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Heat transfer by the motion and mixing of the molecules of a liquid or gas is called convection. Convection Convection involves the transfer of heat by the motion and mixing of "macroscopic" portions of a fluid (that is, the flow of a fluid past a solid boundary). The term natural convection is used if this motion and mixing is caused by density variations resulting from temperature differences within the fluid. The term forced convection is used if this motion and mixing is caused by an outside force, such as a pump. The transfer of heat from a hot water radiator to a room is an example of heat transfer by natural convection. The transfer of heat from the surface of a heat exchanger to the bulk of a fluid being pumped through the heat exchanger is an example of forced convection. Heat transfer by convection is more difficult to analyze than heat transfer by conduction because no single property of the heat transfer medium, such as thermal conductivity, can be defined to describe the mechanism. Heat transfer by convection varies from situation to situation (upon the fluid flow conditions), and it is frequently coupled with the mode of fluid flow. In practice, analysis of heat transfer by convection is treated empirically (by direct observation). Convection heat transfer is treated empirically because of the factors that affect the stagnant film thickness: Convection involves the transfer of heat between a surface at a given temperature (Ts) and fluid at a bulk temperature (Tb). The exact definition of the bulk temperature (Tb) varies depending on the details of the situation. For flow adjacent to a hot or cold surface, Tb is the temperature of the fluid "far" from the surface. For boiling or condensation, Tb is the saturation temperature of the fluid. For flow in a pipe, Tb is the average temperature measured at a particular crosssection of the pipe. The basic relationship for heat transfer by convection has the same form as that for heat transfer by conduction: $$ \dot{Q} = h ~A ~\Delta T $$ where: \(\dot{Q} \) = rate of heat transfer (Btu/hr) h = convective heat transfer coefficient (Btu/hr-ft2-°F) A = surface area for heat transfer (ft2) ΔT = temperature difference (°F) The convective heat transfer coefficient (h) is dependent upon the physical properties of the fluid and the physical situation. Typically, the convective heat transfer coefficient for laminar flow is relatively low compared to the convective heat transfer coefficient for turbulent flow. This is due to turbulent flow having a thinner stagnant fluid film layer on the heat transfer surface. Values of h have been measured and tabulated for the commonly encountered fluids and flow situations occurring during heat transfer by convection. Example: A 22 foot uninsulated steam line crosses a room. The outer diameter of the steam line is 18 in. and the outer surface temperature is 280°F. The convective heat transfer coefficient for the air is 18 Btu/hr-ft2-°F. Calculate the heat transfer rate from the pipe into the room if the room temperature is 72°F. Solution: $$ \begin{eqnarray} \dot{Q} &=& h ~A ~\Delta T onumber \\ &=& h ~(2 \pi ~r ~L) ~\Delta T onumber \\ &=& \left(18 ~{\text{Btu} \over \text{hr-ft-}^{\circ}\text{F}} \right) \left[2 (3.14) (0.75 ~\text{ft}) (22 ~\text{ft}) \right] (280^{\circ}\text{F} - 72^{\circ}\text{F}) onumber \\ &=& 3.88 \times 10^5 ~{ \text{Btu} \over \text{hr} } \end{eqnarray} $$ Many applications involving convective heat transfer take place within pipes, tubes, or some similar cylindrical device. In such circumstances, the surface area of heat transfer normally given in the convection equation (\(\dot{Q} = h ~A ~\Delta T \)) varies as heat passes through the cylinder. In addition, the temperature difference existing between the inside and the outside of the pipe, as well as the temperature differences along the pipe, necessitates the use of some average temperature value in order to analyze the problem. This average temperature difference is called the log mean temperature difference (LMTD), described earlier. It is the temperature difference at one end of the heat exchanger minus the temperature difference at the other end of the heat exchanger, divided by the natural logarithm of the ratio of these two temperature differences. The above definition for LMTD involves two important assumptions: (1) the fluid specific heats do not vary significantly with temperature, and (2) the convection heat transfer coefficients are relatively constant throughout the heat exchanger. Overall Heat Transfer Coefficient Many of the heat transfer processes encountered in nuclear facilities involve a combination of both conduction and convection. For example, heat transfer in a steam generator involves convection from the bulk of the reactor coolant to the steam generator