.

Flow Rate = 4.45 l./min.

Time t min.	Temperature										
	$T_1$ °C	$T_2$ °C	$T_3$ °C	$T_4$ °C	$T_5$ °C	$T_6$ °C	$T_7$ °C	$T_8$ °C	$T_9$ °C	$T_{10}$ °C	$T_o$ °C
0	65	63	64	64	63	64	63	64	64	63	63
1.00	46	60	63	63	62	63	63	63	63	41	63
2.00	38	40	62	63	62	63	63	63	63	39	63
3.00	37	37	41	54	62	63	63	63	63	37	63
4.00	36	36	37	38	47	63	63	63	63	37	63
5.00	36	36	36	36	39	47	62	63	63	37	62
6.00	36	36	36	36	36	39	44	63	63	37	62
7.00	36	36	36	36	36	37	38	44	62	37	60
7.50	36	36	36	36	36	37	37	41	50	37	59
8.00	36	36	36	36	36	37	37	39	42	37	53
8.50	36	36	36	36	36	37	37	38	40	37	49
9.00	36	36	36	36	36	37	37	37	38	37	43
9.50	36	36	36	36	36	37	37	37	37	37	41
10.00	36	36	36	36	36	37	37	37	37	37	39
11.00	36	36	36	36	36	37	37	37	37	37	38
12.00	36	36	36	36	36	37	37	37	37	37	37



Table 14.3

## Experimental Data

Tank Size: L = 1.524 m., D = 0.203 m.

Flow Rate = 4.45 l./min.

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
0	80	80	82	81	80	82	81	81	81	80	80
1.00	40	79	80	81	80	81	81	81	81	37	80
2.00	36	39	43	68	77	80	79	79	79	35	79
3.00	35	36	36	41	69	79	79	79	79	35	79
4.00	35	35	36	36	38	66	77	79	79	35	79
5.00	35	35	36	36	36	40	64	79	79	35	79
6.00	35	35	36	36	36	37	54	78	78	35	79
7.00	35	35	36	36	36	36	40	51	78	35	79
8.00	35	35	36	36	36	36	37	41	55	35	78
8.50	35	35	36	36	36	36	36	39	44	35	78
9.00	35	35	36	36	36	36	36	37	41	35	77
9.50	35	35	36	36	36	36	36	37	39	35	73
10.00	35	35	36	36	36	36	36	36	37	35	49
11.00	35	35	36	35	35	36	36	36	36	35	42
12.00	35	35	36	35	35	36	36	36	36	35	39
13.00	35	35	36	35	35	36	36	36	36	35	36

Table 14.3

(Continued)

Time t min.	Temperature										
	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	T <sub>4</sub> °C	T <sub>5</sub> °C	T <sub>6</sub> °C	T <sub>7</sub> °C	T <sub>8</sub> °C	T <sub>9</sub> °C	T <sub>10</sub> °C	T <sub>11</sub> °C
14.00	35	35	36	36	35	36	36	36	36	35	36
15.00	35	35	36	36	35	36	36	36	36	35	35

Table 15

Experimental Data for Water entering at the top port

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Flow Rate = 4.90

Time t min.	Temperature , T °C			
	Q = 4.90 $\frac{l}{min.}$	Q = 7.29 $\frac{l}{min.}$	Q = 9.60 $\frac{l}{min.}$	Q = 10.88 $\frac{l}{min.}$
0	95	94	95	94
0.50	95	94	95	90
1.00	94	93	93	89
1.50	93	90	89	85
2.00	91	88	87	83
2.50	-	86	84	80
3.00	89	84	82	78
3.50	87	81	79	75
4.00	86	81	78	73
4.50	85	79	76	72
5.00	84	78	74	71
6.00	81	73	70	67
7.00	79	72	67	65
8.00	76	69	65	63
9.00	74	66	62	60



Table 15  
(Continued)

Time t min.	Temperature , T °C			
	Q = 4.90 $\frac{\text{l.}}{\text{min.}}$	Q = 7.29 $\frac{\text{l.}}{\text{min.}}$	Q = 9.60 $\frac{\text{l.}}{\text{min.}}$	Q = 10.88 $\frac{\text{l.}}{\text{min.}}$
10.00	74	64	60	58
11.00	72	62	58	56
12.00	70	-	57	54
13.00	69	59	54	53
14.00	67	58	53	51
15.00	66	56	51	50
16.00	65	55	49	49
17.00	63	-	48	48
18.00	62	53	-	47
19.00	61	51	47	46
20.00	60	49	-	45
21.00	59	46	-	-
22.00	58	-	-	-
23.00	-	43	-	-
24.00	57	-	-	-
28.00	-	41	-	42
30.00	-	40	-	-
32.00	-	39	-	-

Table 15  
(Continued)

Time t min.	Temperature , T °C			
	Q = 4.90 $\frac{\text{l.}}{\text{min.}}$	Q = 7.29 $\frac{\text{l.}}{\text{min.}}$	Q = 9.60 $\frac{\text{l.}}{\text{min.}}$	Q = 10.88 $\frac{\text{l.}}{\text{min.}}$
34.00	-	38	41	-
35.00	49	-	-	-
36.00	-	-	40	-
40.00	-	-	39	-
47.00	-	-	-	40
49.00	45	-	-	39
50.00	-	-	-	38
60.00	43	-	-	-
65.00	42	-	-	-
67.00	41	-	-	-
68.00	40	-	-	-
69.00	39	-	-	-
71.00	39	-	-	-
72.00	38	-	-	-

APPENDIX II

TABULATED AND GRAPHICAL RESULTS

Table 16.1

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.152$  m.Volume = 27.80 l.  $Re_d = 3,215$ 

Flow Rate = 2.30 l./min.

 $T_h = 90$  °C ,  $T_l = 35$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	90	1.000	100.09	103.38
0.50	0.041	90	1.000		
1.00	0.083	90	1.000		
1.50	0.124	90	1.000		
2.00	0.165	90	1.000		
2.50	0.207	90	1.000		
3.00	0.248	90	1.000		
3.50	0.289	90	1.000		
4.00	0.331	90	1.000		
4.50	0.372	90	1.000		
5.00	0.414	90	1.000		
5.50	0.455	89	0.982		
6.00	0.496	89	0.982		
6.50	0.538	89	0.982		
7.00	0.579	89	0.982		
7.50	0.620	89	0.982		

Table 16.1

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_{\theta}$ $^{\circ}\text{C}$	$\frac{T_{\theta} - T_1}{T_h - T_1}$	$\epsilon_{90}$	$\epsilon_{50}$
8.00	0.662	89	0.982	100.09	103.38
8.50	0.703	89	0.982		
9.00	0.744	89	0.982		
9.50	0.786	88	0.964		
10.00	0.827	88	0.964		
10.50	0.868	88	0.964		
11.00	0.910	88	0.964		
11.50	0.951	86	0.927		
12.00	0.992	86	0.927		
12.50	1.084	71	0.654		
13.00	1.075	61	0.473		
13.50	1.117	51	0.291		
14.00	1.158	49	0.254		
15.00	1.241	45	0.182		
16.00	1.323	43	0.145		
17.00	1.406	40	0.091		
18.00	1.487	38	0.054		
19.00	1.571	37	0.086		
20.00	1.654	36	0.018		

Table 16.1

(Continued)

t min.	$\frac{Qt}{V}$	$T_e$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
21.00	1.736	35	0.000	100.09	103.38

Table 16.2

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.152$  m.Volume = 27.80 l.  $Re_d = 6,221$ 

Flow Rate = 4.45 l./min.

 $T_h = 94$  °C,  $T_l = 36$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	95.54	97.97
0.50	0.080	94	1.000		
1.00	0.160	94	1.000		
1.50	0.240	94	1.000		
2.00	0.320	94	1.000		
2.50	0.400	94	1.000		
3.00	0.480	94	1.000		
3.50	0.560	94	1.000		
4.00	0.640	93	0.983		
4.50	0.720	93	0.983		
5.00	0.800	93	0.983		
5.25	0.840	93	0.983		
5.50	0.880	93	0.983		
5.25	0.840	93	0.983		
5.50	0.880	93	0.983		
6.00	0.960	91	0.948		

Table 16.2

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_{\bullet}$ $^{\circ}\text{C}$	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
8.00	1.280	38	0.034	95.54	97.97
9.00	1.440	36	0.000		



Table 16.3

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.152$ Volume = 27.80 l.  $Re_d = 8,993$ 

Flow Rate = 6.43 l./min.

 $T_h = 94$  °C,  $T_l = 35$  °C

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	90.37	92.06
0.50	0.116	94	1.000		
1.00	0.231	94	1.000		
1.50	0.347	93	0.983		
2.00	0.462	93	0.983		
2.50	0.578	93	0.983		
3.00	0.694	92	0.966		
3.50	0.809	92	0.966		
4.00	0.925	89	0.915		
4.25	0.983	52	0.288		
4.50	1.040	48	0.220		
4.75	1.098	46	0.186		
5.00	1.156	42	0.119		
5.25	1.214	39	0.068		
5.50	1.272	38	0.051		
5.75	1.329	37	0.034		

Table 16.3

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
6.00	1.387	36	0.019	90.37	92.06
7.00	1.624	35	0.000		

Table 16.4

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.152$  m.Volume = 27.80 l.  $Re_d = 12,325$ 

Flow Rate = 8.82 l./min.

