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APPENDIX

Appendix A

EXPERIMENTAL DATA

Part I Calibration of Meters:

Triplicated data were obtained and only the average values were reported here.

1. Calibration of hot-water orifice meter

Trial No.	Manometer reading cm.Hg	Average time to collect certain amount of water, min/sec
1	0.4	9/30.25
2	0.8	5/2.7
3	1.5	3/37.85
4	2.1	3/2.9
5	2.7	2/41.8
6	3.5	2/22.5
7	4.2	2/11.0
8	5.1	1/59.15
9	6.6	1/43.65
10	8.3	1/33.05
11	9.4	1/27.7
12	10.7	1/21.5
13	11.7	1/17.75
14	12.9	1/14.75
15	14.0	1/11.8

Weight of empty container 1.8 kg

Weight of container filled with water 34.7 kg

2. Calibration of cold-water orifice meter

Trial NO.	Manometer reading cm. Hg	Average time to collect certain amount of water min./sec.
1	0.85	4/14.3
2	1.3	3/32.6
3	2.15	2/48.7
4	3.1	2/21.7
5	4.05	2/6.0
6	5.5	1/47.6
7	6.4	1/40.75
8	7.35	1/34.25
9	8.4	1/28.4
10	9.4	1/23.75
11	10.1	1/20.8
12	11.3	1/15.9
13	11.8	1/14.5

Weight of empty container 1.8 kg

Weight of container filled with water 34.7 kg

3. Calibration of rotameter

Rotameter reading	Average cc. of fruit juice collected in 1 min.
1	10
2	37.5
3	62
4	87
5	115
6	140
7	168
8	196
9	215
10	240
11	265
12	291
13	320
14	341
15	370

Part II Physical Properties of Orange Juice Determination

1. Determination of density at various concentration at room temperature

concn Bx	wt. of bottle gm.	wt. of bottle + sample 25 ml., gm.
0	25.1562	50.0759
5	20.6434	45.9914
10	26.6652	52.5862
15	24.0045	50.2544
20	29.0276	55.7814
25	25.1562	52.6311
30	32.6967	60.5164
35	25.1602	53.6954
40	20.1559	49.3649
45	26.8783	56.4916
48.5	31.4570	61.1114

2. Determination of viscosity at various concentration at room temperature

concn Bx	Average reading*	
	speed 60	speed 30
0	-	-
5	0.4	0.2
10	0.6	0.4
15	0.7	0.35
20	1.0	0.43
25	1.3	0.6
30	1.8	1.2
35	3.7	2.3
40	6.8	3.9
45	11.3	6.9
48.5	16.2	9.6

* the average reading was obtained from triplicated data

3. Determination of specific heat at various concentration

concn, Bx.	fruit juice		hot water		temp. after mixing °C
	weight, gm	temp, °C	weight, gm	temp, °C	
0	410	29.0	170	55	36.5
5	500	37.6	130	62	42.8
10	500	39.0	132.5	65	44.6
15	500	36.4	127.5	68.2	43.2
20	500	31.2	117.5	70	39.2
25	500	27.2	92.5	52.5	31.6
30	315	29.0	122.5	67	40.5
35	360	28.0	100	60.2	36.5
40	450	26.5	100	61	34.0
45	420	18.6	90	62.8	28.5

4. Determination of Brix concentration of sugar solution

concn. w/w	5	10	15	20	25	30	35	40	45	50
Bx. reading	5	10	15.2	19.8	24.9	30.1	34.9	40	44.9	50.1

Part III Experimental Runs

Experimental run NO.1 Feed rate 0.24 l/m, Steam pressure 3 psi.

