THERMODYNAMIC (t, S) GRAPH FOR MERCURY CONSTRUCTED FROM EXPERIMENTAL DATA ON THE VELOCITY OF SOUND

I. I. Novikov and E. P. Sheludyakov

Thurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, Vol. 2, pp. 137–139, 1966

Recently mercury has been attracting more and more attention. This is because, in the first place, it has been planned to use it in its liquid and vapor phases as a heat conductor and working substance in a whole range of power equipment. It is therefore clear that a study of its thermodynamic properties is of special importance. There have been several attempts to prepare tables of the thermodynamic properties of mercury. Reference can be made to the tables of Scheldon [1] and Eck [2], and to the results of Vukalovich and Fokin[1] and others.

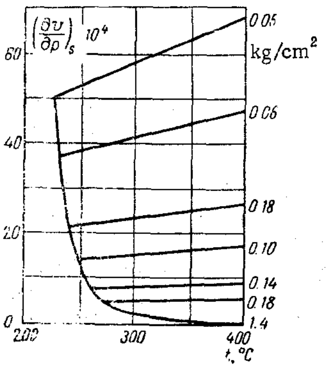

Fig. 1. Values of the derivative $(\partial v/\partial p)_s$ for mercury in the form of isobars and saturation lines.

In constructing the entropy diagram (t, S) for mercury, the authors used a method which employs experimental data on the velocity of sound, the essence of which is as follows. As is well known, the velocity of sound c can be expressed in terms of a specific volume v and the derivative $(\partial p / \partial v)_s$ by the equation

$$c = \sqrt{-gv^2(\partial p / \partial v)_s}\ . \tag{1}$$

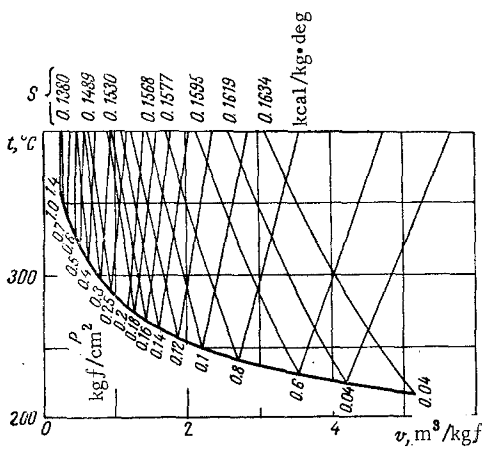

Fig. 2. Isentropic curves for mercury in the coordinates v, t, constructed from data on the velocity of sound.

From the available PVT data it is possible, for a given value of the velocity of sound, to calculate the derivative $(\partial p / \partial v)_s$ for the given state. Then, using the expression for the exact differential of the volume

$$dv = \left(\frac{\partial v}{\partial p}\right)_s dp + \left(\frac{\partial v}{\partial s}\right)_p ds\ ,$$

for the condition s = const we have

$$dv = \left(\frac{\partial v}{\partial p}\right)_s dp, \quad \text{or} \quad \Delta v = \left(\frac{\partial v}{\partial p}\right)_s \Delta p. \tag{2}$$

Equation (2) makes it possible to calculate the change in specific volume v for a chosen isentropic curve s = const and a given pressure change Δp.

Thus an entropy diagram can be constructed directly from the experimental data.

Previously the authors measured the speed of sound in saturated and superheated mercury vapor in the temperature range 225–400° C and pressure range 0.05–2.2 kg/cm². The error in determining the velocity of sound did not exceed 0.5%.

To check the results, the specific volumes of the vapor were calculated from the same equation as used by Vukalovich and Fokin. In addition, the same p_s-S (pressure-entropy) dependence was taken on the saturation line.

Values of the derivative $(\partial v / \partial p)_s$ (Fig. 1) were calculated from equation (1), and using these values the isentropic curves in the coordinates v-t (Fig. 2) were constructed, providing sufficient accuracy for t-S diagrams to be plotted. V and t were calculated at each point on the isentropic curve, using the parameters of the previous point

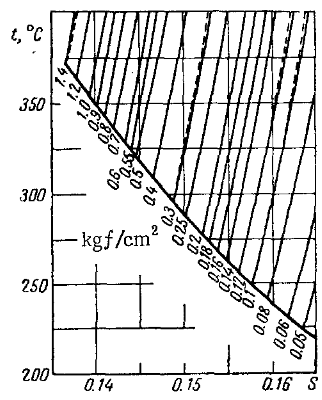

Fig. 3. Isobars for mercury in the coordinates t, S.

by the method of successive approximations. The origins of all the isentropic curves lay on the line of saturation. The results of the calculation of the isobaric and isentropic curves in the coordinates v-t were used to plot isobars and isochors in the coordinates t (°C) and S (kcal/kg·deg) (Fig. 3 and Tables 1 and 2).

In Fig. 3 are also shown isobars, indicated by the broken lines, for p = 0.1, 0.12, 0.3, and 1.4 kg/cm², taken from the data of Vukalovich and Fokin. Near the saturation line the isobars almost

[1]M. P. Vukalovich, L. P. Fokin, The Thermodynamic Properties of Mercury [in Russian], Moscow Power Engineering Institute Report, 1963.