inner tube surface, conduction through the tube wall, and convection from the outer tube surface to the secondary side fluid. In cases of combined heat transfer for a heat exchanger, there are two values for h. There is the convective heat transfer coefficient (h) for the fluid film inside the tubes and a convective heat transfer coefficient for the fluid film outside the tubes. The thermal conductivity (k) and thickness (Δx) of the tube wall must also be accounted for. An additional term (Uo), called the overall heat transfer coefficient, must be used instead. It is common practice to relate the total rate of heat transfer (\(\dot{Q} \)) to the cross-sectional area for heat transfer (Ao) and the overall heat transfer coefficient (Uo). The relationship of the overall heat transfer coefficient to the individual conduction and convection terms is shown in Figure 6. Figure 6: Overall Heat Transfer Coefficient Recalling Equation 2-3: $$ \dot{Q} = U_o ~A_o ~\Delta T_o $$ where Uo is defined in Figure 6. An example of this concept applied to cylindrical geometry is illustrated by Figure 7, which shows a typical combined heat transfer situation. Figure 7: Combined Heat Transfer Using the figure representing flow in a pipe, heat transfer by convection occurs between temperatures T1 and T2; heat transfer by conduction occurs between temperatures T2 and T3; and heat transfer occurs by convection between temperatures T3 and T4. Thus, there are three processes involved. Each has an associated heat transfer coefficient, cross-sectional area for heat transfer, and temperature difference. The basic relationships for these three processes can be expressed using Equations 2-5 and 2-9. $$ \dot{Q} = h_1 ~A_1 ~(T_1 - T_2) $$ $$ \dot{Q} = {k \over \Delta r} ~A_{lm} ~(T_2 - T_3) $$ $$ \dot{Q} = h_2 ~A_2 ~(T_3 - T_4) $$ ΔTo can be expressed as the sum of the ΔT of the three individual processes. ΔTo = (T1 − T2) + (T2 − T3) + (T3 − T4) If the basic relationship for each process is solved for its associated temperature difference and substituted into the expression for ΔTo above, the following relationship results. $$ \Delta T_o = \dot{Q} \left({1 \over h_1 A_1} + { \Delta r \over k ~A_{lm} } + {1 \over h_2 A_2} \right) $$ This relationship can be modified by selecting a reference cross-sectional area Ao. $$ \Delta T_o = { \dot{Q} \over A_o } \left({A_o \over h_1 A_1} + { \Delta r ~A_o \over k ~A_{lm} } + {A_o \over h_2 A_2} \right) $$ Solving for \(\dot{Q} \) results in an equation in the form \(\dot{Q} = U_o ~A_o ~\Delta T_o \). $$ \dot{Q} = { 1 \over \left({A_o \over h_1 A_1} + { \Delta r ~A_o \over k ~A_{lm} } + {A_o \over h_2 A_2} \right) } ~A_o ~\Delta T_o $$ where: $$ U_o = { 1 \over \left({A_o \over h_1 A_1} + { \Delta r ~A_o \over k ~A_{lm} } + {A_o \over h_2 A_2} \right) } $$ Equation 2-10 for the overall heat transfer coefficient in cylindrical geometry is relatively difficult to work with. The equation can be simplified without losing much accuracy if the tube that is being analyzed is thin-walled, that is the tube wall thickness is small compared to the tube diameter. For a thin-walled tube, the inner surface area (A1), outer surface area (A2), and log mean surface area (Alm), are all very close to being equal. Assuming that A1, A2, and Alm are equal to each other and also equal to Ao allows us to cancel out all the area terms in the denominator of Equation 2-11. This results in a much simpler expression that is similar to the one developed for a flat plate heat exchanger in Figure 6. $$ U_o = { 1 \over {1 \over h_1} + { \Delta r \over k } + {1 \over h_2} } $$ The convection heat transfer process is strongly dependent upon the properties of the fluid being considered. Correspondingly, the convective heat transfer coefficient (h), the overall coefficient (Uo), and the other fluid properties may vary substantially for the fluid if it experiences a large temperature change during its path through the convective heat transfer device. This is especially true if the fluid's properties are strongly temperature dependent. Under such circumstances, the temperature at which the properties are "looked-up" must be some type of average value, rather than using either the inlet or outlet temperature value. For internal flow, the bulk or average value of temperature is obtained analytically through the use of conservation of energy. For external flow, an average film temperature is normally calculated, which is an average of the free stream temperature and the solid surface temperature. In any case, an average value of temperature is used to obtain the fluid properties to be used in the heat transfer problem. The following example shows the use of such principles by solving a convective heat transfer problem in which the bulk temperature is calculated. Example: A flat wall is exposed to the environment. The wall is covered