

The chapters at a glance

Beer – the oldest drink	21
1 Raw Materials	35
2 Malt Production	109
3 Wort Production	199
4 Beer Production (Fermentation, Maturation, Filtration)	367
5 Filling the Beer	537
6 Cleaning and Disinfection	691
7 Finished Beer	707
8 Small Scale Brewing	763
9 Waste Disposal and the Environment	783
10 Energy Management in the Brewery and Malting	797
11 Automation and Plant Planning	849

Contents

Beer – The Oldest Fermented Drink for the Common People	25
1 Raw Materials	39
1.1 Barley	39
1.1.1 Barley Cultivation and Varieties	39
- Barley Cultivation	39
- Barley Varieties	40
1.1.2 Barley Cultivation	41
1.1.3 Structure of the Barley Grain	42
- External Structure	42
- Internal Structure	42
1.1.4 Composition and Properties of the Components	44
- Carbohydrates	44
- Proteins	48
- Fats (Lipids)	50
- Minerals	51
- Other Substances	52
- Barley Enzymes	53
1.1.5 Barley Evaluation	55
- Hand Evaluation	55
- Physical and Chemical Examinations	57
- Physiological Examinations	58
1.2 Hops	59
- Growing Regions	59
1.2.2 Harvesting, Drying, Stabilizing Hops	62
- Harvest	62
- Drying	62
- Stabilizing the Hops	62
1.2.3 Hop Cone Structure	63
1.2.4 Composition and Properties of the Hops Components	63
- Bitter Substances or Hop Resins	63
- Hop Oil	64
- Tannins or Polyphenols	66
- Proteins	67
1.2.5 Hop Evaluation	67
- Hand evaluation of the Whole Cone Hops	68
- Bitter Substance Content	68
1.2.6 Hop Varieties	69
1.2.7 Hop Products	70
- Hop Pellets	71
- Hop Extracts	73

1.3	Water.....	77		
1.3.1	Water Cycle	78		
1.3.2	Fresh Water use in the Brewery	78		
1.3.3	Obtaining Water.....	79		
	- Extracting Groundwater	79		
	- Extraction of Spring Water	80		
	- Extraction of Surface Water.....	80		
	- Importance Private Water Supply ...	80		
1.3.4	Water Requirements	81		
	- Drinking Water Requirements.....	81		
	- Brewing Water Requirements	82		
	- Significance of Individual Ions.....	84		
1.3.5	Water Improvement Procedures	85		
	- Procedure to Remove Suspended Matter	85		
	- Removal of Dissolved Materials.....	86		
	- Improving the Residual Alkalinity of Water	87		
	- Water Sterilization	90		
	- Degassing of Water	91		
1.3.6	Possibilities for Saving Water	93		
1.4	Yeast	94		
1.4.1	Structure and Composition of the Yeast Cell	94		
1.4.2	Metabolism of the Yeast Cell	97		
1.4.3	Yeast Multiplication and Growth	98		
1.4.4	Characteristics of Brewing Yeasts ..	100		
	- Morphological Characteristics.....	100		
	- Physiological Differences	100		
	- Fermentation Technology Differences	100		
	- Systematic Classification	101		
1.5	Adjuncts	102		
1.5.1	Corn.....	102		
1.5.2	Rice	103		
1.5.3	Barley	104		
1.5.4	Millet and Sorghum	104		
1.5.5	Wheat	104		
1.5.6	Sugar	105		
1.5.7	Glucose Syrup	106		
1.5.8	Coloring Sugar (also Couleur)	106		
2	Malt Production	109		
2.1	Receiving, Cleaning, Grading, and Transfer of Barley	109		
2.1.1	Receiving the Barley.....	110		
	- Receiving from Trucks or Rail Cars	110		
	- Receiving from Ships	111		
2.1.2	Cleaning and Grading the Barley ...	111		
	- Barley Pre-cleaning	112		
	- Magnetic Devices	113		
	- Dry Destoner	114		
	- Deawner	114		
	- Grain Cleaner.....	115		
	- Barley Grading	116		
2.1.3	Transfer of Barley and Malt.....	120		
	- Mechanical Conveyors	120		
	- Pneumatic Conveyors	123		
2.1.4	Dust Removal Equipment	125		
	- Cyclones	125		
	- Dust Filters	126		
2.2	Drying and Storage of Barley.....	128		
2.2.1	Respiration of the Barley	128		
2.2.2	Drying the Barley	130		
2.2.3	Cooling the Barley	130		
2.2.4	Storing the Barley	131		
	- Storage in Silos	131		
	- Storage in Granaries	132		
	- Pest Infestations	133		
2.3	Steeping the Barley	134		
2.3.1	Processes During Steeping	134		
	- Water Uptake	134		
	- Oxygen Supply	137		
	- Cleaning	137		
2.3.2	Steeping Vessels.....	137		
2.3.3	The Steeping Process	142		
2.4	Germination of the Barley	144		
2.4.1	Processes Occurring During Germination	144		
	- Growth Processes	144		
	- Enzyme Formation	145		
	- Substance Conversion During Germination	147		
	- Conclusions for Performing Germination	154		
2.4.2	Germination Methods	154		
	- Floor Maltings	154		
	- Pneumatically Operated Malting Systems	155		
	- Carrying Out Germination	165		
	- Control of Germination	166		
2.5	Kilning the Malt.....	167		
2.5.1	Changes During Kilning	167		
	- Lowering the Water Content	167		