Time	Steam temp.		Hot water				Vapor temp.				Cooling water						Vac.
			temp.		manometer		condenser NO.1		condenser NO.2		temp. cond.2		temp. cond.1		manometer		
	in	out	in	out	from	to	in	out	in	out	in	out	in	out	from	to	mm.Hg
15:40	-	-	88	75	14.5	16.5	-	-	-	-	25	25	25	25	10	20.5	680
15:45	102	96	"	74	"	"	45	45	44	26	"	"	"	26	10	20.5	680
15:50	"	"	"	75	"	"	46	44	44	26	"	"	"	27	10	20.5	680
15:55	"	"	"	"	"	"	47	43	43	26	"	"	"	27.5	10	20.5	680
16:00	"	"	"	78	"	"	48	34	26	26	"	"	"	"	10	20.5	660
16:05	"	"	"	81	"	"	49	27	26	26	"	"	"	"	10	20.5	650
16:10	"	"	"	83.5	"	"	52.5	26	25.5	25	"	"	"	"	10	20.5	640
16:15	"	"	90	85	"	"	53.0	26	"	"	"	"	"	"	10	20.5	640
16:20	"	"	90	85.5	"	"	53.0	26	"	"	"	"	"	"	10	20.5	640
16:30	"	"	"	86	"	"	53.5	26	"	"	"	"	"	"	10	20.5	640
16:35	"	"	"	86	"	"	53.5	26	"	"	"	"	"	"	10	20.5	640
16:40	"	"	"	86	"	"	53.5	26	"	"	"	"	"	"	10	20.5	640

Feed temp. 40°C Brix 9

Feed quantity 14.7 kg

Product temp. 46°C Brix 16

Product quantity 8.2 kg

Total time consumed 1 hr.

Condensate quantity 6.5 kg

Experimental run NO.2 Feed rate 0.265 l/m , Steam pressure 3 psi

Time	Steam temp.		Hot water				Vapor temp.				Cooling water						Vac. mm.Hg
			temp.		manometer		condenser NO.1		condenser NO.2		temp, cond2		temp. cond.1		manometer		
	in	out	in	out	from	to	in	out	in	out	in	out	in	out	from	to	
14.30	–	–	91	88	13	18	–	–	–	–	25.5	25.5	25.5	25.5	10.2	20.2	680
14.35	102	93.5	91	88	"	"	45	45	44	25.5	"	"	"	26	"	"	680
14.40	"	"	90	88.5	"	"	46	42	40	"	"	"	"	27	"	"	680
14.45	"	"	90	88.5	"	"	47	33	33.5	25.5	25.5	"	26	28.5	"	"	670
14.50	"	"	91	88	"	"	49	34	33	"	"	"	"	"	"	"	660
14.55	"	"	91	87	"	"	51	36	30	"	"	"	"	"	"	"	650
15.00	"	"	91	87	"	"	53	37	29	"	"	"	25.5	28	"	"	640
15.05	"	"	90	87	"	"	53.5	37.5	28.5	"	"	"	"	29	"	"	640
15.10	"	"	90	87	"	"	54	38	"	"	"	"	"	29.5	"	"	635
15.15	"	"	90	87	"	"	54.5	34	27	"	"	"	"	"	"	"	630
15.20	"	"	90	87.5	"	"	"	30.5	26.5	"	"	"	"	"	"	"	630
15.25	"	"	90	89	"	"	"	31	"	"	"	"	"	"	"	"	630
15.30	"	"	91	87.5	"	"	55	31.5	"	"	"	"	"	"	"	"	630
15.35	"	"	90	87	"	"	54.5	35	27.5	"	"	"	"	"	"	"	630

Feed temp. 50°C Brix 9 Feed quantity 14.72 kg

Product temp. 35°C Brix 26 Product quantity 5.0 kg

Condensate quantity 9.7 kg

Total time consumed 1 hr. 6 min.

