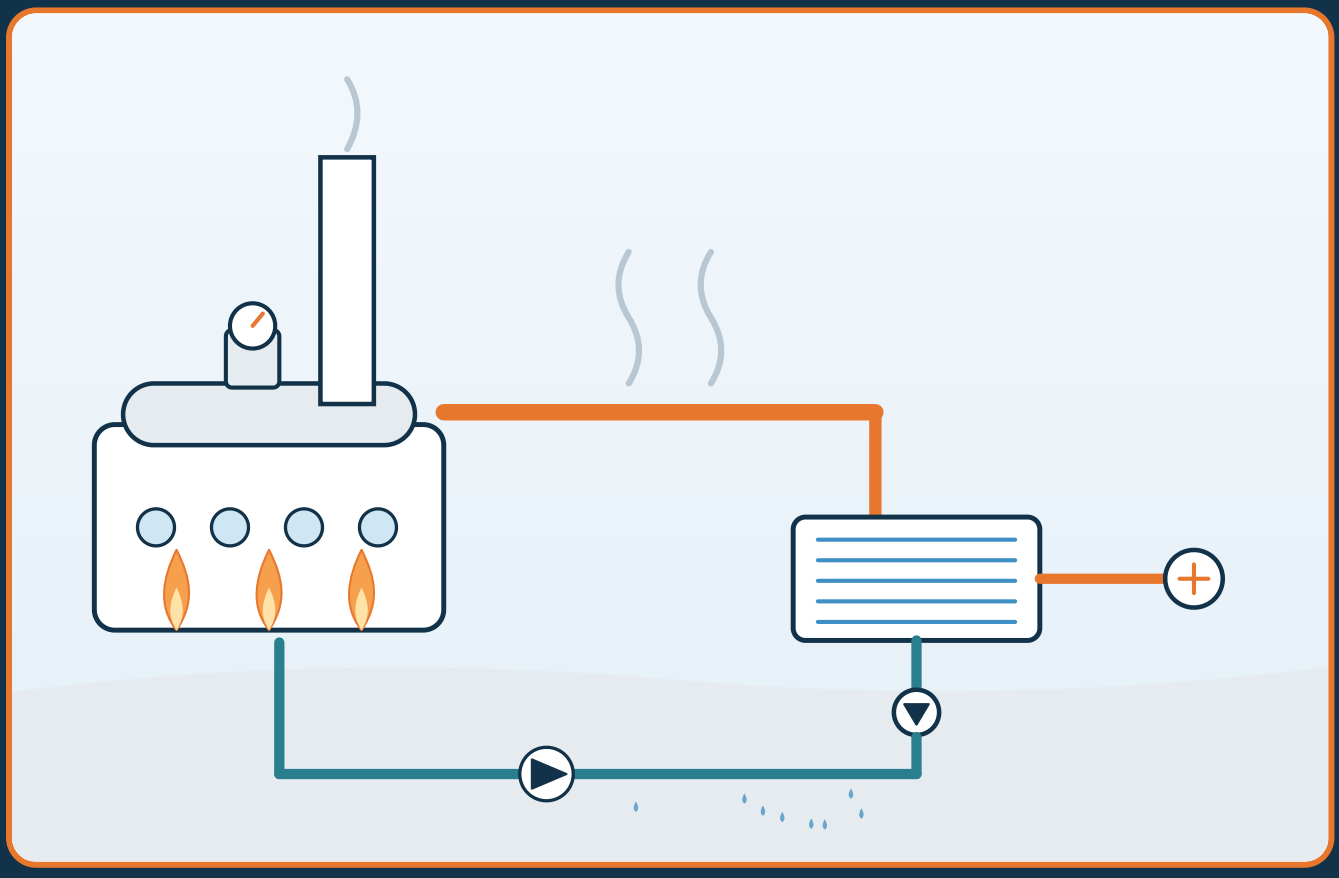
PlantCalcKit

Steam Systems and Boilers Made Simple

A field guide to steam, boilers and condensate

Steam tables · Boilers · Combustion and excess air · Blowdown · Deaerators · Steam pipe sizing · Steam traps · Condensate and flash steam · Insulation · Waste heat recovery · Cost per tonne of steam · Steam balance



FREE SAMPLER — Chapters 1 to 3

Edition 1.0 · November 2026

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Steam Systems and Boilers Made Simple
A field guide to steam, boilers and condensate
Edition 1.0 · November 2026 — free sampler (Chapters 1 to 3)

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Written in our own words from published engineering sources, listed in Appendix G. All diagrams, picture pages and charts are original PlantCalcKit artwork; charts are computed from the worked examples. No equipment maker, chemical supplier or brand is named or recommended.

Site W and all its equipment are made up. Every example value is generic; costs and prices are illustrative.

This guide is for training and engineering estimates. It does not replace your equipment maker's instructions, your boiler inspector's and water-treatment specialist's advice, the published codes and standards, or your plant's approved procedures and safety rules. Where a method follows a code or standard, the calculation is aligned with the publicly documented method; no result in this book claims to meet a code.