- Termination of Germination and Modification	167	2.9.1 Pilsner Malt (Pale Malt)	187
- Formation of Color and Flavor Substances (Maillard Reaction)	167	2.9.2 Dark Malt (Munich type)	187
- Formation of DMS Precursors and Free DMS During Kilning	169	2.9.3 Vienna Malt	188
- Influence of the Kilning Temperature and Duration	169	2.9.4 Brumalt/Melanoidin Malt	188
- Formation of Nitrosamines	170	2.9.5 Caramel Malt	188
- Enzyme Inactivation	171	2.9.6 Acid Malt	189
2.5.2 Structure of the Kiln	171	2.9.7 Short-Grown and Chit Malt	190
- Heating and Ventilation of Kiln	171	2.9.8 Smoked Malt	190
- Older Type Two-floor Kilns	174	2.9.9 Diastase Malt	190
- Kilns with Dumping Floors	174	2.9.10 Roasted Malt	190
- Horizontal Kilns with a Loader and Unloader	175	2.9.11 Roasted Malt Beer	190
- Vertical Kiln	176	2.9.12 Wheat Malt	191
2.5.3 Management of Kilning	177	2.9.13 Malt Extract	192
- Production of Pilsner Malt	178	2.9.14 Malt from Other Bread Cereals	192
- Production of Munich Malt	179	2.9.15 Sorghum Malt	193
- Unloading the Kiln	179	2.9.16 Usage of different types of malt for various types of beer	194
- Control of Kilning	179	2.10 Safety Precautions in Maltings....	196
2.6 Treatment of malt after kilning...	179	3 Wort Production	199
2.6.1 Cooling of the Cured Malt	179	3.1 Milling the Malt.....	199
2.6.2 Malt Cleaning	180	3.1.1 Pretreatment of the Malt	200
2.6.3 Malt Storage	180	- Removal of Dust and Stones	200
2.6.4 Malt Polishing	181	- Weighing the Grist	201
2.7 Yield During Malting	181	3.1.2 Basic Aspects of Milling	203
2.8 Malt Evaluation	181	3.1.3 Dry Milling	204
2.8.1 Hand Evaluation	181	- Six-Roller Mills	204
2.8.2 Mechanical Examinations	182	- Five-Roller Mills	206
- Grading	182	- Four-Roller Mills	206
- Thousand Kernel Weight	182	- Two-Roller Mills	206
- Hectoliter Mass	182	- Grist Mill Rollers	206
- Sinker Test (Floaters)	182	- Conditioned Dry Milling	208
- Glassiness	182	- Grist Case	209
- Friability	182	- Hammer Mills	209
- Acrospire Development	182	- Other Milling Systems.....	212
- Germination Capacity	183	3.1.4 Wet Milling	212
- Density	183	3.1.5 Steep Conditioning	214
- Carlsberg Calcofluor Method	183	3.1.6 Fine Comminution with Water	216
2.8.3 Chemical-technological Examinations	183	3.1.7 Evaluation of the Grist	217
- Water Content	183	3.2 Mashing	219
- Congress Mashing Method	183	3.2.1 Transformations During Mashing ...	219
2.8.4 Malt Supply Contract	186	- Purpose of Mashing	219
2.9 Special Malts and Malts from Other Cereals	187	- Properties of the Enzymes	219
		- Starch Degradation	220
		- Breakdown of the β -glucan	226
		- Breakdown of Proteins	230
		- Conversion of Fatty Acids (Lipids)	231

