LAGER BEER

26 April 1997
A.J. deLange
Brew America Lecture Series

VG 1

OBJECTIVES

- **EXPLORE THE DIFFERENCES BETWEEN LAGER BEER AND ALES**
  - **HISTORICAL PERSPECTIVE**
  - **PROPERTIES**
    - » **COLOR, AROMA, FLAVOR, BODY**
  - **BREWING MATERIALS**
    - » **WATER, GRAIN, HOPS, YEAST**
  - **BREWING METHODS**
    - » **WATER TREATMENT, MASHING, BOIL, CHILL, FERMENTATION, LAGERING**
    - » **EQUIPMENT**
- **BASED ON A CLASS ON PILSNER BREWING**
  - **EMPHASIS ON THAT STYLE AND HOW OTHER STYLES DIFFER**

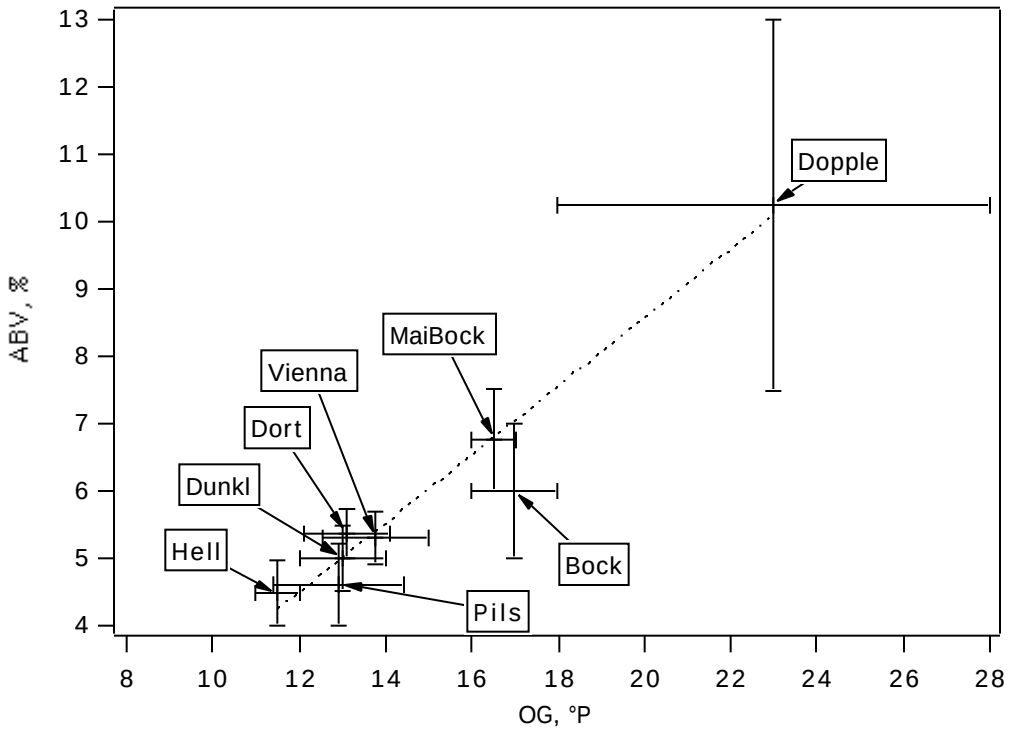
WHAT DISTINGUISHES LAGER

- **EMPHASIS ON MALT, HOPS, WATER**
  - **YEAST CHARACTER MINIMAL - "NEUTRAL"**
    - » **Fusels, Esters Considered Faults**
    - » **But diacetyl, DMS, sulfur often sought to limited extent**
    - » **Often described as "Clean"**
- **HIGH QUALITY INGREDIENTS**
  - **FLAWS NOT MASKED BY YEAST FLAVORS**
- **LESS MODIFIED MALTS**
  - **MORE INTENSIVE MASHING**
    - » **More complicated profiles**
    - » **Decoction mashing/mixed mashing (adjuncts)**
- **BOTTOM FERMENTATION: LOW TEMPERATURE**
- **LONG FLAVOR MATURATION: LOW TEMPERATURE**