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GUIDE

How to use this book

This book explains steam in a process plant in plain words: what steam is, how a boiler makes it, how pipes and traps move it, how condensate and flash steam are recovered, how heat is saved, and what a tonne of steam costs. You do not need to be an expert. If you can read a pressure gauge and use a calculator, you can follow every example.

Who it is for

- **Plant operators** who run boilers and steam users and want to know what the numbers mean.
- **Young engineers** who must check boiler efficiency, size a steam line, run a trap survey or write an energy report.
- **Senior engineers** who want a quick refresher or a training text for their team.

How the book is built

Part	What you learn	Chapters
A	Steam basics: steam tables, heat duty and steam consumption	1 to 3
B	Boilers: combustion, excess air, efficiency, blowdown, feedwater and the deaerator	4 to 10
C	Distribution and traps: pipe sizing, safety, trap types, trap capacity and the survey	11 to 14
D	Condensate, flash and heat recovery: condensate return, flash steam, insulation, waste heat	15 to 18
E	Cost and balance: the cost of a tonne of steam, the steam balance and everyday savings	19 to 20

Each chapter is short and stands alone. At the back you will find a glossary, an FAQ, units and conversions, a formula sheet, printable checklists, answers to all exercises and quizzes, and the list of sources.

The boxes you will see

- **Field check** — a table of what you might see on the plant, what it may mean, and what to check first.
- **Engineer's calculation corner** — a worked example with every step and number, using Site W's equipment.
- **Watch out** — a common mistake or a safety point.
- **Try it** — a short exercise; answers are in Appendix F.
- **Free tools** — QR codes to the free online calculator and the matching Excel toolkit for the chapter.
- **Quick quiz** — five questions to check you have the main ideas.

Ten picture pages show the main equipment as labelled drawings with a parts table: boiler, burner, blowdown system, deaerator, steam header, three trap types, flash vessel and economiser.

Site W and the numbers

All examples follow one made-up plant, Site W (Chapter 1). It has a gas-fired boiler B-101, a fired heater H-501, a deaerator DA-101, a steam header SH-10, a flash vessel FV-210 and a set of traps and insulated lines. The numbers are the example cases of the matching PlantCalcKit Excel toolkits, so you can open a toolkit and see the

same calculation. Where a toolkit has no published example case, the example is Site W's own and the text says so. Every number in the worked examples was computed with a script, not typed by hand. Costs and prices are illustrative only, and each toolkit uses its own price basis, so dollar figures from different chapters are not added together without care (Chapter 19).

Units

SI units come first, with US customary units in brackets where it helps — for example a 50 t/h boiler (110,231 lb/h). Pressures are marked "bar g" (gauge) or "bar a" (absolute). Appendix C has the conversions.

What this book is — and is not

This book helps you understand and check steam equipment. It is **not** a design code, an approved design calculation or a safety study, and it does not replace your equipment maker's instructions, your plant's approved procedures, the boiler inspector's requirements or the engineer responsible for the equipment. Where a method follows a published code or standard, we say it is "aligned with the publicly documented method" — that means we used the published equations, not that the result meets the code. Safety-critical items — boiler water level, combustion and burner management, safety valves, steam hammer, hot condensate and confined spaces — are explained so that you can understand and question them; decisions on them belong to the responsible people and procedures at your site.

FREE TOOLS

Free calculators and Excel toolkits

Every chapter ends with two QR codes: a free online calculator for a quick check, and the matching PlantCalcKit Excel toolkit, which carries out the full calculation of the chapter's worked example with the same numbers. The toolkits show every formula, check every input and print a report. Shop pages are information pages; nothing is bought by scanning a code.

All free calculators
plantcalckit.com/tools/

All Excel toolkits
plantcalckit.com/shop/

Ch.	Chapter	Free calculator	Excel toolkit (does the chapter's calculation)
1	Steam in the plant	Steam tables (IAPWS-IF97) plantcalckit.com/tools/steam-tables/	Utilities Cost Calculator **USD 79** plantcalckit.com/shop/utilities-cost-calculator-excel/
2	Steam tables made simple	Steam tables (IAPWS-IF97) plantcalckit.com/tools/steam-tables/	Utilities Cost Calculator **USD 79** plantcalckit.com/shop/utilities-cost-calculator-excel/
3	Heat duty and steam consumption	Steam tables (IAPWS-IF97) plantcalckit.com/tools/steam-tables/	Heat Duty and Utility Consumption **USD 39** plantcalckit.com/shop/heat-duty-and-utility-consumption-excel/

PART A

Steam basics

Steam tables, heat duty and steam consumption

CHAPTER 1

Steam in the plant

Steam is the plant's heating system in the sky. A boiler turns water into steam, pipes carry it to the users, the users give up its heat and the steam turns back into water — condensate — which should come home to be heated again. This book follows that whole loop. If you can read a pressure gauge and use a calculator, you can follow every example.

