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There are six interrelated properties that define the state of steam: Temperature Pressure Dryness Fraction (within the saturated zone) Enthalpy Internal energy Entropy Fixing the value of any two properties defines the value of all the others. Thus fixing the values of Enthalpy and Entropy is sufficient to define Temperature, Pressure and Internal Energy of the steam. The term “Mollier diagram” (named after Richard Mollier, 1863-1935) refers to any diagram that features Enthalpy on one of the coordinates. Commonly used Mollier diagrams are the enthalpy-entropy (or h-s) diagram (below) and the pressure-enthalpy diagram illustrated at the bottom of this page. The Enthapy-Entropy or h-s diagram: The h-s diagram is one in which Enthalpy values form the vertical axis and Entropy the horizontal axis. The values of the other related properties may be superimposed in the form of supplementary curves. In the diagram below: green lines show steam temperature; blue lines give (absolute) steam pressure; and red lines give the dryness fraction (in the saturated zone). Ideal (isentropic) expansion is represented on the Mollier diagram by a vertical line. Actual expansion of steam always involves some losses represented by an increase in entropy. In the 5AT FDCs, Wardale gives examples of this, for instance in lines 68 to 84 of FDC 1.3 where he calculates the isentropic efficiency of the 5AT at maximum drawbar power. Here he assumes that the steam enters the cylinders at an absolute pressure of 21.39 bar and temperature of 450oC shown as point A in the diagram below. He then assumes that the steam will exhaust at an absolute pressure of 1.5 bar. Thus an isentropic expansion line AB can be drawn vertically at a constant entropy of 7.254 kJ/K kg, with point B being defined by pressure = 1.5 bar. However in FDC 1.3 line 78 Wardale calculates that the actual exhaust steam enthalpy = 2,803 kJ/kg which allows point C to be located on the 1.5 bar pressure line. Thus the actual steam expansion is defined by the line AC. The slope of the line AC is indicative of the isentropic efficiency of the expansion: the nearer the line is to vertical, the higher isentropic efficiency. Actual isentropic efficiency is determined by dividing the specific work done in the cylinder (FDC 1.3 line 82) by the isentropic heat drop between admission and exhaust (FDC 1.3 line 83). Porta used similar lines in his Compounding paper but has simplified them by omitting all the irrelevant lines from his diagrams. Pressure-Enthalpy diagram The Pressure-Enthalpy diagram below is an alternative representation of the Steam Tables, where the axes are Pressure (Vertical) and Enthalpy (Horizonatl) and with curves representing temperature (T), entropy (s), specific volume (v), and dryness fraction (x). The dome-shaped curve represents the limits of saturation – within the dome, steam is saturated. Note: The same points A, B and C from the diagram above are illustrated in red. In this case the line of constant pressure (BC) is straight and the line of constant entropy (AB) is curved. Chart describing internal energy of thermodynamic systems The Mollier enthalpy–entropy diagram for water and steam. The "dryness fraction", x, gives the fraction by mass of gaseous water in the wet region, the remainder being droplets of liquid. An enthalpy–entropy chart, also known as the H–S chart or Mollier diagram, plots the total heat against entropy,[1] describing the enthalpy of a thermodynamic system.[2] A typical chart covers a pressure range of 0.01–1000 bar, and temperatures up to 800 degrees Celsius.[3] It shows enthalpy H {\displaystyle H} in terms of internal energy U {\displaystyle U} , pressure p {\displaystyle p} and volume V {\displaystyle V} using the relationship H = U + p V {\displaystyle H=U+pV\,\!} (or, in terms of specific enthalpy, specific entropy and specific volume, h = u + p v {\displaystyle h=u+pv\!}). The diagram was created in 1904, when Richard Mollier plotted the total heat[4] H against entropy S.[5][1] At the 1923 Thermodynamics Conference held in Los Angeles it was decided to name, in his honor, as a "Mollier diagram" any thermodynamic diagram using the enthalpy as one of its axes.[6] Mollier diagram (chart), I–P units Mollier diagram (chart), US units On the diagram, lines of constant pressure, constant temperature and volume are plotted, so in a two-phase region, the lines of constant pressure and temperature coincide.