indirectly by means of a battery instead of directly through a central station.

Of course, the same problems obtain in regard to gearing and motors, etc., in both systems and do not enter into the question as propounded.

In my judgment the storage battery has a future. You cannot pound the life out of a fact. All the slander and ridicule that has been heaped upon storage batteries does not alter their capacity to do a certain amount of work at a given cost, one ampère second.

Give the storage battery a chance. Let the same engineering skill and ability be applied to the storage system as has already been done with the trolley, and the results will be surprising.

ON THE SPECIFIC HEAT OF BRINES OF DIFFERENT SPECIFIC GRAVITY.*

BY DR. HANS VON STROMBECK.

[*Read by title.*]

If in refrigerating plants the cooling effect is not done directly by the evaporation of the liquid, almost always brine, a solution of sodium chloride (salt) in water is used for transmitting the cold generated in the expansion coils to the place where the cooling effect is wanted. In order to be able to calculate the quantity of a brine of a certain concentration which is required for transmitting the cold generated, the specific heat of the brine must be known. Since the exact values for the specific heat of brines of different specific gravities were not yet known, I determined them by a series of tests. The results showed that the figures obtained from the tests for a certain brine differs more or less from, but is always less than, the figures we obtain by calculating the specific heat of the same brine from its contents of water and sodium chloride.

* From the Laboratory of the De La Vergne Refrigerating Machine Co.

In the following table I give the figures obtained from the tests :

Specific Gravity of the Brine at 60° F.	The Figures in the Preceding Column being its Specific Gravity, the Brine contains Per Cent. of Salt.	Specific Heat of the Brine Calculated from its Contents of Water and Salt, the Specific Heat of the Latter taken to be 0.228.	Determined Specific Heat of the Brine, each Figure being the Average of Four Determinations well agreeing with one another.
1.025	3.446	0.9734	0.96440
1.0375	5.1098	0.9600	0.94284
1.0500	6.8547	0.9471	0.91561
1.0525	8.5377	0.9340	0.89798
1.0730	10.2165	0.9213	0.87819
1.0875	11.8569	0.9085	0.86295
1.1000	13.4960	0.8958	0.85610
1.1125	15.1313	0.8831	0.84233
1.1250	16.7726	0.8710	0.82810
1.1375	18.4264	0.8588	0.81998
1.1500	19.8649	0.8466	0.80631
1.1625	21.3871	0.8349	0.80050
1.1750	22.9030	0.8232	0.79417
1.1875	24.4199	0.8116	0.78936
1.2000	25.8884	0.8001	0.78633

From the graphic representation, it can still better be seen how the specific heats, calculated and determined, differ in a different degree from one another.

The tests were made in the following manner :

The apparatus* (see *Fig. 1*), which I think was first designed by Regnault, is made of brass. Tank *A B C D* is filled to such an extent with water that the end *a* of pipe *a b* dips into the water about one inch. By means of the burners *B' B''* the water in *A B C D* is kept boiling. The steam developed escapes through the pipes *F B* and *E G*, and circulates in the drum *F H I K*. In order to lessen the cooling influence of the air and the loss of heat by radiation, the drum is surrounded by a lagging, the tank and the

* I used this apparatus also for the determination of the specific heat of liquid ammonia (vol. cxxx, No. 780, of this journal) after I had made some alterations.

Graphic representation of the specific heat of brines of different specific gravity.

FIG. 1.—Sectional view of the apparatus.

pipes are polished as brightly as possible. One portion of the steam developed in $A B C D$ while passing the pipes and circulating in the drum is condensed and flows back to tank $A B C D$; another portion escapes through pipe $L M N O$. Pipe $L M$ is enlarged into a box, into the bottom of which pipe $a b$ empties, the top of it being connected with pipe $N O$. Pipe $N O$ is surrounded by box $P Q R S$. This box is always kept filled with cold water from the hydrant which supplies the same at the bottom of the box, the warm water flowing out at the top. Thus the steam, while escaping through $L M N O$ is condensed and through the pipe $a b$ trickles down into tank $A B C D$, where it is transformed into steam again. By this arrangement steam can be developed by the same quantity of water for days without its needing to be renewed. The brass-wire basket T filled with brass tacks, the weight of which, both together, is known, is suspended in the middle of the cylinder $c d e f$ by means of a silk thread and the plug g . The top of the cylinder is closed by the cover $e f$, which is tightened by a rubber ring, the bottom by the lid $c d$, which is covered on the inside by a wooden plate. It can be opened and closed by means of a thread, hook and hinges. The thermometer going through the cover, and also being tightened by a rubber ring, reaches to the top of the brass basket. The dimensions of the thermometer are taken in such a way that $0^{\circ}.01$ can be estimated, and that the column of mercury, when indicating the highest temperature which can be produced in $c d e f$ only projects a little over the cover. Thus the temperature prevailing in the cylinder can directly be read on the thermometer, and no correction is necessary. The wooden partition U , which is intended to keep away from the calorimeter $h i k l$, any influence of the heat caused by the burners $B' B''$, can be moved forwards and backwards between two posts.

