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MOLLIER DIAGRAM FOR AIR

By

Wanda J. Little
von Kármán Gas Dynamics Facility
ARO, Inc.

TECHNICAL DOCUMENTARY REPORT NO. AEDC-TDR-63-190

September 1963

Program Element 61405014/8951, Task 89603

(Prepared under Contract No. AF 40(600)-1000 by ARO, Inc.,
contract operator of AEDC, Arnold Air Force Station, Tenn.)

ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
EQUILIBRIUM AIR
This chart is a composite of sectional parts given by Wanda J. Little, "N Air," AEDC-TDR-63-190, September 1963. The data for it are derived from.

MOLLIER DIAGRAM FOR EQUILIBRIUM

PREPARED BY THE STAFF OF VON KARMAN GAS DYNAMICS FACILITY, ARD, INC., CONTRACT OPERATORS OF ARNOLD ENGINEERING DEVELOPMENT CENTER, UNITED STATES AIR FORCE, ARNOLD AIR FORCE STATION, TENNESSEE. PRINTED BY THE PARTHENON PRESS, NASHVILLE, TENNESSEE, MARCH 1964.
DIAGRAM FOR EQUILIBRIUM AIR

This diagram was prepared by the staff of Von Karman Gas Dynamics, ARO, Inc., contract operators of Arnold Engineering Development Center, United States Air Force Arnold Air Force Station, Tennessee. Printed by Themon Press, Nashville, Tennessee, March 1964.

The data for it are derived from J. Hilsenrath, "Mollier Diagram for Equilibrium Air," September 1963.

The vertical coordinate is the enthalpy function $H/R$ expressed in units of Kelvin. Its values are obtained by multiplying the dimensionless function $H/R$ by the temperature. The horizontal coordinate is the dimensionless entropy function $S/R$. The temperature $T$ is measured in degrees Kelvin. The pressure $p$ is given in atmospheres, the density $\rho$ in amagat units based on the density of air at 0°C and a pressure of one atmosphere. The logarithms are common logarithms to base ten.

For air, one amagat is the equivalent of 0.00129 grams per cubic centimeter or 0.0686 pounds per cubic foot. Enthalpy in calories per gram is equal to $H/R(°K)$ multiplied by 0.0686 and in British thermal units per pound it is equal to $H/R(°K)$ multiplied by 3092.0. The specific enthalpy in feet-squared per second-squared is equal to $H/R(°K)$ multiplied by 3092.0 and in meters-squared per second-squared to $H/R(°K)$ multiplied by 3092.0.

The vertical coordinate is the enthalpy function \( H/R \) expressed in units of degrees Kelvin. Its values are obtained by multiplying the dimensionless function \( H/RT \) by the temperature. The horizontal coordinate is the dimensionless entropy function \( S/R \). The temperature \( T \) is measured in degrees Kelvin. The pressure \( p \) is given in atmospheres, and the density \( \rho \) in amagat units based on the density of air at 0°C and a pressure of one atmosphere. The logarithms are common logarithms to base ten.

For air, one amagat is the equivalent of 0.00129 grams per cubic centimeter or 0.0807 pounds per cubic foot. Enthalpy in calories per gram is equal to \( H/R(°K) \) multiplied by 0.0686 and in British thermal units per pound it is equal to \( H/R(°K) \) multiplied by 0.1234. The specific enthalpy in feet-squared per second-squared is equal to \( H/R(°K) \) multiplied by 3092.0 and in meters-squared per second-squared to \( H/R(°K) \) multiplied by 287.2.
MOLLIER DIAGRAM FOR AIR

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ABSTRACT

A Mollier diagram for air, including the effects of dissociation and ionization, as well as of intermolecular potentials to the second virial correction, is presented. The range of temperatures extends from the saturation line to 15,000 K and the range of densities, from $10^{-7}$ to approximately 200 amagats.

PUBLICATION REVIEW

This report has been reviewed and publication is approved.