[7] Thus, coordinates on the diagram represent entropy and heat.[8] The work done in a process on vapor cycles is represented by length of h, so it can be measured directly, whereas in a T–s diagram it has to be computed using thermodynamic relationship between thermodynamic properties.[1] In an isobaric process, the pressure remains constant, so the heat interaction is the change in enthalpy.[2] In an isenthalpic process, the enthalpy is constant.[2] A horizontal line in the diagram represents an isenthalpic process. A vertical line in the h–s chart represents an isentropic process. The process 3–4 in a Rankine cycle is isentropic when the steam turbine is said to be an ideal one. So the expansion process in a turbine can be easily calculated using the h–s chart when the process is considered to be ideal (which is the case normally when calculating enthalpies, entropies, etc. Later the deviations from the ideal values and they can be calculated considering the isentropic efficiency of the steam turbine used.) Lines of constant dryness fraction (x), sometimes called the quality, are drawn in the wet region and lines of constant temperature are drawn in the superheated region.[3] X gives the fraction (by mass) of gaseous substance in the wet region, the remainder being colloidal liquid droplets. Above the heavy line, the temperature is above the boiling point, and the dry (superheated) substance is gas only. In general such charts do not show the values of specific volumes, nor do they show the enthalpies of saturated water at pressures which are of the order of those experienced in condensers in a thermal power station.[3] Hence the chart is only useful for enthalpy changes in the expansion process of the steam cycle.[3] It can be used in practical applications such as malting, to represent the grain–air–moisture system.[9] The underlying property data for the Mollier diagram is identical to a psychrometric chart. At first inspection, there may appear little resemblance between the charts, but if the user rotates a chart ninety degrees and looks at it in a mirror, the resemblance is apparent. The Mollier diagram coordinates are enthalpy h and humidity ratio x. The enthalpy coordinate is skewed and the constant enthalpy lines are parallel and evenly spaced. Thermodynamic diagrams Contour line Phase diagram Wikimedia Commons has media related to Enthalpy-entropy diagrams. ^ a b c R. K. Rajput (2009), Engineering Thermodynamics, Infinity Science Series / Engineering series (3 ed.), Jones & Bartlett Learning, p. 77, ISBN 978-1-934015-14-8, retrieved 2010-06-25 ^ a b c Y. V. C. Rao (2004), An Introduction to Thermodynamics, Universities Press, p. 70, ISBN 978-81-7371-461-0, retrieved 2010-06-25 ^ a b c d T. D. Eastop, A. Mcconkey (15 Mar 1993), Applied Thermodynamics for Engineering Technologists (5 ed.), Longman, ISBN 978-0-582-09193-1 ^ "total heat" is used equivalently with "enthalpy", a term coined only after 1904, and in wider use from c. the 1920s. ^ Mollier, R. (20 February 1904). "Neue Diagramme zur technischen Wärmelehre" [New charts for engineering thermodynamics]. Zeitschrift des Vereines Deutscher Ingenieure (in German). 48 (8): 271–275. ^ See: Mollier, R. (8 September 1923). "Ein neues Diagramm für Dampfluftgemische" [A new diagram for water vapor-air mixtures]. Zeitschrift des Vereines Deutscher Ingenieure (in German). 67: 869–872. English translation: Mollier, Richard (December 1923). "A new diagram for water vapor-air mixtures". Mechanical Engineering. 45: 703–705. ^ Y. V. C. Rao (2001), Thermodynamics, Universities Press, p. 113, ISBN 978-81-7371-388-0, retrieved 2010-06-25 ^ Robert C. H. Heck (2008), The Steam Engine and Turbine – A Text Book for Engineering Colleges, Read Books, ISBN 978-1-4437-3134-8, retrieved 2010-06-25 ^ Dennis Edward Briggs (1998), Malts and Malting, Springer, p. 499, ISBN 978-0-412-29800-4, retrieved 2010-06-25 Retrieved from " The Engineering ToolBox provides a wide range of free tools, calculators, and information resources aimed at engineers and designers. It offers detailed technical data and calculations for various fields such as fluid mechanics, material properties, HVAC systems, electrical engineering, and more.The site includes resources for common engineering tasks, such as calculating physical properties (e.g., density, viscosity, thermal conductivity), converting units, and designing systems like heating and water distribution. With sections on everything from