POPULARITY

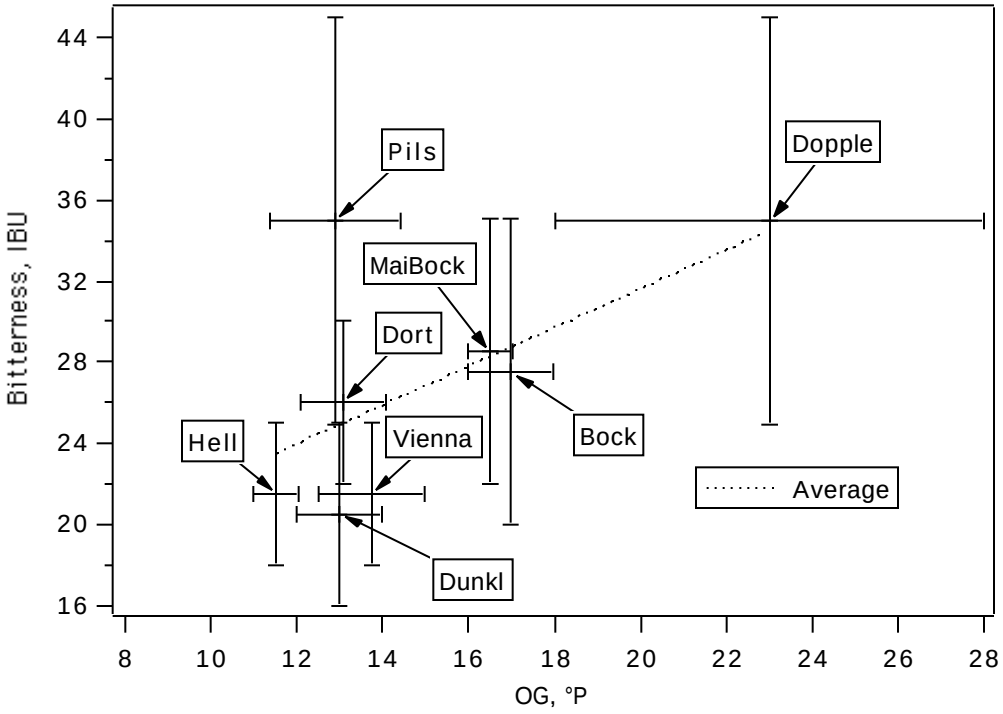
- **MOST BEERS BREWED IN WORLD TODAY ARE LAGERS, ACTUALLY PILSNERS**
- **MODERN TECHNIQUES HAVE SPED UP PROCESSING TIMES (DAYS vs. MONTHS)**
  - **Malting**
  - **Mashing**
  - **Fermentation**
  - **Lagering**
- **MOST OF THESE BEERS ARE PARODIES OF THEIR EUROPEAN FORBEARS**
- **LIGHT, REFRESHING/QUENCHING, APPEARANCE**
- **TRY DOCTORING BUD WITH HOP EXTRACT: YOU MAY BE PLEASANTLY SURPRISED!**