1.1 Why plants use steam

Steam is popular for good reasons. It carries a lot of heat in a small mass: one kilogram of steam condensing at 10 bar g gives up about 1,999.3 kJ, which is about 70 per cent of all the heat needed to turn cold water into 250 °C steam at that pressure (Chapter 2). It moves by itself, because pressure drives it down the pipe without a pump. It gives heat at an almost constant temperature, which is gentle on the product. And it is safe from fire and sparks where fuel gas or hot oil would not be.

The price is the equipment around it: a boiler, a water treatment plant, a pipe network, traps, a condensate return and a lot of insulation. Done well, steam is cheap. Done badly, it is the biggest hidden energy cost in the plant. A boiler like B-101 in this book makes 50 t/h and burns fuel worth about USD 10.0 million a year (illustrative price). One per cent saved is USD 100,000.

1.2 Meet Site W

To keep the numbers real, this book follows one made-up plant, **Site W**. It is generic: not any real plant, and every value is an example you should replace with your own data. Figure 1.1 shows its steam system.

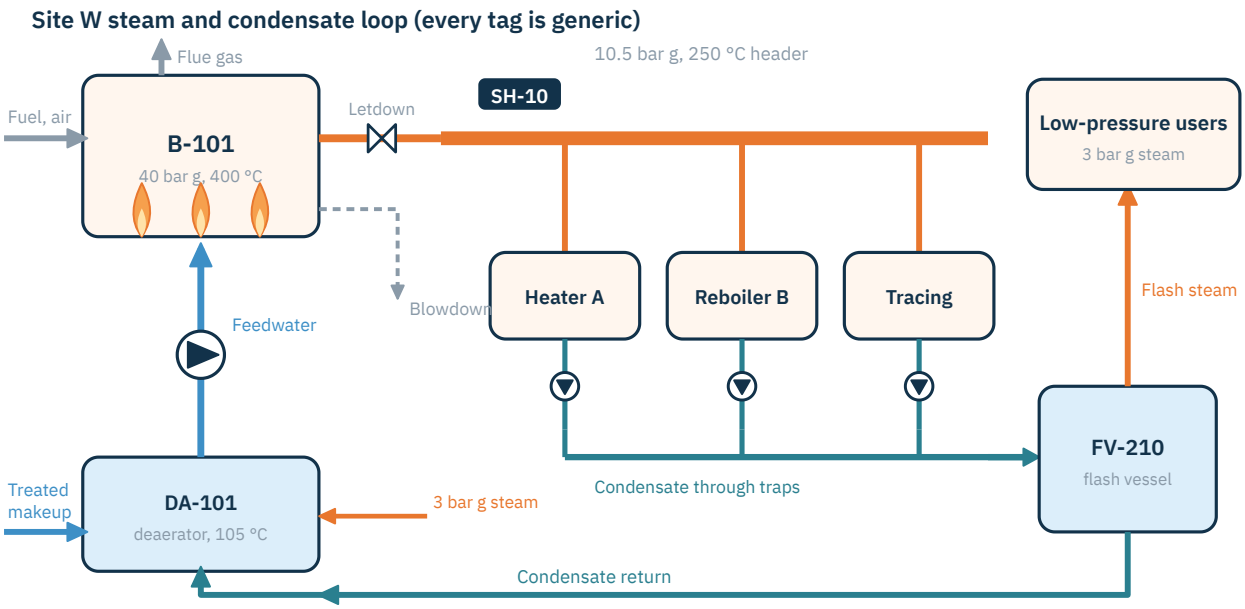


Figure 1.1 — Site W's steam system. Fuel and treated water go into boiler B-101; steam goes to the users through two headers; condensate and flash steam come back through the deaerator.

Tag	Equipment or item	Example case taken from	Chapter
B-101	Water-tube boiler, 50 t/h, 40 bar g, 400 °C, feedwater 105 °C	Boiler Efficiency and Fuel Consumption toolkit	4 to 10
H-501	Fired heater, 20 MW absorbed duty	Fired Heater Efficiency toolkit	8, 18
DA-101	Deaerator at 0.20 bar g	Chapter 10 balance	10
SH-10	Steam header, 10.5 bar g, 250 °C, three segments	Cooling Water and Steam Network Debottlenecking toolkit	11
ST-...	Steam traps on a 10 bar g branch, survey of 20 traps	Steam Trap Sizing and Steam Loss toolkit	12 to 14
FV-210	Flash vessel: 20 t/h of 10 bar g condensate let down to 3 bar g	Condensate Recovery and Flash Steam toolkit	15, 16
SL-250	250 °C steam line, NPS 8, 100 m, outdoors	Thermal Insulation Thickness and Heat Loss toolkit	17

Each worked example uses the same numbers as the example case of the matching PlantCalcKit Excel toolkit, so you can open the toolkit and see every step. Some toolkits were built with different illustrative fuel prices; where that matters, the text says so (Chapter 19 explains why it is worth being careful).

1.3 Five numbers behind every steam question

1. **How much steam flows?** Mass flow in t/h (US: 50 t/h = 110,231 lb/h).
2. **At what pressure and temperature?** Pressure fixes the saturation temperature; extra temperature is superheat.
3. **How much heat does it carry?** Enthalpy times flow. Chapter 2 shows how to read it from steam tables.
4. **How much does it cost?** Fuel, water, chemicals and power per tonne (Chapter 19).
5. **Where does it go?** Users, losses and leaks. A steam balance (Chapter 20) closes the books.

