German Brewing between 1850 and 1900

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This article tries to shed some light on German brewing as it was practiced in the later half of the 19th century. It is largely based on the description of the brewing process as it is found in various books of that time. In particular the Brockhaus Konversationslexikon (conversation encyclopedia) of 1898 and the book Chemie für Laien (layman chemistry). Although neither of them are brewing textbooks, since they were targeted at the curious and affluent part of the public, their description of the brewing process is surprisingly detailed and can only be covered in excerpts in this article. The actual details of the brewing practice of a particular brewery were a well guarded secret that was passed on from generation to generation and rarely published in textbooks. Brewers back than had only a limited knowledge of the science behind brewing and once they found a way that worked they made sure that a competing brewery would not benefit from that knowledge.

The article has been augmented with photos taken at the Bavarian Brewing Museum in Kulmbach (Germany) and the Bauereimuseum at the Maisel's Brewery in Bayreuth (Germany). In addition to that interesting drawings have been taken from various books printed during that time.

To put the article into context, here are some milestones in brewing history that happened around that time:

- 1842 - Joseph Groll brews the first Pilsner at the then called *Bürgerbrauerei* (citizens brewery) in Pilzen
- 1860 - Luis Pasteur discovers that fermentation is brought on by yeast which is a living thing.
- 1874 - Carl von Linde completes the first ice machine. This was at the Spaten brewery in Munich, Germany

The following outline of the brewing process is taken from the book "Chemie fuer Laien" (layman chemistry) which was published in 1860. Occasionally I'll add comments which will be set in *italic*. Native German brewing vocabulary will also be set in *italic* and a fitting translation may be provided in parenthesis. While this book was published in Berlin, which was in the Prussian part of Germany it does make many references to the Bavarian style of brewing:

The brewing process consists of 3 main parts: malting, wort production and fermentation. Only 3 ingredients are used in brewing: water, malt and hops. *Luis Pasteur discovered yeast in the late 1860s, which means that this book was written without the knowledge of yeast although later in this book the author does mention yeast and it being a fungus. Some other books from the same time refer to the yeast as "ferment" and the addition of "ferment" to the wort* At this time even many brew masters strongly believed that only barley can be used in brewing and "that every one who says something else is a fool and who actually believes it is an even bigger fool". But in fact wheat and occasionally oat and rye were malted and could be used as well.

Malting

Malting is nothing more than the germination of the grain and its interruption at the right time. Finding "the right time" is the sign of a skilled brew master. And now that we have the thermometer it has become child's play compared to past times where the bare hand was used to measure the temperature *At this time malting was not as separated from brewing as it is today and most breweries would include malting facilities in which the malt for the beer was made.*

Steeping

Malting itself consists of three steps: steeping, germination and kilning. For the first step a wooden or stony vessel of a size that matches the needs of the brewery is used. This is the *Quellbottich* or *Malzstein* (steeping tun, malt stone or just steep). It's better to make it of stone than of wood as stone vessels are nearly indestructible and don't give off any flavors to the malt. The *Malzstein* is filled to its half with clean and soft river water and the grain is added. It's important that this malt comes from a single source. Otherwise they may behave quite differently in the *Quellbottich*. *Back then they already realized that the growing conditions of the malt have a significant effect on the speed at which it germinates. If a mix was used some of the malt may become overmodified while the other part is still undermodified.*

After the grains have been added to the water, such that the water stands about 6 inches above it, it is well stirred with paddles. Blind grains will immediately rise to the surface and have to be removed since they are not able to germinate and would give the resulting beer a bad taste. It takes about 6 hours to remove everything from the grain which hasn't many uses except for chicken feed. While this is done the water becomes very cloudy and has to be replaced. This has to happen every 12 hours in the summer and ever 24 hours in the winter. Once the water runs clear and colorless the changing of the water stops.

Young and fresh barley malted in the summer takes about 2 to 2 1/2 days until it is fully swollen. Old barley takes up to 4 days in the summer and may take up to 6 and more days in the winter when the temperatures are barely above 8C (46F).

But this process of steeping in tuns leads to the loss of dextrin and sugar (*The author actually wrote "rubber" and sugar. From the use of "rubber" in later sections of this book I gather that "rubber" refers to unfermentable sugars*) which is why the Bavarian style of malting only steeps the grain until all the blind kernels, dirt and dust have been removed. Then the water is drained and the malt is shoveled onto the *Malztenne* (malting floor or just floor) and left to dry on the surface of the pile. After that it is regularly moistened with a watering can and turned. The amount of water is just enough such that none of it runs off the grain onto the floor. All this water will be taken up by the grain and it swells fully.

The test if the malt has fully swollen is done by holding one tip of the grain between thumb and index finger and squeezing it together. If the other end breaks open and the contents of the grain are pushed out it has reached the desired state.

Germination

Germination is the step that follows the steep. It happens on the *Malztenne* which has an even floor without gaps or holes in which grains could hide or the shovel could get caught at. Its size is such that about 3 square feet of floor are available for each shovel of grain. The malt is brought onto the *Tenne* in a rectangular pile that stands about 6 inches high and is left as is until the top doesn't feel wet anymore and the tips of the grains show a little white spot which is the start of the germination. Now the grain is brought to the actual germination phase and for that is shoveled onto a pile that stands about 2 feet high in the winter and about 1 1/2 feet in the summer. The actual height depends on the temperature of the *Tenne* the higher it is the lower the piles will be. It is desirable to have an internal grain pile temperature of about 12 to 15C. This requires larger piles in the winter and lower ones and increased ventilation in the summer. The best seasons for malting are spring and fall as the ambient temperatures are optimal and it is suggested that a brewery should malt all the malt needed during these seasons.

The pile now starts to sweat and emits an apple like aroma. At this stage the thermometer shows a temperature of 5 to 8 C above ambient and if the pile were left as is the germination would proceed with an immense speed. As soon as the rootlets become visible the malt pile is spread out to slow down the germination. In this process the wet and warm grain from the center of the pile is moved outward covering the grain that has so far been on the outside. This cools down the grain from the center and warms the grain from the outer regions. The pile is then left as is until further signs of rootlet growth are visible after which the process of turning the malt is repeated. This is continued until the rootlets are as long as the grain (in case of wheat) or about one quarter longer (in case of barley). When the desired length of the rootlets is reached the germination process is interrupted by spreading the malt on the floor of the *Malztenne* which prevents further warming.

This process takes about 14 days. In order for germination to be even among the malt the brew master has to pay close attention to the temperature of the malt pile. It should never exceed 25 C and that only when the pile is still tall. The highest temperature tends to occur 4 days after the malt has left the steep.

The goal of malting is to convert as much of the flour in the grain into sugar which is what the germination process accomplishes. *Obviously this is not completely true as we know now. Malting is for the development of enzymes and cytolosis, which is the degradation of the cell wall structure in the endosperm.*

During germination sugar is formed but only as much as the sprouting germ needs. However, the brewer wants to convert the complete starch content to sugar before the sprout uses it all. This is why he lets the conversion process start but interrupts it as soon as he thinks that the spout is consuming it.

The views of different brewers about one or the other aspect of steeping and germination are widely different. For example Bavarian brewers prefer the method of steeping on the *Tenne* through sprinkling with water while others completely reject this method. Some say that if the upper layer of malt dries out during the germination process it is ok to sprinkle warm water onto the pile while others believe that this should never been done because of its detrimental effect on the beer quality and that it is better to cover the drier malt with more moist malt. *Back then brewing science has not evolved yet and brewers knew to stick with what has worked for them in the past.* Another example involves the length of the germination process. Some prefer a longer germination because it results in nice looking bright beers while others prefer a shorter germination because it results in more robust tasting beers. But most likely the length of the Germination process has no effect and it depends on the type of grain that is used. *Now we know that the length of the germination process does affect the clarity of the beer. Longer germination leads to higher modified malts which will lead to less haze forming proteins in the final beer. But such malts are also known to produce thinner and less robust tasting beers.*

The transformation of grain into malt causes the transformation of starch into sugar. This is brought on by a peculiar compound that is present in the germination point of each of these grains. The French chemists Payen and Persoz discovered this compound and called it *Diastas* from the Greek word Diastatsis which means expansion or splitting of matter. This *Diastas* is contained in a much larger amount in malt than what is needed to convert its starch into sugar and can therefore be used to convert additional amounts of unmalted grain. *This is where we get the word diastatic power from. Back then they knew that there is something in malt that converts the starches and they knew how to get it but they didn't know about the various enzymes that make up the Diastas.*

Drying and Kilning

The drying of the malt happens on the *Schwelkboden* or *Welkboden* (lit. wilting attic). This is a well ventilated room about five to six times the size of the *Malztenne*. The malt is spread on its floor to stand at most 1 1/2 inches high. It is left there to cool and loose its moisture. It's meant to dry and to wilt. For this purpose the room has ventilation openings that are close to the floor such that the air can easily flow across the layer of malt. The malt is turned six to eight times per day and the dried malt is called *Luftmalz* (air malt). 100 pound barley yield about 92 pound *Luftmalz*. 2 to 3 pound are lost during steeping, 1 1/2 to 2 pound are lost during the germination process and the rest are rootlets that broke off when the malt was germinating on the *Tenne.*

But only rarely is malt used it is air dried form. Generally it is artificially dried in the so called *Darre* (kiln) which is a device that allows the removal of additional moisture through increased temperatures. It is commonly thought that the purpose of the *Darre* is to give the malt a desired level of dark color. But if malt is roasted so dark that the color of the beer is affected, the malt would be lost. The length of the boil and the associated transformation of sugar into caramel are giving the beer its color. *This is an interesting statement. Not only does the author think that kilning malt too strongly would waste it but he also makes a reference that it was common practice to control the beer color though the length of the boil. Now we know that the kilning temperature used has a significant effect on the character of the beer and that this way of controlling the beer color is better than extremely long boils*