- Other Degradation and Breakdown Processes	233	- Zinc Content of the Wort	295
- Biological Acidification	233	- Copper Wort	295
- Composition of the Extract	237	3.4.2 Design and Heating of Wort Kettle	295
- Conclusions for Mashing Process..	239	- Brew Kettle with Direct Heating ...	296
3.2.2 Vessels for Mashing	239	- Brew Kettle with Steam Heating..	296
- Mash Vessels	239	- Wort Kettles with	299
3.2.3 Mashing-In	243	- High-Temperature Wort Boiling ...	307
- Mashing Process	243	- Energy-Saving Wort Boiling Systems	307
- Mashing-In Temperature	244	- Modern Wort Boiling Systems	310
- Mixing the Water and Malt Grist ..	245	- Dynamic Low-Pressure Boiling	311
3.2.4 Mashing Process	246	- Energy Consumption during Wort Boiling	320
- Parameters to Consider when Mashing	247	- Vapor Condensate Cooler	324
- Infusion Process	250	- Pre-Run Vessel	324
- Decotion Process	252	3.4.3 Wort Boiling Process	324
3.2.5 Mashing Duration.....	264	- Boiling the Wort	324
3.2.6 Control of Mashing	265	- Addition of Hops	325
3.2.7 Mashing Intensity	265	3.4.4 Monitoring the Casting Wort	329
3.3 Lautering	265	3.5 Brewhouse Yield	330
3.3.1 Mashing-In Liquor & Sparge Liquor ..	265	3.5.1 Calculating the Brewhouse Yield ...	330
3.3.2 Last Runnings	267	- Determining the Percent by Mass	330
3.3.3 Lautering with the Lauter Tun	268	- Determining the Mass of Extract per 1 hl Wort	332
- Structure of the Lauter Tun	268	- Converting the Hot Casting Wort Volume to Cold Wort Volume	335
- Design of Newer Lauter Tuns	268	- Calculating the Amount of Extract Obtained in the Brewhouse	336
- Operating Sequence when Lautering with a Conventional Lauter Tun ...	272	- Determining the Brewhouse Yield (A_y)	336
3.3.4 Lautering with the Mash Filter	275	3.5.2 Factors Affecting the Brewhouse	337
- Conventional Mash Filters	275	Yield	337
- Mash Filters Next Generation	277	3.5.3 Evaluating the Brewhouse Yield	338
3.3.5 Spent Grains	285	3.6 Brewhouse Equipment	338
- Transfer of Spent Grains	286	3.6.1 Number and Arrangement	338
- Spent Grain Analysis	286	of the Vessels	338
3.4 Wort Boiling.....	289	3.6.2 Vessel Size	339
3.4.1 Processes During Wort Boiling	289	3.6.3 Vessel Material	339
- Dissolution and Transformation of Hop Components	289	3.6.4 Production Capacity of the Brewhouse	339
- Precipitation of Protein	290	3.6.5 Special Brewhouse Types	340
- Evaporation of Water	290	- Brewhouses of Pub Breweries	340
- Wort Sterilization	291	- Integral Brewhouse	341
- Destruction of all Enzymes	291	- Research and Training Brewhouses	341
- Thermal Exposure of the Wort	292	3.7 Casting	342
- Lowering the pH of the Wort	292	3.8 Removal of the Hot Break	342
- Formation of Reducing Substances (Reductones)	292	3.8.1 Coolship	342
- Stripping of Volatile Flavor Substances	293		