If you can answer those five questions for each header of your plant, you understand your steam system better than most.

1.4 The loop in one paragraph

Treated water is deaerated (Chapter 10), pumped into the boiler and heated until it boils. Fuel burns with air in the furnace (Chapters 5 and 6); the hot gas gives most of its heat to the water and leaves up the stack. Boiler water gets saltier as water boils off, so a little is blown down (Chapter 9). The steam passes through headers and pipes (Chapters 11 and 12) to the users, where it condenses. Steam traps let the condensate out but hold the steam in (Chapters 13 and 14). The condensate returns to the deaerator (Chapter 15); where its pressure is higher than the return line, some of it flashes back to steam (Chapter 16). Pipes and tanks are insulated (Chapter 17) and spare heat is recovered (Chapter 18).

Watch out — read this first

Steam is dangerous. It scalds, it can carry enough energy to break pipes, and a boiler stores a great deal of energy as hot, pressurised water. This book explains steam so that you can understand it and check it. It does **not** replace your boiler maker's instructions, the pressure-vessel and boiler rules that apply where you work, your plant's operating procedures, or the engineer responsible for the plant. Safety items (water level, pressure, trapped condensate, combustion) are explained in plain words; decisions about them belong to trained, authorised people.

1.5 Where the money goes

For B-101 the fuel alone costs about USD 25.12 per tonne of steam at the illustrative price of USD 7.5 per GJ. Water, chemicals and power add only about USD 1.09 more (Chapter 19). So the fuel is almost the whole bill, and anything that saves fuel — better combustion, a cooler stack, hot feedwater, less blowdown, fewer leaks, thicker insulation — pays directly. The later chapters take these one by one.

TRY IT

A boiler makes 20 t/h of steam. If each tonne costs USD 26 to make (illustrative), what does a 5 per cent saving in steam use save in a year of 8,000 hours? (Answer in Appendix F.)

FREE TOOLS **Do this chapter's calculation**

Free calculator
Steam tables (IAPWS-IF97) calculator
plantcalckit.com/tools/steam-tables/

Excel toolkit: Utilities Cost Calculator (USD 79)
plantcalckit.com/shop/utilities-cost-calculator-excel/
Topics: The whole water chain · Steam at up to six pressures · Power from every source · Fair heat-recovery credit · Cooling water, air and nitrogen · Monthly data in, averages out

QUICK QUIZ

1. Name three reasons plants use steam.
2. What is condensate and where should it go?
3. Which part of the steam cost is usually largest?
4. Why does this book use one made-up plant?
5. Who decides safety questions such as boiler water level and relief settings?

CHAPTER 2

Steam tables made simple

Every steam calculation starts with a table. Steam tables look scary, but they answer only three questions: *how hot is the steam, how much heat does it hold, and how much room does it take?* Once you can read one line of the table, you can read them all.

2.1 Saturation: the boiling point depends on pressure

Water boils at 100 °C (212 °F) only at atmospheric pressure. At higher pressure it needs a higher temperature to boil. The pair of pressure and temperature at which water and steam can sit side by side is called **saturation**. At 10 bar g the saturation temperature is 184.1 °C (363 °F); at 40 bar g it is 251.8 °C. This is why a pressure gauge on a steam line is also, roughly, a thermometer.

Steam exactly at saturation is called **saturated steam**. Steam hotter than saturation is **superheated**; the difference in temperature is the **degrees of superheat**. B-101's outlet steam at 40 bar g and 400 °C has 148.2 K of superheat above the saturation temperature of 251.8 °C.

2.2 Three kinds of heat

Heating 1 kg of water into steam at constant pressure takes three steps, drawn in Figure 2.1:

1. **Sensible heat of the liquid** raises the water to its boiling point. At 10 bar g, from 20 °C this is 696.5 kJ.
2. **Latent heat** boils the water into steam without changing the temperature. It is the biggest step: 1,999.3 kJ/kg at 10 bar g.
3. **Superheat** raises the steam above saturation. Going from saturation to 250 °C takes another 158.7 kJ/kg.