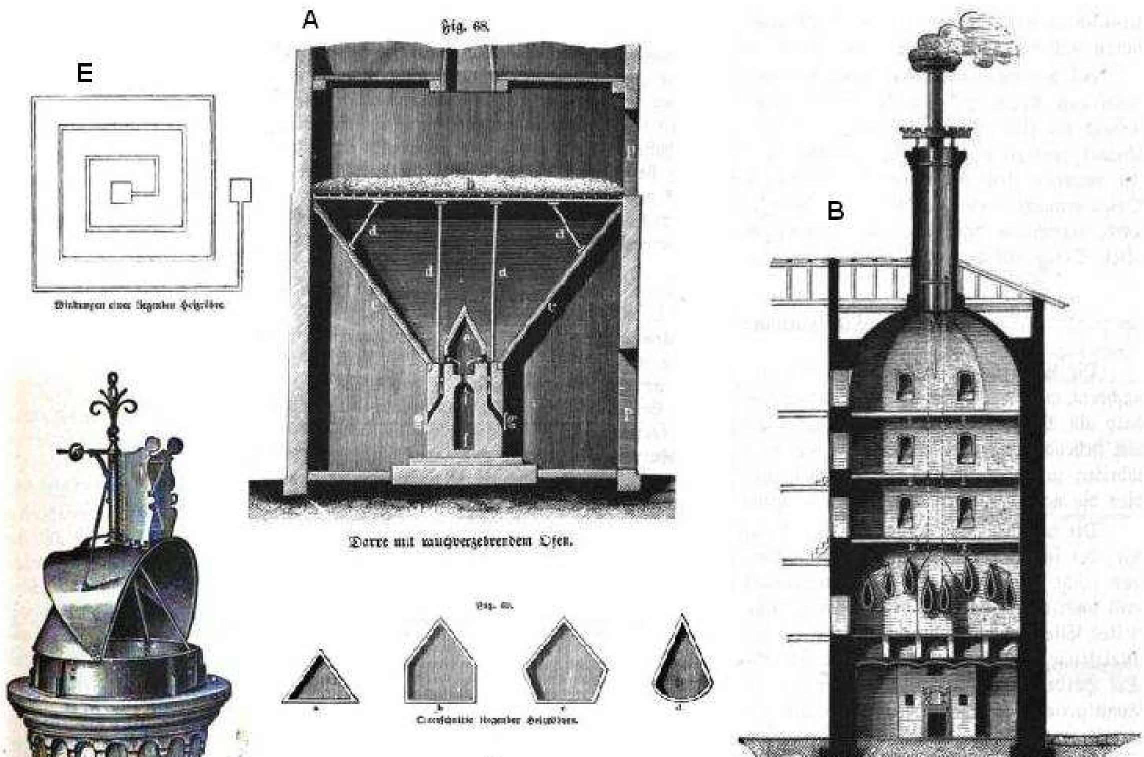

Figure 1 - (A) a schematic drawing of a simple *Darre* with only one grate. This particular kiln design is direct fired. (B) A more complex triple grate kiln design. Note the teardrop shaped cross sections of the heating ducts below the lowest grate. These ducts would carry the hot exhaust fumes from an external furnace (it could be the furnace for the brewhouse or for the brewerie's steam engine) to heat the air in the kiln. (C) A typical design for the hood of a kiln. This hood is able to rotate and the weather vane on its top will make sure that its opening is always away from the wind. This keeps the wind from blowing the moist air back into the kiln. (D) Cross sections of various heating duct designs. Note that they all have a tip on the

top and slanted sides. This is to prevent malt grains from lying on the heating ducts and being subsequently burned. (E) a sample top-view layout if of the heating ducts.

The *Darre* is a large metal mesh generally suspended halfway up in a dedicated building such that it is accessible from all sides. The mesh allows for the hot air to rise through the grain but prevents the grains from falling through. *Figure 1-A shows a simple direct fired kiln. The fire burns in the bottom of that kiln and the hot combustion gases rise through the grain and then through a flue to the outside. Vents on the side of the furnace allow the control of cold air that mixes with the exhaust gases as a crude means of temperature control. The problem with kilns like these is that the wood needs to burn very cleanly which is never the case and the malt gets a smoky and sometimes burnt character.*

The flue has top be large enough to allow for the water vapor to escape unrestricted. At the top of the flue sits a rotating hood (Figure 1C) with an opening that is always turned away from the wind in order to prevent the wind from blowing the water vapor back into the kiln.

Figure 2 - An old malting building in Bayreuth Germany showing a rotating hood

3 different types of kilns exist: *Rauchdarren* (smoke kilns), *Luftdarren* (air kilns) and *Dampfdarren* (steam kilns). Smoke kilns are these for which one does not start a dedicated fire but which are fueled by the smoke from the brew kettle or steam engine's furnace. This allows for a more efficient use of the wood or coal used by the brewery. *Luftdarren* (air kilns) have a dedicated iron furnace that heats the air used for kilning the malt. *Dampfdarren* (steam kilns) are similar to smoke kilns as they use ducts in which hot steam flows and heats the air within the kiln.

The ducts used to carry steam or smoke are not round but have a triangular cross section with the tip directed upward. This is intentional because some of the malt kernels tend to fall through the mesh and if they land and remain on the hot ducts they would get burnt and would impart that burnt aroma onto the malt in the kiln. Figure 1D shows some typical cross sections. It is also important to seal the joints of the ducts in order to prevent the smoke or steam from entering the kiln.

A common improvement these days is the addition of additional grates above each other in the kiln. Malt enters the kiln on the top grate and exists after it has been fully kilned on the lowest grate. The idea is that the air that comes from the lower grates is not saturated with moisture yet and can still remove some moisture from the more moist malt on the upper grates.

The size of the kiln depends on the size of the brewery. A simple single grate with an area of about 100 square feet can kiln about 400 pounds of malt each day. Drying and kilning 100 pounds of malt takes about 25 pound of dry wood. And according to Stohmann and Bailling 100 pounds of barley yield about 92 pounds *Luftmalz* and 80 pounds *Darrmalz* (kilned malt).

When malt is dried in ambient air no chemical changes happen. It just loses water. The drying in the kiln has another goal besides removing the moisture. The *Diastas* formed from the gluten should react with the starch in the grain more strongly. And it is without question if this statement is correct as *Luftmalz* gives much less sugar its extract than the same amount of *Darrmmalz. This is yet another statement which is confusion to us modern brewers. First off the kilning process, at least for base malt, is not supposed to activate the enzymes and create more sugar and secondly air dried malt should give more sugar in mashing since it has a higher diastatic power as the enzymes have not been damaged through kilning. If the malt is not fully dried before the heat in the kiln is turned up the enzymes are severely damaged because of the presence of water. The latter is the case in the production of crystal malt.* Aside from this the roasting also gives the malt the pleasant aromatic taste, the roast aroma, which improves its taste and stability.

The temperature of the kiln has many effects on the beer. The higher it is to some extend the more starch "rubber" is formed. If this temperature is exceeded much of the sugar is converted into caramel and the beer looses much of its strength. *The author talks about the starch being broken down into rubber and sugars, but since there is no actual rubber in the malt extract I assume that he means dextrins with this. In fact higher kilned malts do produce more dextrines and less sugar but only because they have a lower beta amylase content. But he may also be talking about the preparation of crystal malt. That would mean that back then the beers used crystal malt as base malt which doesn't match earlier statements that mentioned that the malt easily breaks apart when rubbed between the fingers.*

	100 kg trockne Gerste	88,81 kg trocknes Malz	Veränderung
Stärkemehl . . .	63,43	48,86	— 14,57
Eiweißartige Körper	16,25	15,99	— 0,26
Dextrin	6,63	6,86	+ 0,23
Zucker	—	2,03	+ 2,03
Fettes Öl	3,08	2,50	— 0,58
Zellstoff	7,10	7,31	+ 0,21
Asche ꝛc.	3,51	5,26	+ 1,75
Zusammen:	100,00	88,81	—

Figure 3 - comparative analysis between barley and malt from Meyers Konversationslexikon, 1893. Top row: 100kg dry barley, 88.81 dry malt, difference. Left hand column: Starch, protein, dextrin, sugar, oil, fiber, ash, total. Note that the starch content was much lower than that of modern barley and that the protein content was much higher.

Previously the Bavarian breweries would rarely kiln their malts above 50 to 60 deg R (63 - 75 C). But this has been abandoned and now the malt is kilned at up to 80 deg R (100 C) and some breweries even go up to 100 deg R (125 C). It was believed that the malt would loose its sugar forming power if kilned too hot. But this only happens if the malt enters the kiln wet and is heated like that. When dry malt is heated it doesn't loose this power but at 80-90 deg R (100-112C) more *Roestgummi* (roast-dextrins) is formed compared to kilning at 50 to 60 deg R (63-75 C). This *Roestgummi* is what makes the beer fuller and more nutritious. It dissolves in the wort like the sugars. The latter is converted to carbonic acid and alcohol during fermentation but that doesn't happen with the *Gummi*. It remains and makes the beer nutritious and heavier than water. *This is yet another indication that the ominous mentioning of "Gummi" (rubber) refers to dextrins and not to actual rubber. Regarding the kiln temperature, we now know that highly kilned malts produce more dextrin rich worts not because dextrin is formed during kilning but because more of the fermentable sugar producing beta amylase is destroyed. This author's statement was also interesting in another sense. It is commonly believed that Bavarian brewers (or at least the ones in Munich) used to kiln their malts high and then started to change the process to create lighter beers with lower kilned malts but the opposite is mentioned here*

The malt is considered done once the rootlets easily come off when the malt is rubbed between the hands and the peculiar malt aroma has developed. And finally, once the color that the brewer desires is reached. Good malt should have the familiar and pleasant yet peculiar smell and should be so light that it floats in water. Some breweries may take a part of the malt and roast it completely brown. The resulting malt is called *Farbmalz* (colored malt) and is used to give the beer a nice dark color. The process of making it is simple. It is placed into large drums and roasted like coffee beans.

Wort production

Mashing is separated into 4 different sections: Milling of the malt, dough-in, boiling of the wort and the chilling of the wort. *It appears that the author considers the complete hot side of the brewing process as mashing*

Malt milling

To grind the malt one uses the common mill only reluctantly as it crushes the malt too finely for it not to be dissolved in water and form a paste from which one tries in vain to produce a clear beer. But some places have a malt tax and brewers are not allowed to own their mills. But where it is necessary to use the common mill the deficiencies of grinding in them are counteracted by wetting the malt. Generally water of 1/8 of the malts weight is added and the malt is well distributed by shoveling it from all sides of the pile. After a rest of 12-18 hours the malt is brought to the mill where it is ground with a wider than usual gap between the millstones.

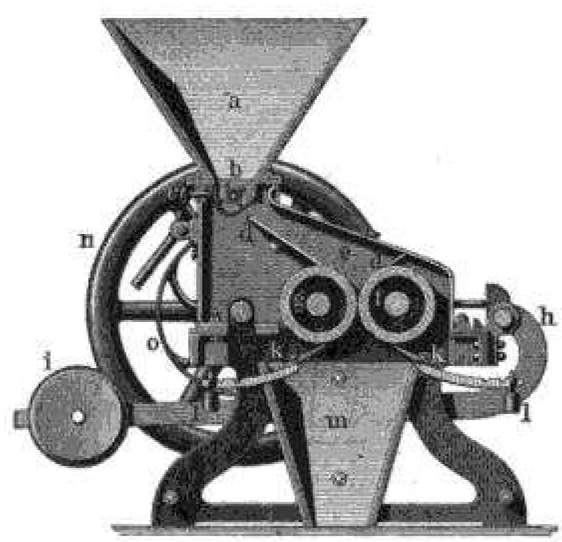

Fig. 1. Malzquetsche.

Figure 3 - Drawing of a malt mill (from Meyers Konversations-lexikon, 1893). The malt enters through the funnel a and hits a rotating prism b. From there it falls into the enclosed space e and onto the rollers f and g. g is fixed while f is movable and pressed against g through the lever l and the counter weight i. The scrapers k and k are pressed against the rollers and remove grains that stick to the rollers. The crushed malt falls down the chute m into a bin

One is better off of if one owns a mill. In this case the mill consists of two cast iron rollers between which the malt is crushed. They are operated by two day laborers or a steam engine. Malt that is crushed with such mills doesn't need to be wetted but it still needs to be ridded of dust and other uncleanliness as they would impede a foul taste onto the beer.