 $T_h = 94$  °C,  $T_l = 35$  °C

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	82.90	87.23
0.25	0.079	94	1.000		
0.50	0.159	94	1.000		
0.75	0.238	94	1.000		
1.00	0.317	94	1.000		
1.25	0.396	94	1.000		
1.50	0.476	94	1.000		
1.75	0.555	94	1.000		
2.00	0.634	94	1.000		
2.25	0.714	93	0.983		
2.50	0.793	93	0.983		
2.75	0.872	78	0.729		
3.00	0.951	51	0.271		
3.25	1.031	45	0.169		
3.50	1.110	44	0.152		
3.75	1.189	42	0.119		

Table 16.4

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
4.00	1.269	38	0.051	82.90	87.23
4.25	1.348	37	0.034		
4.50	1.427	37	0.034		
4.75	1.506	37	0.034		
5.00	1.586	36	0.017		
5.25	1.665	36	0.017		
5.50	1.744	35	0.000		

Table 17.1

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Volume = 49.56 l.  $Re_d = 3,215$ 

Flow Rate = 2.30 l./min.

 $T_h = 91$  °C ,  $T_l = 34$  °C

$t$ min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	91	1.000	93.56	97.70
1.00	0.046	91	1.000		
2.00	0.093	91	1.000		
3.00	0.139	91	1.000		
4.00	0.186	91	1.000		
5.00	0.232	90	0.982		
6.00	0.278	90	0.982		
7.00	0.325	90	0.982		
8.00	0.371	90	0.982		
9.00	0.418	90	0.982		
10.00	0.464	90	0.982		
11.00	0.510	90	0.982		
12.00	0.557	90	0.982		
13.00	0.603	90	0.982		
14.00	0.650	90	0.982		
15.00	0.696	89	0.965		

Table 17.1

(Continued)

t min.	$\frac{Qt}{V}$	T °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
16.00	0.743	89	0.965	93.56	97.70
17.00	0.789	89	0.965		
18.00	0.835	89	0.965		
19.00	0.882	88	0.947		
20.00	0.928	87	0.930		
20.50	0.951	85	0.895		
21.00	0.975	78	0.772		
21.50	0.998	65	0.544		
22.00	1.021	56	0.386		
22.50	1.044	50	0.281		
23.00	1.067	46	0.211		
23.50	1.091	44	0.175		
24.00	1.114	42	0.140		
25.00	1.160	40	0.105		
26.00	1.207	39	0.088		
27.00	1.253	38	0.070		
28.00	1.299	36	0.035		
29.00	1.346	34	0.000		

Table 17.2

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Volume = 49.56 l.  $Re_d = 6,221$ 

Flow Rate = 4.45 l./min.

 $T_h = 94$  °C ,  $T_l = 35$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	91.68	95.50
1.00	0.090	94	1.000		
2.00	0.180	94	1.000		
3.00	0.269	93	0.983		
4.00	0.359	93	0.983		
5.00	0.449	93	0.983		
6.00	0.539	93	0.983		
7.00	0.629	93	0.983		
8.00	0.718	93	0.983		
9.00	0.808	92	0.966		
10.00	0.898	92	0.966		
10.50	0.943	83	0.813		
11.00	0.988	60	0.424		
11.50	1.033	49	0.237		
12.00	1.077	46	0.186		
12.50	1.122	42	0.119		

Table 17.2

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
13.00	1.167	40	0.085	91.68	95.50
14.00	1.257	38	0.051		
14.50	1.302	36	0.017		
15.00	1.347	35	0.000		



Table 17.3

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Volume = 49.56 l.  $Re_d = 8,993$ 

Flow Rate = 6.43 l./min.

 $T_h = 95$  °C ,  $T_l = 36$  °C

$t$ min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	95	1.000	81.92	86.20
1.00	0.130	95	1.000		
2.00	0.260	95	1.000		
3.00	0.389	95	1.000		
4.00	0.519	94	0.983		
5.00	0.649	94	0.983		
6.00	0.778	93	0.966		
6.50	0.843	84	0.813		
7.00	0.908	59	0.390		
7.50	0.973	48	0.203		
8.00	1.038	44	0.135		
8.50	1.103	41	0.085		
9.00	1.168	40	0.068		
10.00	1.297	37	0.017		
11.00	1.427	36	0.000		

Table 17.4

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Volume = 49.56 l.  $Re_d = 12,325$ 

Flow Rate = 8.82 l./min.

 $T_h = 96$  °C,  $T_l = 36$  °C

$t$ min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	96	1.000	76.64	81.50
1.00	0.178	96	1.000		
2.00	0.356	95	0.983		
3.00	0.534	95	0.983		
3.50	0.623	94	0.967		
4.00	0.712	91	0.917		
4.50	0.801	89	0.883		
5.00	0.890	50	0.233		
5.50	0.979	44	0.133		
6.00	1.068	43	0.117		
7.00	1.246	40	0.067		
8.00	1.424	38	0.033		
9.00	1.602	37	0.017		
10.00	1.780	36	0.000		

Table 18.1

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.Volume = 111 l.  $Re_d = 3,215$ 

Flow Rate = 2.30 l./min.

 $T_h = 94$  °C,  $T_l = 34$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	85.76	88.17
1.00	0.021	94	1.000		
2.00	0.041	94	1.000		
3.00	0.062	94	1.000		
4.00	0.083	94	1.000		
5.00	0.104	94	1.000		
6.00	0.124	94	1.000		
7.00	0.145	94	1.000		
8.00	0.166	94	1.000		
9.00	0.186	94	1.000		
10.00	0.207	94	1.000		
11.00	0.228	94	1.000		
12.00	0.249	94	1.000		
13.00	0.269	94	1.000		
14.00	0.290	94	1.000		
15.00	0.311	94	1.000		

Table 18.1

(Continued)

t min.	$\frac{Qt}{V}$	$T_{\bullet}$ °C	$\frac{T_{\bullet} - T_1}{T_h - T_1}$	$\epsilon_{90}$	$\epsilon_{50}$
16.00	0.332	94	1.000	85.76	88.17
17.00	0.352	94	1.000		
18.00	0.373	94	1.000		
19.00	0.394	94	1.000		
20.00	0.414	94	1.000		
21.00	0.435	94	1.000		
22.00	0.456	94	1.000		
23.00	0.477	94	1.000		
24.00	0.497	94	1.000		
25.00	0.518	94	1.000		
27.00	0.559	94	1.000		
29.00	0.601	94	1.000		
30.00	0.622	94	1.000		
32.00	0.663	94	1.000		
34.00	0.705	94	1.000		
36.00	0.746	94	1.000		
38.00	0.787	94	1.000		
39.00	0.808	93	0.983		
40.00	0.829	92	0.967		

Table 18.1

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_c$ °C	$\frac{T_c - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
41.00	0.849	90	0.933	85.76	88.17
42.00	0.870	85	0.850		
43.00	0.891	71	0.617		
44.00	0.912	55	0.350		
45.00	0.932	50	0.267		
46.00	0.953	47	0.217		
47.00	0.974	44	0.167		
48.00	0.995	43	0.150		
49.00	1.015	42	0.133		
50.00	1.036	40	0.100		
51.00	1.057	39	0.083		
52.00	1.077	38	0.067		
53.00	1.098	37	0.050		
54.00	1.119	35	0.017		
55.00	1.140	34	0.000		

Table 18.2

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Volume = 111 l.

 $Re_d = 6,221$ 

Flow Rate = 4.45 l./min.

 $T_h = 96$  °C ,  $T_l = 34$  °C

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	96	1.000	82.38	86.14
1.00	0.040	96	1.000		
2.00	0.080	95	0.984		
3.00	0.120	95	0.984		
4.00	0.160	95	0.984		
5.00	0.200	95	0.984		
6.00	0.241	95	0.984		
7.00	0.281	95	0.984		
8.00	0.321	95	0.984		
9.00	0.361	95	0.984		
10.00	0.401	95	0.984		
11.00	0.441	95	0.984		
12.00	0.481	95	0.984		
13.00	0.521	95	0.984		
14.00	0.561	95	0.984		
15.00	0.601	95	0.984		

Table 18.2

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_0$ °C	$\frac{T_0 - T_1}{T_0 - T_1}$	$\epsilon_{90}$	$\epsilon_{50}$
16.00	0.641	95	0.984	82.38	86.14
17.00	0.682	95	0.984		
18.00	0.722	95	0.984		
19.00	0.762	94	0.968		
20.00	0.802	93	0.952		
21.00	0.842	89	0.887		
22.00	0.882	63	0.418		
23.00	0.922	50	0.258		
24.00	0.962	44	0.161		
25.00	1.002	43	0.145		
26.00	1.042	42	0.129		
27.00	1.082	41	0.113		
28.00	1.123	39	0.081		
29.00	1.163	38	0.065		
30.00	1.203	37	0.048		
31.00	1.243	36	0.032		
32.00	1.283	35	0.016		
33.00	1.323	34	0.000		

Table 18.3

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.Volume = 111 l.  $Re_d = 8,993$ 

Flow Rate = 6.43 l./min.

 $T_h = 95$  °C ,  $T_l = 35$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	95	1.000	78.40	82.38
1.00	0.058	95	1.000		
2.00	0.116	95	1.000		
3.00	0.174	94	0.983		
4.00	0.232	94	0.983		
5.00	0.290	94	0.983		
6.00	0.348	94	0.983		
7.00	0.405	94	0.983		
8.00	0.463	94	0.983		
9.00	0.521	94	0.983		
10.00	0.579	94	0.983		
11.00	0.637	94	0.983		
12.00	0.695	94	0.983		
13.00	0.753	94	0.983		
14.00	0.811	84	0.817		
15.00	0.869	55	0.333		



Table 18.3

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
16.00	0.927	43	0.133	78.40	82.38
17.00	0.985	40	0.083		
18.00	1.043	39	0.067		
19.00	1.101	38	0.050		
20.00	1.159	37	0.033		
21.00	1.216	36	0.017		
22.00	1.274	36	0.017		
23.00	1.332	35	0.000		

Table 18.4

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.Volume = 111 l.  $Re_d = 12,325$ 

Flow Rate = 8.82 l./min.