with a layer of insulation 1 in. thick whose thermal conductivity is 0.8 Btu/hr-ft-°F. The temperature of the wall on the inside of the insulation is 600°F. The wall loses heat to the environment by convection on the surface of the insulation. The average value of the convection heat transfer coefficient on the insulation surface is 950 Btu/hr-ft2-°F. Compute the bulk temperature of the environment (Tb) if the outer surface of the insulation does not exceed 105°F. Solution: Find heat flux (\(\dot{Q}'' \)) through the insulation. $$ \dot{Q} = k ~A \left({ \Delta T \over \Delta x }\right) $$ $$ \begin{eqnarray} { \dot{Q} \over A } &=& 0.8 ~{\text{Btu} \over \text{hr-ft-}^{\circ}\text{F}} \left({ 600^{\circ}\text{F} - 105^{\circ}\text{F} \over 1 ~\text{in} } ~{ 1 ~\text{ft} \over 12 ~\text{in} } }\right) onumber \\ &=& 4752 ~{ \text{Btu} \over \text{hr-ft}^2 } \end{eqnarray} $$ Find the bulk temperature of the environment. $$ \begin{eqnarray} \dot{Q} &=& h ~A ~(T_{ins} - T_b) onumber \\ (T_{ins} - T_b) &=& { \dot{Q} \over h ~A } onumber \\ T_b &=& T_{ins} - { \dot{Q}'' \over h } onumber \\ T_b &=& 105^{\circ}\text{F} - { 4752 ~{ \text{Btu} \over \text{hr-ft}^2 } \over 950 ~{\text{Btu} \over \text{hr-ft-}^{\circ}\text{F}} } onumber \\ T_b &=& 100^{\circ}\text{F} \end{eqnarray} $$ A heat source, like an engine, stove, melting pot or a person, will generate a convective vertical air flow as indicated in the figure below. Air Velocity The air velocity in the center of the air flow at a distance above the floor can be calculated as vc = c1 (P / l)1/3 (1) where vc = air velocity in center of the air flow (m/s) c1 = constant characterizing the actual application, typical values ranging 1 to 2 P = heat power from the source (kW) l = distance above the floor and the heat source (m) Air Flow Volume The air flow volume in a distance above the the floor can be calculated as Q = c2 P1/3 l5/3 (2) where Q = air flow volume (m3/s) c2 = constant characterizing the actual application, values ranging 0.05 to 0.15 (typical 0.06) Example - Convective Air Flow above an Engine The heat loss from the surface of an engine is 10 kW. If c1 = 1.5, the air velocity 3 meters above the engine can be estimated to vc = 1.5 ((10 kW) / (3 m))1/3 = 2.2 m/s With c2 = 0.06 the volume flow can be estimated to Q = 0.06 (10 kW)1/3 (3 m)5/3 = 0.8 m3/s Convective air flows from typical heat sources like people, computers, radiators and more. Hot or cold vertical surfaces generates vertical air flows - calculate air velocity and volume flow. Sizing of exhaust hoods - air volume flow and capture velocities - online exhaust hood calculator. Heat transfer between a solid and a moving fluid is called convection. This is a short tutorial about convective heat transfer. Heat energy transferred between a surface and a moving fluid with different temperatures - is known as convection. In reality this is a combination of diffusion and bulk motion of molecules. Near the surface the fluid velocity is low, and diffusion dominates. At distance from the surface, bulk motion increases the influence and dominates. Convective heat transfer can be forced or assisted convection natural or free convection Forced or Assisted Convection Forced convection occurs when a fluid flow is induced by an external force, such as a pump, fan or a mixer. Natural or Free Convection Natural convection is caused by buoyancy forces due to dens ity differences caused by temperature variations in the fluid. At heating the density change in the boundary layer will cause the fluid to rise and be replaced by cooler fluid that also will heat and rise. This continues phenomena is called free or natural convection. Boiling or condensing processes are also referred to as a convective heat transfer processes. The heat transfer per unit surface through convection was first described by Newton and the relation is known as the Newton's Law of Cooling. The equation for convection can be expressed as: q = hc A dT (1) where q = heat transferred per unit time (W, Btu/hr) A = heat transfer area of the surface (m2, ft2) hc = convective heat transfer coefficient of the process (W/(m2oC, Btu/(ft2 h oF)) dT = temperature difference between the surface and the bulk fluid (oC, F) Heat Transfer Coefficients - Units 1 W/(m2K) = 0.85984 kcal/(h m2 oC) = 0.1761 Btu/(ft2 h oF) 1 Btu/(ft2 h oF) = 5.678 W/(m2 K) = 4.882 kcal/(h m2 oC) 1 kcal/(h m2 oC) = 1.163 W/(m2K) = 0.205 Btu/(ft2 h oF) Overall Heat Transfer Coefficients Convective Heat Transfer Coefficients Convective heat transfer coefficients - hc - depends on type of media, if its gas or liquid, and flow properties such as velocity, viscosity and other flow and temperature dependent properties. Typical convective heat transfer coefficients for some common fluid flow applications: Free Convection - air, gases and dry vapors : 0.5 - 1000 (W/(m2K)) Free