3.8.2	Settling Tank	343	4.1.1	Yeast as the Brewer's Most Important Partner	369
3.8.3	Whirlpool	343	4.1.2	Metabolism of the Yeast.....	371
	- Operating Principle of Whirlpool ..	343		- Fermentation of Sugar	371
	- Whirlpool Design	344		- Protein Metabolism	376
	- Wort Clarification in Whirlpool	345		- Carbohydrate Metabolism	378
	- Clarification with the Clarisaver ...	346		- Mineral Metabolism	378
3.8.4	Separators	348	4.1.3	Formation and Breakdown of Fermentation By-products	380
	- Principle of Centrifugation	348		- Diacetyl (Vicinal Diketones)	381
	- Types of Centrifugal Separators (Centrifuges)	348		- Aldehydes (Carbonyles)	384
	- Design and Operation of Self-Cleaning Separators.....	349		- Higher Alcohols	384
	- Hot Wort Separation	351		- Esters	384
	- Removing the Hot Break With a Decanter.....	351		- Sulfur Compounds	386
3.8.5	Recovery of the Cloudy Wort	351		- Organic Acids	387
3.9	Cooling and Clarifying the Wort .	352		- Evaluation Criteria for Flavor Substances in Beer	387
3.9.1	Processes During Cooling	352	4.1.4	Additional Processes & Conversions	388
	- Wort Cooling	352		- Changes in the Composition of the Proteins	388
	- Formation and Optimal Removal of Cold Break	352		- Lowering of the pH Value	389
	- Changes in Wort Concentration ..	353		- Changes in the Redox Properties of Beer	389
3.9.2	Wort Cooling Equipment	353		- Changes in the Beer Color	390
	- Structure of Plate Heat Exchanger	353		- Precipitation of Bitter Substances and Tannins	390
	- Operating Principle of Plate Heat Exchanger	354		- CO ₂ content of the Beer	390
	- Advantages of the Plate Heat Exchanger	356		- Clarification and Colloidal Stabilization of the Beer	390
3.9.3	Basic Principles and Performance of Wort Aeration	357	4.1.5	Effects of Various Factors on Yeast	390
	- Wort Aeration Methods	357	4.1.6	Flocculation of the Yeast (Break Formation)	392
	- Timing of Yeast Aeration	359	4.1.7	Degeneration of the Yeast	393
3.9.4	Equipment for Cold Break Removal	359	4.1.8	Physiological Condition of Yeast	393
3.9.5	Wort Cooling Lines	359	4.2	Yeast Cultivated in Pure Form	395
3.10	Continuous Wort Production	360	4.2.1	Basics of Yeast Propagation	395
3.11	Process control in brewhouse	362	4.2.2	Extraction of Suitable Yeast Cells ...	396
3.12	Accident prevention in the brewhouse	363	4.2.3	Propagation in the Laboratory	396
3.12.1	Accident Prevention in the Mill	363	4.2.4	Yeast Propagation in the Brewery ..	398
3.12.2	Accident Prevention when Working in Vessels	363		- Pure Yeast Culture Plants	398
3.12.3	Accident Prevention when Working with Separators	364		- Optimized Yeast Management According to Back	402
4	Beer Production.....	369		- Single-Vessel Pure Culture Procedure	403
4.1	Changes During Fermentation and Maturation	369		- Open Yeast Propagation	404
			4.3	Conventional Fermentation and Maturation	406

4.3.1	Fermenting Tubs–Open Fermentation Cellar Equipment	406			
	- Fermenting Tubs	406			
	- Layout of the Open Fermentation Cellar	406			
4.3.2	Fermentation Cellar Yield	409			
4.3.3	Open Primary Fermentation Process ..	409			
	- Pitching	410			
	- Fermentation Management in the Fermenting Tub	412			
	- Attenuation	413			
	- Transfer Pumping from the Tun ...	416			
4.3.4	Yeast Collection in the Tun	418			
4.3.5	Processes During Beer Maturation in Conventional Tanks	419			
	- Saturation of the Beer with Carbon Dioxide under Positive Pressure	419			
	- Clarification of the Beer	420			
4.3.6	Equipment in Conventional Storage Cellars	420			
	- Storage Cellar Equipment	420			
	- Storage Tanks	420			
4.3.7	Storage in Conventional Tanks	422			
	- Transfer Pumping	422			
	- Pressure Regulation Bunging	423			
4.3.8	Storage Vessel Tapping	424			
	- Establishing the Connection	424			
	- Pressure During Tapping and Emptying	424			
4.3.9	Drawing Off from Conventional Tanks	425			
	- Blending Unit	425			
	- Pressure Regulator	425			
	- Recovery of Yeast Beer	425			
	- Deep Cooling of the Beer	425			
	- Fore- and Post-Run	426			
4.4	Fermentation/Maturation in Cylindroconical Tanks (CCTs)	426			
4.4.1	Construction and Installation of Cylindroconical Tanks	426			
	- Construction, Shape and Material of the CCT	426			
	- Size of CCT	427			
	- Installation and Arrangement of the CCTs	429			
4.4.2	Cylindroconical Tank Fittings	430			
	- Control and Operating Elements and Safety Fittings	430			
	- Cooling of the CCT	438			
	- Possible Methods for Controlling and Automating Cooling	444			
4.4.3	Fermentation and Maturation in a Cylindroconical Tank	447			
	- Special Points to Consider Fermen- tation and Maturation in CCTs	448			
	- Cold Fermentation – Cold Maturation	451			
	- Cold Fermentation with Specific Maturation in a CCT	452			
	- Warm Fermentation Without Pressure – Cold Maturation	452			
	- Pressure Fermentation	453			
	- Cold Fermentation – Warm Maturation	453			
	- Cold Primary Fermentation with Programmed Maturation	453			
	- Warm Primary Fermentation with Normal or Forced Maturation	454			
4.4.4	Yeast Collection from the CCT	454			
	- Yeast Collection Time	454			
	- Yeast Collection Methods	456			
	- Treatment and Storage of the Yeast Crop	456			
	- Inspection of the Yeast Crop	458			
4.4.5	Beer Quality Before Filtration	459			
4.4.6	Beer Recovery from Surplus Yeast (Tank- Bottom Beer, Yeast Beer)	459			
	- Separation by means of Sedimen- tation or Filter Pressing	459			
	- Yeast Separation	459			
	- Beer Recovery Using a Decanter ...	460			
	- Membrane Filtration of the Yeast	461			
	- Treatment of the Beer from Surplus Yeast (Yeast Beer)	462			
4.4.7	CO ₂ Recovery	463			
4.4.8	Immobilized Yeast	465			
4.5	Beer Filtration	466			
4.5.1	Filtration Methods	467			
	- Separation Mechanisms	467			
	- Filter Medium Carriers	468			
	- Filter Aids	468			
4.5.2	Filter Designs	472			
	- Mass Filters	472			
	- Precoat Filters	472			