Table 1

Isobars in the Coordinates t (°C), S[kcal/kg•deg] (p in kg/cm^2)

t	S	t	S	t	S	t	S	t	S	t	S
$p = 0.05$		320	0.1600	400	0.1604	360	0.1557	380	0.1497	400	0.1447
224.5	0,1634	320	0.1609	$p = 0.16$		380	0.1565	400	0.1504	$p = 0.8$	
240	0.1643	340	0.1618	268	0.1539	400	0.1573	$p = 0.5$		341.5	0.1412
260	0.1654	360	0.1626	280	0.1545	$p = 0.25$		318.8	0.1448	360	0.1419
$p = 0.06$		380	0.1634	300	0.1554	286.7	0.1504	340	0.1457	380	0.1427
230.9	0.1619	400	0.1642	320	0.1563	300	0.1510	360	0.1465	400	0.1434
240	0.1623	$p = 0.12$		340	0.1570	320	0.1518	380	0.1474	$p = 0.9$	
360	0.1633	256.7	0,1568	360	0.1578	340	0.1526	400	0.1482	349.2	0.1403
280	0.1644	260	0.1564	380	0.1585	360	0.1534	$p = 0.55$		360	0.1407
300	0.1654	280	0.1573	400	0.1593	380	0.1542	322.5	0.1441	380	0.1415
$p = 0.08$		300	0.1582	$p = 0.18$		400	0.1550	340	0.1448	400	0.1422
241.0	0.1595	320	0.1591	272.9	0.1530	$p = 0.3$		360	0.1456	$p = 1.0$	
260	0.1604	340	0.1599	280	0.1533	294.4	0.1489	380	0.1464	355.0	0.1394
280	0.1614	260	0.16075	300	0.1542	300	0.1492	400	.1471	360	0.1396
300	0.1623	380	0.1616	320	0.1551	320	0.1501	$p = 0.6$		380	0.1405
320	0.1632	400	0.1624	340	0.1559	340	0.1509	327.0	0.1434	401	0.1413
340	0.1641	$p = 0.14$		360	0.1567	360	0.1517	340	0.1439	$p = 1.2$	
360	0.6050	262.7	0.1550	380	0.1574	380	0.1525	360	0.1447	364.0	0.1380
380	0.1659	280	0.1558	400	0.1583	400	0.1532	380	0.14555	380	0.1386
400	0.1668	300	0.1566	$p = 0.4$		$p = 0.4$		400	0.14625	400	0.1394
$p = 0.1$		320	0.1574	277.3	0.1521	308.0	0.1466	$p = 0.7$		$p = 1.5$	
249.0	0.1577	340	0.1581	300	0.1532	320	0.1471	335.9	0.1422	373.0	0.1368
260	0.1582	360	0.1589	320	0.1540	340	0.1480	360	0.1432	380	0.13705
280	0.1591	380	0.1597	340	0.1548	360	0.1489	380	0.1440	400	0.13775

Table 2

Isochors in the Coordinates t, S (v, m^3/kg), t in °C,
S in kcal/kg•deg

t	S	t	S	t	S
$v = 0.2$		360	0.1494	340	0.1590
371.7	0.1370	380	0.1500	360	0.1595
380	0.1372	400	0.1506	380	0.1600
400	0.1376	$v = 1.0$		400	0.1605
$v = 0.3$		284.3	0.1508	$v = 3.0$	
347.2	0.1404	300	0.1512	237,5	0.1604
360	0.14075	320	0.15175	260	0.1611
380	0.1414	340	0.15225	280	0.16165
400	0.1420	360	0.1528	300	0.1622
$v = 0.4$		380	0.1533	320	0.1627
330.3	0.1430	400	0.1538	340	0.1632
340	0.1432	$v = 1.5$		360	0.1638
360	0.1436	226	0.1544	380	0.1643
380	0.1441	280	0.1547	400	0.1649
400	0.1446	300	0.1553	$v = 3.5$	
$v = 0.5$		320	0.1558	231.6	0.1617
318.7	0.1448	340	0.1564	260	0.1626
340	0.1453	360	0.1569	280	0.1632
370	0.1458	380	0.15745	300	0.1636
380	0.1463	400	0.1580	320	0.1643
400	0.1468	$v = 2.0$		340	0.1649
$v = 0.7$		253.6	0.1568	360	0.1655
301.8	0.1476	280	0.1575	380	0.1661
320	0.1482	300	0.1580	400	0.1667
340	0.1488	320	0.1585		

coincide with the present results (continuous lines), but diverge somewhat at higher temperatures; however, in all cases the maximum deviation does not exceed 1%.

REFERENCES

1. L. A. Scheldon, Properties of mercury vapor. Trans. ASME, 46, 1924.

2. H. Eck, Zahlentafel und Diagramme für Quecksilberdampf, Forschung, no. 1, 4, 1933.

3. I. I. Novikov and Yu. S. Trelin, "The construction of entropy diagrams from experimental data on the velocity of sound," Atomnaya energiya, vol. 10, no. 5, 1961.

16 March 1965 Novosibirsk