Convection - water and liquids: 50 - 3000 (W/(m2K)) Forced Convection - air, gases and dry vapors: 10 - 1000 (W/(m2K)) Forced Convection - water and liquids: 50 - 10000 (W/(m2K)) Forced Convection - liquid metals: 5000 - 40000 (W/(m2K)) Boiling Water : 3.000 - 100.000 (W/(m2K)) Condensing Water Vapor: 5.000 - 100.000 (W/(m2K)) Heat Exchanger Heat Transfer Coefficients Convective Heat Transfer Coefficients Convective Heat Transfer Coefficient for Air The convective heat transfer coefficient for air flow can be approximated to hc = 10.45 - v + 10 v1/2 (2) where hc = heat transfer coefficient (kCal/m2h°C) v = relative speed between object surface and air (m/s) Since 1 kcal/m2h°C = 1.16 W/m2°C or 1 W/m2°C = 0.862 kcal/m2h°C (2) can be modified to hcW = 1.16 (10.45 - v + 10 v1/2) (2b) where hcW = heat transfer coefficient (W/m2°C) Note! - this is an empirical equation and can be used for velocities 2 to 20 m/s. Convective Air Flow from a single Heat Source Example - Convective Heat Transfer A fluid flows over a plane surface 1 m by 1 m. The surface temperature is 50oC, the fluid temperature is 20oC and the convective heat transfer coefficient is 2000 W/m2oC. The convective heat transfer between the hotter surface and the colder air can be calculated as q = (2000 W/m2oC) ((1 m) (1 m)) ((50 oC) - (20 oC)) = 60000 (W) = 60 (kW) Convective Heat Transfer Calculator Convective Heat Transfer Chart Convective Heat Transfer Chart (pdf) Arithmetic Mean Temperature Difference in Heat Exchangers - AMTD - and Logarithmic Mean Temperature Difference - LMTD - formulas with examples - Online Mean Temperature Calculator. Heat transfer when steam condensates. Conductive heat transfer takes place in a solid if there is a temperature gradient. Calculate the vertical air flow and air velocity generated by a single heat source. Convective air flows from typical heat sources like people, computers, radiators and more. Hot or cold vertical surfaces generates vertical air flows - calculate air velocity and volume flow. Heat-transfer in heat exchangers are reduced by fouling. Overall heat transfer coefficients in common heat exchanger designs - tubular, plate or spiral. Average overall heat transmission coefficients for fluid and surface combinations like Water to Air, Water to Water, Air to Air, Steam to Water and more. Walls or heat exchangers - calculate overall heat transfer coefficients. Effective Temperature of air in movement. Formula: Q = h × A × (Ts - Tf)Heat transfer by convection is one of the fundamental ways thermal energy moves from one place to another. This process involves the movement of heat through fluids (both liquids and gases) and is driven by the temperature difference between the fluid and a solid surface. The formula for calculating heat transfer by convection is expressed as:Q = h × A × (Ts - Tf)Breaking Down the Convection Heat Transfer FormulaQThis represents the rate of heat transfer, measured in watts (W).hThe convective heat transfer coefficient, measured in watts per square meter per kelvin (W/m²K). This coefficient depends on the fluid's properties and the nature of the convection (natural or forced).AThe surface area through which heat is being transferred, measured in square meters (m²).TsThe surface temperature of the solid, measured in kelvin (K) or degrees Celsius (°C).TfThe fluid temperature, measured in kelvin (K) or degrees Celsius (°C).Real-Life Example: Cooling a Hot EngineImagine an automobile engine that needs to be cooled. The surface area of the engine exposed to the cooling fluid (e.g., air) is 1.5 square meters. The convective heat transfer coefficient is 50 W/m²K. The engine's surface temperature is 120°C, and the air temperature is 25°C. Using our convection heat transfer formula:Q = h × A × (Ts - Tf)We plug in the values:Q = 50 W/m²K × 1.5 m² × (120°C - 25°C)Calculating the temperature difference:Q = 50 W/m²K × 1.5 m² × 95 KFinally, the rate of heat transfer:Q = 7125 WIn this scenario, 7125 watts of heat energy is being transferred from the engine to the surrounding air by convection.Optimizing Heat Transfer EfficiencyOne of the most critical aspects of engineering is optimizing heat transfer efficiency. Engineers must consider factors such as the fluid velocity, the fluid's properties, and the design of the surface area. Improving these variables can significantly enhance the efficiency of the heat transfer process, reducing energy consumption and improving the performance of thermal systems.Data ValidationTo ensure accurate results, the input values should be checked for validity:The surface temperature Ts and fluid temperature Tf should be in the same unit of measurement.The convective heat transfer coefficient h should be a positive value.The surface area A should be a positive value.Frequently Asked Questions1. What is the significance of the convective heat transfer