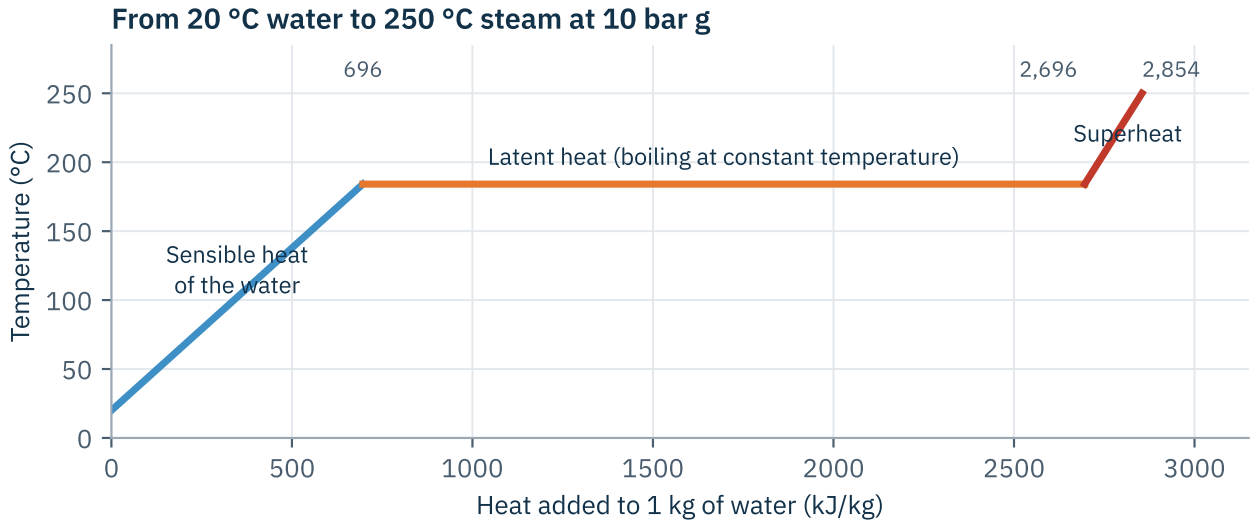


Figure 2.1 — Heat added to 1 kg of water at 20 °C at 10 bar g (11.01 bar a) up to 250 °C steam. The flat stretch is the latent heat; it is 70 % of the 2,854.5 kJ total.

Enthalpy (symbol *h*, kJ/kg) is simply the total heat content measured from a reference point. Steam tables list *h*f for the saturated liquid, *h*fg for the latent heat and *h*g for the saturated steam, where *h*g = *h*f + *h*fg. US tables use Btu/lb; 1 kJ/kg = 0.4299 Btu/lb.

2.3 Reading the table

Figure 2.2 and the table below are computed from the IAPWS-IF97 industrial formulation, the standard used for steam tables worldwide.

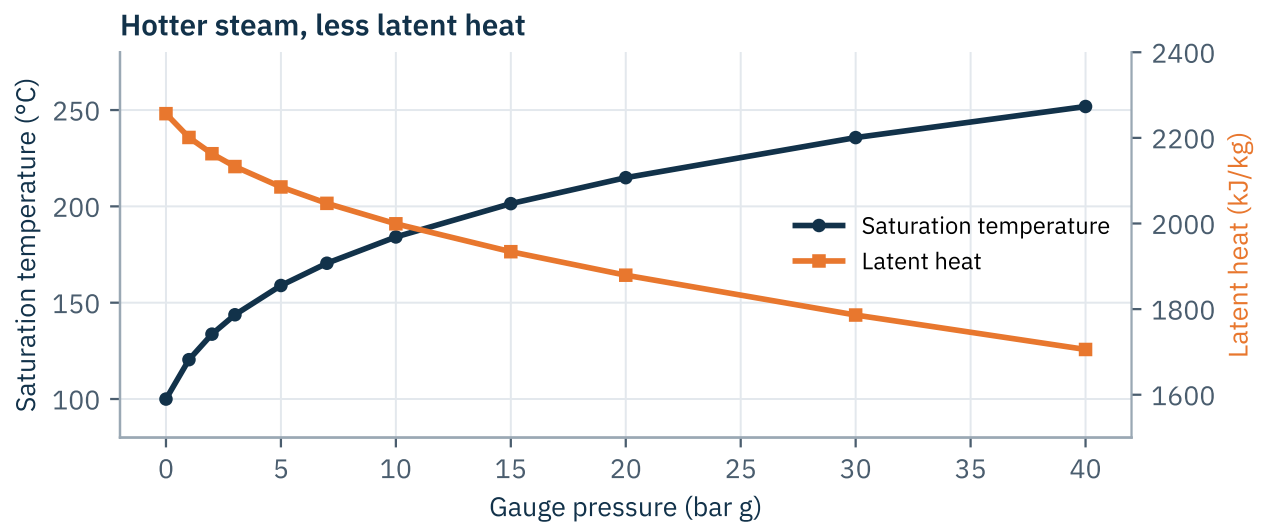


Figure 2.2 — Saturation temperature and latent heat against gauge pressure. Temperature rises steeply at low pressure; latent heat falls as pressure rises, so low-pressure steam delivers more heat per kilogram when it condenses.