acoustics to hydraulics, it serves as a comprehensive tool for both students and professionals in technical and engineering disciplines. Most engineering installations and equipment are subjected to (and designed to withstand) a variety of atmospheric conditions and over a wide range of temperature, pressure, humidity and other related factors. But how do these thermodynamic quantities affect one another, and how does one property differ in relation to changes in the other? After all, these would play a critical role in the design of engineering systems. In order to determine the relationships between these thermodynamic quantities, a scientist named Richard Mollier researched these quantities over many years and developed what is called the Mollier diagram. What is the Mollier Diagram? Mollier enthalpy-entropy chart for steam, US units. Image credit: Emok The Mollier diagram is a tool used by engineers to predict, theoretically, the performance of systems and installations. The Mollier diagram, also called the enthalpy (h) – entropy (s) chart or h-s chart, is a graphical representation of thermodynamic properties of materials. In general, it is a relationship between enthalpy (measure of the energy of a thermodynamic system), air temperature, and moisture content. Mollier Diagram Origins Richard Mollier created the Mollier chart in 1904, after years of researching the thermodynamic properties of various media and plotting those quantities in charts and diagrams. He plotted a number of other charts with enthalpy as one of the axes, and in 1923, it was decided that all such charts would be named Mollier diagrams, in his honour. Note: The Mollier diagram is a variation of the psychrometric chart, which also plots the thermodynamic properties of moist air. Although they appear vastly different at first glance, rotating the chart by ninety degrees and looking at the mirror image shows the close resemblance between the two charts. In other words, one can be converted to the other. How to Use the Mollier Diagram Typically, the Mollier chart covers pressure in the range of 0.01 to 1000 bar and up to 800 oC temperature. Mollier diagrams can be plotted for different fluids. The following is the Mollier diagram for water and steam. The “dryness fraction”, x, gives the fraction by mass of gaseous water in the wet region, the remainder being droplets of liquid. Image credit: Markus Schweiss Given two thermodynamic quantities, the other ones can easily be calculated from the Mollier chart. Given a dry bulb temperature (that indicated in a thermometer placed away from direct solar radiation) of 21 oC and relative humidity of 50%, the state of air is indicated as below: From the Mollier diagram, we can conclude that: Enthalpy of the air is about 40 kJ/kg. Wet bulb temperature (thermodynamic temperature of a mixture of air with water vapour) is approximately 14.5 oC. Specific Humidity (mass of water vapour in a unit mass of moist air sample) is 0.0076. Given a dry bulb temperature of 19 oC and a wet bulb temperature of 12 oC, from the Mollier diagram, the other quantities would be: Enthalpy = approximately 33 kJ/kg Specific humidity = ~0.0056 Applications of the Mollier Chart Industrial and commercial applications include: Power plant design Design of steam turbines Weather forecasting Design of refrigeration systems Heating and cooling systems Design of compressors The Mollier chart is also very helpful in malting (the process of germinating cereal grains by soaking them in water, and then preventing further germination by drying them in hot air – used to make malted shakes, whiskey, beer etc.) Conclusion Mollier diagrams are very helpful in engineering design and are used extensively in the academic world, where the understanding of fundamental concepts is important. However, for practical applications, handling bigger size Mollier charts with good resolution becomes cumbersome. Availability of Mollier diagram software has come in handy for many engineers. The software is usually capable of handling both graphics and computations, which makes it hard to resist its use. The calculations are much more accurate. Additionally, they offer other advantages like being able to incorporate a wide range of values, eliminating the use of interpolation etc. Whether in the form of software or actual physical charts, the Mollier diagram has proved to be an important tool for engineers, and will be, for many more years to come. Learn how the