- Layer Filters (Frame Filter)	486	5 Filling the Beer	539
- Membrane Filter	487	5.1 Filling Returnable Glass Bottles	539
- Multi Micro System	488	5.1.1 Returnable Glass Bottles	539
- Filtration Applications	488	- Advantages and Disadvantages of	
- Kieselguhr-Free Beer Filtration	488	Glass Bottles	539
4.6 Beer Stabilization.....	496	- Glass Bottle Production	539
4.6.1 Biological Stabilization of Beer	496	- Bottle Shapes	539
- Pasteurization	497	- Bottle Color.....	541
- Flash Pasteurization (HTST)	497	- Surface Treatment	541
- Hot Filling of Beer	499	- Scuffing	542
- Pasteurization in Tunnel Pasteurizer	499	- Bottle Aftercoating	542
- Cold-Aseptic Treatment of the		- Light Glass Returnable Bottles	542
Beer	500	- Process Steps in the Filling of	
4.6.2 Colloidal Stabilization of Beer	501	Returnable Glass Bottles	542
- Nature of Colloidal Hazes	501	5.1.2 Cleaning Returnable Glass Bottles ..	542
- Improving the Colloidal Stability		- Sorting Empties.....	543
of Beer	502	- Factors Influence Bottle Cleaning ...	543
- Technological Measures for Improving		- Bottle Washing Machines	544
Colloidal Stability.....	502	- Cleaning Solution	558
- Addition of Stabilizing Agents	503	- Cleaning and Maintenance Work	
- Dosing with Downstream Hop		on the Bottle Cleaning Machine ..	563
Products	510	- Offloading New Glass Bottles and	
4.6.3 Filtration Plant	511	Cans	563
4.6.4 Flavor Stability	513	5.1.3 Inspection of the Cleaned Returnable	
- Aging Process	513	Glass Bottles	564
- Factors to Promote Flavor Stability	515	5.1.4 Bottle Filling	570
- Measures to Avoid Oxygenation		- Principles of Filling	570
During Filtration and Filling	516	- Principles of Bottle Filling Machine	
- Measures to Prevent Negative Influences		Design	572
on the Flavor Stability After Filling	517	- Key Assemblies of Bottle Filling	
4.7 Carbonation of the Beer	519	Machines	573
4.8 Special Beer Production Methods	520	- Construction and Mode of Operation	
4.8.1 High-Gravity Brewing	520	of the Filling Valves	576
4.8.2 Ice Beer Production	523	- High-pressure Injection	588
4.8.3 Processes for Removing Alcohol	525	5.1.5 Closing the Bottles	588
- Membrane Separation Process	525	- Closing with Crown Corks	589
- Thermal Process/Distillation	529	- Closing with a Swing Stopper	593
- Suppression of Alcohol Formation	532	5.1.6 Cleaning the Filler and Closer	594
4.9 Accident Prevention During Fermenta-	534	5.1.7 Inspection of the Filled and Closed	
tion, Maturation, and Filtration ...	534	Bottles	598
4.9.1 Risk of Accidents due to Fermentation		- Filling Height Verification	598
Carbon Dioxide	534	- Oxygen in the Bottle Neck	600
4.9.2 Work in Pressure Vessels	535	5.1.8 Pasteurization in Bottles	602
4.9.3 Working with Kieselguhr	536	- Basics of Pasteurization in Bottles	602
4.9.4 General Accident Prevention		- Essential Components of the Tunnel	
Information	536	Pasteurizer	603
		- Safety Measures During	