Gauge pressure bar g (psig)	Saturation temp. °C (°F)	Liquid h kJ/kg	Latent heat kJ/kg	Steam h kJ/kg	Steam volume m³/kg	Steam density kg/m³
0 (0)	100.0 (212)	419.0	2,256.5	2,675.5	1.6733	0.60
1 (15)	120.4 (249)	505.6	2,201.0	2,706.5	0.8803	1.14
2 (29)	133.7 (273)	562.1	2,163.0	2,725.1	0.6033	1.66
3 (44)	143.7 (291)	605.2	2,133.0	2,738.2	0.4610	2.17
5 (73)	158.9 (318)	670.9	2,085.4	2,756.2	0.3149	3.18
7 (102)	170.5 (339)	721.3	2,047.1	2,768.4	0.2400	4.17
10 (145)	184.1 (363)	781.4	1,999.3	2,780.7	0.1772	5.64
15 (218)	201.4 (395)	858.8	1,934.1	2,792.9	0.1236	8.09
20 (290)	214.9 (419)	920.1	1,879.2	2,799.4	0.0949	10.54
30 (435)	235.7 (456)	1,017.1	1,786.2	2,803.3	0.0645	15.51
40 (580)	251.8 (485)	1,094.7	1,705.7	2,800.4	0.0485	20.61

Look at three things in the table:

- **Latent heat falls** with pressure: 2,163.0 kJ/kg at 2 bar g but 1,705.7 kJ/kg at 40 bar g. A kilogram of low-pressure steam condenses to give more heat than a kilogram of high-pressure steam.
- **Steam density rises** with pressure: 1.14 kg/m³ at 1 bar g against 20.61 kg/m³ at 40 bar g, 18.1 times more. That is why high-pressure steam can use smaller pipes (Chapter 11).

- **Steam is bulky next to water.** At atmospheric pressure, 1 kg of steam takes about 1,604 times the volume of 1 kg of water. A leak of liquid becomes a cloud, and condensing steam in a closed space makes a vacuum.

2.4 Wet steam and dryness

Steam leaving a boiler or a long pipe often carries tiny drops of water. The **dryness fraction** x is the mass of steam in each kilogram of the mixture. Wet steam has the enthalpy $h = hf + x \cdot hfg$. At 10 bar g and x = 5 per cent wet (x = 0.95), h = 2,680.7 kJ/kg, and the user loses 100.0 kJ/kg of latent heat compared with dry saturated steam. Drops also erode pipes and bends, and foul control valves. Superheat gives a safety margin: the steam can lose some heat on the way before it starts to condense.

ENGINEER'S CALCULATION CORNER **Worked example: heat needed for B-101's steam**

1. Steam at 40 bar g and 400 °C leaves B-101 with h = 3,212.6 kJ/kg (IAPWS-IF97).
2. Feedwater at 105 °C and the boiler pressure has h = 443.2 kJ/kg.
3. Heat to add = 3,212.6 − 443.2 = **2,769.4 kJ per kg of steam**.
4. For 1 t/h (0.2778 kg/s): 2,769.4 × 0.2778 = **769 kW** (2.62 MMBtu/h). For B-101's 50 t/h the steam alone takes 38,464 kW.
5. Check with the toolkit: the Boiler Efficiency and Fuel Consumption toolkit reports the same steam heat of 38,464 kW for its example case. The Utilities Cost Calculator toolkit holds the same IAPWS-IF97 steam tables as workbook formulas for up to six steam pressures.

FIELD CHECK **Reading a steam pressure and temperature pair**

What you see	What it may mean	First thing to check
Temperature equals the table value for the pressure	Saturated steam, dry or wet	Dryness: look for water in sample or separator
Temperature well above saturation	Superheated steam	Desuperheater setting if the user wants saturated
Temperature below saturation for the pressure	The reading is wrong (water, not steam) or there is air in the steam	Sensor position; air vents; trap operation
Pressure falls but temperature does not	Sensor lag or a long thermowell	Sensor response; compare with a second reading

Watch out — gauge and absolute pressure

Tables list absolute pressure (bar a) or gauge pressure (bar g). Gauge = absolute − 1.01325. Use the wrong one and a 10 bar g steam line becomes a 10 bar a line with a 6 K temperature error. Check the column heading every time.

TRY IT

Find the heat needed to turn 1 kg of water at 105 °C into steam at 40 bar g and 400 °C, then the heat per kg of 97 per cent dry steam at 10 bar g (x = 0.97). (Answer in Appendix F.)

FREE TOOLS **Do this chapter's calculation**

Free calculator
Steam tables (IAPWS-IF97) calculator
plantcalckit.com/tools/steam-tables/

Excel toolkit: Utilities Cost Calculator
(USD 79)
plantcalckit.com/shop/utilities-cost-calculator-excel/
Topics: The whole water chain · Steam at up to six pressures · Power from every source · Fair heat-recovery credit · Cooling water, air and nitrogen · Monthly data in, averages out

QUICK QUIZ

1. What is saturation?
2. Which is bigger at 10 bar g, the sensible heat from 20 °C to boiling or the latent heat?
3. What is the dryness fraction?
4. Why does latent heat fall as pressure rises?
5. How do you convert gauge to absolute pressure?

CHAPTER 3

Heat duty and steam consumption

A heat user does not care how steam is made. It cares how many kilowatts it needs. Turning that duty into tonnes of steam — and into a cost — is the most useful skill in this whole book, because it lets you check a meter, size a pipe or judge a project in two lines.