Mollier Diagram visually represents steam properties like pressure, temperature, and enthalpy for engineering applications.Understanding the Mollier Diagram for SteamThe Mollier Diagram, named after Richard Mollier who first introduced it in 1904, is a graphical representation of the physical properties of moist air. It is an essential tool used in engineering, particularly in the fields of thermodynamics and HVAC (heating, ventilation, and air conditioning) systems. The diagram provides a visual representation of how different properties of steam, such as pressure, temperature, enthalpy, entropy, and volume, interrelate. This can be especially useful in designing and analyzing the performance of steam turbines, boilers, and other equipment where steam is used as a working fluid.Understanding the AxesThe Mollier Diagram is usually plotted with entropy (s) on the x-axis and enthalpy (h) on the y-axis. Enthalpy represents the total heat content of the steam, while entropy is a measure of the steam’s disorder or randomness. Each line on the diagram represents a series of constant values for different properties:Temperature lines: These are almost vertical lines that slant slightly to the left, indicating the temperature of the steam at various combinations of entropy and enthalpy.Pressure lines: These lines are also nearly vertical but slant slightly more than temperature lines. They represent the pressure of the steam.Specific volume lines: Represented by lines that are horizontally oriented, showing the space occupied by a specific mass of steam.Saturation curve: This is a distinct curve that separates the diagram into two regions – the left of the curve denotes the wet region (where steam contains moisture), and the right side denotes the superheated steam region.Reading the DiagramTo effectively use a Mollier Diagram, you need to be able to find a specific point on the diagram, which corresponds to the state of steam at any given condition. From this point, you can read off various properties directly:Finding a known property: For example, if the pressure and temperature of steam are known, locate the pressure line first, then move along this line to the point where it intersects with the corresponding temperature line.Reading other properties: From this intersection point, you can read directly or follow lines to find other properties such as specific volume, enthalpy, or entropy.Applications of Mollier DiagramThe Mollier Diagram is extensively used in engineering analysis and design involving steam. Some common applications include:Steam turbine design and analysis: Engineers use the diagram to estimate the work output and efficiency of different stages of the turbine.Heat exchangers: The diagram can be used to analyze the heat transfer between steam and other mediums without direct interaction.Refrigeration cycles: Though primarily for steam, similar diagrams can be used for refrigerants in various refrigeration cycles to analyze and optimize performance.ConclusionThe Mollier Diagram for steam is a vital graphic representation that aids in the understanding and calculation of the thermodynamic properties of steam. By allowing engineers to visualize the relationships and interactions between different properties of steam, it greatly simplifies the process of designing and optimizing thermal systems. Whether for educational or professional purposes, mastering the Mollier Diagram is essential for anyone involved in thermodynamics and HVAC system design and analysis. Download the Testbook APP & Get Pass Pro Max FREE for 7 Days10,000+ Study NotesRealtime Doubt Support71000+ Mock TestsRankers Test Series+ more benefitsDownload App Now Thermodynamic Steam Tables Thermodynamics Directory | Heat Transfer Directory Related Resources: Saturated Steam Tables - Metric Units Saturated Steam Tables Steam tables consist of two sets of tables of the energy transfer properties of water and steam saturated steam tables and superheated steam tables. Portions of the tables are shown in Figure A-2. Both sets of tables are tabulations of pressure (P), temperature (T), specific volume (n), specific enthalpy (h), and specific entropy (s). The following notation is used in steam tables. Some tables use v for n (specific volume) because there is little possibility of confusing it with velocity. The saturated steam tables give the energy transfer properties of saturated water and saturated steam for temperatures from 32 to 705.47F (the critical