Many brewers use cats to control the destruction brought on by mice in the malt storage. While the cats don't eat malt they have a bad habit that cannot be broken. They never leave their droppings on the open floor but always bury it in the malt. While the dry matter is easily removed through sieving later it is the wet excrements that that penetrate the malt and give a disgusting taste and aroma that can make its way into the beer. *I found it interesting that the author dedicated two full paragraphs to elaborate on the problem with cats and their excrements which means that this was a real problem back then.*

Water

It is beyond words how indifferent most brewers are towards the water. There are so many salts and minerals in water which looks so clear and colorless. But just look at the boiler of a steam engine in which the lime scale can be many inches thick.

Now these brewers, who are indifferent to their water, are correct when they say that these salts and minerals will be precipitated and removed through the boil, fermentation and the salts and acids in the beer. But they also admit that this process consumes not unimportant compounds from the beer, some of which are necessary for its pleasant taste and stability. And that more of them would be retained in the beer if they wouldn't have to clean the water. *It seems that back then there was very little understanding of the importance of minerals and their acceptable ranges in the brewing water.*

The author goes on to mention that soft water is the best water for brewing but that in cities like Munich, where the water is so hard that the chalk encrusts the rocks in the river Isar, brewers make some of the best beers. He also mentions Buton ales and the very hard water that they are made with. All in all there is no conclusion why that is.

Brewhouse technology

The main vessel in mashing is the mash tun. Its size depends on the size of the brewery but it has to be designed such that it holds twice as much volume as the beer that should be brewed.

The following description of brewhouse technology in the 2nd half of the 19th century has been pieced together from different sources.

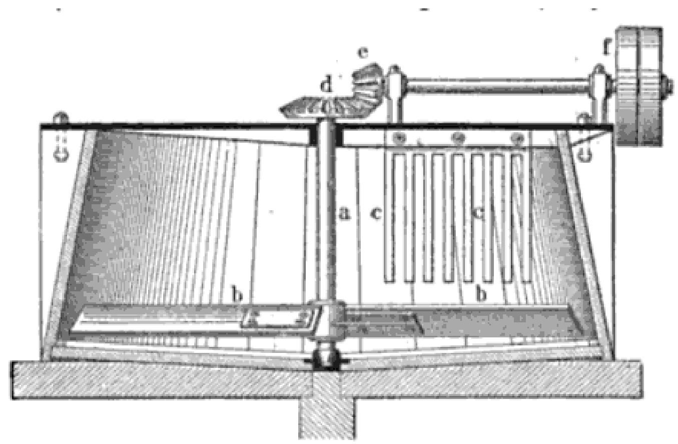

Fig. 4. Maischmaschine für kleinere Brauereien.

Figure 5 - Schematic drawing of a small mash tun from Meyers Konversationslexikon of 1893

Small breweries would consist of 2 vessels. One is used for mashing and lautering and another one is used for boiling the mash and the wort. Only the latter had the ability to be heated. The heat would come either from a coal or wood fire that was located under that kettle. Figure 6 shows a picture of such a mash tun as well as the boil kettle. The mash tun would be made from either iron or wood. Wood was able to better retain the heat of the mash while ion was more durable and more easily maintained. Figure 5 shows the cross section through such a mash tun. The shaft a in the middle propels 2 titled blades b close to the bottom of the tun. Their purpose was to keep the mash from settling and generate a rotating motion. The vertical bars c would then create turbulences that mixed the mash. The mash tun also contains a perforated false bottom which allows it to be used as a lauter tun. This false bottom sits 2-4 inches above the actual bottom and could be made of wood or iron with iron being more popular. Between the false and the true bottom is a valve that allows the wort to be drained. In larger designs multiple valves may exist each of which is connected to a different section though pipes.

Figure 6 - The mash tun (left) and boil kettle (right) of a small brewery as it is on display in the Bavarian Brewing Museum in Kulmbach Germany

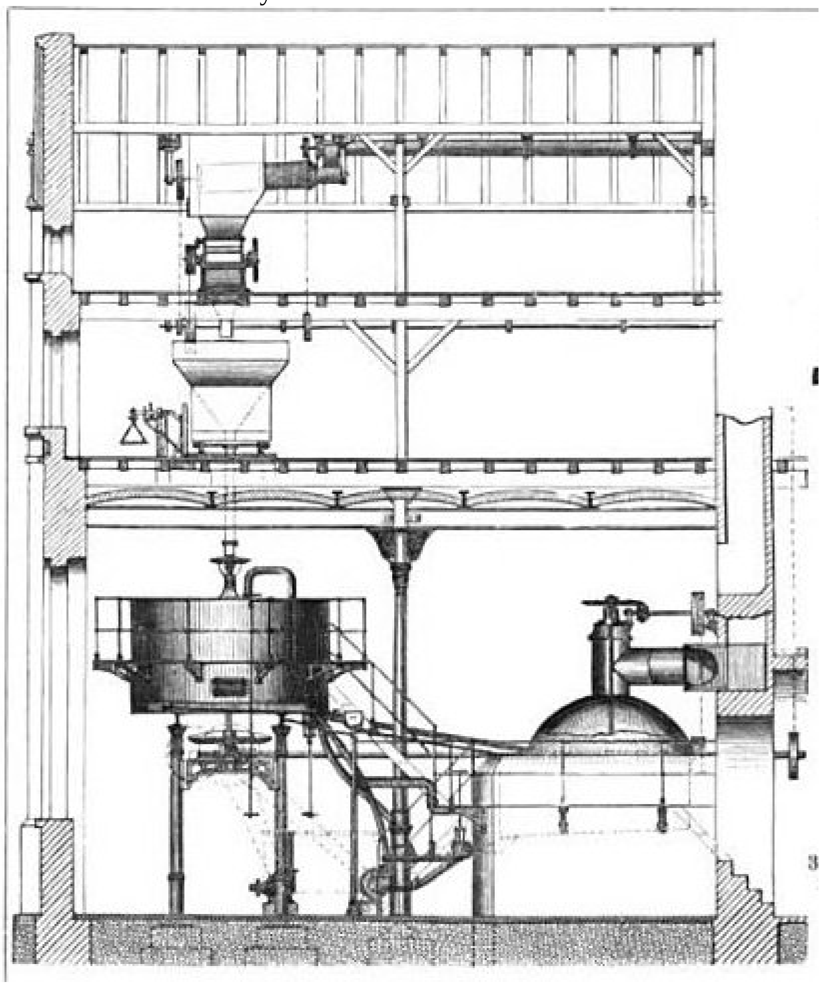

Figure 7 - Schematic drawing of a more modern and more mechanized brewhouse. Taken from Brockhaus' Konversations-lexikon of 1898. Note the malt mill on the top floor, the grist case on the floor below and the chute through which the malt falls into the mash tun. The lower right shows the boil kettle which is mostly encased with a brick structure that houses the furnace which provides the heat. This type of brew house uses a pump to pump the mash from the kettle back into the mash tun. Figure 8 shows almost the exact same brew house rebuild in the Bavarian Brewing Museum.

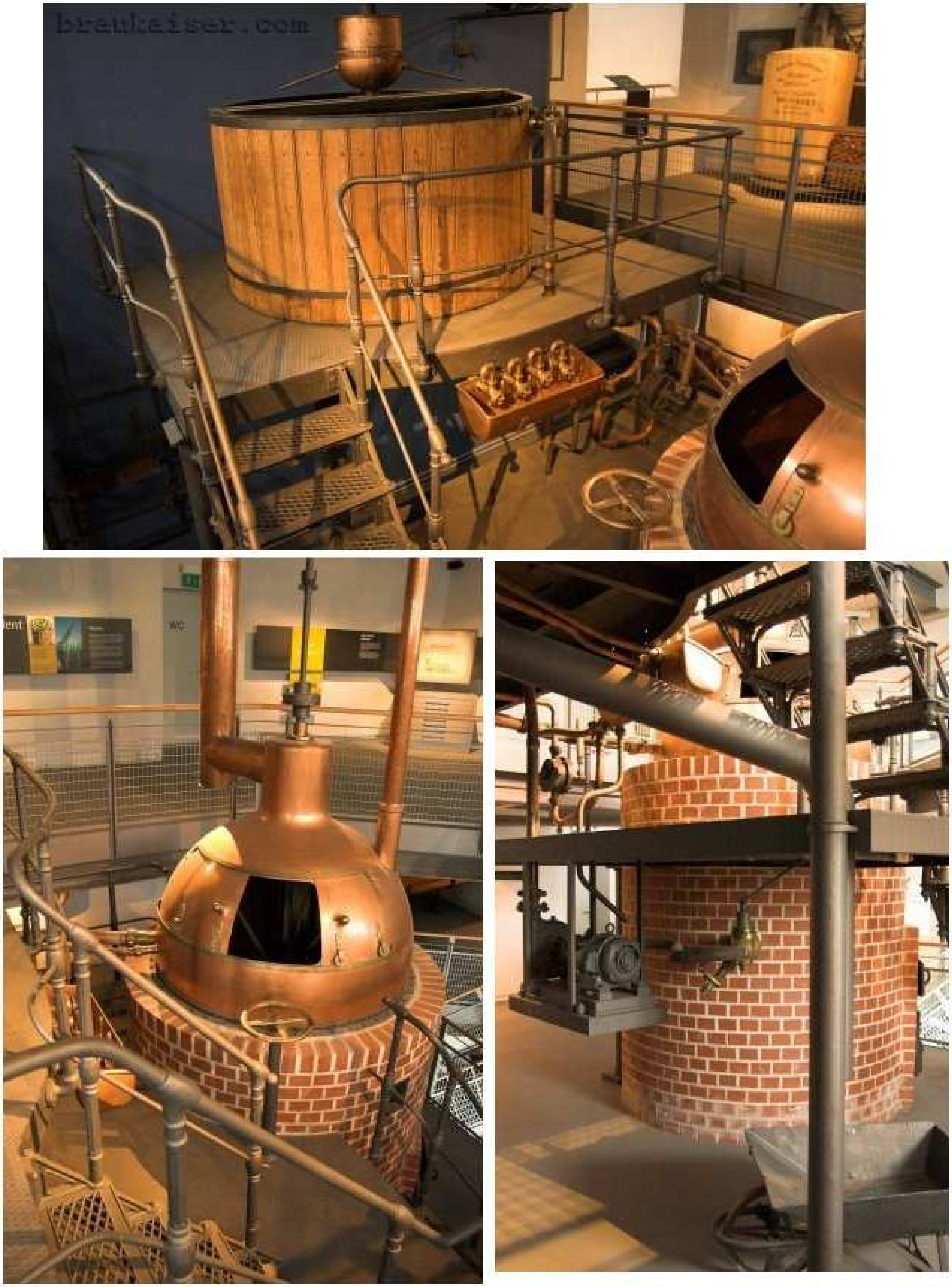

Figure 8 - Simple two vessel brewhouse on display in the Bavarian Brewing Museum in Kulmbach, Germany