The brass calorimeter $h i k l$, the weight of which is known, is filled with a weighed quantity of the brine, the specific heat of which is to be determined. It is provided with a thermometer, and the agitator m , by means of which the temperature of the brine is equalized in all parts.

The dimensions of the former again are taken in such a way that $0^{\circ}01$ can be estimated, and that the column of mercury, when indicating the temperature of the brine in the beginning of the test, does not project much over the surface of the same. Calorimeter *h i k l* is put in the wooden box *n o p q*. The board *V W*, which supports the whole apparatus, has the groove *r s* in its longitudinal extension. Box *n o p q* having at its bottom the projecting board *n* fitting groove *r s*, can easily be made to slide forward and backward under the cylinder *c d e f*, after partition *U* has been moved backwards. After the apparatus is properly adjusted, the burner *B*, *B*_{II} are lit. When the thermometer in *c d e f* indicates a constant temperature, the temperatures indicated by each thermometer and the time are noted down, partition *U* is moved backwards, lid *c d* swung open, box *n o p q* slid under cylinder *c d e f*, basket *T* lowered into calorimeter *h i k l*, box *n o p q* slid back, partition *U* removed into its previous place, and the ascension of the thermometer in the calorimeter *h i k l* is watched. As soon as it begins to go down, the time is noted down again, thus giving us the number of seconds during which the thermometer ascended. From the moment it begins to descend, during some minutes the temperatures indicated by the thermometer every sixty seconds are noted down. From the figures thus obtained, the specific heat of the brine can be calculated.

Further below, I give the four authentic proofs for the determination of the specific heat of brine of 1.1875 specific gravity. In the following I shall add to each item the figures obtained from the third of these four tests.

If *M* means the weight of brass tacks and basket together (446.0 grammes);

σ means the specific heat of brass (0.0939);

m means the weight of the brine filled into the calorimeter *h i k l* (510.0 grammes);

T means the temperature prevailing in cylinder *c d e f* (95° 771 Cels.);

τ means the temperature of the brine indicated by the thermometer at the beginning of the test (21° 20);

τ_1 means the temperature of the brine indicated by the thermometer at the end of the test ($28^{\circ}05$);

x means the specific heat of the brine that is to be determined;

we arrive at the following equation:

$$x m (\tau_1 - \tau) = \sigma M (T - \tau_1) \quad (1)$$

In this equation we did not take into consideration the heat which is absorbed by the brass of the calorimeter *h k l*, and the thermometer in it for being heated up from τ to τ_1 degrees.

If μ means the weight of the brass calorimeter (75.2 grs.);

μ_2 means the weight of the thermometer in it;

σ_2 means the specific heat of the thermometer, and these values are introduced into equation (1);

we obtain equation

$$x m (\tau_1 - \tau) + \sigma \mu (\tau_1 - \tau) + \mu_2 \sigma_2 (\tau_1 - \tau) = \sigma M (T - \tau_1) \quad (2)$$

$\mu_2 \sigma_2$ is determined in the following manner: The thermometer is put in warm water, then put in a weighed quantity of cooler water and it is observed what temperature the water has obtained by the bringing in of the thermometer.

If θ means the temperature of the thermometer when put in the water;

ϑ means the temperature of the water before the thermometer was put in;

ϑ_1 means the temperature of the water after the thermometer had been put in;

m_1 means the weight of the water;

we obtain

$$\sigma_2 \mu_2 (\theta - \vartheta_1) = m_1 (\vartheta_1 - \vartheta)$$

or

$$\sigma_2 \mu_2 = \frac{m_1 (\vartheta_1 - \vartheta)}{\theta - \vartheta_1}$$

The value for $\sigma_2 \mu_2$ is the same in all tests. The observations having been:

θ ,	$= 29^{\circ} 84$	$29^{\circ} 18$	$29^{\circ} 77$	$29^{\circ} 78$
δ ,	$= 20^{\circ} 85$	$20^{\circ} 74$	$20^{\circ} 80$	$20^{\circ} 82$
ϑ_1 ,	$= 23^{\circ} 06$	$22^{\circ} 67$	$22^{\circ} 86$	$22^{\circ} 96$
m_1 ,	$= 5.7$ grs.	5.7 grs.	5.7 grs.	5.7 grs.

we find $\mu_2 \sigma_2 = 1.86$ grs. 1.67 grs. 1.69 grs. 1.78 grs.

average of $\mu_2 \sigma_2$ $= 1.75$ grs. of water.

