ANSI/AHRI Standard 470-2006
(Formerly ARI Standard 470-2006)

2006 Standard for

Performance Rating of Desuperheater/Water Heaters

Approved American National Standard
ANSI

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Note:

This standard supersedes ARI Standard 470-2001.

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PERFORMANCE RATING OF DESUPERHEATER/WATER HEATERS

Section 1. Purpose

1.1 *Purpose.* The purpose of this standard is to establish for Desuperheater/Water Heaters: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

1.1.1 *Intent.* This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.2 *Review and Amendment.* This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 *Scope.* This standard applies to Desuperheater/Water Heaters supplied as separate components, as defined in Section 3 and using single component and azeotropic refrigerants only.

2.2 *Exclusions.* This standard does not apply to Desuperheater/Water Heaters supplied as components of factory-assembled refrigeration or air conditioning units. This standard does not apply to systems using zeotropic refrigerants.

Section 3. Definitions

Definitions. All terms in this document follow the standard industry definitions in the current edition of *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration* unless otherwise defined in this section.

3.1 *Desuperheater/Water Heater.* A factory-made assembly of elements by which refrigerant vapor flow and water flow are maintained in such heat transfer relationship that the refrigerant vapor is desuperheated and the water is heated.

3.2 *Field Fouling Allowance.* Provisions for anticipated Fouling Factor during use.

3.2.1 *Fouling Factor.* The thermal resistance due to fouling accumulated on the heat transfer surface.

3.3 *Net Heating Capacity.* The useful heat exchanged between the refrigerant vapor and the water being heated. This value is the product of the mass flow rate of water, the specific heat of water and the water temperature rise, Btu/h [W].

3.3.1 *Clean Tube Capacity.* This is the Net Heating Capacity of the heat exchanger, Btu/h [W], with clean tubes at the Standard Rating Conditions.

3.4 *Published Rating.* A statement of assigned values of those performance characteristics, under stated rating conditions, by which a unit may be chosen to fit its application. These values apply to all Desuperheater/Water Heaters of like nominal size and type (identification) produced by the same manufacturer. As used herein, the term Published Rating includes all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.4.1 *Application Rating.* A rating based on tests performed at application Rating Conditions.

3.4.2 *Standard Rating.* A rating based on tests performed at Standard Rating Conditions.

3.5 *Rating Conditions*. Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

3.5.1 *Standard Rating Conditions*. Rating Conditions used as the basis of comparison for performance characteristics.

3.6 *"Shall" or "Should."* "Shall" or "should" shall be interpreted as follows:

3.6.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.6.2 *Should.* "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

Section 4. Test Requirements

4.1 *Test Requirements.* The tests shall be conducted in accordance with the test procedure contained in Appendix C.

Section 5. Rating Requirements

5.1 *Published Ratings.* Published Ratings consist of Standard Ratings and Application Ratings. Such ratings shall be based on tests of Desuperheater/Water Heaters with the refrigerant specified in the ratings.

5.2 *Standard Ratings.* Published Ratings shall include the Standard Rating, given for one of the Standard Rating Conditions shown in Table 1 and properly identified as the Standard Rating. Standard Ratings shall be based on tests with initially clean tubes.

5.3 *Application Ratings.* Application Ratings give performance data at operating conditions other than those shown in Table 1. Application Ratings shall contain all information shown in 6.2. When Application Ratings include water-side Field Fouling Allowance(s) they shall be calculated by the method specified in 5.4. Published Ratings shall be subject to the tolerances of this standard.

5.3.1 Either Application Ratings or a method of adjusting the clean tube ratings may be presented to show the effect of various water-side Field Fouling Allowances. These calculation methods or method of adjusting these ratings shall be calculated in accordance with 5.4.

5.4 *Determination of Ratings.* Ratings shall be determined in accordance with the following (where steady state operation is in a condensing mode, this analysis will be in error):

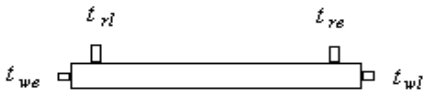
5.4.1 *Clean Tube Ratings.* Published Ratings shall be determined by test with initially clean tubes at conditions specified for the selected system in Table 1 and conducted in accordance with Appendix C. The results of these tests shall be accepted as including a Fouling Factor of zero.