 $T_h = 96$  °C ,  $T_l = 35$  °C

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	96	1.000	74.53	79.06
1.00	0.079	95	0.984		
2.00	0.159	95	0.984		
3.00	0.238	95	0.984		
4.00	0.318	94	0.967		
5.00	0.397	94	0.967		
6.00	0.477	94	0.967		
7.00	0.556	94	0.967		
8.00	0.636	94	0.967		
9.00	0.715	94	0.967		
10.00	0.795	79	0.721		
11.00	0.874	51	0.262		
12.00	0.954	45	0.164		
13.00	1.033	42	0.115		
14.00	1.112	41	0.098		
15.00	1.192	41	0.098		

Table 18.4

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\varepsilon_{90}$	$\varepsilon_{50}$
16.00	1.271	39	0.066	78.53	79.06
17.00	1.351	38	0.049		
18.00	1.430	37	0.033		
19.00	1.510	36	0.016		
20.00	1.590	35	0.000		

Table 19.1

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.356$  m.Volume = 151.40 l.  $Re_d = 3,215$ 

Flow Rate = 2.30 l./min.

 $T_h = 96$  °C ,  $T_l = 34$  °C

t min.	$\frac{Qt}{V}$	$T_c$ °C	$\frac{T_c - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	96	1.000	76.85	80.27
1.00	0.015	96	1.000		
2.00	0.030	96	1.000		
3.00	0.045	96	1.000		
4.00	0.060	96	1.000		
5.00	0.075	96	1.000		
6.00	0.090	96	1.000		
7.00	0.106	95	0.984		
8.00	0.122	95	0.984		
9.00	0.137	95	0.984		
10.00	0.152	95	0.984		
11.00	0.167	95	0.984		
12.00	0.182	95	0.984		
13.00	0.197	95	0.984		
14.00	0.213	95	0.984		
15.00	0.228	95	0.984		

Table 19.1

(Continued)

t min.	$\frac{Qt}{v}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\varepsilon_{90}$	$\varepsilon_{50}$
16.00	0.243	95	0.984	76.85	80.27
17.00	0.258	95	0.984		
18.00	0.273	95	0.984		
19.00	0.289	95	0.984		
20.00	0.304	95	0.984		
21.00	0.319	95	0.984		
22.00	0.334	95	0.984		
23.00	0.349	95	0.984		
24.00	0.365	95	0.984		
25.00	0.380	95	0.984		
26.00	0.395	95	0.984		
28.00	0.425	95	0.984		
30.00	0.456	95	0.984		
32.00	0.486	95	0.984		
34.00	0.517	95	0.984		
36.00	0.547	95	0.984		
38.00	0.577	94	0.965		
40.00	0.608	94	0.965		
42.00	0.638	94	0.965		

Table 19.1

(Continued)

t min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
44.00	0.668	94	0.965	76.85	80.27
46.00	0.679	93	0.952		
48.00	0.729	92	0.935		
50.00	0.760	91	0.919		
52.00	0.790	91	0.919		
53.00	0.805	88	0.871		
54.00	0.820	83	0.790		
55.00	0.836	75	0.661		
56.00	0.851	67	0.532		
57.00	0.866	59	0.403		
58.00	0.881	54	0.323		
59.00	0.896	51	0.274		
60.00	0.991	48	0.226		
61.00	0.927	46	0.194		
62.00	0.942	44	0.161		
63.00	0.957	43	0.145		
64.00	0.972	42	0.129		
65.00	0.989	41	0.113		
66.00	1.005	40	0.097		

Table 19.1

(Continued)

t min.	$\frac{Qt}{V}$	$T_c$ °C	$\frac{T_c - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
67.00	1.018	39	0.081	76.85	80.27
68.00	1.033	38	0.065		
69.00	1.048	36	0.032		
70.00	1.063	35	0.016		
71.00	1.079	34	0.000		

Table 19.2

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.356$  m.Volume = 151.40 l.  $Re_d = 6,221$ 

Flow Rate = 4.45 l./min.

 $T_h = 93$  °C,  $T_l = 34$  °C

t min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	93	1.000	75.17	80.44
1.00	0.029	93	1.000		
2.00	0.059	93	1.000		
3.00	0.088	93	1.000		
4.00	0.118	92	0.983		
5.00	0.147	92	0.983		
6.00	0.176	92	0.983		
7.00	0.206	92	0.983		
8.00	0.235	92	0.983		
9.00	0.265	92	0.983		
10.00	0.294	92	0.983		
11.00	0.323	92	0.983		
12.00	0.353	92	0.983		
13.00	0.382	92	0.983		
14.00	0.419	92	0.983		
15.00	0.441	92	0.983		



Table 19.2

(Continued)

t min.	$\frac{Qt}{V}$	$T_{\bullet}$ °C	$\frac{T_{\bullet} - T_1}{T_h - T_1}$	$\epsilon_{90}$	$\epsilon_{50}$
16.00	0.470	92	0.983	75.17	80.44
17.00	0.450	92	0.983		
18.00	0.529	92	0.983		
19.00	0.558	92	0.983		
20.00	0.588	92	0.983		
21.00	0.517	92	0.983		
22.00	0.647	92	0.983		
23.00	0.676	91	0.966		
24.00	0.705	91	0.966		
25.00	0.735	90	0.949		
26.00	0.764	85	0.864		
27.00	0.794	83	0.831		
28.00	0.823	68	0.576		
29.00	0.852	57	0.390		
30.00	0.862	49	0.254		
31.00	0.911	46	0.203		
32.00	0.941	43	0.153		
33.00	0.970	42	0.136		
34.00	0.999	42	0.136		

Table 19.2

(Continued)

t min.	$\frac{Qt}{V}$	$T_{\bullet}$ $^{\circ}C$	$\frac{T_{\bullet} - T_1}{T_h - T_1}$	$\epsilon_{90}$	$\epsilon_{50}$
35.00	1.029	40	0.102	75.17	80.44
36.00	1.058	39	0.085		
37.00	1.088	38	0.068		
38.00	1.117	37	0.051		
39.00	1.146	36	0.034		
40.00	1.176	35	0.017		
41.00	1.205	34	0.000		

Table 19.3

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.356$  m.Volume = 151.40 l.  $Re_d = 8,993$ 

Flow Rate = 6.43 l./min.

 $T_h = 94$  °C,  $T_l = 34$  °C

$t$ min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	70.30	73.25
1.00	0.042	94	1.000		
2.00	0.085	94	1.000		
3.00	0.127	94	1.000		
4.00	0.170	94	1.000		
5.00	0.212	94	1.000		
6.00	0.255	94	1.000		
7.00	0.297	94	1.000		
8.00	0.340	94	1.000		
9.00	0.382	94	1.000		
10.00	0.425	94	1.000		
11.00	0.467	94	1.000		
12.00	0.510	94	1.000		
13.00	0.552	94	1.000		
14.00	0.595	94	1.000		
15.00	0.637	94	1.000		

Table 19.3

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
16.00	0.680	92	0.967	70.30	73.25
17.00	0.722	83	0.817		
18.00	0.764	60	0.433		
19.00	0.807	50	0.267		
20.00	0.849	45	0.183		
21.00	0.892	43	0.150		
22.00	0.934	40	0.100		
23.00	0.977	39	0.083		
24.00	1.019	38	0.067		
25.00	1.062	37	0.050		
26.00	1.104	36	0.033		
27.00	1.147	35	0.017		
28.00	1.189	35	0.017		
29.00	1.232	34	0.000		

Table 19.4

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.356$  m.Volume = 151.40 l.  $Re_d = 12,325$ 

Flow Rate = 8.82 l./min.

 $T_h = 94$  °C,  $T_l = 34$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	66.78	69.77
1.00	0.058	94	1.000		
2.00	0.117	94	1.000		
3.00	0.175	94	1.000		
4.00	0.233	94	1.000		
5.00	0.291	94	1.000		
6.00	0.350	94	1.000		
7.00	0.408	94	1.000		
8.00	0.466	94	1.000		
9.00	0.524	94	1.000		
10.00	0.583	94	1.000		
11.00	0.641	91	0.950		
12.00	0.699	75	0.683		
13.00	0.757	54	0.333		
14.00	0.816	51	0.283		
15.00	0.874	50	0.267		

Table 19.4

(Continue)

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
16.00	0.932	46	0.200	66.78	69.77
17.00	0.990	44	0.167		
18.00	1.049	42	0.133		
19.00	1.107	39	0.083		
20.00	1.165	38	0.067		
21.00	1.223	37	0.050		
22.00	1.282	36	0.033		
23.00	1.340	35	0.017		
24.00	1.398	35	0.017		
25.00	1.456	34	0.000		

Table 20.1



## Results

Tank Size:  $L = 0.305$  m.,  $D_h =$  hydraulic diameter =  $0.508$  m.

Volume =  $111$  l.  $Re_d = 3,215$

Flow Rate =  $2.30$  l./min.