coefficient?The convective heat transfer coefficient h is crucial in determining how effectively heat is transferred between the solid surface and the fluid. A higher h value indicates a more efficient heat transfer process. The coefficient depends on factors like the fluid's viscosity, thermal conductivity, and flow velocity.Changing the surface area directly impacts heat transfer by convection. A larger surface area allows for more fluid to come into contact with the surface, which enhances the heat exchange process. More surface area means that the heat can be absorbed or released over a wider area, increasing the overall heat transfer rate. Conversely, a smaller surface area limits the fluid interaction, resulting in lower heat transfer efficiency. Thus, increasing surface area facilitates greater convective heat transfer.Increasing the surface area A enhances the rate of heat transfer, as there is more area available for the exchange of thermal energy. This principle is often applied in heat exchanger designs to improve heat dissipation.3. Can the convection heat transfer formula be used for both heating and cooling scenarios?Yes, the formula is applicable for both heating and cooling. The direction of heat transfer depends on the temperature difference between the solid surface and the fluid. If Ts is greater than TfHeat is transferred from the fluid to the solid (heating). Conversely, if Tf is greater than TsHeat is transferred from the fluid to the solid (heating).SummaryUnderstanding and accurately calculating heat transfer by convection is essential for optimizing thermal systems in various applications, from automotive engineering to HVAC systems. By mastering the formula Q = h × A × (Ts - Tf) and considering factors such as the heat transfer coefficient, surface area, and temperature difference, engineers and scientists can design more efficient and effective systems. Source: Convection is responsible for the wind that we experience. Without convection, we could never feel a cool breeze on a hot day. What is convection?Convection is the transfer of energy as heat by movement of the heated substance itself, as current in fluids (liquids and gases). In convection, particles with higher energy move from one location to another carrying their energy with them. Convection is responsible for a lot of things in our lives, from the breezes we feel on a windy day to the currents in our oceans. If you've ever stood on the beach and felt the wind, you have experienced convection. Source: How does heat transfer during convection?During convection, particles gain heat energy and move from one location to another. As these particles move, they carry their heat energy with them. Heat transfer occurs when these higher energy particles move from warmer areas to cooler areas. The particles in the bottom of the tea pot to the right have more heat energy because there is higher temperature there. As these particles move towards the top of the tea pot, they transfer heat energy to the particles there because they are in an area of lower temperature. This means that as the particles move from the bottom of the pot to the top, they heat up the water near the top of the pot. Source: Source: The water in a tea pot shows us how heat transfers during convection. The particles with more heat energy move from areas of higher temperature to lower temperature, transferring heat energy. Source: Do all particles heat up the same way? Not all particles heat up the same way. Uneven heating can result in convection, both in the air and in water. This causes currents in the atmosphere (wind) and in bodies of water on earth which are important factors in weather and climate. As warm air near Earth's surface rises and then cools as it goes up, a convection current is set up in the atmosphere. On a smaller scale, convection currents near bodies of water can cause local winds known as land and sea breezes, like those on the left. Source: Let's see it in action!Below is a video that shows heat transfer through convection. This video explains how convection works, the relationship between convection and winds, and how convection affects our lives. As you watch the video, pay attention to how the molecules move and how heat is transferred. Source: On your notecatcher, draw how particles in a beaker move during the convection of heat Now that you know all about convection, you're ready to move onto... radiation! Heat is one of the significant components of phase change that is associated with work and energy. Heat transfer is defined as the process of flow of heat from an object at a higher temperature to an object at a lower temperature. The heat flow equation covers the heat transfer mechanism, such as the conduction equation, convection formula, thermal radiation, and evaporate cooling.On this page, we will understand the heat