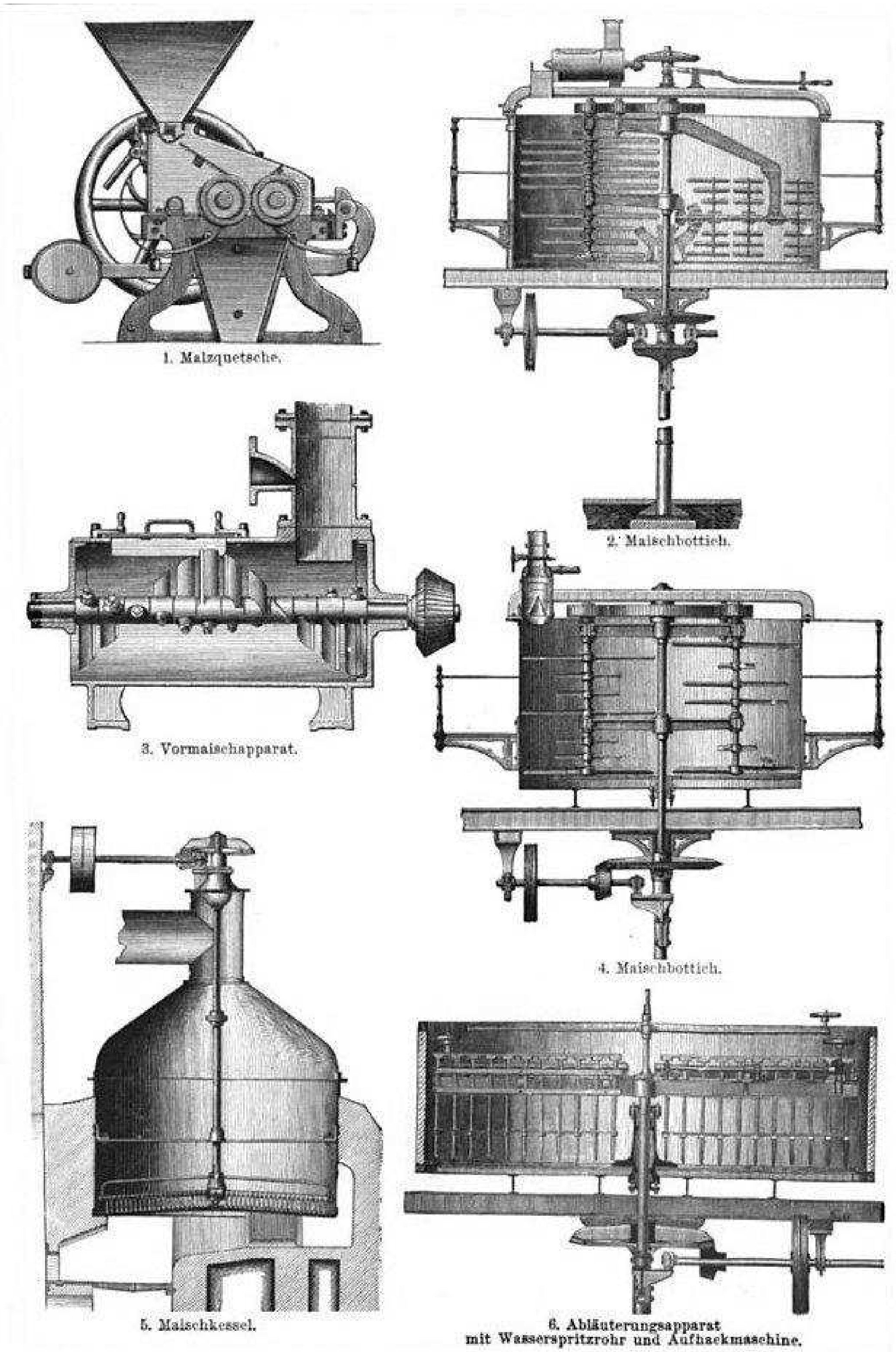

Figure 9 - Various elements of the brew house from Brockhaus' Konversations-lexikon, 1898. 1. malt mill; 2. mash tun with elaborate raking and mixing mechanism; 3. *Vormaishapparat*. This was one of the designs used to mix the water with the malt at dough-in. Water and malt would enter from the upper right and the

rotating paddles would thoroughly mix the water and malt; 4. yet another mash tun design; 5. Boil kettle with drag chains that would keep the wort and mash from sorching; 6. Lauter tun with cutting rakes.

Mashing

Once we have good malt and the best possible water we can continue to dough-in. Its purpose is to dissolve the soluble compounds of the malt (sugar, dextrins and *Diastas*) as well as the yet unconverted starch. If possible the spent grain should not contain any soluble compounds. But this is a godly wish which is far from being granted.

Not only does mashing dissolve compounds from the malt it is also a chemical process which converts the still present starch into dextrins and sugar. The sugar is giving the beer it spirit and the dextrins are giving it is nutritiousness.

In England where a very strong beer is brewed the brewer uses about 180 pounds of water for each 100 pounds of malt where as, without a doubt, German brewers are using much more otherwise the beers wouldn't be as thin. They are using 750 to 800 pounds of water for each 100 pounds of malt.

The author asked a brewer in Stuttgart whom he has known for a long time how much malt he is using for a particular amount of water. "Nobody ever heard that from my mouth and even though you are not a brewer I will not make an exception", was the answer. If this simple ratio is such a secret imagine how much more secretive brewers are with respect to the time, temperature and other conditions. They are stubborn in their reticence as much as they are stubborn in sticking to their methods which they consider their own even though in some cases it is obvious that they have to be called inappropriate.

This statement clearly shows how difficult it is to get true insider information about brewing techniques and practices from that time. Unlike today there was no only little communication between the brewers and the idea of brewing schools or science didn't exist either. All the knowledge was handed down within the brewery

We will now look at the Thick-mash or Decoction-mash method which is commonly used in Germany. One half of the water is added to the malt already in the mash tun. While people mix this mash the other half of the water is brought to a boil in the boil kettle. This takes several hours (*I was surprised by that*) and only when the water and malt are completely mixed can the now hot water be added while under constant stirring and mixing the temperature of the mash rises to 35 C.

A significant part of this mash is scooped into the boil kettle and under constant stirring brought to a boil as quickly as possible. Based on the brewer the boil is continued for one half to one and a half hours. This is called the first thick mash boil.

After this is completed the boiling mash is brought back into the mash tun and under constant stirring the temperature rises to 45 to 50 C. Now another third of the mash is brought back into the brew kettle. (*Note that the author doesn't mention a rest at this temperature. I assume that in this particular version of this mash the 2nd decoction was pulled as soon as the 1st one had been mixed in completely*) This is the 2nd thick mash boil and after it is complete and returned to the mash the temperature rises to 60-65 C.

Another source indicates that the heating of the first decoction should take 40 - 45 minutes. This makes sense as a significant part of the conversion actually happens during the heating of the decoction especially since the decoction method described here doesn't hold a rest after the return of the 2nd decoction. A rest will be held later but only after the 3rd decoction which is a lauter decoction

After this the extract that has already formed is boiled. For this the liquid that has formed between the false bottom and the actual bottom is drained into the boil kettle as well as that that follows. This is called the lauter mash. It will also be boiled for a quarter to half hour and returned to the mash tun where it raises the temperature to 75C which is exactly the temperature at which the starch is converted into sugar. Some other authors report that temperature to be 65C.

I'm surprised that this worked the way he describes it. After 3 decoctions, one of which was a thin decoction, hardly any enzymes will be left. While a-amylase still works at 75C there shouldn't be enough left to convert all the starch. But as I pointed out earlier, most of the starch conversion must have taken place during the heating time of the decoctions. Looks like that the "other authors", which the author mentioned, were closer to the desired rest temperature for the saccharification rest.

To give this process the necessary time, after the mash has been mixed well, the tun is carefully covered. 2 hours does this take. During this time the brew kettle as well as the lauter grant is cleaned. And now everything is drained that collects under the false bottom. This is done with the valve fully opened and the wort draws flour with it which has collected under the false bottom. The wort is again returned to the mash tun where it is mixed with the mash and what is now running though the perforated bottom runs pretty clear and is heated in the brew kettle. This is called the first wort and gives the actual main beer.

In some places the drain is closed after the run-off of the first wort and a 2nd quantity of boiling water is added to the spent grain which gives the so called *Nachbier* (after beer). It is understandable that after the first operation a non unsignificant amount of unconverted starch, coagulated protein and *Diastas* remains and that much of the good wort remains in the spend grain which acts like a sponge. Most of this is dissolved with this 2nd infusion. The first wort is brought to a boil in the boil kettle and in some places the same is done with the *Nachbier* (*this is what is commonly known as party gyle in English brewing and it looks as if this also existed in German brewing*) while in others it is sold to the poor.

The method outlined here experiences not only where the Bavarian beer is brewed but also in Bavaria itself many changes. Because of which every place has its own beer and that even in large places like Munich beers are very different from each other.

Later the author also describes a technique where water is sprinkled onto the spent grain to "push out" the remaining first wort. This is essentially fly sparging.

There are 2 cliffs that need to be avoided in mashing: too little time for sugar formation and too much time for vinegar formation. If too little time is used the wort won't become sweet. But if it stands on the spent grain for too long it will become sour. The use of *Luftmalz* (air malt) is more prone to give sour beers than the use of dark kilned malts. The dark malt formed roast dextrins, an essential oils, which protects against the souring of the mash. *We now know that this is not what happens. The more highly kilned malts simply have less viable mash spoiling organisms on them because they have been subjected to a higher temperature*. This is the reason why lager beers are not brewed in the summer. Only top fermented beers which are not expected to last for more than a few weeks anyway. A slight sourness is part of the *Leipziger Gose*, the *Berliner Weissbier* and the *Wiener Bluzerbier* (*this is the only reference to a mysterious sour beer brewed in Vienna that I was able to find*). But for Barvaian beers such a level of sourness is a major flaw that makes the beer undrinkable.

Boiling

Whether the wort has been produced using the English method or the one in which the mash is boiled boiling the wort cannot be skipped. There are always 2 reasons that require boiling. For one the wort produced is never strong enough that it can be left as is without removing part of the water through boiling and secondly the wort contains proteins that need to be coagulated through boiling which lets them settle to the bottom and helps with clearing the beer.

In addition to that the boil does either remove or convert other compounds. For example are the dextrins contained in the beer converted into real sugar and the sugar already present is converted into syrup-sugar which is sweeter than the first and through its color has a big influence on the color of the beer. *The statements about the conversion of dextins to sugar and sugar to sweeter sugar are extremely outdated. The last statement seems to refer to Mailliard reactions that increase the color of the beer.*

The boiling of the wort is done differently in southern Germany as it is done in northern Germany and England. In Bavaria and Wuertemberg brewers have a desire to boil the wort quickly and for a shorter time which is why they prefer large and shallow kettles that can be heated fast and quickly evaporate the unnecessary water.

Brewers in northern Germany and England want to boil the beers (*the author wrote beers even though he means worts*) for a longer time without dramatically reducing its quantity. The worts are also made much stronger which reduces the need of boiling off as much water as in southern Germany. As a result the kettles in use are much deeper.