$T_h = 94$  °C ,  $T_l = 38$  °C

$t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	40.50	50.82
1.00	0.021	94	1.000		
4.00	0.083	94	1.000		
8.00	0.166	94	1.000		
12.00	0.249	94	1.000		
13.00	0.269	93	0.982		
16.00	0.332	93	0.982		
16.50	0.342	93	0.982		
17.00	0.352	93	0.982		
17.50	0.363	93	0.982		
18.00	0.373	93	0.982		
18.50	0.383	91	0.946		
19.00	0.394	90	0.929		
19.50	0.404	89	0.911		
20.00	0.414	88	0.893		
20.50	0.425	87	0.875		

Table 20.1

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
21.00	0.435	85	0.839	40.50	50.82
21.50	0.445	84	0.821		
22.00	0.456	82	0.786		
23.00	0.477	80	0.750		
23.50	0.487	77	0.696		
24.00	0.497	74	0.643		
24.50	0.508	72	0.607		
25.00	0.518	71	0.589		
25.50	0.528	68	0.535		
26.00	0.539	66	0.500		
27.00	0.559	65	0.482		
28.00	0.580	64	0.464		
29.00	0.601	63	0.446		
30.00	0.622	62	0.429		
31.00	0.642	60	0.393		
32.00	0.663	58	0.357		
33.00	0.684	56	0.321		
34.00	0.705	54	0.286		
35.00	0.725	53	0.268		



Table 20.1

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
36.00	0.746	51	0.232	40.50	50.82
37.00	0.767	50	0.214		
39.00	0.808	49	0.196		
40.00	0.829	48	0.179		
41.00	0.850	47	0.161		
42.00	0.870	46	0.143		
43.00	0.891	45	0.125		
44.00	0.912	43	0.089		
45.00	0.932	42	0.071		
46.00	0.953	39	0.018		
47.00	0.974	39	0.018		
48.00	0.995	39	0.018		
49.00	1.015	38	0.000		

Table 20.2

## Results

Tank Size:  $L = 0.305$  m.,  $D_h = 0.508$  m.

Volume = 111 l.  $Re_d = 6,221$

Flow Rate = 4.45 l./min.

$T_h = 100$  °C ,  $T_l = 38$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	100	1.000	38.80	49.70
0.50	0.020	100	1.000		
1.00	0.040	100	1.000		
2.00	0.080	100	1.000		
3.00	0.120	100	1.000		
5.00	0.200	100	1.000		
5.50	0.220	99	0.984		
6.00	0.241	99	0.984		
8.00	0.321	98	0.968		
9.00	0.361	97	0.952		
9.50	0.387	95	0.919		
10.00	0.401	92	0.871		
10.50	0.421	90	0.839		
11.00	0.441	87	0.790		
11.50	0.461	82	0.710		
12.00	0.481	79	0.661		

Table 20.2

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
12.50	0.501	76	0.613	38.80	49.70
13.00	0.521	72	0.548		
13.50	0.541	70	0.516		
14.00	0.561	67	0.468		
14.50	0.581	64	0.419		
15.00	0.601	62	0.387		
15.50	0.621	60	0.355		
16.00	0.641	58	0.323		
16.50	0.661	57	0.306		
17.00	0.682	56	0.290		
17.50	0.702	54	0.258		
18.00	0.722	52	0.226		
18.50	0.742	51	0.210		
19.00	0.762	49	0.177		
20.00	0.802	48	0.161		
21.00	0.842	47	0.145		
22.00	0.882	46	0.129		
23.00	0.922	45	0.113		
25.00	1.002	44	0.097		

Table 20.2

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
26.00	1.042	43	0.081	38.80	49.70
27.00	1.082	42	0.065		
30.00	1.203	41	0.048		
31.00	1.243	40	0.032		
32.00	1.283	39	0.016		
33.00	1.323	38	0.000		

Table 20.3

## Results

Tank Size:  $L = 0.305$  m.,  $D_h = 0.508$  m.Volume = 111 l.  $Re_d = 8,993$ 

Flow Rate = 6.43 l./min.

 $T_h = 100$  °C ,  $T_l = 39$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	100	1.000	37.50	42.37
1.00	0.058	100	1.000		
2.00	0.116	100	1.000		
3.00	0.174	100	1.000		
4.00	0.232	99	0.984		
5.00	0.290	99	0.984		
5.50	0.319	98	0.967		
6.00	0.348	96	0.934		
6.50	0.377	94	0.902		
7.00	0.405	90	0.836		
7.50	0.434	86	0.770		
8.00	0.463	79	0.656		
8.50	0.492	75	0.590		
9.00	0.521	70	0.508		
9.50	0.550	65	0.426		
10.00	0.579	64	0.410		

Table 20.3

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
10.50	0.608	61	0.361	37.50	42.37
11.00	0.637	57	0.295		
11.50	0.666	56	0.279		
12.00	0.695	55	0.262		
12.50	0.724	54	0.246		
13.00	0.753	53	0.230		
14.00	0.811	51	0.197		
14.50	0.840	50	0.180		
15.00	0.869	49	0.164		
16.00	0.927	48	0.148		
17.00	0.985	47	0.131		
18.00	1.043	45	0.098		
19.00	1.101	44	0.082		
20.00	1.159	44	0.082		
21.00	1.216	43	0.066		
24.00	1.390	42	0.049		
25.00	1.448	41	0.033		
26.00	1.506	40	0.016		
27.00	1.564	39	0.000		

Table 20.4

## Results

Tank Size:  $L = 0.305$  m.,  $D_h = 0.508$  m.

Volume = 111 l.

 $Re_d = 12,325$ 

Flow Rate = 8.82 l./min.

 $T_h = 101$  °C ,  $T_l = 39$  °C

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	101	1.000	35.38	45.72
1.00	0.079	101	1.000		
2.00	0.159	101	1.000		
3.00	0.238	101	0.984		
4.00	0.318	100	0.919		
5.00	0.397	96	0.919		
5.50	0.437	94	0.887		
6.00	0.477	80	0.661		
6.50	0.516	73	0.548		
7.00	0.556	70	0.500		
7.50	0.596	64	0.403		
8.00	0.636	62	0.371		
8.50	0.675	61	0.355		
9.00	0.715	57	0.290		
9.50	0.755	55	0.258		
10.00	0.795	53	0.226		

Table 20.4

(Continued)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
10.50	0.834	52	0.210	35.38	45.72
11.00	0.874	50	0.177		
11.50	0.914	48	0.145		
12.00	0.954	47	0.129		
13.00	1.033	46	0.113		
14.00	1.112	45	0.097		
15.00	1.192	44	0.081		
16.00	1.271	43	0.065		
17.00	1.351	42	0.048		
18.00	1.430	41	0.032		
19.00	1.501	40	0.016		
20	1.589	39	0.000		



Table 21.1

Results for Various  $\Delta T$ Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Volume = 49.56 l.  $Re_d = 6,221$ 

Flow Rate = 4.45 l./min.

 $T_h = 63$  °C,  $T_l = 37$  °C ( $\Delta T = 26$  °C)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	63	1.000	61.70	-
1.00	0.090	63	1.000		
2.00	0.180	63	1.000		
3.00	0.269	63	1.000		
4.00	0.359	63	1.000		
5.00	0.449	62	0.962		
6.00	0.539	62	0.962		
7.00	0.629	60	0.885		
7.50	0.673	59	0.846		
8.00	0.718	53	0.615		
8.50	0.763	49	0.462		
9.00	0.808	43	0.231		
9.50	0.853	41	0.154		
10.00	0.898	39	0.077		
11.00	0.988	38	0.038		
12.00	1.077	37	0.000		

Table 21.2

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Volume = 49.56 l.  $Re_d = 6,221$ 

Flow Rate = 4.45 l./min.

 $T_h = 71$  °C,  $T_l = 38$  °C ( $\Delta T = 33$  °C)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	71	1.000	72.10	-
1.00	0.090	71	1.000		
2.00	0.180	71	1.000		
3.00	0.269	71	1.000		
4.00	0.359	71	1.000		
5.00	0.449	71	1.000		
6.00	0.539	71	1.000		
7.00	0.629	71	1.000		
8.00	0.718	68	0.909		
8.50	0.763	50	0.364		
9.00	0.808	45	0.212		
9.50	0.853	42	0.121		
10.00	0.898	41	0.091		
11.00	0.988	39	0.030		
12.00	1.077	39	0.030		
13.00	1.167	38	0.000		

Table 21.3

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Volume = 49.56 l.  $Re_d = 6,221$ 

Flow Rate = 4.45 l./min.

 $T_h = 90$  °C,  $T_l = 35$  °C ( $\Delta T = 45$  °C)

t min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	80	1.000	72.52	-
1.00	0.090	80	1.000		
2.00	0.180	79	0.978		
3.00	0.269	79	0.978		
4.00	0.359	79	0.978		
5.00	0.449	79	0.978		
6.00	0.539	79	0.978		
7.00	0.629	79	0.978		
8.00	0.718	78	0.956		
8.50	0.963	78	0.956		
9.00	0.808	77	0.933		
9.50	0.853	73	0.844		
10.00	0.898	49	0.311		
11.00	0.988	42	0.156		
12.00	1.071	39	0.089		
13.00	1.167	36	0.022		

Table 21.3

(Continued)

$t$ min.	$\frac{Qt}{V}$	$T_o$ $^{\circ}C$	$\frac{T_o - T_l}{T_h - T_l}$	$\varepsilon_{90}$	$\varepsilon_{50}$
14.00	1.257	36	0.022	72.52	
15.00	1.302	35	0.000		

Table 22.1

Results for the water entering at the top port

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Volume = 111 l.

Flow Rate = 4.90 l./min.