3.1 Duty: two simple formulas

Almost every duty comes from one of two formulas:

- **Sensible heat** (the temperature changes): **Q = ṁ × cp × ΔT**. Water has cp ≈ 4.18 kJ/kg·K. Oils and organic liquids are lower, often 1.8 to 2.5 kJ/kg·K; use your own data.
- **Latent heat** (a liquid boils or a vapour condenses): **Q = ṁ × λ**.

Units: with ṁ in kg/s and heat in kJ/kg, Q comes out in kW. 1 kW = 3,412 Btu/h = 0.003412 MMBtu/h.

3.2 From duty to steam

Steam gives heat by condensing. If the condensate leaves at saturation temperature (the usual simple assumption), each kilogram of steam delivers its latent heat *h*fg. So

ṁ steam = Q ÷ *h*fg

If the condensate leaves cooler than saturation — "subcooled" — the steam also gives up that extra sensible heat and less steam is needed. If the steam is superheated, add the superheat. The steam table of Chapter 2 gives *h*fg: 2,133.0 kJ/kg at 3 bar g and 1,999.3 kJ/kg at 10 bar g.

3.3 Site W's heat users

Site W has six streams (generic, generated for this book). Four are steam users, one is cooled by cooling water and one uses an electric heater.

Stream	What it does	Duty (kW)	Utility	Steam (t/h)
W-110	Heats 29.64 t/h (30 m³/h) of process water, 20 → 80 °C	2,066	LP steam, 3 bar g	3.49
Heater A	Heats 120 t/h of oil (cp 2.2 kJ/kg·K), 80 → 130 °C	3,667	MP steam, 10 bar g	6.60
Reboiler B	Boils 12 t/h of solvent (latent heat 330 kJ/kg, assumed)	1,100	MP steam, 10 bar g	1.98
Tank heating and tracing	Keeps lines and tanks warm	1,500	LP steam, 3 bar g	2.53
Product cooler	Removes heat from the product	1,800	Cooling water, 10 K rise	— (156 m³/h)
Electric heater	Small trim heater	150	Electricity	—

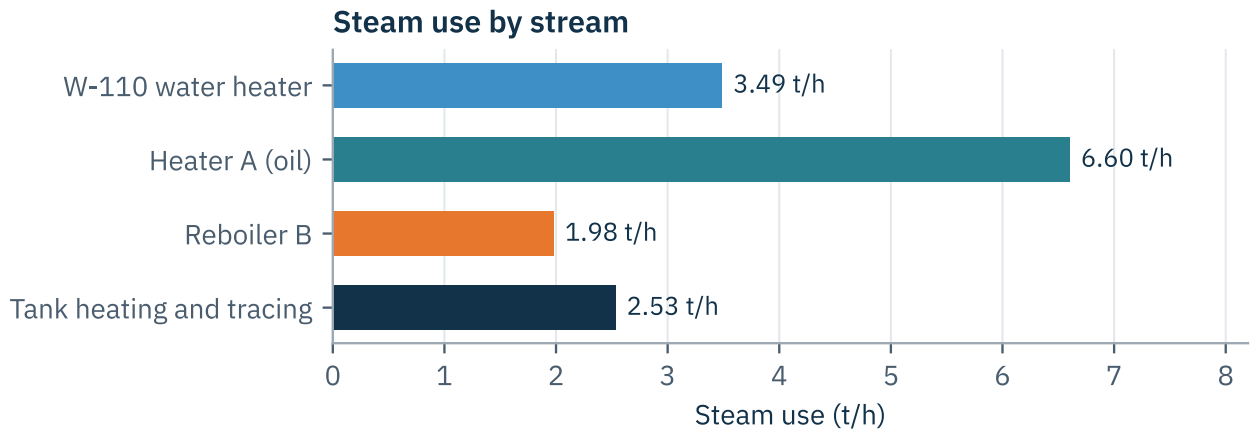


Figure 3.1 — Steam used by Site W's four steam streams. Heater A takes almost half of the 14.60 t/h.

ENGINEER'S CALCULATION CORNER **Worked example: steam for the water heater W-110**

1. Mass flow = 30 m³/h × 988.0 kg/m³ ÷ 3,600 = 8.2 kg/s (water density at the mean temperature of 50 °C from IAPWS-IF97).
2. Mean specific heat between 20 and 80 °C: 4.183 kJ/kg·K (from the steam-table enthalpies of liquid water).
3. Duty Q = 8.2 × 4.183 × 60 = **2,066 kW**.
4. Steam at 3 bar g: *h*fg = 2,133.0 kJ/kg, so steam = 2,066 ÷ 2,133.0 = 3.49 t/h.
5. If the condensate left the heater at 100 °C instead of saturation, it would give up another 185.9 kJ/kg: steam falls to 3.21 t/h, 8.0 % less. This is why good condensate return from heaters pays.
6. Over 8,000 hours the four steam streams carry 66,665 MWh of heat. The Heat Duty and Utility Consumption toolkit does this for up to ten streams and ten utilities, with cost per year.