But we have to make one correction more. In these equations we admitted the difference $\tau_1 - \tau$ to be in reality

FIG. 2.

all the heat given by the brass tacks and basket to the brine in the calorimeter, to the calorimeter itself and to the thermometer in it. But this supposition is not true, as during the tests the brine, calorimeter and thermometer lost heat by radiation and by the cooling influence of the air. Without this loss of heat the thermometer would not only have gone up to τ_1 degrees (see Fig. 2), but a little more, to $\tau_1 + \delta$ degrees. This δ is determined in the following manner:

It took s seconds ($45''$) to raise the temperature of the brine from τ to τ_1 degrees. Then after having stopped a moment, the thermometer began to go down. It went

down in the first sixty seconds from τ_1 to τ_2 , in the next sixty seconds from τ_2 to τ_3 , from τ_3 to τ_4 , from τ_4 to τ_5 , or the decreases were $\tau_1 - \tau_2$, $\tau_2 - \tau_3$, $\tau_3 - \tau_4$, $\tau_4 - \tau_5$, the values

$$\frac{\tau_1 + \tau_2}{2} \quad \frac{\tau_2 + \tau_3}{2} \quad \frac{\tau_3 + \tau_4}{2} \quad \frac{\tau_4 + \tau_5}{2}$$

representing the average temperatures prevailing during each sixty seconds. It is :

$$\tau_1 - \tau_2 = \frac{\tau_1 + \tau_2}{2} \cdot 60 \cdot k_1$$

$$\tau_2 - \tau_3 = \frac{\tau_2 + \tau_3}{2} \cdot 60 \cdot k_2$$

$$\tau_3 - \tau_4 = \frac{\tau_3 + \tau_4}{2} \cdot 60 \cdot k_3$$

$$\tau_4 - \tau_5 = \frac{\tau_4 + \tau_5}{2} \cdot 60 \cdot k_4$$

If we dissolve these equations for k , we obtain

$$k_1 = \frac{2 (\tau_1 - \tau_2)}{(\tau_1 + \tau_2) 60}$$

$$k_2 = \frac{2 (\tau_2 - \tau_3)}{(\tau_2 + \tau_3) 60}$$

$$k_3 = \frac{2 (\tau_3 - \tau_4)}{(\tau_3 + \tau_4) 60}$$

$$k_4 = \frac{2 (\tau_4 - \tau_5)}{(\tau_4 + \tau_5) 60}$$

and by taking the average of $k_1 k_2 k_3 k_4$, the value of k , *i. e.*, of a coefficient, which multiplied by the number of seconds which the test lasted, and by the average temperature prevailing during each second, gives the fraction of a degree δ by which more the thermometer in the calorimeter would have gone up, if there had been no loss of heat by radiation and by the cooling influence of the air.

The average temperature during the s seconds (45'') while the thermometer ascended having been

$$\frac{\tau + \tau_1}{2} \text{ degrees,}$$

we have

$$\delta = \frac{\tau + \tau_1}{2} \cdot s \cdot k$$

or the real number of degrees by which the brine in the calorimeter was heated up was $\tau_1 + \delta - \tau$ degrees.

We observed

$$\begin{array}{lll} \tau = 21^{\circ}20 & \frac{\tau + \tau_1}{2} = 24^{\circ}625 & s = 45'' \\ \tau_1 = 28^{\circ}05 & \tau_1 - \tau_2 = 0^{\circ}10 & \\ \tau_2 = 27^{\circ}95 & \tau_2 - \tau_3 = 0^{\circ}05 & \\ \tau_3 = 27^{\circ}90 & \tau_3 - \tau_4 = 0^{\circ}04 & \\ \tau_4 = 27^{\circ}86 & \tau_4 - \tau_5 = 0^{\circ}02 & \\ \tau_5 = 27^{\circ}84 & & \end{array}$$

Introducing these figures into the equations above-mentioned, we obtain

$$\left. \begin{array}{l} k_1 = 0.000060 \\ k_2 = 0.000030 \\ k_3 = 0.000024 \\ k_4 = 0.000012 \end{array} \right\} k = 0.000031$$

Hence follows $\delta = 24.625 \cdot 0.000031 \cdot 45 = 0.34$ and $\tau_1 + \delta = 28.084$ and $\tau_1 + \delta - \tau = 6.884$.