Experimental run NO.3 Feed rate 0.29 l/m, Steam pressure 3 psi

Time	steam temp.		Hot water				Vapor temp.				Cooling water						Vac. mm.Hg
			temp.		manometer		condenser NO.1		condenser NO.2		temp. cond.2		temp. cond.1		manometer		
	in	out	in	out	from	to	in	out	in	out	in	out	in	out	from	to	
15.00	–	–	89	88	12	19	–	–	–	–	25.5	25.5	26	26	10.5	19.8	
15.05	102	92	90	88	"	"	43	40	38	25.5	"	26	26	27	"	"	
15.10	"	"	90	88.5	"	"	44	42	43.5	"	"	26.5	26	28	"	"	670
15.15	"	"	89	86.5	"	"	45	46	"	"	"	27	27	29	"	"	670
15.20	"	91.5	88	85	"	"	51	47	45	"	"	26.5	26	30	"	"	650
15.25	"	"	89	85	"	"	52.5	49	49	28.0	"	26	26	30.5	"	"	640
15.30	"	"	89	86	"	"	52	51	50	25.5	"	26	25.5	30	12	19	640
15.35	"	"	90	88.5	"	"	52	49	49	"	"	26	25.5	31	13	17.5	640
15.40	"	"	90	86	"	"	53.5	51	51	28.5	"	26.5	25.5	32.5	13	17.5	640
15.45	"	"	89	85.5	"	"	53.5	49.5	49	28	"	26	26	32	13	17.5	640
15.50	"	"	90	87	"	"	54	52	52.5	"	"	26	26	32.5	14	16.5	640
15.55	"	"	90	87	"	"	54	52.5	52	"	"	26	26	32.5	14	16.5	640

Feed temp. 50°C Brix 11 Feed quantity 13.2 kg

Product temp. 37.5°C Brix 28.5 Product quantity 4.8 kg

Condensate quantity 8.4 kg

Total time consumed 58 min.

Experimental run NO.4   Feed rate 0.318 l/m, Steam pressure 3 psi

Time	steam temp.		Hot water				Vapor temp.				Cooling water						Vac. mm.Hg
			temp.		manometer		condenser NO.1		condenser NO.2		temp. cond.2		temp. cond.1		manometer		
	in	out	in	out	from	to	in	out	in	out	in	out	in	out	from	to	
13.40	102	96	94	88	12.5	18.5	-	-	-	-	26.5	26	26	27	9.5	20.5	
13.45	"	94	92	88	"	"	47	46.5	47	28	26.5	26	26	29.0	"	"	670
13.50	"	93	90	88	"	"	49	48	48	29	"	27	27	30	"	"	660
13.55	"	92	89	87	"	"	51.5	41	41	28	"	27	27	30.5	"	"	650
14.00	"	92	88	83.5	"	"	54	46.5	45.5	28	"	27	27	30.5	"	"	630
14.05	"	92	89	86	"	"	54.5	45	33	27	"	26.5	27	30.5	"	"	630
14.10	"	92	89	87	"	"	54	42	32.5	27	"	26.5	27	30.5	"	"	630
14.15	"	92	89	87	"	"	54.5	38	30.5	26.5	"	26.5	27	30.5	"	"	630
14.20	"	92	89	87	"	"	54.5	38	30.5	26.5	"	26.5	27	30.5	"	"	630