3.4 Cost of the utilities

Duty only becomes a decision when you put a price on it. Using the steam costs worked out in Chapter 19 (USD 21.8 per tonne at 3 bar g, USD 22.2 per tonne at 10 bar g — illustrative), the steam streams cost: W-110 USD 608,614 a year, Heater A USD 1,172,371, Reboiler B USD 351,711, tank heating USD 441,774; together USD 2,574,470. The electric heater at an illustrative USD 100 per MWh costs USD 120,000. Notice that a little electric heater costs several times as much per unit of heat as steam does — usually a reason to look for a steam or hot-water alternative.

3.5 Heat recovery hint

Site W cools one stream (1,800 kW to cooling water) while heating others. Whenever the same plant both heats and cools, a heat exchanger between the two may pay. The cooler's duty (1,800 kW) is almost as large as W-110's (2,066 kW); if the product temperature is high enough, the product could warm the process water first. Feasibility depends on temperatures: the hot stream must stay hotter than the cold stream all along the exchanger (a "temperature cross" is not allowed), and the minimum difference decides the area. A pinch study is the proper tool; the toolkit only flags the opportunity.

FIELD CHECK **When a steam user is not getting its duty**

What you see	What it may mean	First thing to check
Outlet temperature low, control valve wide open	Not enough steam pressure, or heater fouled	Steam pressure at the heater; fouling
Condensate backs up in the heater	Trap too small, or back pressure too high	Trap capacity; return-line pressure (Chapter 14)
Steam use above calculated	Leaks, bypassed trap, or heater duty higher than design	Trap survey; flow meter calibration
Steam use below calculated	Meter low, or heat coming from another source	Meter; other heat sources

Watch out — mixing units

A duty in kW, a flow in t/h and a heat in kJ/kg look similar and are easy to mix. Write the units beside every number: kW = kJ/s; t/h × kJ/kg ÷ 3.6 = kW. The check "t/h × hfg ÷ 3.6" saves many errors.

TRY IT

Heat 15 t/h of water from 20 °C to 90 °C with 3 bar g saturated steam, condensate leaving at saturation. Find the duty in kW and the steam in t/h. (Answer in Appendix F.)

FREE TOOLS **Do this chapter's calculation**

Free calculator
Steam tables (IAPWS-IF97) calculator
plantcalckit.com/tools/steam-tables/

Excel toolkit: Heat Duty and Utility Consumption (USD 39)
plantcalckit.com/shop/heat-duty-and-utility-consumption-excel/
Topics: Up to 10 streams · 10 utilities · Your site data · Totals by utility · Feasibility checks · Heat recovery hint

QUICK QUIZ

1. Write the formulas for sensible and latent duty.
2. How is steam flow found from a duty?
3. Why does subcooled condensate reduce steam use?
4. What temperature condition must a heat recovery exchanger meet?
5. Which costs more per unit of heat, steam or an electric heater?

APPENDIX G

Sources

Every chapter was written in our own words from the published references below. No text, tables or figures were copied; all diagrams and charts are original PlantCalcKit artwork, and the charts were computed from the worked examples. Where a method follows a code or standard, the calculation is aligned with the publicly documented method; that is not a claim that any result meets the code. Book citations give title, edition and subject, not page numbers. **Edition caveat:** the edition named is the one the method was written from; editions of standards and handbooks change, so check the current edition before you rely on any equation, constant or limit for design, testing or a contract. Constants that are plant-specific or toolkit defaults (for example the 40 m/s screening velocity, the Souders–Brown constant K = 0.107 m/s, steel specific heat 0.49 kJ/kg·K and every price) are labelled as such in the text and are not taken from a standard.

General (all chapters)

- IAPWS-IF97, *Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam* (2007 revision) — all water and steam properties, evaluated with the open-source `iapws` implementation. Edition caveat: the 2007 revised release is the version used; check the IAPWS website for later releases.
- *Perry's Chemical Engineers' Handbook* (Green and Perry, eds), 8th ed., 2008 — general reference for steam, heat transfer, fluid flow and boiler topics. Edition caveat: the 8th edition is named; a later edition may have different section numbers.
- *Thermodynamics: An Engineering Approach* (Çengel and Boles), 9th ed. — steam properties, energy balances, nozzle flow and the throttling (isenthalpic) process.
- *Improving Steam System Performance: A Sourcebook for Industry* (US Department of Energy, Advanced Manufacturing Office), 2nd ed. — steam system practice, boiler, distribution, trap, condensate and heat recovery topics. Edition caveat: the second edition is named; DOE also publishes a series of Steam Tip Sheets, updated from time to time.
- NIST Special Publication 811, *Guide for the Use of the International System of Units* (2008 edition) — unit conversions.

Chapter 1 — Steam in the plant

- DOE Steam System Sourcebook (above) — the steam system as a whole: generation, distribution, end use and recovery.

Chapter 2 — Steam tables made simple

- IAPWS-IF97 (above) — saturation properties, enthalpy, specific volume, superheat.
- Çengel and Boles (above) — property tables, quality (dryness fraction), wet steam enthalpy.

Chapter 3 — Heat duty and steam consumption

- Çengel and Boles (above) — sensible and latent heat, steam for a duty.
- Perry's (above) — heat duty and utility consumption in process heating.

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