$T_h = 95$  °C ,  $T_l = 38$  °C

Time $t$ min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	95	1.000	11.10	-
0.50	0.022	95	1.000		
1.00	0.044	94	0.982		
1.50	0.066	93	0.965		
2.00	0.088	91	0.930		
3.00	0.132	89	0.895		
3.50	0.155	87	0.860		
4.00	0.177	86	0.842		
4.50	0.199	85	0.825		
5.00	0.221	84	0.807		
6.00	0.265	81	0.807		
7.00	0.309	79	0.719		
8.00	0.353	76	0.667		
9.00	0.397	74	0.632		
10.00	0.441	74	0.632		
11.00	0.486	72	0.596		

Table 22.1

(Continued)

Time t min.	$\frac{Qt}{V}$	T °C	$\frac{T_e - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
12.00	0.530	70	0.561	11.10	-
13.00	0.574	69	0.544		
14.00	0.618	67	0.509		
15.00	0.662	66	0.491		
16.00	0.706	65	0.474		
17.00	0.750	63	0.439		
18.00	0.795	62	0.421		
19.00	0.839	67	0.404		
20.00	0.883	60	0.386		
21.00	0.927	59	0.368		
22.00	0.971	58	0.351		
24.00	1.059	57	0.228		
35.00	1.545	49	0.193		
49.00	2.163	45	0.123		
60.00	2.649	43	0.088		
65.00	2.869	42	0.070		
67.00	2.958	41	0.053		
68.00	3.002	40	0.035		
69.00	3.046	39	0.018		

Table 22.1

(Continued)

Time t min.	$\frac{qt}{V}$	$T_c$ °C	$\frac{T_c - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
71.00	3.134	39	0.018	11.10	
72	3.178	38	0.000		

Table 22.2

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Volume = 111 l.

Flow Rate = 7.29 l./min.

 $T_h = 94$  °C ,  $T_l = 38$  °C

Time t min.	$\frac{Qt}{V}$	$T$ °C	$\frac{T - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	11.10	-
0.50	0.033	94	1.000		
1.00	0.066	93	0.982		
1.50	0.099	90	0.929		
2.00	0.131	88	0.893		
2.50	0.164	86	0.857		
3.00	0.197	84	0.821		
3.50	0.230	81	0.768		
4.00	0.263	81	0.768		
4.50	0.296	79	0.732		
5.00	0.328	78	0.714		
5.50	0.361	76	0.679		
6.00	0.394	73	0.625		
7.00	0.460	72	0.607		
8.00	0.525	69	0.554		



Table 22.2

(Continued)

Time t min.	$\frac{Qt}{V}$	$T_{\circ}$ °C	$\frac{T_{\circ} - T_1}{T_h - T_1}$	$\varepsilon_{90}$	$\varepsilon_{50}$
9.00	0.591	66	0.500	11.10	-
10.00	0.657	64	0.464		
11.00	0.722	62	0.429		
13.00	0.854	59	0.375		
14.00	0.919	58	0.357		
15.00	0.985	56	0.321		
16.00	1.051	55	0.304		
18.00	1.182	53	0.268		
19.00	1.248	51	0.232		
20.00	1.314	49	0.196		
21.00	1.379	46	0.143		
23.00	1.511	43	0.089		
28.00	1.839	41	0.054		
30.00	1.970	40	0.053		
32.00	2.102	39	0.026		
34.00	2.233	38	0.000		

Table 22.3

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Volume = 111 l.

Flow Rate = 9.60 l./min.

 $T_h = 95$  °C ,  $T_l = 39$  °C

Time $t$ min.	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	95	1.000	11.10	-
0.50	0.043	95	1.000		
1.00	0.086	93	0.964		
1.50	0.129	89	0.893		
2.00	0.173	87	0.857		
2.50	0.216	84	0.804		
3.00	0.259	82	0.768		
3.50	0.302	79	0.714		
4.00	0.345	78	0.696		
4.50	0.388	76	0.661		
5.00	0.432	74	0.625		
6.00	0.518	70	0.554		
7.00	0.604	67	0.500		
8.00	0.691	65	0.464		
9.00	0.777	62	0.411		
10.00	0.863	60	0.375		

Table 22.3

(Continued)

Time t min	$\frac{Qt}{V}$	$T_{\circ}$ °C	$\frac{T_0 - T_1}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
11.00	0.950	58	0.340	11.10	-
12.00	1.036	57	0.321		
13.00	1.122	54	0.268		
14.00	1.209	53	0.250		
15.00	1.295	51	0.214		
16.00	1.381	49	0.179		
17.00	1.468	48	0.161		
19.00	1.640	47	0.143		
34.00	2.935	41	0.036		
36.00	3.114	40	0.018		
40.00	3.459	39	0.000		

Table 22.4

## Results

Tank Size:  $L = 1.524$  m.,  $D = 0.305$  m.

Volume = 111 l.

Flow Rate = 10.88 l./min.

 $T_h = 94$  °C ,  $T_l = 38$  °C

Time $t$ min	$\frac{Qt}{V}$	$T_o$ °C	$\frac{T_o - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
0	0	94	1.000	11.10	-
0.50	0.049	90	0.929		
1.00	0.098	89	0.911		
1.50	0.147	85	0.839		
2.00	0.196	83	0.804		
2.50	0.245	80	0.750		
3.00	0.294	78	0.714		
3.50	0.342	75	0.661		
4.00	0.391	73	0.625		
4.50	0.440	72	0.607		
5.00	0.489	71	0.589		
6.00	0.587	67	0.518		
7.00	0.685	65	0.482		
8.00	0.783	63	0.446		
9.00	0.881	60	0.393		
10.00	0.978	58	0.358		

Table 22.4

(Continued)

Time t min.	$\frac{Qt}{V}$	$T_e$ °C	$\frac{T_e - T_l}{T_h - T_l}$	$\epsilon_{90}$	$\epsilon_{50}$
11.00	1.076	56	0.321	11.10	-
12.00	1.174	54	0.286		
13.00	1.272	53	0.268		
14.00	1.370	51	0.232		
15.00	1.468	50	0.214		
16.00	1.565	49	0.196		
17.00	1.663	48	0.179		
18.00	1.761	47	0.161		
19.00	1.859	46	0.143		
20.00	1.957	45	0.125		
28.00	2.740	42	0.071		
47.00	4.599	40	0.036		
49.00	4.794	39	0.018		
50.00	4.901	38	0.000		

Table 23.1

Experimental Data and ResultsStorage Tank with Copper Lining ( $\Gamma = 0.3320$ )Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.

Flow Rate = 2.3 l./min., Volume = 27.80 l.

 $(T_0$  and  $T_1$  were measured at  $\eta = 1$ ,  $T_2$  and  $T_3$  at  $\eta = 0.50$ )

t min.	$T_0$ °C	$T_1$ °C	$T_2$ °C	$T_3$ °C	$\frac{Qt}{V}$	$\frac{T_0 - T_1}{T_h - T_l}$
0	96	95	96	95	0	1.000
1.00	96	95	96	95	0.046	1.000
2.00	96	95	96	95	0.093	1.000
3.00	96	95	96	95	0.139	1.000
4.00	96	95	96	95	0.186	1.000
5.00	96	95	96	95	0.232	1.000
6.00	96	95	95	94	0.278	1.000
7.00	96	95	94	94	0.325	1.000
8.00	96	94	89	89	0.371	1.000
9.00	96	94	76	75	0.418	1.000
10.00	96	94	64	66	0.464	1.000
11.00	96	94	48	52	0.510	1.000
12.00	96	94	42	45	0.557	1.000
13.00	95	94	39	41	0.603	0.984
14.00	95	93	37	39	0.650	0.984
15.00	95	93	37	38	0.696	0.934

Table 23.1  
(Continued)

t min.	T <sub>o</sub> °C	T <sub>1</sub> °C	T <sub>2</sub> °C	T <sub>3</sub> °C	$\frac{Qt}{V}$	$\frac{T_o - T_1}{T_h - T_1}$
16.00	94	93	36	37	0.743	0.743
17.00	93	93	36	37	0.789	0.789
18.00	92	92	35	36	0.835	0.934
19.00	91	91	35	36	0.882	0.918
20.00	90	90	35	35	0.928	0.902
21.00	82	83	35	35	0.975	0.775
22.00	65	68			1.021	0.492
23.00	46	48			1.067	0.180
24.00	40	42			1.114	0.082
25.00	37	38			1.160	0.033
26.00	36	38			1.207	0.016
27.00	36	37			1.253	0.016
28.00	35	36			1.299	0.000

Table 23.2

Experimental Data and ResultsStorage Tank with Copper Lining ( $\Gamma = 0.2929$ )Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.

Flow Rate = 4.45 l./min., Volume = 27.80 l.