Feed temp. 60°C   Brix 10   Feed quantity 9.65 kg

Product temp 40°C   Brix 25   Product quantity 3.5 kg

Total time consumed 42 min.   Condensate quantity 6.1 kg

Experimental run NO.5   Feed rate 0.344 l/m , Steam pressure 3 psi

Time	Steam temp.		Hot water				Vapor temp.				Cooling water						Vac. mm.Hg
			temp.		manometer		condenser NO.1		condenser NO.2		temp. cond.2		temp. cond.1		manometer		
	in	out	in	out	from	to	in	out	in	out	in	out	in	out	from	to	
16.30	102	95	90	88	13	18	–	–	–	–	27.5	27.5	27.5	28	9.5	21	675
16.35	"	"	90	89	"	"	45	38	35	38	"	27.5	"	29	"	"	675
16.40	"	"	90	88	"	"	47	39.5	39	38	"	"	28	30	"	"	675
16.45	"	"	90	87	"	"	48	43.5	43	29	"	"	28	31	"	"	660
16.50	"	94.5	89	86	"	"	50	46.5	46	30.5	"	28	28	31.5	"	"	650
16.55	"	"	89	88	"	"	52.5	52.5	50.5	30.5	"	28	28	31.5	"	"	640
17.00	"	"	90	88.5	"	"	55	52	52.5	30.5	"	28	28	32	"	"	630
17.05	"	"	91	87	"	"	55	51	49.5	29.5	"	28	28	31.5	"	"	630
17.10	"	"	89	86	"	"	55	50	45.5	28	"	27.5	28	31.5	"	"	630
17.15	"	"	89	86	"	"	55	50	47.5	30	"	27.5	28	31.5	"	"	630
17.20	"	93.5	88	85	"	"	55.5	50	47.5	30.5	"	27.5	28	32	"	"	630
17.25	"	"	89	84	"	"	55	45	34	30.5	"	27.5	28	30.5	"	"	630
17.30	"	"	89	85	"	"	54	37	31	30.5	"	28	28	29.5	"	"	630
17.35	"	"	88	86	"	"	54	38	31	30.5	"	27.5	28	29.5	"	"	630
17.40	"	"	89	85	"	"	54	37	31	30.5	"	28	28	29.5	"	"	630
17.45	"	"	88	84	"	"	54	37	31	30.5	"	27.5	28	29.5	"	"	630
17.50	"	"	88	86	"	"	54	37	31	30.5	"	27.5	28	29.5	"	"	630

Feed temp. 50°C   Brix 10   Feed quantity 16.35 kg

Product temp. 40°C   Brix 24   Product quantity 7.1 kg

Total time consumed 1 hr 20 min.   Condensate quantity 9.25 kg

<u>Experimental run NO.6</u> Feed **rate 0.37 l/m** , Steam pressure 3 psi

Time	steam temp.		Hot water				Vapor temp.				Cooling water						Vac. mm.Hg
			temp.		manometer		condenser NO.1		condenser NO.2		temp. cond.2		temp. cond.1		manometer		
	in	out	in	out	from	to	in	out	in	out	in	out	in	out	from	to	
14.50	102	98	91	80	15.2	16.7	–	–	–	–	28.5	28.5	28.5	29	13.5	17.5	660
14.55	"	97.5	91	81	"	"	49	46	45	29	"	29	29	31	"	"	660
15.00	"	98	90	80	"	"	49	46	46.5	29	"	30	29	32.5	"	"	660
15.05	"	"	90	81	"	"	50	49	48.5	30	"	30	30.5	33.5	"	"	650
15.10	"	"	91	81	"	"	51	50	50	31	"	30	29.5	34	"	"	650
15.15	"	"	90	79	"	"	55	42	45.5	30	"	30	29	33.5	"	"	630
15.20	"	"	90	79.5	"	"	56	39	40	30	"	30	28	33	"	"	620
15.25	""	"	91	82	"	"	55.5	35	30	29	"	28.5	28.5	31.5	"	"	630
15.30	"	"	91	83.5	"	"	55.5	34.5	29.5	28	"	28.5	28.5	32	"	"	620
15.35	"	"	90	81	"	"	56	34.5	29.5	28	"	28.5	28.5	32.5	"	"	620
15.40	"	"	91	81	"	"	56	34.5	29.5	28	"	28.5	28.5	32.5	"	"	620