Table 1. Standard Rating Conditions

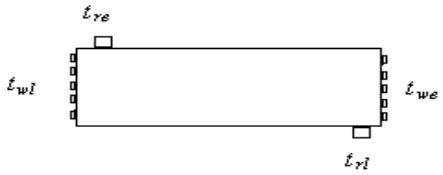
Type System	Saturated Temperature of Entering Refrigerant Vapor		Actual Temperature of Entering Refrigerant Vapor		Temperature of Entering Water		Temperature of Leaving Water	
	°F	°C	°F	°C	°F	°C	°F	°C
Air Cooled	125	51.7	220	104	90 and 120	32 and 48.9	140	60.0
Water Cooled	105	40.6	180	82.2	90 and 120	32 and 48.9	140	60.0
Note: Ratings are for single component and azeotropic refrigerants only. Zeotropic refrigerants are excluded.								

5.4.2 *Fouled Tube Ratings.* From the results of the clean tube tests, calculate the clean tube overall heat transfer coefficient, U_c. Then, mathematically add the specified Fouling Factor to the reciprocal of the clean tube U_c and calculate the fouled ratings for publication, using the following methods, as applicable.

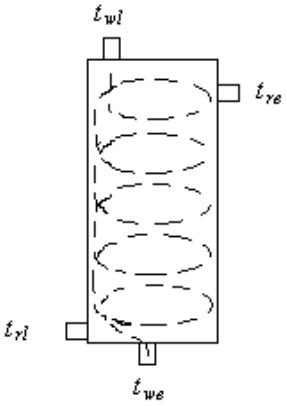
a. Tube-in-tube (counter flow arrangement shown - parallel flow also covered).



b. Single tube pass shell-and-tube (counter flow arrangement shown - parallel flow also covered).



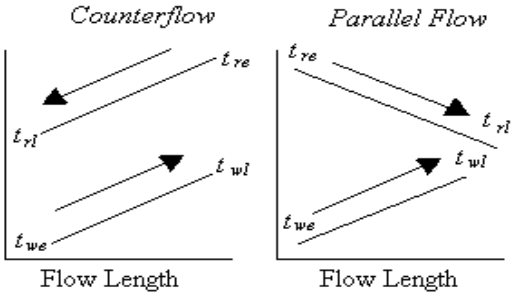
c. Coil-in-shell, single pass (counter flow arrangement shown - parallel flow also covered).



Obtain U_c from the following equation:

$$U_c = \frac{q}{A \times (LMTD)_c} \qquad 1$$

where $(LMTD)_c$ is defined by:



for counter flow:

$$(LMTD)_c = \frac{(t_{re} - t_{wl}) - (t_{rl} - t_{we})}{ln\left[\frac{t_{re} - t_{wl}}{t_{rl} - t_{we}}\right]} \quad 2a$$

for parallel flow:

$$(LMTD)_c = \frac{(t_{re} - t_{we}) - (t_{rl} - t_{wl})}{ln\left[\frac{t_{re} - t_{we}}{t_{rl} - t_{wl}}\right]} \quad 2b$$

The total thermal resistance is equal to the reciprocal of the overall coefficient of heat transfer:

$$R_c = \frac{1}{U_c} = \frac{A \times (LMTD)_c}{q} \quad 3$$

The next step in determination of fouled ratings is the calculation of the total thermal resistance including fouling. This is found by adding the specified Fouling Factor to the clean-tube overall resistance, as illustrated below.

1. Refrigerant outside tubes (fouling inside):

   a. Basing calculations on outside surface area:

   $$R_{fo} = R_{co} + r_{fi}\left(\frac{A_o}{A_i}\right) \quad 4a$$

   b. Basing calculations on inside surface area:

   $$R_{fi} = R_{ci} + r_{fi} \quad 4b$$

2. Refrigerant inside tubes (fouling outside):

   a. Basing calculations on outside surface area:

   $$R_{fo} = R_{co} + r_{fo} \quad 5a$$

   b. Basing calculations on inside surface area:

   $$R_{fi} = R_{ci} + r_{fo}\left(\frac{A_i}{A_o}\right) \quad 5b$$

Now calculate the following:

C_{hot} = ($\dot{m} \cdot c_p)_r$ = Hot fluid (refrigerant) capacity rate at Rating Conditions, Btu/(h · °F) [W/°C]

C_{cold} = ($\dot{m} \cdot c_p)_w$ = Cold fluid (water) capacity rate at Rating Conditions, Btu/ (h · °F) [W/°C]

C_{min} = The smaller of C_{hot} or C_{cold}

C_{max} = The larger of C_{hot} or C_{cold}

$q_{max} = C_{min}\ (t_{re} - t_{we})$, Btu/h [W]

$$NTU = \frac{A}{R_f \cdot C_{min}},\ dimensionless \qquad 6$$

where R_f is based on area A.