transfer formula, the rate of heat transfer formula, and the type of heat flow equation in detail.Heat Flow EquationThe formula heat energy describes the amount of heat transferred from one object to another.So, the amount of heat transferred from one object to another is determined by the following heat transfer formula: Q = mcΔTHere,Q is the amount of heat added to the systemc = Specific heat capacity of the systemAt constant Volume, c becomes cVSimilarly, at constant pressure, c becomes cPBesides this, The mass of the system is “m,” and ΔT is the temperature difference, measured in K.The transfer of heat occurs through the following three different processes:Now, let’s understand the formula for the types of heat transfer:Conduction FormulaHeat conduction is the transmission of internal thermal energy as a result of the collisions of microscopic particles and the motion of electrons within a body.The conduction equation is given by: q = - k ▽THere,q = Local heat flux density - k = material’s conductivity, and▽T = temperature gradientNow, talking about the heat flux formula, it is given by:Φq = - k \[\frac{dT(x)}{dx}\]Here,Φq = heat flux = the heat divided by the area = \[\frac{Q}{A}\] Thermal conductivity is k, and T is the temperatureThe SI unit of heat flux is W/m\[^{2}\] or Watt per meter square. Convection FormulaThe convection formula is: Q = h A ΔT Here,Q = the rate of heat transfer h = convection heat transfer coefficientA = the exposed surface area, and ΔT = the difference in temperature The temperature difference is between a solid surface and surrounding fluidFor the convection equation unit, we have the following heat transfer coefficient formula: h = \[\frac{Q}{\Delta T}\]Therefore, the SI unit of convection coefficient is W/(m\[^{2}\]K).Rate of Heat Transfer FormulaThe rate of heat transfer formula is:\[\frac{Q}{t}\] = \[\frac{kA(T_{2} - T_{1})}{d}\]Here,\[\frac{Q}{t}\] = rate of heat transfer in watts per second (W/s) or kilocalories per second (Kg/s)k = a thermal conductivity of the material(T\[_{2}\] - T\[_{1}\]) = a temperature difference across the slabd = thickness of the slab, andA = surface area of the slabThermal Conductivity EquationThe thermal conductivity equation is: Q = \[\frac{Qd}{A \Delta T}\]Here,k = thermal conductivity, measured in W/m.KQ = amount of heat transfer, measured in Joules/second or Wattsd = distance between the two isothermal planesA = surface area in square meters ΔT = the temperature differenceConclusionThe heat generated by the movement of particles in the system. Heat transfer is a process of the exchange of heat from a high-temperature body to a low-temperature body. Heat energy transferred between a surface and a moving fluid with different temperatures - is known as convection. In reality this is a combination of diffusion and bulk motion of molecules. Near the surface the fluid velocity is low, and diffusion dominates. At distance from the surface, bulk motion increases the influence and dominates. Convective heat transfer can be forced or assisted convection natural or free convection Forced or Assisted Convection Forced convection occurs when a fluid flow is induced by an external force, such as a pump, fan or a mixer. Natural or Free Convection Natural convection is caused by buoyancy forces due to dens ity differences caused by temperature variations in the fluid. At heating the density change in the boundary layer will cause the fluid to rise and be replaced by cooler fluid that also will heat and rise. 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Convective heat transfer can be forced or assisted convection natural or free convection Forced or Assisted Convection Forced convection occurs when a fluid flow is induced by an external force, such as a pump, fan or a mixer. Natural or Free Convection Natural convection is caused by buoyancy forces due to dens ity differences caused by temperature variations in the fluid. At heating the density change in the boundary layer will cause the fluid to rise and be replaced by cooler fluid that also will heat and rise. This continues phenomena is called free or natural convection. Boiling or condensing processes are also referred to as a convective heat transfer processes. The heat transfer per unit surface through convection was first described by Newton and the relation is known as the Newton's Law of Cooling. The equation for convection can be expressed as: q = hc A dT (1) where q = heat transferred per unit time (W, Btu/hr) A = heat transfer area of the surface (m2, ft2) hc = convective heat transfer coefficient of the process (W/(m2oC, Btu/(ft2 h oF)) dT = temperature difference between the surface and the bulk fluid (oC, F) Heat Transfer Coefficients - Units 1 W/(m2K) = 0.85984 kcal/(h m2 oC) = 0.1761 Btu/(ft2 h oF) 1 Btu/(ft2 h oF) = 5.678 W/(m2 K) = 4.882 kcal/(h m2 oC) 1 kcal/(h m2 