temperature) and for the corresponding pressure from 0.08849 to 3208.2 psi. Normally, the saturated steam tables are divided into two parts: temperature tables, which list the properties according to saturation temperature (Tsat); and pressure tables, which list them according to saturation pressure (Psat). Figure A-2 shows a portion of a typical saturated steam temperature table and a portion of a typical saturated steam pressure table. The values of enthalpy and entropy given in these tables are measured relative to the properties of saturated liquid at 32F. Hence, the enthalpy (hf) of saturated liquid and the entropy (sf) of saturated liquid have values of approximately zero at 32F. Most practical applications using the saturated steam tables involve steam-water mixtures. The key property of such mixtures is steam quality (x), defined as the mass of steam present per unit mass of steam-water mixture, or steam moisture content (y), defined as the mass of water present per unit mass of steam-water mixture. The following relationships exist between the quality of a liquid-vapor mixture and the specific volumes, enthalpies, or entropies of both phases and of the mixture itself. These relationships are used with the saturated steam tables. In order to solve problems in Thermodynamics,information concerning the "state" of the substance studied must be obtained. Usually,two properties (for example, v, p, T, h, s) of the substance must be known in order to determinethe other needed properties. These other properties are usually obtained utilizingeither the Mollier diagram (if the substance is steam) or the saturated and superheated steam tables,as shown in the Figures A-1 and A-2. The following two examples illustrate the useof the Mollier diagram and the steam tables. Example 1: Use of Mollier Chart. Superheated steam at 700 psia and 680F is expanded at constant entropyto 140 psia. What is thechange in enthalpy? Solution: Use the Mollier Chart. Locate point 1 at theintersection of the 700 psia and the 680F line. Read h = 1333 Btu/lbm. Follow the entropy line downward verticallyto the 140 psia line and read h = 1178 Btu/lbm. h = 1178 - 1333 = -155 Btu/lbm If the substance is not water vapor, the "state" of the substance is usually obtained through the use of T-s (temperature-entropy) and h-s (enthalpy-entropy) diagrams, available in most thermodynamics texts for common substances. The use of such diagrams is demonstrated by the followingtwo examples. Example 3: Use of the h-s diagram Mercury is used in a nuclear facility. What is the enthalpy of the mercury if its pressure is100 psia and its quality is 70%? Solution: From the mercury diagram, Figure A-3 of Appendix A, locate the pressure of 100 psia. Follow that line until reaching a quality of 70%. The intersection of the two lines gives anenthalpy that is equal to h = 115 Btu/lbm. Example 4: Use of the T-s diagram Carbon dioxide is used in a particular process in which the pressure is 100 psia and the temperatureis 100F. What is the enthalpy value of the gas? Solution: From the carbon dioxide diagram, Figure A-4 of Appendix A, locate the pressure of 100 psia. Follow that line until reaching a temperature of 100F. The intersection of the two lines gives an enthalpy that is equal to h = 316 Btu/lbm. Once the various states have been fixed for the particular process the substance has passed through (for example, going from a saturated liquid state to a compressed liquid state across a pump), energy exchanges may be determined as was shown in Example 1. The energy exchanges are never 100 percent efficient, as already discussed. The degree of efficiency obtained by the system depends upon the process through which the system has passed. Generally, the efficiency of a component depends upon how much friction exists in the flow of the substance, the pressure drops within the system, the inlet and outlet temperatures, and various other factors. The properties affecting the efficiency of the system are determined by use of the charts and diagrams mentioned in this section. When power cycles are utilized for large systems, the efficiency of each component should be maximized in order to have the highest possible overall efficiency for the system. Each component affects the system efficiency in a different manner. To maximize efficiency, the practical approach to large systems is to have multistage expansion with reheat between stages andregenerators in the system where applicable.