The shape of the kettle has little importance. It can be shaped like a large rectangular box or completely cylindrical. And it can also have the form of a typical kettle. But in all cases it has to be heated by a fire whose hot gases not only heat the bottom but also the sides. Figure 11 shows such a kettle. V is the kettle which is filled with wort and on a grate beneath it burns a fire. The kettle is suspended on the masonry by its upper rim. And below that it rests on additional supports.

In England where most of the work is done with steam engines it is common to heat the kettle with steam. If this is available it is preferred since a burning of the wort is nearly impossible with such kettles. But if no steam engine exists in the brewery the added investment for a steam kettle is not worth it.

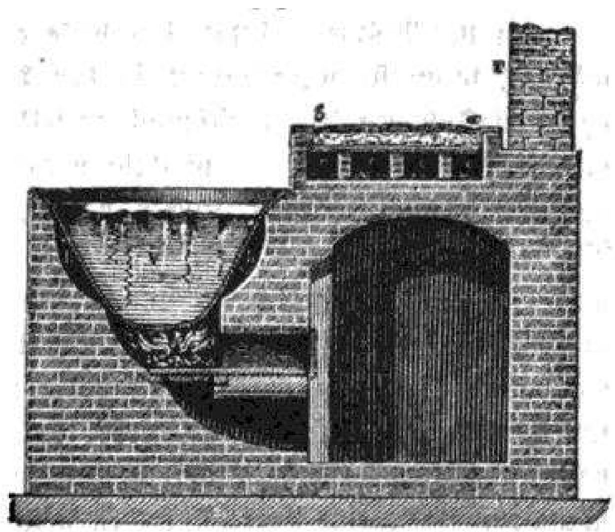

Figure 11 - cross section of a direct fired brew kettle. From Chemie Fuer Laien, 1860

The wort contains many protein like substances. These would, if left unchanged, have a detrimental effect on the taste as they change though a foul and sour fermentation. Would the wort be only a solution of sugars the boiling would not be necessary. We see this with grape and fruit juice. Both of which go through a wine fermentation and are then able to last for many years. But this is not possible with beer because the wort contains too many compounds destine for decay. The wort is boiled to coagulate and precipitate these compounds. *Little did the author know that the problem are not so much the proteins in the wort, which would indeed be nutrients for beer spoilage organisms, but the large amount of spoiling organisms present on the malt which are killed during* the boil. But either way they were correct: wort needs to be boiled and juice doesn't need to.

Hops

But wort is also boiled for another reason. So far we didn't talk about one of the main ingredients of beer; the hops. It forms the spice for all bitter beers. Wort as it comes from the malt is displeasingly sweet and something has to be added to change this to the better. Among all substances that were tried, hops are the most pleasant and the least harmful.

The hop plant carries a large number of scaly flowers that look like small pine cones. Similar to the grain that lies behind each scale of the pine cone, the seed of the pine, the hop flower has grains too, but much smaller. These grains and the small round glands that surround them have an exceptionally lovely balsam like smell and a spicy bitter taste.

Figure 12 - Map of the middle European hop gowing regions between 1842 and 1927. Bavarian Brewing Museum Kulmbach (Germany)

The extraction of these substances, the essential oils, is it what the mixing of wort with hops does. One speaks of the narcotic effect of [the hops] but it is so insignificant that a well prepared beer, enjoyed in excess, is harmful more though its *Weingeist* (wine spirit, *the alcohol in the beer*) than the hops. Sure it is true that a hoppy beer assists in the excretion of the liquid excrements, which is not a drawback. The stimulating and invigorating properties of a bitter beer stem almost completely from the hops. The bitter compound of the hops is stronger than the sweetness of the malt and overpowers it and it is unpleasant to some people. But even the noble and very spoiled ladies get used to this taste quite easily and after that, every beer that doesn't have this taste seems tasteless and unpleasant to them.

Figure 13 - A closer look at the southern German and Czech hop growing regions

It is important that the hops are of good quality. They are gown in many regions but not everywhere do they grow well, receive the necessary care or ripen enough. After they have been picked they need to be dried quickly in air and sun. The remaining water is removed in heated rooms and after that they are pressed and packaged into large bales. These bales are covered with paper which is then covered with varnish. The paper and the varnish keep the moisture out and stored like that the hops can last for a few years without loosing their aroma. *Neither in the hop museum in Tettnang nor in the Brewing Museum in Kulmbach did I see hop bales that were covered with paper and varnish. The old hop bales I saw there were just large bags made from cloth. Which tells me that it may not have been very common to seal the bales with paper and varnish.*

Because of this aroma wort is boiled with hops. The boil extracts the hops which gives their bitterness and their aroma to the beer. They give the taste that is especially pleasant in a good Bavarian beer. They also give the beer the necessary stability because beer that is not hopped is constantly changing and not always to the better. As soon as the process of alcohol production is complete and no more sugar is left another form of fermentation starts which produces vinegar from alcohol. The beer becomes sour. This vinegar fermentation is stopped by the essential oils of the hops.

The author puts a lot of focus on the fact that the preserving character of hops stems from the essential oils and not from the iso-alpha-acids that are formed during the boil. It is entirely possible that this is only the opinion of the author. But even in other texts from this time period I find references to contraptions that were designed to capture the essential oils from the escaping steam and returning them to the wort later.

The following paragraphs describe two fairly unique ways of adding the hops to the wort

When the hops are boiled one gets the extract but the essential oils escape. So it would be logical not to boil the wort. This is possible because proteins already coagulate before boiling temperatures. Just look at the way good coffee or tee is made. It is known that boiling the coffee or tea ruins it and that a good coffee or tee is only steeped in hot water.

It is difficult to understand that this commonly known practice can also be used for hops and a Herr Tizard has to come along to show the brewers the light and sell them an open secret as new. Tizard's process works as follows:

Below the mash tun is the so called grant which collects the wort run off from the mash. This grant gets a perforated bottom. Close to the actual bottom is copper tubing through which boiling steam is run. The hops are placed on top of this tubing and are covered with a perforated plate to prevent it from floating up. Steam is run through the pipes as soon as the grant is half full in order to heat the wort and keep it at 95 C. Now wort is slowly drawn from the grant and new wort from the mash enters the grant. The flow rates are matched and adjusted such that the wort inside the grant remains at 95 C. The pump with draws the wort from the grant reaches under the perforated plate and the opening of this pipe is covered with a mesh to hold back the hops. New wort is always coming into contact with the hops through this mechanism.

This is an interesting concept indeed. It sounds like first wort hopping with a hop back right after the mash tun and I assume that they didn't worry about not boiling off DMS with the use of this no boil practice. Or maybe the DMS is later evaporated on the cool ship and "Berieslungskuehler" (see wort cooling for an explanation of this device). This is the first time I read about such a hopping method and I doubt that it was commonly used.

The amount of hops that are used is very different and depends on the weight and quality of the malt, the more sugar it contains the more hops are needed, as well as the taste of the drinkers and lastly the purpose of the beer: whether or not it is destined for long storage, for export or early consumption. It is because of this that that nobody can say how much hops are used per malt. The quantity changes from 1/4 pound to 14 pound per 100 pound malt. For beers that are exported to hot regions (the Englishmen wants to drink his porter and Ale even in Jamaica and Calcutta) up to 18-20 pounds might be used. *This book is also covering English brewing to some extend but I have been cutting this out so far*

Some breweries use a different method to boil the hops. All the hops are boiled in the brew kettle with only a small amount of wort. Not even a 10th of it. After this has boiled for 15 min the rest is added and all of it is boiled as usual. This is supposed to achieve a form of "hop roasting" during which the hops loose some of their aroma but give the beer its own pleasant taste which one considers especially exquisite in Bavaria.

This hop roasting is very interesting indeed (it may even be the original form of first wort hopping) and warrants some experimentation in home brewing

Cooling

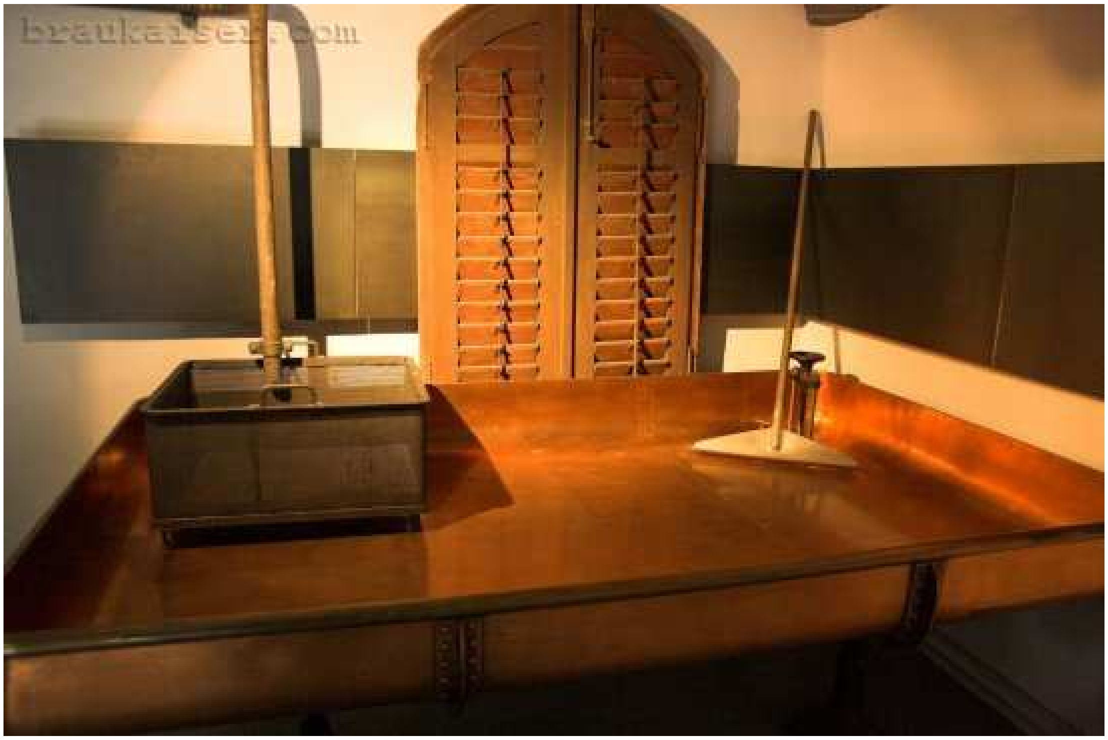

Figure 15 - A copper cool ship as it is on display at the Bavarian Brewing Museum in Kulmbach. The actual area of this cool ship in a brewery would be much larger. The wort is scooped or pumped into the metal basket which holds back some of the break material and the hop matter. Once the wort has cooled it will be drained with the drain that can be seen at the far corner on the right hand side.