oC) = 1.163 W/(m2K) = 0.205 Btu/(ft2 h oF) Overall Heat Transfer Coefficients Convective Heat Transfer Coefficients Convective heat transfer coefficients - hc - depends on type of media, if its gas or liquid, and flow properties such as velocity, viscosity and other flow and temperature dependent properties. Typical convective heat transfer coefficients for some common fluid flow applications: Free Convection - air, gases and dry vapors : 0.5 - 1000 (W/(m2K)) Free Convection - water and liquids: 50 - 3000 (W/(m2K)) Forced Convection - air, gases and dry vapors: 10 - 1000 (W/(m2K)) Forced Convection - water and liquids: 50 - 10000 (W/(m2K)) Forced Convection - liquid metals: 5000 - 40000 (W/(m2K)) Boiling Water : 3.000 - 100.000 (W/(m2K)) Condensing Water Vapor: 5.000 - 100.000 (W/(m2K)) Heat Exchanger Heat Transfer Coefficients Convective Heat Transfer Coefficients Convective Heat Transfer Coefficient for Air The convective heat transfer coefficient for air flow can be approximated to hc = 10.45 - v + 10 v1/2 (2) where hc = heat transfer coefficient (kCal/m2h°C) v = relative speed between object surface and air (m/s) Since 1 kcal/m2h°C = 1.16 W/m2°C or 1 W/m2°C = 0.862 kcal/m2h°C (2) can be modified to hcW = 1.16 (10.45 - v + 10 v1/2) (2b) where hcW = heat transfer coefficient (W/m2°C) Note! - this is an empirical equation and can be used for velocities 2 to 20 m/s. Convective Air Flow from a single Heat Source Example - Convective Heat Transfer A fluid flows over a plane surface 1 m by 1 m. The surface temperature is 50oC, the fluid temperature is 20oC and the convective heat transfer coefficient is 2000 W/m2oC. The convective heat transfer between the hotter surface and the colder air can be calculated as q = (2000 W/m2oC) ((1 m) (1 m)) ((50 oC) - (20 oC)) = 60000 (W) = 60 (kW) Convective Heat Transfer Calculator Convective Heat Transfer Chart Convective Heat Transfer Chart (pdf) Arithmetic Mean Temperature Difference in Heat Exchangers - AMTD - and Logarithmic Mean Temperature Difference - LMTD - formulas with examples - Online Mean Temperature Calculator. Heat transfer when steam condensates. Conductive heat transfer takes place in a solid if there is a temperature gradient. Calculate the vertical air flow and air velocity generated by a single heat source. Convective air flows from typical heat sources like people, computers, radiators and more. Hot or cold vertical surfaces generates vertical air flows - calculate air velocity and volume flow. Heat-transfer in heat exchangers are reduced by fouling. Overall heat transfer coefficients in common heat exchanger designs - tubular, plate or spiral. Average overall heat transmission coefficients for fluid and surface combinations like Water to Air, Water to Water, Air to Air, Steam to Water and more. Walls or heat exchangers - calculate overall heat transfer coefficients. Effective Temperature of air in movement. Convective heat transfer , often referred to simply as convection , is the transfer of heat from one place to another by the movement of fluids . Convection is usually the dominant form of heat transfer in liquids and gases. Although often discussed as a distinct method of heat transfer, convective heat transfer involves the combined processes of conduction (heat diffusion) and advection (heat transfer by bulk fluid flow). The convective heat transfer coefficient (h), defines, in part, the heat transfer due to convection. The convective heat transfer coefficient is sometimes referred to as a film coefficient and represents the thermal resistance of a relatively stagnant layer of fluid between a heat transfer surface and the fluid medium. Common units used to measure the convective heat transfer coefficient are: 1 W/(m2 K) = 0.85984 kcal/(h m2 ° C) = 0.1761 Btu/(ft2 h ° F) 1 kcal/(h m2 ° C) = 1.163 W/(m2 K) = 0.205 Btu/(ft2 h ° F) Btu/hr - ft2 - °F = 5.678 W/(m2 K) = 4.882 kcal/(h m2 ° C) Convection involves the transfer of heat by the motion and mixing of "macroscopic" portions of a fluid (that is, the flow of a fluid past a solid boundary). The term natural convection is used if this motion and mixing is caused by density variations resulting from temperature differences within the fluid. The term forced convection is used if this motion and mixing is caused by an outside force, such as a pump. The transfer of heat from a hot water radiator to a room is an example of heat transfer by natural convection. The transfer of heat from the surface of a heat exchanger to the bulk of a fluid being pumped through the heat exchanger is an example of forced convection. Heat transfer by convection is more difficult to analyze than heat transfer by conduction because no single property of the heat transfer medium, such as thermal conductivity, can be defined to describe the mechanism. Heat transfer by convection varies from situation to situation (upon