Feed temp. 70°C Brix 10.5 Feed quantity 14.55 kg

Product temp. 46°C Brix 16.8 Product quantity 8.975 kg

Total time consumed 50 min. Condensate quantity 5.5 kg

Experimental run NO.7 Feed rate 0.265 l/m, Steam pressure 3 psi

Time	steam temp.		Hot water				Vapor temp.				Cooling water						Vac. mm.Hg
			temp.		manometer		condenser NO.1		condenser NO.2		temp. cond.2		temp. cond.1		manometer		
	in	out	in	out	from	to	in	out	in	out	in	out	in	out	from	to	
13.40	120	90.5	88	86	12.5	18.5	–	–	–	–	27	28.5	28	29	10.5	20	660
13.45	"	90	87	86	"	"	45	30	29	26	"	29	28.5	29.5	"	"	660
13.50	"	90	88	87	"	"	49	31	31.5	26	"	30.5	27	29	"	"	660
13.55	"	90	86	84.5	"	"	50	45	43.5	26.5	"	28	27	29	"	"	650
14.00	"	90	86	84.5	"	"	51	50	50.5	28	"	26	28	30.5	"	"	660
14.05	"		87	84.5	"	"	53	49	45	27	"	26	27.5	30.5	"	"	640
14.10	"	89	88	85	"	"	54.5	39	31	27	"	26	27	30	"	"	630
14.15	"	90.5	86	83	"	"	55	45	43.5	27	"	27	27	30.5	"	"	630
14.20	" "	91.5	88	85.5	"	"	55	39	31	27	"	26.5	27	30	"	"	630
14.25	"	91.5	88	85	"	"	55	40.5	31.5	27	"	26.5	27	30	"	"	630
14.30	"	91.5	88	85	"	"	55	42	32	27	"	26.5	27	30	"	"	630
14.35	"	92	88	85.5	"	"	55.5	44	33.5	27	"	27	27	30.5	"	"	630
14.40	"	92	88	85	"	"	55.5	44	33.5	27	"	27	27	30.5	"	"	630

Feed temp. 60°C Brix 12.2

Product temp. 38°C Brix 28

Total time consumed 1 hr

Feed quantity 14.4 kg

Product quantity 6.25 kg

Condensate quantity 8.05 kg

Part IV Analysis of Orange Juice *

1. Total titratable acidity

a. Juice before processing: 10 ml. juice titrate with 0.102N. NaOH

Exp. run NO	1	2	3	4	5	6	7
ml. NaOH	16.5	6.75	9.6	6.4	6.4	5.5	8.6

b. Juice after processing: 10 ml. concentrate juice diluted to 20 ml. and pipetted 10 ml. to titrate with 0.102N. NaOH

Exp. run NO	1	2	3	4	5	6	7
ml. NaOH	15.5	10.8	14.4	9.3	7.8	4.6	10.7

2. Vitamin C content

a. Juice before processing: 10 ml. juice titrate with 0.00808 N. Iodine solution.

Exp. run NO	1	2	3	4	5	6	7
ml. Iodine soln	4.15	4.60	3.45	5.30	3.80	3.30	5.70

b. Juice after processing: 25 ml. concentrate juice was titrated with the same Iodine solution, but no present of blue color occurred.

* ml. reported here was obtained from triplicated data

Appendix B

SAMPLE OF CALCULATIONS

Part I Calibration of Meters

1. Calibration of hot-water, cold-water orifice meter

(Trial NO.1 for hot-water orifice meter was illustrated here)

wt. of water flowed during the recorded time = 34.7 - 1.8

= 32.9 kg

the time recorded = 9 min 30.3 sec

Therefore, the flow rate of water $= \frac{32.9(60)}{(9\times 60+30.3)} = 3.46$ kg/min

2. Calibration of rotameter (Trial NO.1)

flow of juice = 10 cc

time = 1 min

Therefore, the flow rate of juice $= \frac{10}{1000} = 0.01$ liter/min

Part II Physical Properties of Orange Juice Determination

1. Determination of density (for concn 5 Bx.)

wt. of bottle = 20.6434 g

wt. of bottle + sample 25 ml. = 45.9914 g

The wt. of sample 25 ml. = 25.3480 g

Then, the density of juice = 25.3480/25

= 1.0139 g/ml

2. <u>Determination of viscosity</u> (for conc$\underline{n}$ 5 Bx)