Pasteurizing	604	5.5.7	Cleaning the Can Filler and Closer ..	648
5.1.9 Labeling and Foiling the Bottles	605	5.5.8	Widgets	648
- Labels and Foils	605	5.5.9	Inspection of the Filled Cans	649
- Label Adhesive	606	5.5.10	Pasteurization of Cans	650
- Basic Principle of Labeling	608	5.5.11	Wraparound Labeling of Cans	650
- Labeling Machine Designs	609	5.5.12	Dating the Cans	651
- Head Folding with Foils	610	5.6	Filling into Casks, Kegs, Party Casks, and Large Cans.....	652
- Dating the Labels	610	5.6.1	Wooden Barrels and Barrel Filling ..	652
5.2 Particularities when Filling Non- returnable Glass Bottles	612	5.6.2	Kegs and Fittings	655
5.2.1 Offloading New Glass Bottles	612	- Material, Shape, and Size of Keg	655	
5.2.2 Rinsing (Flushing)	612	- Keg Fittings	656	
5.3 Filling PET Bottles	613	- Plastic Kegs	656	
5.3.1 PET Bottles	613	5.6.3	Keg Cleaning and Filling	657
- Structural Properties of PET	613	- Keg Cleaning	658	
- Barrier Properties of PET	614	- Keg Filling	658	
- Barrier Technologies	614	5.6.4	Keg Plants	660
- Importance of the Scavenger	616	5.6.5	Filling Small and Party Kegs	660
5.3.2 Production of PET Bottles	617	5.6.6	Filling Large Cans	661
- Manufacturing the Preforms	617	5.7 Transportation and Packaging ...	662	
- Stretching and Blow-molding PET Bottles	617	5.7.1	Transport Containers	662
- Inspection of the Produced PET Bottles	618	5.7.2	Treatment of Plastic Crates	664
- Rinsing New Bottles	618	- Rejecting Third-party and Damaged Crates and Bottles	664	
5.3.3 Transporting PET Bottles	618	- Washing the Crates	665	
5.3.4 Filling PET Bottles	620	- Crate Magazine	665	
5.3.5 Closing PET Bottles	620	5.7.3	Transport Technology	666
- Plastic Screw Closures	620	- Bottle and Can Transport	666	
- Aluminum Roll-on Caps	622	- Container Transport	670	
5.3.6 Labeling PET Bottles.....	624	5.7.4	Packing Technology	671
5.4 Filling Plastic Bottles as Returnable Bottles.....	625	- Packing Head and Packing Tulips..	671	
5.4.1 PEN/PLA	625	- Packer Types	672	
5.4.2 Cleaning of Returnable Plastic Bottles	626	5.7.5	Palletizing and Depalletizing Equipment	677
5.4.3 Foreign Substance Inspection	626	- Robot Technology	677	
5.5 Filling in Cans	631	- Design and Function of the Palletizers and Depalletizers	677	
5.5.1 Cans and Can Closures	631	- Stacking Full Package Pallets	680	
5.5.2 Storing, Depalletizing, and Offloading the Empty Cans	634	- Pallet Transport Systems	680	
5.5.3 Inspection of the Empty Cans	635	- Pallet Set Positions	680	
5.5.4 Rinsing the Cans	635	- Infeed and Discharge Equipment ..	680	
5.5.5 Filling of the Cans	636	- Pallet Magazines	681	
- Mechanical Can Fillers	637	- Pallet Inspection	681	
- Can Filler with Volumetric Filling ..	639	- Securing Pallets	681	
5.5.6 Closing the Cans	646	- Palletizing in Keg Filling	682	
		5.8 Complete Filling Plants	683	
		5.9 Beer Loss	687	