ALCOHOL vs OG



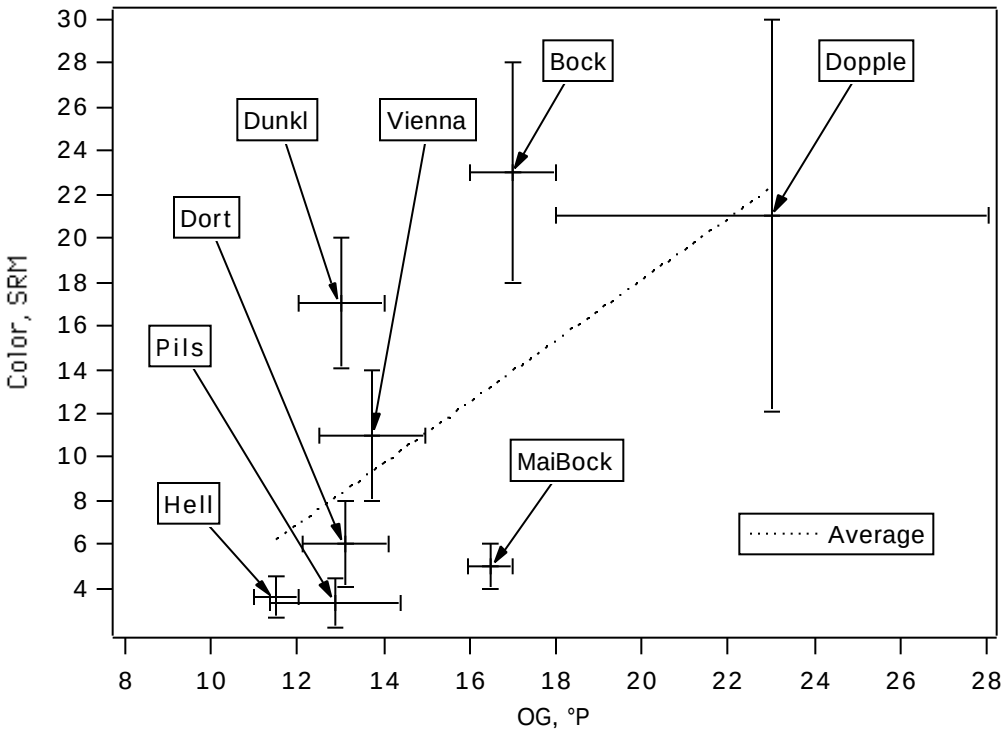
VG 5

BITTERNESS vs OG



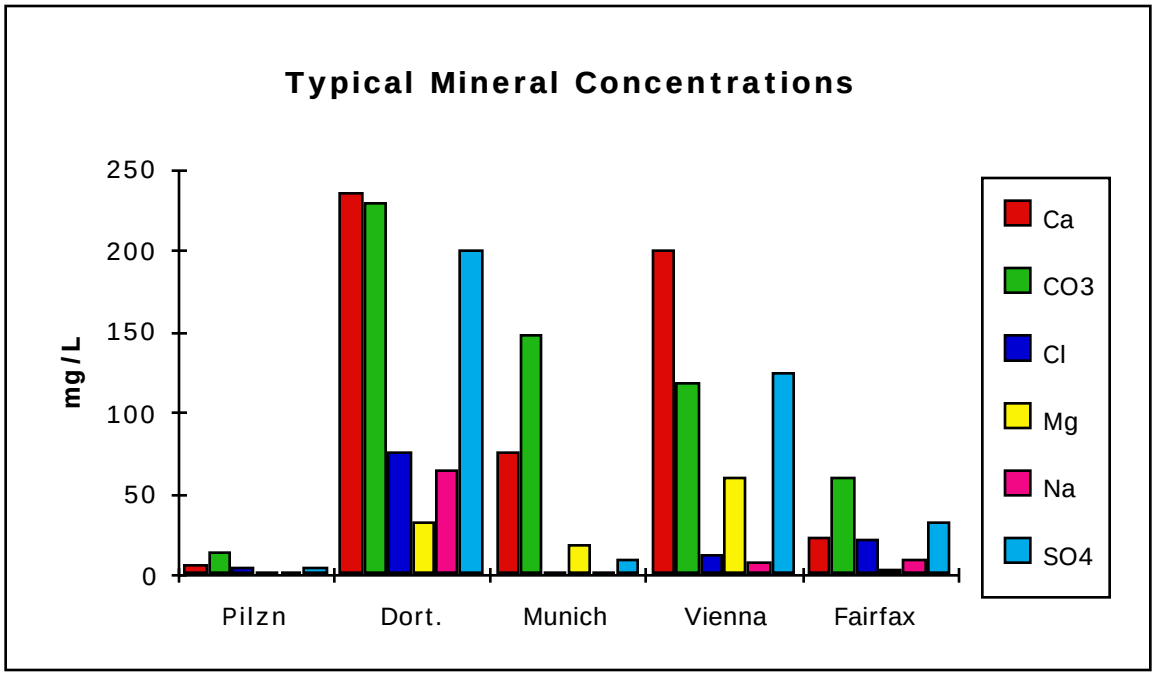
VG 6

COLOR vs OG



VG 7

LAGER WATER



VG 8

HISTORY

- **ACCIDENTAL DISCOVERY ATTRIBUTED TO BAVARIAN MONASTERY BREWERS**
  - **Beer brewed in the spring was stored in ice caves for use during the summer**
  - **This method of storage led to selection of yeasts which settled to the bottom of the storage container**
  - **Not only was the stability of the beer enhanced but flavor improvements were noted.**
  - **Systematized starting with Benno Scharl, Bavarian monk, ca 1810 working near Munich**
- **TWO PIONEERS ADOPT BOTTOM FERMENTING YEAST IN 1841**
  - **Gabriel Sedelmyer (Munich - Spaten)**
  - **Anton Dreher (Vienna/Michalovice/Budapest)**

HISTORY II

- **ONE YEAR LATER (1842)BAVARIAN MONK SMUGGLES YEAST INTO BOHEMIA**
- **MECHANICAL REFRIGERATION BECOMES PRACTICAL**
  - **Adopted by Dreher and Sedelmyer in late 1860's**
- **BOHEMIAN GLASS INDUSTRY**
- **Jacob Christian Jacobsen (Student of Sedelmyer; founded Carlsberg)**
  - » **Took Spaten yeast to Copenhagen**
  - » **Emile Hansen: (Carlsberg) first single cell culture:1883**

HISTORY III - PLZEN

- **CHRONOLOGY**
  - **2 January 1839: brewing citizens of Plzen appeal for establishment of city brewery and maltings**
    - » **Competition from Bavarian lagers**
  - **15 September 1839: Excavation for "Bürgerliches Brauhaus" begun**
  - **5 October 1842: First barrels broached**
    - » **"There was universal acclaim at the sight of its magnificent golden hue, with the snow-white froth floating atop, and cheers rose up from the lips of the drinkers as they imbibed the full body and the exquisite taste unparalleled by any other beer, which was the boast of this home produce."**