For speed 60

average reading	=	0.4
factor for speed 60 rpm	=	1
Then, the viscosity	=	0.4 × 1 = 0.4 centipoise

For speed 30

average reading	=	0.2
factor for speed 30 rpm	=	2
Then, the viscosity	=	0.2 × 2 = 0.4 centipoise

3. <u>Determination of specific heat</u> (s)

3.1 To find the heat capacity of thermos

wt. of water	=	410 gm
specific heat of water	=	1

Let the heat capacity of the thermos be m

The temp. increase of water and thermos	=	36.5 - 29
	=	7.5 $^{\circ}$C
The temp.of hot water used = 170 gm and its temp.	=	55 $^{\circ}$C
The temp. decrease of hot water	=	55 - 36.5
	=	18.5 $^{\circ}$C

The heat balance of the mixing is

$$(410 \times 1 + m)(7.5) = 170 \times 1 \times 18.5$$

$$m = 9.322 \quad Cal/^{\circ}C$$

3.2 To find the specific heat of orange juice at each concentration (For the sample of conc$\underline{n}$ 5 Bx)

Let s be the specific heat of the sample

wt. of sample	=	500 g
temp. of sample	=	$37.6^{\circ}C$
wt. of hot water	=	130 g
temp. of hot water	=	$62^{\circ}C$
temp. after mixing	=	$42.8^{\circ}C$

The heat balance is

$$(500s + 9.322)(42.8 - 37.6) = 130(62 - 42.8)$$

$$s = \left[\frac{130(19.2)}{5.2} - 9.322\right] / 500$$

$$= 0.9413 \quad Cal/g^{\circ}C$$

Part III Experimental Run (sample shown here was for exp. run no.1)

1. The mass balance

1.1 Overall mass balance

Feed	=	14.7 kg
Product	=	8.2 kg

The overall mass balance around the evaporating chamber yields,

calculated condensate	=	14.7 - 8.2 = 6.5 kg
But the measured condensate	=	6.5 kg
Therefore, the percentage less	=	0 %

1.2 Component mass balance

1.2.1 solid content balance

Feed was 14.7 kg with 9° Brix

Therefore, the solid content in feed $= \frac{14.7 \times 9}{100} = 1.323$ kg

Product was 8.2 kg with 16^{0} Brix

Therefore, the solid content in product $= \frac{8.2 \times 16}{100} = 1.31$ kg

Hence, the solid content loss $= 1.323 - 1.31$

$= 0.031$ kg

$= \frac{0.013(100)}{1.323} = 0.98$ %

1.2.2 water content balance

Water in feed $= 14.7 - 1.323 = 13.377$ kg

water in product $= 8.2 - 1.13 = 6.89$ kg

Therefore, the water in condensate $= 13.377 - 6.89 = 6.487$ kg

2. Evaporation/concentration ratio

The evaporation/concentration ratio, e $= C_p/C_F$

$= 16/9 = 1.78$

or e $= F/P$

$= 14.7/8.2 = 1.79$

3. The heat balance

Overall heat balance around the evaporating chambor

Let the reforence temp. be $0^{o}C$

According to the definition of specific heat

$q = ms \Delta t$

The enthalpy of feed, $q_1 = 14.7 \times 1000 \times 0.96(40-0)$

$= 558.6 \times 10^3$ Cal.