In every brewery an awfully awkward and large device, the cool ship, requires a formidable and if the brewery has a decent capacity a huge room. Each cubic foot of beer requires 6 square feet surface area. Over centuries one has been using this awkward thing (in newer times one has made useful changes) mainly because people are creatures of habit. Forty years ago the author has suggested changes to the cooling device used by the brewers of Berlin. Their usefulness is quite evident to these intelligent men but "the beer is such an erratic thing that it should not be treated different from what it is used to. A skylight or hatch more or less open or opened on the wrong side will spoil the beer"

I included this passage here because it illustrates very nicely how little the brewers knew about the details of brewing beer. One problem with the cool ship is that a very large surface area of the beer is open to the elements. If the hatches are not opened correctly, wind may blow wort spoling organisms onto the wort and the beer will go sour more quickly. Back then they didn't really know why the beer would go sour, just that it happens if the hatches are not opened correctly

A cool ship may be made from wood or metal and needs to be perfectly level. Wooden cool ships deteriorate and lead to beer spoilage very easily because they absorb small amounts of wort which can start a fermentation in the next batch that enters the cool ship. Another drawback of the wooden cool ships is that wood is a poor conductor of heat and that the wort doesn't cool as quickly. Because of this most cool ships are now made from iron. The large bottom which would bend under the weight of the wort sits on a grate. The rest of the design is very similar to the wooden cool ships. And because iron is a better conductor of heat the wort cools faster.

It is known that the wort should be cooled as fast as possible to remain in contact with the air the least amount of time. It is also known that a steaming liquid cools faster if the steam is moved away from the surface with an draft such that new steam can be formed which draws heat from the liquid. But the problem is that the purpose of fast cooling is to minimize the contact with air. But such a draft over the wort, even if it cools the wort in half the time, would be worse than having the wort stand without that draft twice as long, since in the later case the steam forms a protective blanket. *Again, the author was not aware that the contaminants in the air and not the air itself were the problem.*

But if such draft is created under the cool ship it would cool the wort through the iron wall and not disturb the steam on the wort's surface. Such a draft is best created with a centrifugal blower which doesn't have to be large. A foot in diameter and rotating with a sufficient speed is enough.

But iron cool ships have a negative effect on the wort when they are new. The wort absorbed tannic acid from the hops (*I think it is more the acidity of the wort and not the acids from the hops*) and this acid reacts with the iron. The result is a black tint of the wort as if someone added ink. This alone could be enough to condemn such cool ships but fortunately this iron salt settles with the yeast after completed fermentation and secondly the cool ships quickly loose their staining ability. They'll get covered with a thin layer of beer stone which protects the iron from the tannic acid in the wort.

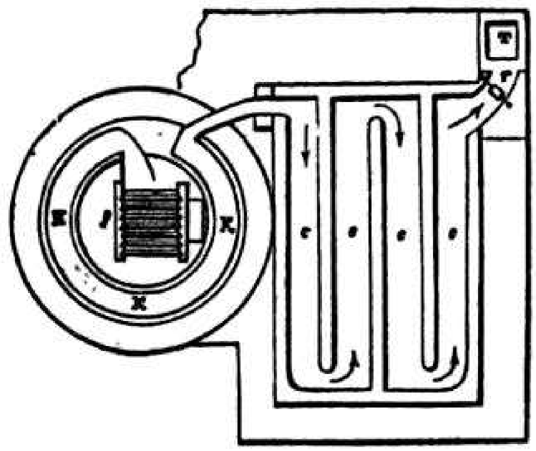

Figure 16 - Top view of a wort "refrigerator" taken from Chemie Fuer Laien. This is basically a hybrid between a cool ship and a counter flow chiller and can be seen as a direct ancestor of the counter flow or plate chillers of today's brew houses

There is no question as to where the cool ship should be located. It is best located outside the brew house uncovered in the shade of the brewery buildings. The cooling of the wort should not take more than 12 hours although this limit is oftentimes exceeded. Covering the cool ship should be possible if the weather requires it. During the winter, under clear skies and if the cool ship stands free without any cover the cooling can take as little as 2 hours. But during spring or fall, i.e. the end and the beginning of the brewing season, the day time temperatures are too high to allow for a quick enough cooling and cooling at night is more effective.

Fig. 11. Berieselungskühler.

Figure 17 - *Berieslungskuehler* from Meyer's Konversationslexikon 1893

Much more practical than the cool ships are the so called *Refrigeratoren* (*as we will see later, this word does not refer to a refrigerator or refrigeration technology as we know it today*) which have been mentioned by Tizar. Figure 16 shows the floor plan of such a unit. A brewery, that would need a 600 square feet cool ship, only needs one half that size. The figure shows the rectangular cool ship on the right and the kettle on the left. In reality they would not sit as close together and are preferably separated by a wall. The cool ship is not a flat open space but it is an artificial "river" that meanders between dividers over the cool ship. This is why this cool ship is not horizontal but slanted. Its drain would be placed at its lowest point. From the boil kettle the wort is scooped into a channel that allows it to flow onto the cool ship and as it exits it will be much colder. But it is cooled even more by having a metal pipe that lies on the bottom of the cool ship and follows the meander of the wort flow. Cold water is pumped through this pipe, which is twice as wide as it is thick and which then flows against the flow of the wort until it exists below the channel that comes from the kettle. The purpose of this water and why it flows against the stream of wort is obvious. It should cool the wort and because the wort will be coldest near the exit it needs to be offered the coldest water at that point. And because of that one can do in 15 min what took 6-8 hours on a conventional cool ship. But it should be added that not all the wort is cooled in 15 min only the amount that is currently on the cool ship. The cooling of all the wort takes as long as it takes to empty the kettle.

The temperature to which the wort needs to be cooled depends on the type of beer and the type of fermentation. Light and top fermented beers are only cooled to 20 C while Bavarian beers and the related bottom fermented types need to be cooled to 7 or even 6 degree Celsius.

Another device that was popular for cooling the wort is the "Berieslungskuehler" as shown in Figure 17. These devices have a corrugated surface over which a thin film of wort would run down from the top to the bottom where it is caught in a trough and then moved to the fermentation vessel. Cold water is pumped through its inside. It enters at the bottom and it exits on the top. Advanced models would have two stages. The bottom half was cooled with ice water and the top half with well water. This was a more efficient use of the ice water. While these Berieslungskuehler can also be used instead of a cool ship their use was more common after the wort has already been cooled substantially on a cool ship.

The careful reader may have already noticed that one important part is missing: aeration of the wort. Back then they didn't know that yeast needs O_2 *for proper fermentation. All they knew is that prolonged wort contact with the air make a beer sour. But the use of a cool ship and especially a "Berieslungskuehler" with its thin film of wort trickling down on its side provided enough air contact for sufficient oxygen uptake of the wort.*

Figure 18 - A *Berieslungskuehler* and a *Trubsack*. The *Trubsack* was a triangular bag in which the wort held back by the trub and hop matter was extracted. After the wort has been drawn from the cool ship the wet trub would be filled into the *Trubsack* and the wort was then pressed from it

Fermentation

The production of a good beer depends very much on the chemical process which we call fermentation. As a result the brewer has to give it his utmost attention. If it runs poorly the beer will be bad even if all other processes ran well and were controlled with care. But if it runs well it is possible to compensate for small mistakes made up to this point. Except if the wort got sour because in this case the 2nd fermentation already happened before the 1st one started.

The beer fermentation is divided into two groups: top fermentation and bottom fermentation. Both types convert the sugar into alcohol and carbonic acid. But in beer this conversion should not be run until completion because one likes to get not only alcohol but also substance in the beer. The alcohol makes the beer invigorating, the carbonic acid gives it the refreshing taste, the unconverted sugars make it nutritious and the hops give it the spice. The fermentation should not destroy these properties nor should it affect them negatively and that's why it is so important to control it well. *Today we know that there are fermentable and unfermentable carbohydrates in the wort and that the yeast can consume only the fermentable ones anyway*

Besides the mentioned primary purpose the fermentation should also facilitate the precipitation of a substantial amount of the protein. The more it is removed the more stable the beer will be. But the beer should never become void of any fermentation substrate, because unlike vine it is not a fully fermented beverage. If it would become that, it would stop being pleasantly drinkable. The carbon dioxide, which is formed through fermentation, is a substantial condition for the pleasant taste. In vine it is not present because there the fermentation is complete and all the carbon dioxide has escaped. *It sounds as if the author was not aware that carbon dioxide can be trapped in the beer if the vessel is closed and that it can retain its carbonation even after complete fermentation.* To prevent such staling of the beer it needs to retain enough fermentation substrate so it can slowly ferment throughout its existence. This is the same with Champagne.

The temperature has a major effect on the course of the fermentation. At a temperature of 15 or more degrees (C) is the fermentation turbulent, quick and very active. At 7 C or less the fermentation is quiet and much slower. During the faster fermentation at higher temperatures the yeast rises to the top. This is brought on by carbon dioxide bubbles that lift the yeast to the top which is why this process is called top fermentation (*Obergaerung*). At lower temperatures less carbon dioxide is produced and the bubbles are too small to carry anything else but themselves and the yeast falls to the bottom. This is why this process is called bottom fermentation (*Untergaerung*).

Top yeast causes top fermentation and bottom yeast causes bottom fermentation. But with the right temperature the type of the yeast can be changed. If one takes the foam rich of yeast of a top fermentation and adds it to wort and lets this stand at a temperature of 5C then the yeast is doing a bottom fermentation. Only little rises to the top. If one uses this yeast for fermenting fresh wort at low temperatures again then the former top yeast will completely transform into bottom yeast. Likewise can one create top fermentation and top yeast from bottom yeast by fermentation at 15 or more degrees C. *This is an interesting observation. We know now that ale yeast is not going to change into lager yeast just based on the temperature but what may have happened is that the yeast that was used was not a pure ale or lager strain. It was a mix of strains and fermentation at lower temperatures benefited the lager type cells and fermentation at higher temperatures benefited the ale type cells.*

Light beers, which aren't expected to last a long time, are fermented with top yeast. It finishes the fermentation quickly, converts lots of the sugar into alcohol and produces lots of carbon dioxide (the reason for the strong foaming of the *Weissbier*). But because the fermentation is done at higher temperatures they tend to get sour very easily and the protein is not precipitated as completely. Such beers are not stable and need to be consumed quickly.

For beers whose small amounts of sugar should not ferment completely, like the Bavarian and other lager beers, a the bottom fermentation is chosen. In this case the process is a slow one and the beers can be consumed months after being brewed. The protein settles out with the yeast and during their shelf life these beers will get better with every day.

For top and bottom the process of fermentation is divided into three different phases. During the first, which starts after the addition of the yeast, sugar is converted into alcohol and new yeast is formed from the nitrogen compounds. The temperature of the fermenting substance rises. This part is called the rapid or wild fermentation.