The actual heat transfer under fouled conditions, q_f, is calculated from

$$q_f = \varepsilon\, q_{\max} \qquad 7$$

where ε is determined for either counter flow or parallel flow arrangements of the exchanger types shown in 5.4.2, items a, b and c.

Counter flow, where $C_{min} \neq C_{max}$

$$\varepsilon = \frac{1 - EXP^{\,-NTU\left(1 - C_{min}/C_{max}\right)}}{1 - \left(C_{min}/C_{max}\right) EXP^{\,-NTU\left(1 - C_{min}/C_{max}\right)}} \qquad 8a$$

where $C_{min} = C_{max}$:

$$\varepsilon = \frac{NTU}{\left(1 + NTU\right)} \qquad 8b$$

Parallel flow:

$$\varepsilon = \frac{1 - EXP^{\,-NTU(1 + C_{min}/C_{max})}}{1 + (C_{min}/C_{max})} \qquad 8c$$

Now having the actual heat transfer under fouled conditions, the leaving water and refrigerant temperatures can be calculated from:

$$t_{wl} = t_{we} + \frac{q_f}{C_{cold}} \qquad 9a$$

$$t_{rl} = t_{re} - \frac{q_f}{C_{hot}} \qquad 9b$$

The combination of q_f, t_{we} and t_{re} define the fouled ratings at the given operating conditions.

5.5 *Symbols and Subscripts*. The symbols and subscripts used in Equations 1 through 9 are as follows:

Symbols:

A = Total heat transfer area, ft^2 [m^2]
C = Flow-stream capacity rate ($\dot{m} \cdot c_p$), Btu/(h · °F) [W/°C]
c_p = Specific heat at constant pressure, Btu/(lb · °F) [kJ/(kg · °C)]
ε = Exchanger heat transfer effectiveness
EXP = Base of natural logarithm, e
$LMTD$ = Log mean temperature difference, °F [°C]
$\dot{m}$ = Fluid mass flow rate, lb/h [kg/s]

NTU = Number of exchanger heat transfer units
q = Total heat transfer rate, Btu/h [W]
R = Total thermal resistance, h · ft^2 · °F/Btu [m^2 · °C/W]
r = Individual thermal resistance term, h · ft^2 · °F/Btu [m^2 · °C/W]
t = Temperature, °F [°C]
U = Overall heat transfer coefficient, Btu/(h · ft^2 · °F) [W/(m^2 · °C)]

Subscripts:

c = Clean
e = Entering
f = Fouled or fouling
i = Inside
l = Leaving
o = Outside
r = Refrigerant
w = Water

5.6 *Tolerances.* To comply with this standard, published Net Heating Capacity shall be based on data obtained in accordance with the provisions of this standard, and shall be such that any production unit selected at random and tested in accordance with this standard shall have a Net Heating Capacity not less than 95% of the Published Rating, a water pressure drop not more than 110% of the published water pressure drop and a refrigerant pressure drop not more than 110% of the published refrigerant pressure drop.

Section 6. Minimum Data Requirements for Published Ratings

6.1 *Minimum Data Requirements for Published Ratings.* As a minimum, Published Ratings shall include all Standard Ratings. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 470." All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of AHRI Standard 470." Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

6.2 *Published Ratings.* Published Ratings shall state all the pertinent operating conditions and shall include the following:

a. Refrigerant designation(s) per ANSI/ASHRAE Standard 34 with Addenda
b. Entering refrigerant temperature, °F [°C]
c. Entering refrigerant pressure, psig [kPa gage]
d. Net Heating Capacity, Btu/h [W]
e. Water flow rate, gpm [L/s]
f. Water pressure drop, psi or ft H_2O [kPa]
g. Refrigerant side pressure drop, psi [kPa]
h. Refrigerant mass flow rate, lb/h [kg/s]
i. Fouling Factor (water-side), ft^2 · h · °F/Btu [m^2 · °C/W]

Plus at least one of the following:

j. Entering water temperature, °F [°C]
k. Leaving water temperature, °F [°C]

6.3 Published Ratings shall be accompanied by the following information:

a. Design pressures for water-side and refrigerant-side, psig [kPa gage]
b. Minimum water flow rate, gpm [L/s], at minimum entering water temperature, °F [°C]
c. Maximum recommended flow rate, gpm [L/s]
d. If only clean tube ratings are published, a statement shall be included to contact the manufacturer if fouled tube ratings are required.