 $T_h = 96$  °C,  $T_l = 36$  °C

t min.	$T_c$ °C	$T_1$ °C	$T_2$ °C	$T_3$ °C	$\frac{Qt}{V}$	$\frac{T_o - T_l}{T_h - T_l}$
0	96	95	96	94	0	1.000
1.00	96	95	95	93	0.090	1.000
2.00	95	95	95	93	0.180	0.983
3.00	95	94	95	92	0.269	0.983
4.00	95	94	95	94	0.359	0.983
5.00	95	94	91	90	0.449	0.983
6.00	95	94	54	57	0.539	0.983
7.00	95	93	42	46	0.629	0.983
8.00	94	93	39	42	0.718	0.967
9.00	94	93	37	39	0.808	0.967
10.00	92	92	35	38	0.898	0.933
11.00	81	81	35	37	0.988	0.750
12.00	50	50	35	36	1.077	0.233
13.00	45	46			1.167	0.150
14.00	41	43			1.257	0.083



Table 23.2

(Continued)

t min.	$T_o$ °C	$T_1$ °C	$T_2$ °C	$T_3$ °C	$\frac{Qt}{V}$	$\frac{T_o - T_1}{T_h - T_1}$
15.00	39	41			1.347	0.050
16.00	38	40			1.437	0.033
17.00	37	39			1.526	0.017
18.00	36	37			1.616	0.000

Table 23.3

Experimental Data and ResultsStorage Tank with Copper Lingin ( $\Gamma = 0.2720$ )Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.Flow Rate =  $6.43$  l./min., Volume =  $27.80$  l. $T_h = 95$  °C ,  $T_l = 34$  °C

t min.	$T_o$ °C	$T_1$ °C	$T_2$ °C	$T_3$ °C	$\frac{Qt}{V}$	$\frac{T_o - T_l}{T_h - T_l}$
0	95	93	95	93	0	1.000
1.00	95	94	95	94	0.130	1.000
2.00	94	93	94	93	0.260	0.984
3.00	94	93	91	90	0.389	0.984
4.00	94	93	71	73	0.519	0.984
5.00	93	92	43	48	0.649	0.967
6.00	92	92	37	41	0.778	0.951
6.50	72	73	34	38	0.843	0.623
7.00	60	61	34	36	0.908	0.426
8.00	45	46			1.038	0.180
9.00	40	42			1.168	0.098
10.00	36	38			1.297	0.033
11.00	35	38			1.427	0.011
12.00	35	37			1.557	0.016

Table 23.4

Experimental Data and ResultsStorage Tank with Copper Lining ( $\Gamma = 0.2543$ )Tank Size:  $L = 1.524$  m.,  $D = 0.203$  m.

Flow Rate = 8.82 l./min., Volume = 27.80 l.

 $T_h = 92$  °C,  $T_l = 34$  °C

t min.	$T_o$ °C	$T_1$ °C	$T_2$ °C	$T_3$ °C	$\frac{Qt}{V}$	$\frac{T_o - T_l}{T_h - T_l}$
0	92	91	92	90	0	1.000
1.00	92	91	91	90	0.178	1.000
2.00	92	91	90	89	0.356	1.000
3.00	92	90	53	57	0.534	1.000
4.00	91	90	39	44	0.712	0.983
4.50	78	79	36	40	0.801	0.759
5.00	50	54	34	38	0.890	0.276
5.50	40	44	34	36	0.979	0.103
6.00	37	39	34	36	1.068	0.052
7.00	36	38			1.246	0.034
8.00	35	37			1.424	0.017
9.00	35	37			1.602	0.017
10.00	34	36			1.780	0.000

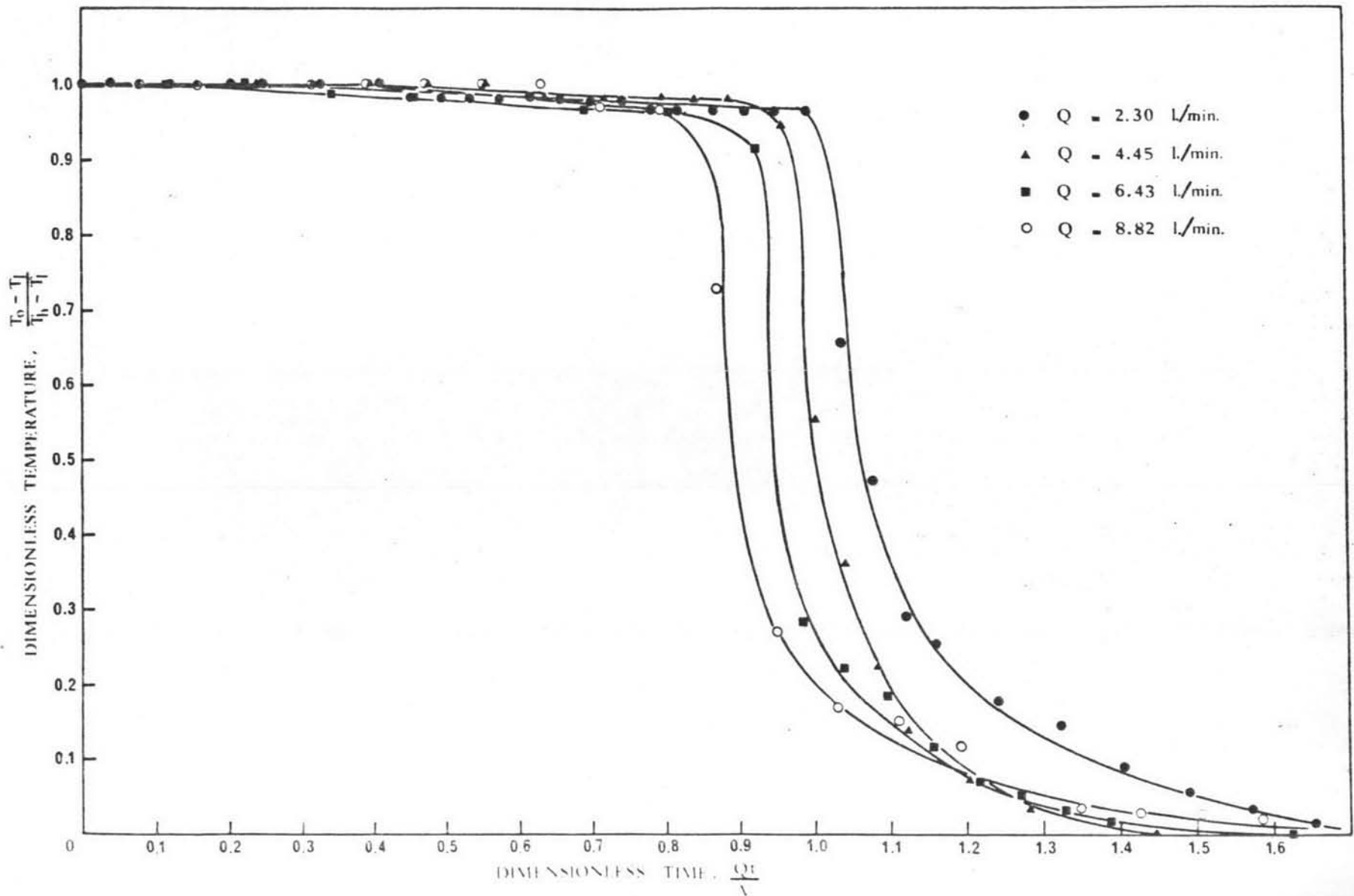


Figure 17 Dimensionless temperature  $\frac{T_0 - T}{T_h - T_l}$  as a function of dimensionless time  $\frac{Qt}{V}$  at various flow rates with  $L = 1.524$  m.,  $D = 0.152$  m.

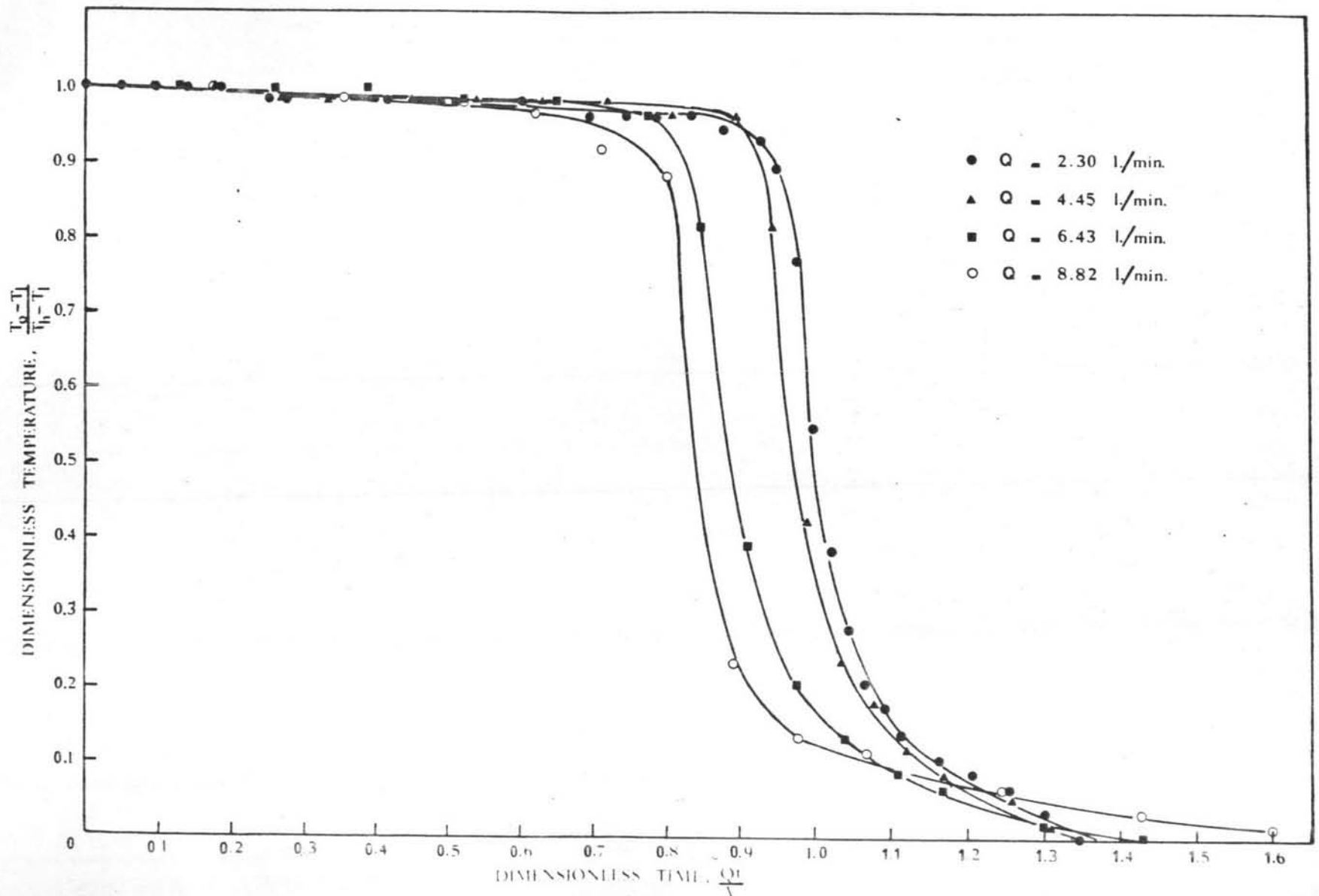


Figure 18 Dimensionless temperature,  $\frac{T_p - T_f}{T_o - T_f}$  as a function of dimensionless time,  $\frac{Q t}{V}$  at various flow rates with  $L = 1.524$  m.,  $D = 0.203$  m.