the fluid flow conditions), and it is frequently coupled with the mode of fluid flow. In practice, analysis of heat transfer by convection is treated empirically (by direct observation). Convection heat transfer is treated empirically because of the factors that affect the stagnant film thickness: Fluid velocity Fluid viscosity Heat flux Surface roughness Type of flow (single-phase/two-phase) Convection involves the transfer of heat between a surface at a given temperature (T1) and fluid at a bulk temperature (Tb). The exact definition of the bulk temperature (Tb) varies depending on the details of the situation. For flow adjacent to a hot or cold surface, Tb is the temperature of the fluid "far" from the surface. For boiling or condensation, Tbis the saturation temperature of the fluid. For flow in a pipe, Tb is the average temperature measured at a particular crosssection of the pipe. The basic relationship for heat transfer by convection has the same form as that for heat transfer by conduction: Q = h · A · ΔT where Q = rate of heat transfer (Btu/hr) h = convective heat transfer coefficient (Btu/hr-ft2 - °F) A = surface area for heat transfer (ft2) ΔT = temperature differnece (°F) or Q = hc · A · (Ts - Ta) where Q = heat transferred per unit time (W) A = heat transfer area of the surface (m2) hc = convective heat transfer coefficient of the process (W/(m2 K) or W/(m2 ° C)) Ts = Temperature surface Ta = Temperature air The convective heat transfer coefficient (h) is dependent upon the physical properties of the fluid and the physical situation. Typically, the convective heat transfer coefficient for laminar flow is relatively low compared to the convective heat transfer coefficient for turbulent flow. This is due to turbulent flow having a thinner stagnant fluid film layer on the heat transfer surface. Values of h have been measured and tabulated for the commonly encountered fluids and flow situations occurring during heat transfer by convection. Example calculations: A 22 foot uninsulated steam line crosses a room. The outer diameter of the steam line is 18 in. and the outer surface temperature is 280oF. The convective heat transfer coefficient for the air is 18 Btu/hr-ft 2 - oF. Calculate the heat transfer rate from the pipe into the room if the room temperature is 72 oF. Solution Q = h · A · ΔT Q = h (2 · π · r · L) ΔT Q = (18 Btu / (hr-ft2-°F) · 2 · (3.14157) · (0.75 ft) · (22 ft) · (280°F - 72°F) Q = 3.88 x 105 Btu/hr Many applications involving convective heat transfer take place within pipes, tubes, or some similar cylindrical device. In such circumstances, the surface area of heat transfer normally given in the convection equation ( ) varies as heat passes through the cylinder. In addition, the temperature difference existing between the inside and the outside of the pipe, as well as the temperature differences along the pipe, necessitates the use of some average temperature value in order to analyze the problem. This average temperature difference is called the log mean temperature difference (LMTD), described earlier. It is the temperature difference at one end of the heat exchanger minus the temperature difference at the other end of the heat exchanger, divided by the natural logarithm of the ratio of these two temperature differences. The above definition for LMTD involves two important assumptions: (1) the fluid specific heats do not vary significantly with temperature, and (2) the convection heat transfer coefficients are relatively constant throughout the heat exchanger. Related: Joanna Śmietańska, PhDPhD, AGH University of Krakow, Cracow, PolandJoanna Śmietanska-Nowak is an academic teacher at AGH University of Science and Technology in Kraków. Her research interests focus on protein crystallography and modulated systems, though she has previously worked on photocatalysis and energy storage systems, including supercapacitors and Li-ion batteries. She has participated in and led several research projects funded by the Polish National Science Centre. While working at Omni, she primarily developed calculators related to physics, chemistry, and mathematics. In her free time, she enjoys playing board games, cooking, hiking, and brewing beer. See full profileCheck our editorial policy38 people find this calculator helpfulWith this heat transfer calculator, finding the heat rates for different types of heat transfer will be no challenge for you! Heat transfer occurs every time you bring objects of different temperatures into contact with each other. So, there are many examples of heat transfer in daily life when heat is transferred from one object to another. The concept of heat and the mechanisms of heat transfer are central to engineering and industrial and domestic equipment design. In the text below, we will discuss the heat transfer formula. So let's start by explaining what he