The second phase is the secondary fermentation (*Nachgaerung*). And while the conversion of the sugar still continues it is much slower and most of the yeast formed during the first phase settles out. The turbid beer clears up. The third phase is called the impalpable. It happens after the settling of the yeast and clarification. During that time the continued fermentation and yeast growth is so slow that there is still the fermentation of sugar and formation of carbon dioxide but the settling of the yeast is so slight that it is a mere haze on the side of the bottle on which it was laying. A haze that the maid pretends not being able to remove but which needs to be removed if one doesn't want to drink sour beer since it would immediately start the second stage of fermentation in the next beer that is filled into that bottle. *Second fermentation means in this context the souring of the beer as this is seen as yet another fermentation stage that happens to the beer.*

The bottom fermentation

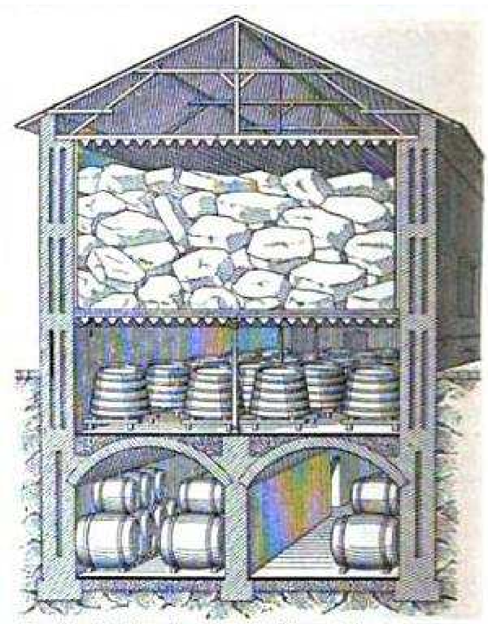

Fig. 13. Kellerräume mit Obereislagerung.

Figure 1 - Schematic drawing of a fermentation building with ice storage on top, primary fermentation floor below and lagering cellars at the bottom. Meyers Konversationslexikon, 1893

Of significant importance is the locality in which the fermentation takes place. It has to be as deep as possible in the ground or surrounded by thick walls such that the outside temperature has no effect on the fermentation room. It needs to be vented but only at night as the temperatures during the day fluctuate too much and it is important to have a constant temperature. This is easiest during the winter. During fall and spring this is only possible through artificial means like sufficient ice reserves.

The rooms have to be kept clean with the utmost care. Any foul smell is dangerous for the wort. It either influences the beer or lays the seed for spoilage.

The vessels are usually made from wood and require an even greater cleanliness than the mash and cooling vessels as these only hold the wort for a few hours whereas the fermentation vats hold the beer for ten to fourteen days. These vats are oftentimes made quite large and can hold up to three thousand liter. In Bavaria they have ones that can hold even ten thousand liter for the beer production during the winter. But they can only be used during the winter as temperature rise during fermentation is significantly in such large volumes.

Some brewers mix some of the wort from the cool ship with the yeast and then add this to the wort in the vat. Others take some wort, add it to the yeast and let this come to fermentation before they add it to the remaining wort. But every one swears that their method is the correct one and that large losses are eminent if it is done differently.

It is clear that the complete distribution of the yeast in the wort is the first requirement and this distribution is best achieved if the yeast is first mixed with some wort until it is thin. This is then added to the main batch and stirred. This is repeated multiple times during the first 12 hours.

The amount of yeast that should be pitched also depends on the view of the brewer. About 1/2 to 2/3 percent of the batch volume are taken. Too much yeast is disadvantageous because it can lead a displeasing taste to the beer, one that is similar to home baked bread. In addition to that, the longer the beer should last the less yeast should be used. The condition, that the yeas is in, and the fermentation temperature also need to be considered.

Figure 2 - Wooden primary fermentation vats as they were in use in the latter half of the 19th century. (Bavarian Brewing Museum, Kulmbach, Germany)

During the first 12 hours the surface starts to get covered by a light white foam. These are small carbon dioxide bubbles which are covered with a thin layer of wort. This happens first close to the walls and then progresses towards the center. Most of the bubbles stay together but some burst and release their carbon dioxide which gives the peculiar stinging smell and that prickling in the nose. At first only when one leans into the vat, but later when more and more carbon dioxide is produced it will spill out of the vat and onto the floor and cover it such that a dog lost in the fermentation rooms immediately falls over and dies of asphyxiation.

After three to four days the rising foam forms a foamy mass, the *Kraeusen*, which starts to subside as the fermentation slows. All that is left is a thin brown cover which mostly consists of the bitter resins of the hops. There is only little yeast in that layer. The yeast falls to the bottom which clears the beer more and more.

The beer is now called *Jungbier* (young beer) or *Gruenbier* (green beer) and its clearing indicates that it is ready to be put into the lagering casks where it will continue with the much slower and longer secondary fermentation which is necessary to give the beer is drinkability. To test if a beer is ready to be racked to the lagering vessels a sample can be brought into a warm place. If it clears quickly and only little yeast settles out in flocks the beer is ready. *This is the point in fermentation when the yeast starts to flocculate because all or most of the maltose has been consumed.*

The wort had a specific consistency. The sugar and dextrins made it heavier than water. But after the fermentation process it is much lighter. This dilution is called "*Attenuation*" in the new technical chemistry and it results from the fermentation having converted some of the heavier sugars into lighter alcohol.

The weight of the wort is determined with an instrument called the *Saccharometer* (*old wort for hydrometer*). The depth with which it sinks into the wort indicates how much sugar and dextrins this wort has. Let's assume that the wort had a weight of 13 percent (*This is pretty much equal to 13 Plato*). After the eight to ten day main fermentation it shows only 6 percent. One would say that half of the sugar has been converted into alcohol. But this dilution can also be higher or lower. It depends very much on the way that the malt was kilned. *Luftmalz* (air malt) gives more sugar and thus more alcohol than heavily kilned brown malt which will not give an as "spirit rich" beer. *It should be noted that it seems that they did not make a distinction between true and apparent extract of the beer. Since the 6 Plato were read from the beer with a hydrometer it means that this is the apparent extract and the real extract or sugar content is still higher than 6 percent.*

It is difficult to say how much time the main fermentation will take as much of this depends on the temperature and the quality of the yeast. But the stage to which it has progressed greatly influences the secondary fermentation. The more complete the primary fermentation was the slower the secondary fermentation will be. The brewer uses this fact to either produce a beer that can be consumed quickly but is less stable or a beer that takes longer to be drinkable but will be more shelf stable.

When the beer is transferred the layer covering it needs to be removed. This is understood as it would give the beer a harsh bitter taste. The beer also needs to be clear and free of yeast. The last bit of beer that was standing over the yeast is allowed to settle and added later to the lagering casks.

Fermentation produces new yeast which is a fungus that grows rapidly where there is food and the nitrogen rich compounds of the malt are especially suited. The old non-viable yeast settles first. The newly formed and most viable yeast settles next and after that a thin liquid yeast settles which is useless. *It is interesting to note that Luis Pasteur discovered yeast in the same year that this book was published; 1860*

Since the yeast is of such importance, brewers don't grow it new for each batch. They don't discard the sediment but remove the thin slurry on top and then scrape off the good yeast without getting too much of the old and useless bottom layer. This requires some skill and is done with large scrapers.

Once the yeast as been collected and is stored in fresh water the vat is cleaned with water and large brooms using the utmost care to clean especially in the corners.

Figure 3 - Old wooden lagering casks. Visible in front of these casks is a *Verschneidbock* which was used to blend up to 3 casks. The sight glasses on that device were used to check when a particular cask is already drawing yeast. The upright tubes in the lower right corner are part of a *Wasserspundapparat* which is a pressure sensitive relieve valve where the counter pressure is created by columns of water. (Maisels Brewery Museum, Bayreuth, Germany)

When the lager beer is transferred to the lagering casks they are generally filled completely and are closed (*Verspunded*) only once the secondary fermentation has ceased completely. The longer that secondary fermentation took the longer the beer needs to be kept bunged. Such beer also has the best stability and with longer storage it becomes stronger and better.

It seems that at the time when this book was written the concept of the controlled venting of the head pressure in the casks was not commonly used yet. The amount of carbonation was only controlled though the amount of residual sugar at the time at which the cask was bunged. And based on the description this happened fairly late which leads me to believe that the lager beers of 1860 were not well carbonated at all. The Bavarian Brewing Museum however showed devices that were used to control the head pressure in the lagering vessels.

Top Fermentation

When it comes to top fermented beers, the author lists a lot of different techniques. Interesting was that even some "Lagerbier" was top fermented, especially in northern Germany. The fermentation temperature was above 15C but the beer was filed into casks and lagered like the bottom fermented beer. This is basically how Alt and Koelsch are brewed.

It also talks about summer beer and how it has to be top fermented because the low temperatures for bottom fermentation cannot be achieved during the summer. This contradicts the Figure 5 which shows select "Sommerbiers" as bottom fermented beers. These beers are generally consumed shortly after the primary fermentation is over and contain much more carbonation. They also have the tendency to go sour pretty quickly. The Bavarian wheat beer (Weissbier) for example is even brewed without hops

I. Obergärige Biere.

Erzeugungsländer und -Orte, Biersorten	Alkohol in Prozent	Extraktgehalt in Prozent	Mineralbestandteile in Prozent	Stammwürzegehalt in Proz. (Balling)	Wirklicher Vergärungsgrad
Münchener Weißb., Schramm	3,75	5,73	—	12,9	55,7
" " Schneider	3,57	5,62	—	12,5	55,0
" weißer Salvator, Schramm	5,56	9,30	—	19,6	52,6
Berliner Weißbier	2,82	4,21	—	9,6	56,3
Adambier, Westfalen	7,38	3,37	0,284	7,3	80,5
Lichtenhainer	3,20	4,50	0,200	0,74	58,1
Jenaer	3,00	6,10	—	1,91	48,79
Gose	5,00	4,30	—	13,8	69,0
Schwedisches Dricka	1,04	2,87	—	4,9	43,0
Engl. Porter, London } ältere	6,90	6,80	—	19,61	65,32
Burton Ale } Analysen	5,90	14,50	—	25,11	42,55
Pale Ale von Baß & Co. (neuere Analyse)	5,14	6,17	—	15,9	61,2
Englischer Porter (neuere Analyse)	5,72	7,43	0,40	18,8	60,6
Belgischer Lambic	5,94	3,30	—	14,63	77,44
" Faro	4,33	5,15	—	13,48	61,77
Belgisches Gerstenbier	4,77	2,70	—	11,94	77,38

top fermented beers

brewing regions and beer types	alcohol by weight in percent	real extract in percent	original gravity in percent	real attenuation in percent	apparent attenuation in percent
Münchner Weißbier Schramm	3.8	5.7	12.9	55.7	67.9
" " Schneider	3.6	5.6	12.5	55.0	67.1
Schramm	5.6	9.3	19.6	52.6	64.1
Berliner Weißbier	2.8	4.2	9.6	56.3	68.7
Adambier, Westfalen	7.4	3.4	17.3	80.5	98.2
Lichtenhainer	3.2	4.5	10.7	58.1	70.9
Jenaer	3.0	6.1	11.9	48.8	59.5
Gose	5.0	4.3	13.8	69.0	84.1
Schwedisches Dricka	1.0	2.8	4.9	43.0	52.4
Engl. Porter, London (old analysis)	6.9	6.9	19.6	65.0	79.3
Burton Ale (old analysis)	5.9	14.5	25.0	42.0	51.2
Pale Ale von Bass & Co (new analysis)	5.1	6.2	15.9	61.0	74.4
Englischer Porter (new analysis)	5.7	7.3	18.8	61.0	74.4
Belgian Lambic	5.9	3.4	14.6	77.0	93.9
Belgian Faro	4.3	5.1	13.4	62.0	75.6
Belgian Barleybeer	4.8	2.7	11.9	77.0	93.9