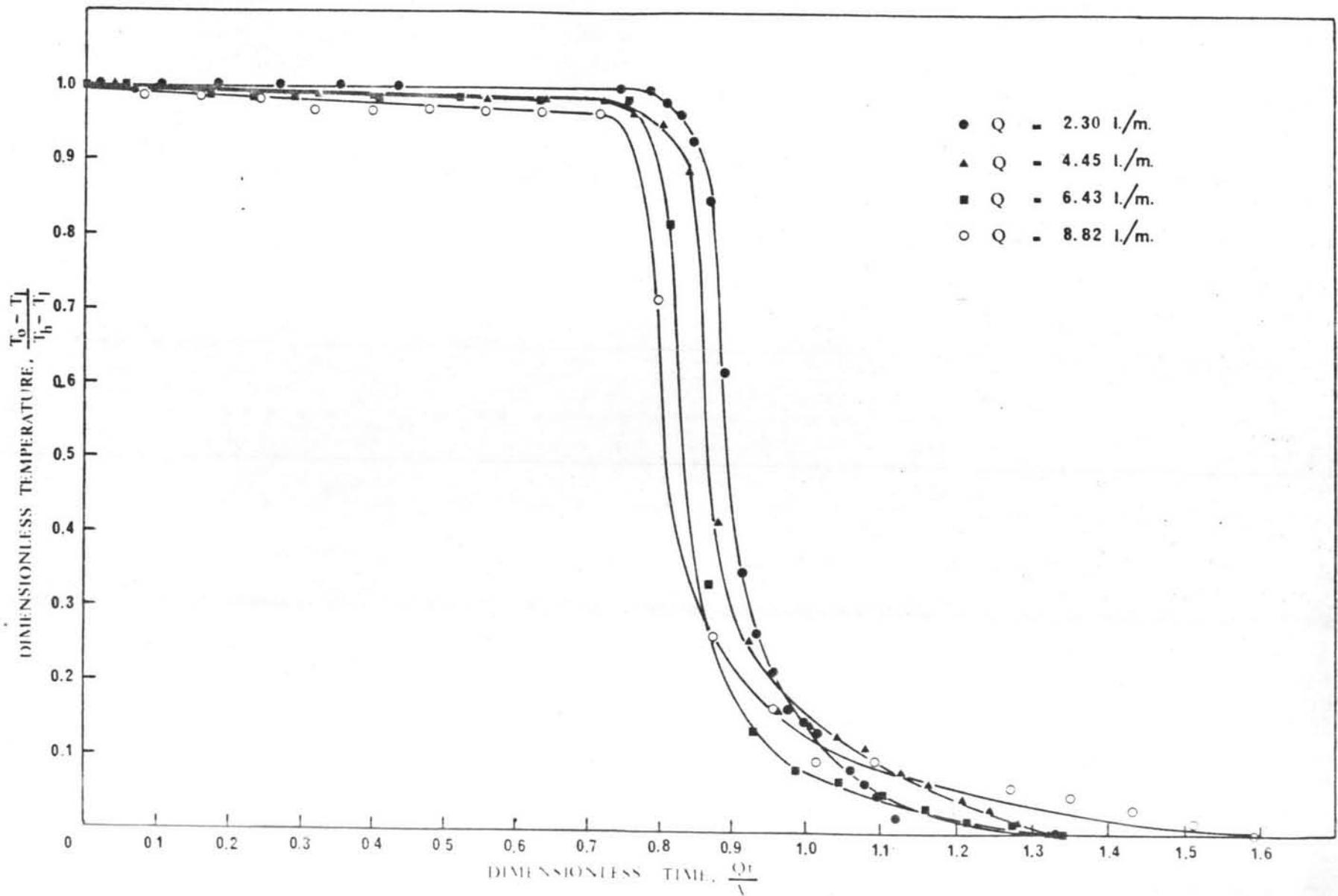


Figure 19 Dimensionless temperature  $\frac{T_0 - T_1}{T_h - T_1}$  as a function of dimensionless time,  $\frac{Q_1}{V}$  at various flow rates with  $L = 1.524$  m.,  $D = 0.305$  m.

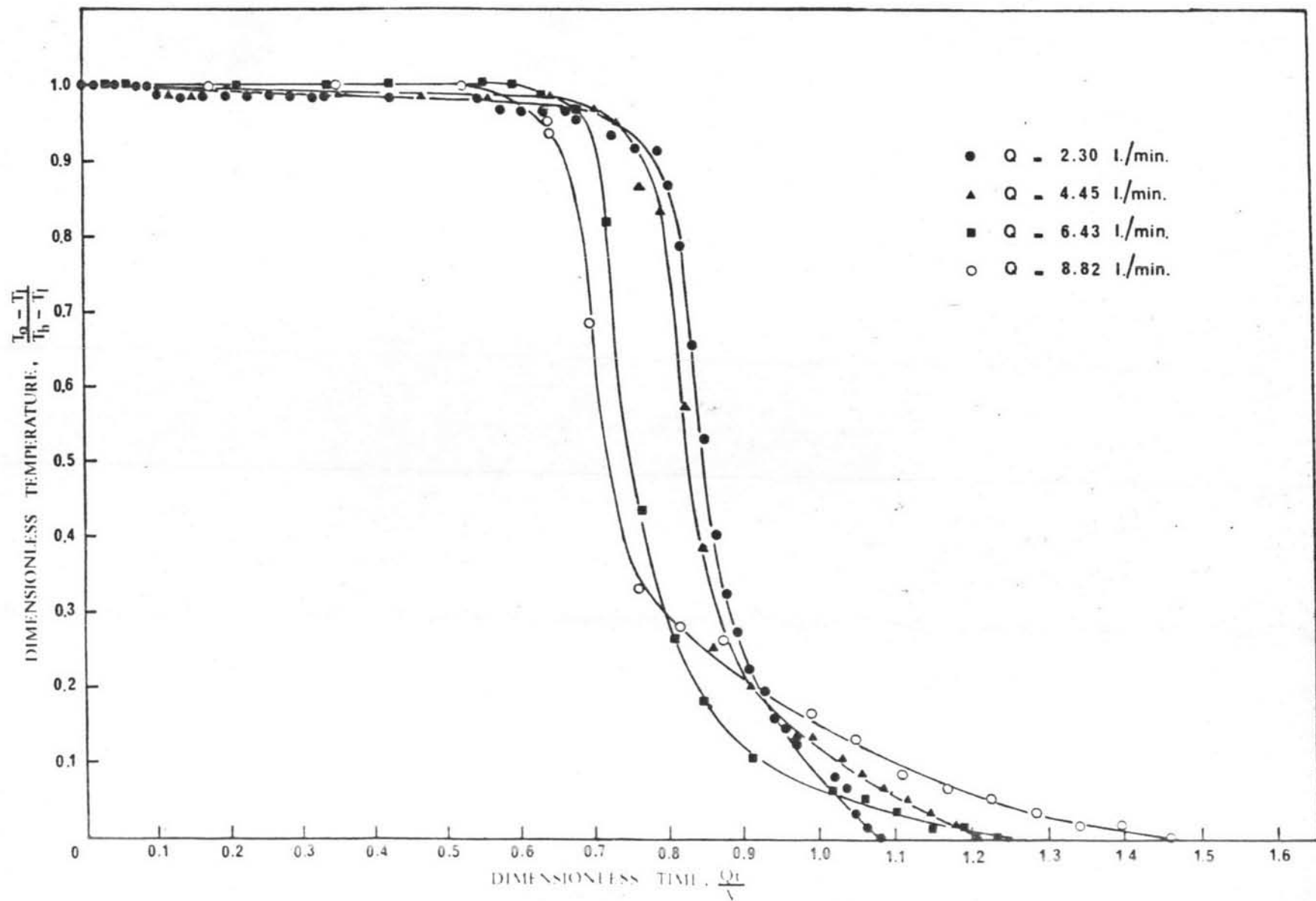


Figure 20 Dimensionless temperature  $\frac{T_0 - T_1}{T_h - T_1}$  as a function of dimensionless time,  $\frac{Qt}{V}$  at various flow rates with  $L = 1.524$  m.,  $D = 0.356$  m.