5.9.1	Calculating the Amount of Sales Beer Produced.....	687	- Kölsch	729
5.9.2	Stock Taking and Conversion to Sales Beer	687	- Ale	729
5.9.3	Calculation of the Volume Loss	689	- Stout	730
5.9.4	Calculation of Malt Usage in kg Malt/hl Sales Beer	690	- Porter	730
5.9.5	Importance of the Loss and Ways to Reduce It	690	- Belgian Beer Types	730
6	Cleaning and Disinfection	693	7.3.2	Bottom Fermented Beer Types
6.1	Materials and their Behavior Towards Cleaning Agents	693	- Pilsner Type Beers	731
6.1.1	Aluminum Vessels	693	- Lager Beer/Full Beer	732
6.1.2	Chrome-Nickel Steel Vessels, Pipes, and Fittings	694	- Export	733
6.1.3	Hoses and Seals	696	- Black Beer	733
6.2	Cleaning Agents	697	- Festbier	734
6.3	Disinfectants	698	- Ice Beer	734
6.4	Cleaning and Disinfection using a CIP System	700	- Märzen	734
6.5	Cleaning Procedure	705	- Bock Beer.....	734
6.6	Mechanical Cleaning	706	- Double Bock Beer.....	735
6.7	Monitoring of Cleaning and Disinfection	707	- Alcohol-Free Beer	735
6.8	Occupational Health and Safety for Cleaning and Disinfection	707	- Low-Carb Beer (Diet Beer)	736
7	The Finished Beer	709	- Light Beer	737
7.1	Beer Ingredients	709	- Malt Drink	737
7.1.1	Components of Beer	709	- Other Special Beer Types	738
7.1.2	Beer and Health	712	- Mixed Beer Beverages	738
7.2	Taste and Foam	713	7.3.3	Trends Regarding the Development of Beer Types not Corresponding to the Purity Law
7.2.1	Beer Taste	713	7.4	Quality Testing
- Beer Aroma	713	7.4.1	Tasting the Beer	744
- Palatefulness	716	7.4.2	Microbiological Testing	745
- Carbonation	716	7.4.3	Beer Analysis	749
- Bitterness of the Beer	717	- Analysis of the Original Gravity	749	
7.2.2	Beer Foam	717	- Measurement of Beer Color	753
7.3	Types of Beer and their Particularities	721	- Measurement of the pH Value	753
7.3.1	Top Fermented Beers	721	- Measurement of the Oxygen Content in Beer	754
- Special Features of Top Fermentation	721	- Measurement of the Diacetyl Content in Beer	755	
- Wheat Beer	724	- Measurement of Head Retention .	755	
- Berliner Weisse	728	- Measurement of the Carbon Dioxide Content	756	
- Altbier	728	- Measurement of Bitterness Units .	757	
		- Measurement of the Haze Tendency	757	
		- Filterability of the Beer	758	
		- Other Tests	758	
		7.5	Process Measurement and Analysis Technology	759
		7.5.1	Temperature Measuring Devices	759
		7.5.2	Flow Meters	759

7.5.3	Filling Level Meters	760	9.3.1	Spent Grain and Spent Hops	795
7.5.4	Density Meters	760	9.3.2	Trub	796
7.5.5	Optical Online Measuring Technology.....	761	9.3.3	Surplus Yeast	797
7.5.6	Oxygen Meters	763	9.3.4	Kieselguhr Sludge	797
7.5.7	pH Value Meters	763	9.3.5	Used Labels	797
7.5.8	Conductivity Meters	764	9.3.6	Broken Glass	798
7.5.9	Threshold Value Probes	764	9.3.7	Beer Cans	798
7.5.10	Pressure Meters	764	9.3.8	Minor Sources of Waste	798
8	Small Scale Brewers	767	9.4	Emissions	798
8.1	Pub Brewery (brew pub)	768	9.4.1	Dust and Dust Emissions	798
8.1.2	Considerations for Planning a Pub Bre- wery.....	770	9.4.2	Brewhouse Emissions	798
8.2	Microbrewery	774	9.4.3	Exhaust Gas Emissions	798
8.3	Contract Brewer	776	9.4.4	Sound Emissions	798
8.4	Home Brewer	776	9.5	Recycling PET Bottles	799
8.4.1	The Legal Side of Hobby Brewing ...	776	9.5.1	Inspecting the PET Recyclate	800
8.4.2	Procuring the Raw Materials	776	10	Energy Management in the Brewery and Malting.....	801
8.4.3	Malt Production on a Small Scale	777	10.1	Energy Requirements in Malt and Beer Production	801
8.4.4	Beer Production for the Home Brewer	778	10.2	Steam Boiler Systems	802
	- Specifications	779		- Fuels	802
	- Calculating the Bulk	779		- Steam	803
	- Calculation of the Mashing-In Liquor.....	782		- Steam Boilers	805
	- Calculating the Total Mash.....	782		- Steam Engines	809
	- Lautering.....	783		- Combined Heat and Power Plants (CHP)	810
	- Calculation of the Sparge Liquor ..	783	10.3	Refrigeration Plants	812
	- Wort Boiling	784	10.3.1	Refrigerants and Cooling Agents ...	812
9	Waste Disposal and the Environment.....	787		- Refrigerants	812
9.1	Environmental Law	788		- Cooling Agents	813
9.2	Wastewater	788		- Operating Principle Refrigeration ..	813
9.2.1	Wastewater Costs	788	10.3.2	Compression Refrigeration Plants ..	817
9.2.2	Definition of Wastewater Terms	790		- Operating Principle	817
9.2.3	Wastewater Treatment	791		- Evaporator	819
	- Aerobic Wastewater Treatment Plants	791		- Compressors	819
	- Anaerobic Wastewater Treatment Plants	792		- Condensers (Liquefiers)	821
	- Amount and Composition of Brewery Wastewater	793		- Control Valve	822
	- Wastewater Treatment with Mixing and Equalizing Tanks	793		- Ice Water Storage System	823
9.3	Residues and Waste	795	10.3.3	Absorption Cooling Machine	824
			10.3.4	Space and Liquid Cooling	824
				- Cooling of Conventional Fermentation and Storage Cellars	825
				- Modern Refrigeration Plants	826
				- Liquid Cooling	826
			10.3.5	Advice for the Economical Operation of Refrigeration Plants	829