Section 7. Marking and Nameplate Data

7.1 *Marking and Nameplate Data.* As a minimum, each Desuperheater/Water Heater shall have the following information shown in a conspicuous place:

a. Name of manufacturer
b. Manufacturer's model number
c. Design working pressure for the water side
d. Design working pressure for the refrigerant side

Section 8. Conformance Conditions

8.1 *Conformance.* While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's *Purpose* (Section 1) and *Scope* (Section 2) unless such product claims meet all of the requirements of the standard and all the requirements of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

APPENDIX A. REFERENCES – NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

A1.1 ANSI/ASHRAE Standard 34-2004 with Addenda, *Designation and Safety Classification of Refrigerants,* 2004, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.2 ANSI/ASHRAE Standard 41.1-1986 (RA 2006), *Standard Method for Temperature Measurement,* 2006, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.3 ASHRAE *Handbook – Fundamentals*, 2005, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.4 ASHRAE *Terminology of Heating, Ventilation, Air Conditioning and Refrigeration*, Second Edition, 1991, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.5 ASME Standard PTC 19.5-2004, *Flow Measurement,* 2004, American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017, U.S.A.

APPENDIX B. REFERENCES – INFORMATIVE

B1 Listed here are standards, handbooks and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

B1.1 ANSI/ASHRAE Standard 41.2-1987 (RA 92), *Standard Methods for Laboratory Air Flow* Measurement, 1992, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

APPENDIX C. METHOD OF TESTING DESUPERHEATER/WATER HEATERS – NORMATIVE

C1 *Purpose.* This appendix prescribes methods of testing for rating Desuperheater/Water Heaters.

C2 *Scope.* This appendix applies to Desuperheater/Water Heaters supplied as a separate component.

C3 *Definitions.*

C3.1 *Definitions.* Definitions of this appendix are identical with those in Section 3 of this standard.

C4 *Test Results*.

C4.1 Test results shall be expressed in the following terms:

a. Net Heating Capacity, Btu/h [W]
b. Entering water temperature, °F [°C]
c. Leaving water temperature, °F [°C]
d. Entering refrigerant temperature, °F [°C]
e. Water flow rate, gpm [L/s]
f. Refrigerant mass flow rate, lb/h [kg/s]
g. Water-side pressure drop through heat exchanger, psi or ft H_2O [kPa]
h. Refrigerant-side pressure drop through heat exchanger, psi [kPa]
i. Pressure of refrigerant entering heat exchanger, psig [kPa gage]
j. Refrigerant designation(s), per ANSI/ASHRAE Standard 34 with Addenda

C4.2 The test record shall include the date, observers' names, essential identifying physical data of the Desuperheater/Water Heater tested, refrigerant used, all test readings, reference to instrument calibrations and computations, and the determined results.

C5 *Test Methods.*

C5.1 *Standard Test Methods.*

C5.1.1 Tests shall consist of measurement of the following at specified conditions:

a. Entering and leaving water temperatures, °F [°C]
b. Entering and leaving refrigerant temperatures, °F [°C]
c. Entering refrigerant pressure, psig [kPa gage]
d. Water-side pressure drop, psi or ft H_2O [kPa]
e. Refrigerant-side pressure drop, psi [kPa]
f. Water flow rate, gpm [L/s]
g. Refrigerant mass flow rate, lb/h [kg/s]
h. Ambient temperature, °F [°C]

C5.1.2 The heat balance shall be calculated by the following:

a. Multiply the mass flow rate of water by the specific heat and temperature difference between entering and leaving water (Net Heating Capacity, Equation C4) and adding to this the heat lost by the refrigerant through the external surfaces of the heat exchanger (Equation C1)

b. Multiply the refrigerant mass flow rate by the enthalpy differences between entering and leaving refrigerant (Equation C3).

A heat balance calculated to compare C5.1.2a and C5.1.2b shall be within 5%.

C5.1.3 The water flow rate shall be determined in accordance with C6.4.1.

C5.1.4 Refrigerant flow rate shall be determined in accordance with C6.4.2.

C5.1.5 The enthalpy difference between the entering and leaving refrigerant shall be determined from temperature and pressure measurements and the applicable thermodynamic properties of the refrigerant.

C5.1.6 The heat lost through the external surfaces of the heat exchanger to the ambient air shall be determined by:

$$q_o = \frac{A \cdot LMTD}{R} \qquad \text{C1}$$

and

$$R = \frac{x}{k} + \frac{1}{h_s} \qquad \text{C2}$$

C5.1.7 The heat absorbed by the water is the product of the mass flow, the specific heat and the temperature difference between entering and leaving water (Equation C4).

C5.1.8 The heat rejected from the refrigerant is the product of the refrigerant mass flow rate and the enthalpy difference between the refrigerant entering and leaving the Desuperheater/Water Heater.

$$q = \dot{m}_r \left(H_e - H_l \right) \qquad \text{C3}$$

C6 *Instruments, Test Apparatus, and Thermodynamic Properties.*

C6.1 *General*.