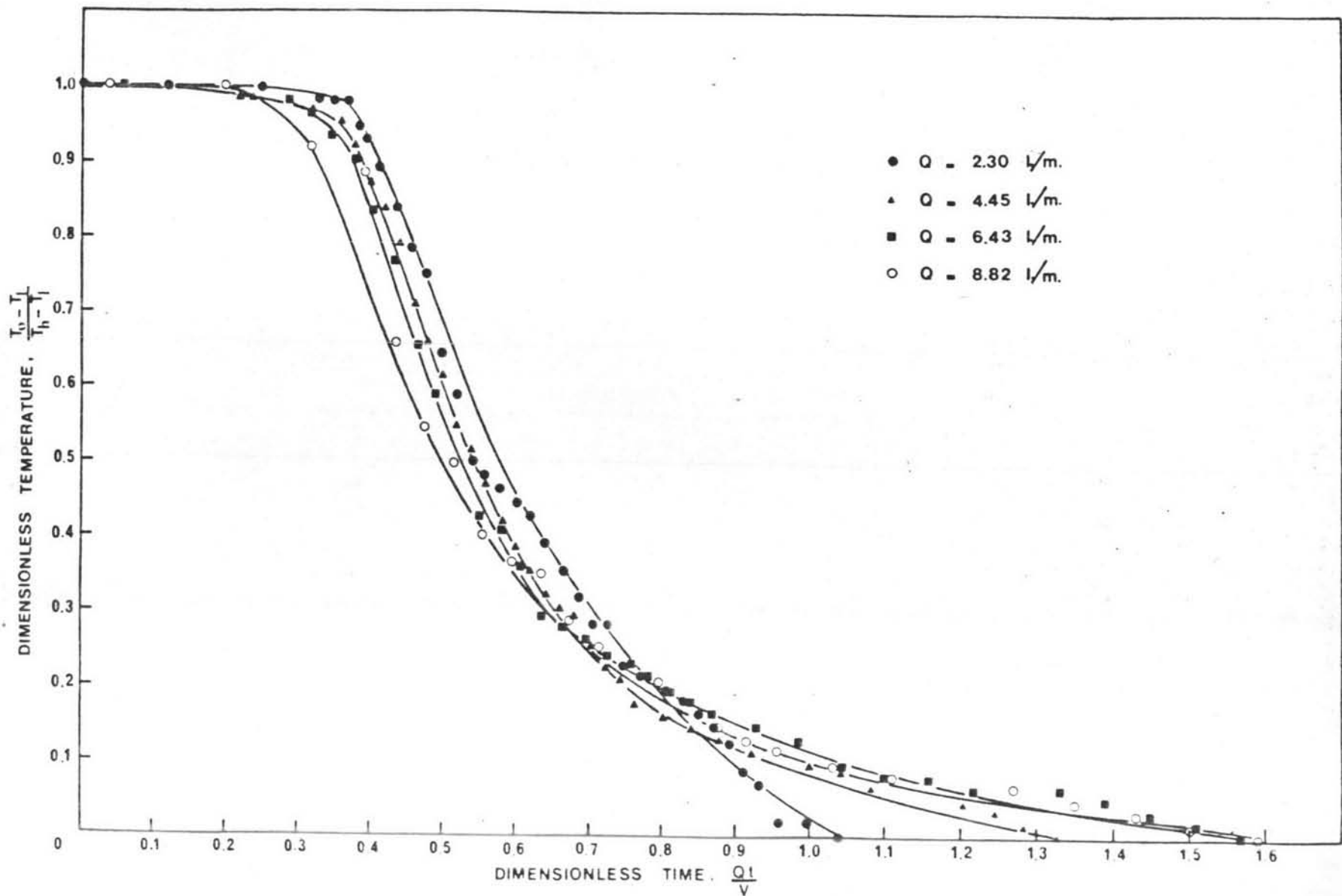


Figure 2: Dimensionless temperature,  $\frac{T_o - T_l}{T_h - T_l}$  as a function of dimensionless time,  $\frac{Ql}{V}$  at various flow rates with  $L = 0.305 \text{ m.}$   $D = 0.508 \text{ m.}$



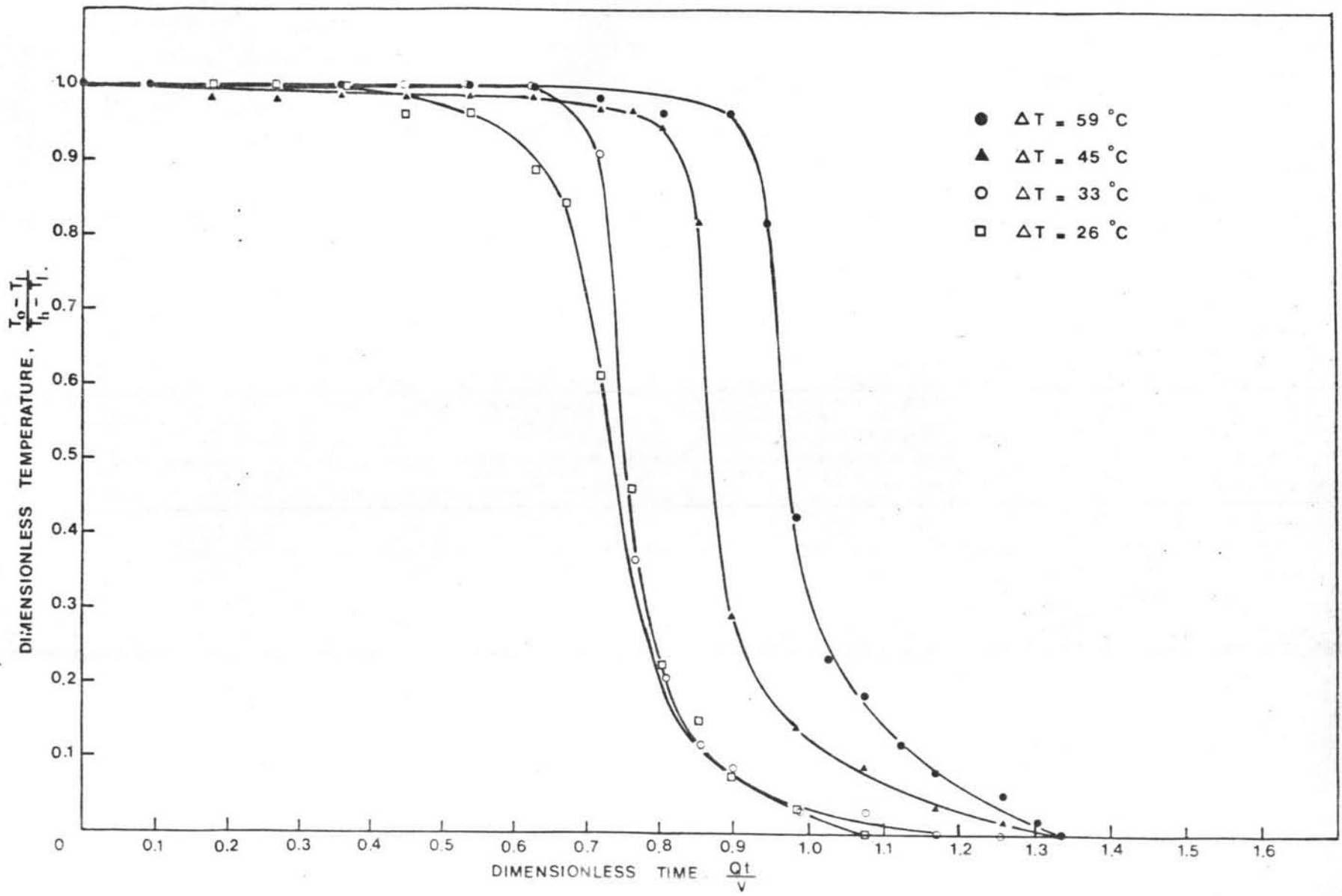


Figure 22 Dimensionless temperature  $\frac{T_0 - T_l}{T_h - T_l}$  as a function of dimensionless time  $\frac{Qt}{V}$  at various temperature differences with  $L = 1.524 \text{ m}$ ,  $D = 0.203 \text{ m}$ .

**APPENDIX III**

**MISCELLANEOUS**

Table 24

Density and Specific Heat of  
Solid-Phase Storage Materials

Material	Density Kg/m <sup>3</sup>	Specific heat KJ/°K-Kg
Aluminum	2700	0.88
Aluminum sulfate	2710	0.75
Brick	1698	0.84
Calcium chloride	2510	0.67
Earth dry	1698	0.84
Potassium chloride	1980	0.67
Sodium carbonate	2510	1.09
Cast iron	7754	0.46
River rocks	2245-2566	0.71-0.92

Table 25

## Physical Properties of Water

T °C	Density $\rho$ g/cm <sup>3</sup>	Viscosity $\mu$ cp	Heat Capacity $c_p$ Cal/g.°C
0	0.9999	1.7870	1.0080
8	0.9999	1.4730	1.0028
16	0.9990	1.1589	1.0002
24	0.9973	0.9321	0.9990
32	0.9951	0.7926	0.9986
40	0.9923	0.6530	0.9987
48	0.9890	0.5784	0.9991
56	0.9852	0.5038	0.9997
60	0.9832	0.4665	1.0001
64	0.9811	0.4442	1.0005
72	0.9767	0.3995	1.0016
80	0.9718	0.3548	1.0029
88	0.9667	0.3257	1.0046
96	0.9612	0.2966	1.0065
100	0.9584	0.2821	1.0076

Table 26

## Rotameter Calibration

% Rotameter	Flow Rate l./min.
90	8.82
80	7.56
70	6.43
60	5.37
50	4.45
40	3.25
30	2.23
20	1.25

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