10.4 Electrical Systems	830		
10.4.1 Supply of Electrical Energy	830		
10.4.2 Power Factor $\cos \phi$	831		
10.4.3 Transforming the Electric Current ..	833		
10.4.4 Safety Measures	833		
10.4.5 Information Concerning the Economical Use of Electrical Energy	834		
10.4.6 Other Energy Sources	834		
10.5 Pumps, Fans, and Compressors ..	835		
10.5.1 Pumps	835		
- Rotary Pumps	835		
- Positive Displacement Pumps	838		
- Dimensioning of Pumps	842		
- Speed Control of Pumps	842		
- Lubricative Ring Seal	843		
10.5.2 Fans and Compressors.....	844		
- Fans and Blowers	844		
10.5.3 Compressed Air Systems	844		
- Air Compressors.....	845		
- Air Dryers	848		
- Pressure Tanks	849		
- Compressed Air Network	849		
- Air Filters.....	850		
 11 Automation and Plant Planning ...	 853		
11.1 Notes about the Use of Measurement and Control Technology	853		
11.1.1 General Information	853		
11.1.2 Requirements Concerning the Measu- rement Uncertainty of the Measuring Technology Used	853		
11.1.3 Requirements for Installation Location and Cleaning/Disinfection	854		
11.1.4 Operational Reliability and Plant Safety Requirements	856		
11.1.5 Maintenance and Upkeep Requirements	856		
11.1.6 Requirements for Automatic Controls	857		
11.2 Plant Planning	859		
11.2.1 Introduction	859		
- General Planning Considerations	859		
- General Information About the Planning Process	860		
11.2.2 Basic Aspects of Plant Planning	862		
11.2.3 Different Procedures for Plant Planning and Realization	864		
		11.2.4 Important Documents and Documentation in Plant Planning ...	865
		- General Information	865
		- The Procedure Scheme	866
		- The Basic Mimic Diagram	868
		- The Procedural Mimic Diagram	868
		- The Piping and Instrumentation Mimic Diagram	868
		- Piping and Assembly Plans	871
		- The Process Description	871
		- The Design of Implementation Documents	872
		11.2.5 Notes on Contract Design	873
		11.2.6 Commissioning and Performance Run	874
		11.2.7 Project Conclusion	874
		11.2.8 Project Documentation	875
		11.3 Plant Design and Requirements .	876
		11.3.1 General Information	876
		11.3.2 Requirements for the Automation of Modern Plants	876
		11.3.3 Hygienic Design of Pipework and Equipment	876
		11.3.4 Operational Safety Requirements for Plants	877
		- Media Separation	877
		- Protecting the Plant Against Prohibited Pressures	879
		11.3.5 Notes on the Design of Pipework ...	880
		- General Information	880
		- Pipe Connections	880
		- Installing Pipework and Designing Pipe Holders	882
		- Flow Velocity in Pipework/Pressure Losses	884
		- Measures Against Water Hammer and Vibrations	887
		- Venting Pipework, Oxygen Removal	887
		- Design of Heat Insulation for Pipework	888
		- Design of Pipe Outlets	888
		- Protecting Pipework Against Frost and Plugging	888
		- Dead Spaces in Pipework	889
		- Steam Pipes	889
		11.3.6 Notes on Pipe Connection, Use of Fittings, and Sample Collection	889

- General Information 889
- Manual Connecting Technique 890
- Fixed Piping 890
- Fittings for Pipes and
Plant Components 891
- Sampling Fittings 893
- Fitting Designs 894
- 11.3.7 Notes on the Design and Operation of
CIP Stations – Requirements for
Automatic Cleaning and Disinfection 896
- 11.3.8 Notes Regarding the Storage of
Chemicals 898
- 11.3.9 Notes Regarding the Surface Quality
of Machines and Apparatuses 898

Appendix

- Conversion of legally defined and commonly
used measurement units 901
- List of advertisers 904
- Reference to diagrams and documents
used in this book 905
- Literature references 909
- Index 920