The enthalpy of concentrate juice, $q_2 = 8.2 \times 1000 \times 0.91(46-0)$

$= 342.7 \times 10^3$ Cal

From the vacuum readings, the temperatures were correlated, the mean temp. was then calculated as:

min. vacuum 640 mm.Hg	= $47^{\circ}C$
max. vacuum 680 mm.Hg	= $55.5^{\circ}C$

Then, the average saturated vapor temp.(Tv) = $\dfrac{55.5 - 47}{\ln \dfrac{55.5}{47}} = 51.5^{\circ}C$

From the steam table, the enthalpy of saturated steam is 619, 502 Cal/kg

Therefore, the enthalpy of satd. water vapor,

$$q_3 = 6.5 \times 619{,}502$$
$$= 4026.7 \times 10^3 \text{ Cal}$$

The enthalpy transferred from the hot water to the evaporating chamber,

$$q_4 = (4026.7+342.7-558.6) \times 10^3$$
$$= 3810.8 \times 10^3 \text{ Cal}$$

Total time consumption = 1 hr

Then, the rate of enthalpy transferred = $3810.8 \times 10^3/3600$

$$= 1.059 \times 10^3 \text{ Cal/sec}$$

4. <u>To find heat transfer coefficient of hot-water</u>

According to the Seban and Shimazaki's correlation equation for flow in closed conduit with constant the heat transfer coeff. is expressed as:

$$\frac{h_{loc}D}{k} = 5+0.025\,(RePr)^{0.8}$$

For rectangular conduit, $D = 4\,r_H$

where r_H = hydraulic radius

$$= \frac{14.6 \times 2.0}{(2 \times 14.6+2 \times 2)} = 0.88 \text{ cm}$$

k = thermal conductivity of water at T_h

= 1.646×10^{-3} Cal/sec cm °C (Kern)

T_h = average temp. of hot water

= 84.6° C

Re = Reynold's number = $\frac{\rho u D}{\mu}$ = $\frac{4 r_H u \rho}{\mu}$

= $\frac{4 r_H}{\mu} \frac{w}{A}$

μ = viscosity of water at T_h

= 0.3375×10^{-2} poise (g/cm sec) (Perry)

Therefore, Re = $\frac{4 \times 0.88 \times 10.5 \times 1000}{0.3375 \times 10^{-2} \times 60 \times 14.6 \times 2.0}$

= 6250

Pr = Prandt's number = $\frac{c_p \mu}{k}$

c_p = specific heat at T_h

= 1.00383 Cal/g°C (Perry)

Therefore, Pr = $\frac{1.00383 \times 0.3375 \times 10^{-2}}{1.646 \times 10^{-3}}$

= 2.06

Consequently, $\frac{hD}{k}$ = $5 + 0.025(6250 \times 2.06)^{0.8}$

= 5 + 48.5 = 53.5

Therefore, the heat transfer coefficient,

h = $\frac{53.5 \times 1.646 \times 10^{-3}}{4 \times 0.88}$

= 0.025 Cal/sec cm^{2}°C

5. <u>To find the temperature difference within the hot-water region</u>

Referring to Fig.2, p.27 ., the rate of heat transfer from the hot water to the evaporating chamber,

$$q_4 = h A \Delta t = h A (T_h - T_s')$$

The total surface area for heat transfer,

$$A = 14.6 \times 175 = 2555 \text{ cm}^2$$

Then,

$$T_h - T_s' = \frac{1.06 \times 10^3}{0.025 \times 2555} = 16.6^{\circ}C$$

6. <u>To find the temperature difference within the heated plate</u>

According to the Fourier's equation, the rate of heat transfer from the hot water to the evaporating chamber,

$$q_4 = k A \Delta t = \frac{k A}{\Delta x} (Ts' - Ts)$$

where k = thermal conductivity of the heated plate

= 9.4 Btu/hr ft $^{\circ}F$

= 0.039 Cal/sec cm $^{\circ}C$

A = 2555 cm^2

Δx = thickness of the plate = 0.64 cm

Therefore,

$$Ts' - Ts = \frac{1.06 \times 10^3 \times 0.64}{0.039 \times 2555} = 6.8^{\circ}C$$

7. <u>Temperature difference between the plate surface (Ts) and the vaporization temp.(Tv)</u>