C6.1.1 Instruments, whose types and accuracies are listed below, shall be calibrated against standards before and after each test.

C6.2 *Temperature Measuring Instruments.*

C6.2.1 Temperature measurements shall be made in accordance with ANSI/ASHRAE Standard 41.1.

C6.3 *Pressure Measuring Instruments.*

C6.3.1 All pressure measuring instruments shall have accuracy within 1% of the absolute pressure readings or within 2% of the differential pressure readings.

C6.4 *Flow Measuring Instruments.*

C6.4.1 *Water Flow Measuring Instruments.*

C6.4.1.1 Flow meter accuracy shall be within 2% over the range of flows measured.

C6.4.2 *Refrigerant Flow Measuring Instruments.*

C6.4.2.1 Refrigerant flow rate measurements shall be made with one or more of the following instruments.

a. Liquid refrigerant flow meter
b. Gaseous refrigerant flow meter

C6.4.2.2 A refrigerant calorimeter may also be used to calculate the refrigerant mass flow rate. In this approach, the calorimeter is used to accurately measure the amount of heat required to evaporate and superheat the refrigerant flowing through it. The refrigerant mass flow rate is determined by dividing the heat input, including leakage losses, by the enthalpy difference between the entering and leaving refrigerant.

C6.4.2.3 Accuracy of either the direct or indirect refrigerant mass flow rate measurement shall be within 2% of the range of mass flows calculated.

C6.4.2.4 Instruments shall be applied and used in accordance with ASME PTC 19.5.

C6.4.3 *Thermodynamic Properties of Refrigerants.* Thermodynamic properties of refrigerants shall be obtained from the current issue of the ASHRAE *Handbook-Fundamentals*.

C7 *Test Procedure*

C7.1 *General*

C7.1.1 The Desuperheater/Water Heater, the selected instruments, and test apparatus shall be assembled, connected, tested, dehydrated, evacuated, and charged with refrigerant. If necessary, a refrigerant superheater may be used to assure accuracy of measurements and to obtain specified conditions.

C7.1.2 The water-side surfaces of the heat exchangers shall be cleaned immediately prior to the test. This method gives clean tube test results.

C7.1.3 The refrigerant system shall be checked for non-condensables. Non-condensables present for a test intended for rating shall not exceed that amount which increases the condenser pressure more than the equivalent of 0.5 °F [0.3 °C].

C7.2 *Operation and Limits.*

C7.2.1 Start the system and maintain the specified conditions in accordance with the following tolerances:

a. The arithmetic average of pressure readings used to determine refrigerant enthalpies and refrigerant saturated temperatures shall not vary from the required values by more than 2% of their absolute values nor shall the individual pressure readings vary by more than this amount from the average value. Pressure readings shall be converted to absolute values to determine refrigerant saturated temperatures.

b. The arithmetic average of temperature readings of water and refrigerant entering and leaving the Desuperheater/ Water Heater shall not vary from the specified value by more than 1.0°F [0.6°C] nor shall the individual readings vary by more than this amount from the average value.

C7.2.2 After establishment of steady flow conditions, all required readings shall be taken at intervals of not less than fifteen minutes, and the test shall be continued until two consecutive sets of readings are within the specified limits.

C8 *Computation of Results.*

C8.1 The Net Heating Capacity, q, is given as follows:

$$q = (\dot{m} \cdot c_p \cdot \Delta t)_w \qquad \text{C4a}$$

$$[q = 1000(\dot{m} \cdot c_p \cdot \Delta t)_w] \qquad \text{C4b}$$

C9 *Symbols and Subscripts.* The symbols and subscripts used in Equations C1 through C4 are as follows:

Symbols:

A = External surface area, ft^2 [m^2]
c_p = Specific heat at constant pressure, Btu/(lb · °F) [kJ/(kg · °C)]
Δt = Temperature difference between the entering and leaving water, °F [°C]
H = Enthalpy of refrigerant, Btu/lb [J/kg]
h = Film coefficient, defined as 2 Btu/(h · ft^2 · °F) [11W/(m · °C)]
k = Thermal conductivity of insulation, Btu/(h · ft · °F) [W/(m · °C)]
$LMTD$ = Log mean temperature difference, °F [°C]
$\dot{m}$ = Mass flow rate, lb/h [kg/s]
q = Heat transfer rate, Btu/h [W]
R = Total thermal resistance, h · ft^2 · °F/Btu [m^2 · °C/W]
x = Insulation thickness, ft [m]

Subscripts:

e = Entering
l = Leaving
o = External surfaces
r = Refrigerant
s = Surface
w = Water