Larry D. Fitzgerald
Capt, USAF
Aerospace Sciences Division
DCS/Research

Donald R. Eastman, Jr.
DCS/Research
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NOMENCLATURE

H/R  Enthalpy in °K, obtained by multiplying the dimensionless function H/RT by the temperature in °K
log  Common logarithm to base 10
p    Pressure, atm
R    Gas constant
S/R  Entropy, dimensionless
T    Temperature, °K
ρ/ρ₀ Density in amagats, based on ρ₀ at 0°C and one atm of pressure
1.0 INTRODUCTION

This air Mollier diagram was prepared for the purposes of data reduction in the operation of wind tunnels at the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), USAF. This diagram represents the most recently available information on the thermodynamic properties of air, including the effects of dissociation, ionization, and of intermolecular potentials to the second virial correction. The diagram covers the range of temperatures from the saturation line to 15,000°K and the range of densities from $10^{-7}$ to from 200 to 250 amagats. Above 1500°K, the plotted data are taken from the tables of Hilsenrath and Klein (Ref. 1), whereas the data below 1500°K are derived from the tables of Humphrey and Neel (Ref. 2) which combine information from various sources, notably the tables of Din (Ref. 3). Data below 90°K, as well as all data at densities below $10^{-7}$ amagat, were generated mainly by extrapolation, using the method described in Ref. 4. The tables of Din (Ref. 3) provide explicit data for the saturation line at pressures from one atmosphere upwards. At pressures below one atmosphere, the saturation line is based on the work of Furukawa and McCoskey (Ref. 5) and of Erickson and Creekmore (Ref. 6), the latter being based on vapor-pressure data for pure nitrogen and oxygen.

Enthalpy, expressed as $H/R$ having dimensions of degrees Kelvin, is plotted vertically on a logarithmic scale through four decimal orders of magnitude. The dimensionless entropy, $S/R$, is the other basic variable. Lines at constant density are identified by their values of $\log \rho/\rho_0$, in which the ratio $\rho/\rho_0$ is the density in amagats. The constant pressure lines are marked in atmospheres and the constant temperature in degrees Kelvin.

The appendix contains a short list of useful conversion factors.

REFERENCES


Manuscript received August 1963.


## APPENDIX

<table>
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<tr>
<th>Conversion Factors To Change</th>
<th>To</th>
<th>With Units of</th>
<th>Multiply by</th>
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<tr>
<td>( \frac{H}{R} )</td>
<td>( \frac{H}{RT} )</td>
<td>None</td>
<td>( \frac{1}{T(\circ K)} )</td>
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<tr>
<td>( \frac{H}{R} )</td>
<td>°R</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>( H )</td>
<td>( \frac{ft^2}{sec^2} )</td>
<td>3.09235 (10^3)</td>
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</tr>
<tr>
<td></td>
<td>( \frac{Btu}{lb} )</td>
<td>1.23406 (10^{-1})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \frac{cal}{gm} )</td>
<td>6.86042 (10^{-2})</td>
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</tr>
<tr>
<td>( \frac{S}{R} )</td>
<td>S</td>
<td>( \frac{ft^2}{sec^2\circ K} )</td>
<td>3.09235 (10^3)</td>
</tr>
<tr>
<td></td>
<td>( \frac{ft^2}{sec^2\circ R} )</td>
<td>1.71797 (10^3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \frac{Btu}{lb\circ R} )</td>
<td>6.85590 (10^{-2})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \frac{Btu}{lb\circ K} )</td>
<td>1.23406 (10^{-1})</td>
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</tr>
<tr>
<td></td>
<td>( \frac{cal}{gm\circ K} )</td>
<td>6.86402 (10^{-2})</td>
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<tr>
<td>( \rho )</td>
<td>( \rho_0 )</td>
<td>( \frac{gm}{cm^3} )</td>
<td>1.29304 (10^{-3})</td>
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<tr>
<td></td>
<td>( \frac{lb}{in.} )</td>
<td>4.67143 (10^{-5})</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \frac{lb}{ft^3} )</td>
<td>8.07223 (10^{-2})</td>
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Fig. 6 Air Mollier Diagram
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