From the experimental data,

$$T_h - T_v = 84.6 - 51.5 = 33.1^{\circ}C$$

Therefore,

$$Ts - Tv = (T_h - T_v) - (T_h - Ts) - (Ts' - Ts)$$

$$= 33.1 - 16.6 - 6.8 = 9.7^{\circ}C$$

8. The theoretical mass flow-rate of concentrate juice

According to the theoretically derived equation as shown in chapter 3, the relationship between the initial mass flow rate and the final mass flow rate is expressed as:

$$\left(\Gamma_o^{4/3} - \Gamma_L^{4/3} \right) = 0.925 \frac{(Ts - Tv)}{\lambda} \left(\rho^2 k^3 g \frac{\cos\theta}{\mu} \right)^{1/3}$$

where Γ_o is the initial mass flow rate per unit width, calculated from data of rotameter reading and feed density.

Hence, $\Gamma_o = \dfrac{0.24 \times 1000 \times 1.032}{60 \times 14.6}$

$= 0.2827$ g/sec cm

and $\Gamma_o^{4/3} = 0.1856$

Γ_L is the final mass flow rate per unit width.

It was calculated from the collected weight of concentrate juice divided by the total time consumed and the plate width.

Therefore, experimental mass flow rate of concentrate juice

$= \dfrac{8.2 \times 1000}{14.6 \times 3600} = 0.1560$ g/sec cm

$Ts - Tv = 9.7\ ^\circ C$

$\lambda = 6.195 \times 10^{2}$ Cal/g

$\rho = 1.045$ (from average concn) g/ml

$k = 1.534 \times 10^{-3}$ Cal/sec cm °C (Perry)

(based on the assumption that the thermal conductivity of orange juice was equal to that of water)

$g = 981$ cm/sec^2

$\cos\theta = \cos 60^\circ = \frac{1}{2}$

$\mu = 0.55 \times 10^{-2}$ g/cm sec

Then, $\Gamma_o^{4/3} - \Gamma_L^{4/3} = \frac{0.925(9.7)}{6.195 \times 10^2} \left[\frac{(1.045)^2 (1.534 \times 10^{-3})^3 981}{2 \times 0.55 \times 10^{-2}} \right]^{1/3}$

$= 0.1785$

$\Gamma_L^{4/3} = \Gamma_o^{4/3} - 0.1785 = 0.1856 - 0.1785$

$= 0.0071$

Therefore the theoretical mass flow-rate per unit width of concentrate juice,

$\Gamma_L = 0.0245 \ g/_{sec\ cm}$

Part IV Analysis of Juice

1. Total titratable acidity (example a of run no.1)

Normality of NaOH = 0.102

ml. of NaOH used = 16.5

Molecular wt. of citric = 192.12

Therefore, citric content $= \frac{0.102(16.5)}{100} \times \frac{19212}{3} \times 10$

$= 1.08 \ g/_{100\ ml.}$

2. Vitamin C content (example a. of run no.1)

Normality of Iodine solution = 0.00808

From standard Iodine solution

1 ml. 0.01 N = 0.88 mg ascorbic acid

which is equal to 1.2376 ml of 0.00808 N.

ml. of Iodine solution used = 4.15

Therefore, vitamin C content $= \frac{0.88 \times 4.15}{1.2376}$ mg ascorbic/10 ml

$= 29.5 \ mg/_{100\ ml}$

VITA

Miss Suwanna Roongtanapirom received her Bachelor Degree of Science in the field of Food Technology from Faculty of Science, Chulalongkorn University in 1970.

She has been joining the teaching staff in the Department of Chemical Technology where she graduated since then. The subjects which she used to handle in collaboration with other senior lecturers are: Raw Materials for Food Processing, Food and Nutrition, Food Chemistry, Food Evaluation, Food Processing, and Food Quality Control.

She began her master study in June 1973 and completed the program in April 1975.