Introducing this correction into equation (2) we obtain equation

$$\begin{aligned} x m (\tau_1 + \delta - \tau) + \sigma \mu (\tau_1 + \delta - \tau) + \sigma_2 \mu_2 (\tau_1 + \delta - \tau) \\ = \sigma M [T - (\tau_1 + \delta)] \end{aligned} \quad (3)$$

and by dissolving it for x we have

$$\begin{aligned} x = \frac{\sigma [M (T - (\tau_1 + \delta)) - \mu (\tau_1 + \delta - \tau)] - \mu_2 \sigma_2 (\tau_1 + \delta - \tau)}{m (\tau_1 + \delta - \tau)} \\ = 0.79053 \end{aligned}$$

AUTHENTICAL PROOFS FOR THE SPECIFIC HEAT OF BRINE OF 1.1875 SP. GR.

	I.	II.	III.	IV.
M ,	446.0 grs.	446.0	446.0	446.0
μ ,	75.2 "	75.2	75.2	75.2
σ ,	0.0939	0.0939	0.0939	0.0939
$\mu_2 \sigma_2$,	1.75 grs.	1.75	1.75	1.75
m ,	510.0 "	510.0	510.0	510.0
T ,	95.74	95.85	95.77	96.04
τ ,	21.36	21.84	21.20	21.50
τ_1 ,	28.22	28.62	28.05	28.36
τ_2 ,	28.15	28.57	27.95	28.27
τ_3 ,	28.12	28.54	27.90	28.20
τ_4 ,	28.11	28.50	27.86	28.16
τ_5 ,	28.10	28.46	27.84	28.12
$\tau_1 - \tau_2$,	0.07	0.05	0.10	0.09
$\tau_2 - \tau_3$,	0.03	0.04	0.05	0.07
$\tau_3 - \tau_4$,	0.01	0.04	0.04	0.05
$\tau_4 - \tau_5$,	0.01	0.03	0.02	0.04
h ,	0.000018	0.000017	0.000031	0.000037
S ,	60'	100	45	50
δ ,	0.0268	0.043	0.034	0.045
$\tau_1 + \delta$,	28.2468	28.663	28.084	28.405
$\tau_1 + \delta - \tau$,	6.8868	6.823	6.884	6.905
$T - (\tau_1 + \delta)$,	67.4932	67.187	67.686	67.635
χ ,	0.78778	0.79180	0.79053	0.78732
Average of χ ,	0.78936			

This average value differs from the highest value obtained, 0.31 per cent.

This average value differs from the smallest value obtained, 0.26 per cent.

If we have to determine the specific heat of a solid body which is soluble in water (in this case salt), we put a weighed quantity of it in the basket T which, of course, is to be made of brass sheathing in this case, and in the calorimeter $h i k l$ a liquid which does not dissolve the body (in this case mineral oil), and the specific heat of which is known.

If M_1 means the weight of the salt, filled into the basket;

m_1 means the weight of the mineral oil;

σ_1 means its specific heat;

μ_1 means the weight of the empty brass basket;

α_1 means the specific heat of the salt that is to be determined, the other letters having the same meaning as formerly;

we arrive at the following equation:

$$\alpha_1 m_1 (\tau_1 + \delta - \tau) + \mu_2 \sigma_2 (\tau_1 + \delta - \tau) + \sigma [\mu (\tau_1 + \delta - \tau) - \mu_1 (T - (\tau_1 + \delta))] \\ \alpha_1 = \frac{M_1 (T - (\tau_1 + \delta))}{M_1 (T - (\tau_1 + \delta))}$$

I obtained as average figure of the specific heat of salt 0.228.

ADDITIONAL NOTES ON THE COMPOSITION OF THE LIQUID AMMONIA OF THE TRADE, ETC.

BY DR. HANS VON STROMBECK.

A few weeks ago, just after my paper "On the Composition of the Liquid Ammonia of the Trade" had been presented to the Chemical Section of the Institute, Mr. Louis Block, Chief Engineer of the De La Vergne Refrigerating Machine Company, showed me a piece of a black, dough-like paste which had been scraped out of the compressor of a refrigerating machine. He said that this paste had interfered with the proper working of the valves of the compressor, and thus with the proper working of the whole plant, and requested me to ascertain how this paste could have been formed, and how its formation could be prevented. The weight of the paste scraped out was only 35.24 grains or about one-twelfth ounce. As a superficial examination of the paste showed the presence of a considerable percentage of iron, I thought first that the mineral oil used in the compressor might contain some mineral acid or some fatty oil which by setting free fatty acid had acted on the valves of the compressor. But an examination of the oil used proved it to be pure mineral oil of the same chemical and physical