Figure 4 - Analysis data of a few top fermented beers of the time. An apparent attenuation column has been added to the translation on the right hand side. From Brockhaus' Konversationslexikon, 1893

II. Untergärige Biere.

Erzeugungsländer und -Orte, Biersorten	Alkohol in Prozent	Extraktgehalt in Prozent	Mineralbestandteile in Prozent	Stammwürzegehalt in Proz. (Balling)	Wirklicher Vergärungsgrad
Bayern: München.					
Hofbräuhausbock (1896)	4,84	10,96	—	19,9	45,0
Pschorrbräubock (1895)	3,42	11,67	—	18,1	35,4
Zacherl-Salvator	4,88	9,57	0,27	18,7	48,7
Leistbräu-Märzenbier	4,45	7,71	—	16,1	52,2
Hofbräuhausdoppelbier	3,79	7,26	—	14,5	49,9
Spatenbräutafelbier	8,17	12,90	0,40	27,4	67,4
Sommerbier Augustiner	4,13	6,94	—	14,8	53,2
Sommerbier Spatenbräu	3,70	7,39	—	14,4	48,9
Sommerbier Bürgerbräu	3,39	8,03	—	14,5	44,5
Sommerbier Kochelbräu	4,27	6,27	—	14,4	56,6
Sommerbier Löwenbräu	4,15	6,47	—	14,4	55,1
Winterbier Hofbräuhaus	3,76	6,90	—	14,1	51,1
Winterbier Spatenbräu	3,02	8,24	—	14,0	41,2
Winterbier Bürgerbräu	3,46	7,37	—	14,0	47,3
Winterbier Löwenbräu	3,53	6,92	—	13,7	49,4
Winterbier Augustinerbräu	3,92	6,65	—	14,1	53,0
Exportbier Bürgerbräu	3,57	7,88	0,21	14,7	46,4
Helles Spatenbräu	2,69	6,50	—	11,7	45,7
Nürnberg.					
Freiherrlich von Tucherisches Bier	3,45	6,88	—	13,5	49,1
Kulmbach.					
Exportbier der ersten Kulmbacher Export-Bierbrauerei	4,48	8,80	—	18,7	52,9
Dunkles Kulmbacher	4,47	9,17	—	17,6	47,8
Übriges Deutschland.					
Berliner helles Bier	3,40	4,50	—	11,1	59,2
» Lagerbier	3,44	6,20	—	13,0	52,0
Hamburger Lagerbier	3,98	6,76	0,25	14,7	54,0
Dortmunder Bier	4,68	5,05	—	14,0	64,0
Österreich.					
Schwechater Lagerbier	4,30	6,54	—	14,7	55,7
» Märzenbier	4,27	6,50	—	14,6	55,6
Aktienbrauerei Eger, Lagerbier	3,79	4,71	0,21	11,9	60,5
» » Abzugbier	2,94	2,07	0,17	9,8	58,6
Pilsener Bier	3,71	4,87	—	12,0	59,4
Budweiser Schankbier	3,84	4,28	0,20	12,0	58,3

bottom fermented beers

brewing regions and beer types	alcohol by weight in percent	real extract in percent	original gravity in percent	real attenuation in percent	apparent attenuation in percent
Bavaria Munich					
Hofbräuhausbock (1896)	4.8	11.0	19.9	44.9	54.8
Pschorrbräubock (1895)	3.4	11.7	18.1	35.5	43.3
Zacherl-Salvator	4.9	9.6	18.7	48.8	59.5
Leistbräu-Märzenbier	4.5	7.7	16.1	52.1	63.6
Hofbräuhausdoppelbier	3.8	7.3	14.5	49.9	60.9
Spatenbräutafelbier	8.2	12.9	27.4	52.9	64.5
Augustiner	4.1	6.9	14.8	53.1	64.8
Spatenbäu	3.7	7.4	14.4	48.7	59.4
Sommerbier Bürgebräu	3.4	8.0	14.5	44.6	54.4
Kochelbräu	4.3	6.3	14.4	56.5	68.9
Löwenbräu	4.2	6.5	14.4	55.1	67.2
Hofbräuhaus	3.8	6.9	14.1	51.1	62.3
Spatenbäu	3.0	8.2	14.0	41.1	50.2
Winterbier Bürgebräu	3.5	7.4	14.0	47.4	57.8
Löwenbräu	3.5	6.9	13.7	49.5	60.4
Augustinerbräu	3.9	6.7	14.1	52.8	64.4
Exportbier Bürgerbräu	3.6	7.9	14.7	46.4	56.6
Helles Spatenbräu	2.7	6.5	11.7	44.4	54.2
Nuremberg					
Freiherr von Tuchersches Bier	3.5	6.9	13.5	49.0	59.8
Kulmbach					
Exportbier der Ersten Kulmbacher Export-Bierbrauerei	4.5	8.8	18.7	52.9	64.6
Dunkles Kulmbacher	4.5	9.2	17.6	47.9	58.4
Rest of Germany					
Berliner helles Bier	3.4	4.5	11.1	59.5	72.5
" Lagerbier	3.4	6.2	13.0	52.3	63.8
Hamburger Lagerbier	4.0	6.8	14.7	54.0	65.9
Dortmunder Bier	4.7	5.1	14.0	63.9	78.0
Austria					
Schwechater Lagerbier	4.3	6.5	14.7	55.5	67.7
" Märzenbier	4.3	6.5	14.6	55.5	67.7
Aktienbrauerei Eger, Lagerbier	3.8	4.7	11.9	60.4	73.7
" " Abzugbier	2.9	2.1	9.8	78.9	96.2
Wilfener Bier	3.7	4.9	12.0	59.4	72.5
Budweiser Schankbier	3.8	4.3	12.0	64.3	78.5

Figure 5 - Analysis data of a few bottom fermented beers of the time. An apparent attenuation column has been added to the translation on the right hand side. From Brockhaus' Konversationslexikon, 1893

Analysis data from select beers of the time

The following tables have been taken from Brockhaus' Konversationslexikon, 1893. They list the alcohol by weight, real extract, starting extract (called "Stammwuerze" in German brewing) and real attenuation. In the translation I added the apparent attenuation for these beers as this is the attenuation number that we home brewers generally work with

One thing that immediately becomes obvious is that most of these beers are very poorly attenuated by modern standards. Most beers have an apparent attenuation in the 60s and only a few make it into the 70s or higher. Back then beer was considered food and was expected to be nutritious.

Another interesting observation is that the "summer beer (Sommerbier) was also a lager as it is listed under the bottom fermenting beers. Up to this point I always assumed the Sommerbiere were top fermented beers

Various Beer Styles

The following is a description of various beer styles as they were described in "Chemie fuer Laien". They obviously don't represent all the types of beers that were brewed back then.

Salvator-Bier

After we looked at the brewing process we will have a look at especially famous and popular beers.

We will start with the strongest of the bottom fermented beers, the *Salvator-Bier*. It gets its name from a brewery in Munich and its fame from its strength. Only the best ingredients are used and Bavarian breweries take pride in the fact that they brew their beer in an accredited traditional manner and with a constant quality. For the *Salvator-Bier* one takes 3 1/4 *Berliner Scheffel* (1 such *Scheffel* is 55 liter) malt and 3 1/2 *Pfund* (one such *Pfund* is 380g) to make 170 *Quart* beer (one such *Quart* is about 0.95 liter). The rest of the procedure is pretty much the standard Bavarian brewing method. The *Salvator-Bier* is always brewed using a decoction mash and the thick mash boils about 1/2 hour longer than usual.

After the wort has been drawn into the boil kettle the length of the boil will determine the color of the beer. The hops are added 1 hour before the end of the boil. Assumed that the beer needs to boil for 5 hours to get the degree of color that the beer drinker prefers, the hops are added after the beer has already boiled for 4 hours, because only the finest part of the hops, the aroma and the essential oils, should be extracted. But that this wouldn't be better accomplished if the hops were only steeped is obvious. But this is how it is done in Bavaria and by doing so not only the finest but also the roughest part of the hops, the bitterness, is extracted.

The wort is cooled to 10 C and pitched with more yeast than usual to accelerate the primary fermentation which still takes 12 days because of the strength of the wort. But it is not left in the primary fermentation vat until the beer has cleared. Instead it is transferred to the secondary fermentation casks for a strong secondary fermentation. Once it is complete the beer is transferred again for the actual lagering and maturation.

During neither of these fermentations will the beer be *spunded* (bunged) which results in very low carbonation of the final beer and the taste is not as refreshing as one is used to from other Bavarian beers. In Berlin there is a brewery that brews a foaming *Salvator-Bier* which has this delicious and refreshing taste.

The Munich *Salvator-Bier* has a deep dark color but is never as clear as wine. It is pretty clear but never what one would call bright. It also has a strong bitter finish which is evidence than not only the "finest" was extracted from the hops. The alcohol content is about 5 1/2 percent which makes it the one of the strongest beers brewed in Germany.

Bockbier

With its 4 1/2 to 5 percent alcohol, it is the next strongest beer to the *Salvator-Bier*. And similar to the *Salvator-Bier* it is brewed with decoction mashing but with less malt and hops. Only 3 1/2 *Berliner Scheffel* malt and 2 1/2 *Pfund* hops are used to brew 200 *Quart* beer. But still this beer is much stronger, one might say double, as the common Bavarian beer. It is only served during the month of May. The Bavarians enjoy strong beer and would drink even more of that since the *Hofbraeuhaus* barely fits the guests which come there in May and has never enough wait staff. Which why it is not unheard of, that a guest may take the next empty mug, rinse it himself and get in line for the next beer. He even finishes it while standing and continues to do so as long as he dares if we wants to get home on his feet. Hardly anyone gets a seat during the *Bockbier* season.

For the *Bockbier* The wort is chilled to 7 to 8 C and the fermentation takes 10 to 12 days. After that it is transferred to the lagering casks for a secondary fermentation. Once the strong secondary fermentation is complete the casks are topped off with *Bockbier* and lightly bunged. This allows some carbonation to build up but not enough for the beer to carry a big head. Only a slight layer of foam but more than what the *Salvator* shows.

Bamberger Bier

This belongs to those beers brewed in Bavaria for which the so called Lautermash is used. The crushed and dry malt is added to the mash tun and the water is brought to a boil in the boil kettle. Once it boils it is cooled to 85 C through the addition of cold water. This water is then added to the mash tun such that it enters from the bottom. The dry grain will swim on that water. The water is added in two to three steps and every half or third respectively is added after half an hour. Only after all the water has been added the mash is stirred. This takes about half and hour and after that the temperature of the mash will be about 10 C lower than what the water was in the kettle.

The mash rests for about an hour after and then some wort is drawn off and moved to the boil kettle where it is boiled with all the hops. This basically "roasts" the hops and gives the *Bamberger Bier* its peculiar taste.

Once the wort from the mash tun has cleared it is drawn into the boil kettle. One *Scheffel* malt and 2 1/2 to 3 *Pfund* of the best hops yields 7 *Eimer* beer (*means buckets but I don't know how large such a bucket was*).

The cooling on the cool ship, pitching of the yeast and fermentation is the same as with the other bottom fermented beers.