  - **1842: First available in Prague**
  - **1856: First available in Vienna**
  - **1862: "Virtually conquered" Paris**
  - **1900: Daily beer train to Vienna**

HISTORY IV - PILS

- **THE STYLE CAUGHT ON LIKE WILDFIRE**
- **WIDELY IMITATED THROUGHOUT EUROPE**
- **MIGRATED TO AMERICA AND THE REST OF THE WORLD**
- **MOST BEER CONSUMED IN THE WORLD TODAY IS A PILSNER DERIVATIVE**
  - **Many of these are scarcely recognizable as Pilsner**
  - **If light is good lighter must be better???**
  - **Use of adjuncts, mixed mashing minimized malt flavors**
  - **Diminution of hops to near or below threshold (12-14 IBU)**
  - **Use of special enzymes (Light beers)**

PILSNER URQUELL PROFILE

- **Original Gravity: 1.049 (12.1°P)**
- **Apparent Final Gravity: 1.014 (3.7°P)**
- **Apparent Attenuation: 69%**
- **Real Attenuation: 55%**
- **pH: 4.6**
- **Bitterness: 43 IBU**
- **Color: 4.2°L/SRM (10 EBC) (Dark Straw)**
- **"Stinging" hops**
- **Nutty, caramel**
  - **Part of caramel sweetness from diacetyl 0.15ppm (above threshold)**
- **Soft, smooth, sweet malt character**
- **Full bodied**

VG 13

SHOULD P.U. BE THE STANDARD?

- **C.J. LINTNER:**
  - **"The genuine Pilsner beer, brewed in Plzen, is distinguished from other brands of the same variety, by margins of taste which fail to be detected by analytical methods, nor can they be defined on scientific grounds. And yet, they are present in this beer. It can be asserted, though, that these factors are given by the local character, that is, they cannot be found in any other brewery."**
- **MOLD HAS BEEN STOLEN FROM CELLAR WALLS**
- **P.U. HAS BOUGHT GAMBRINUS...**
  - **Research underway to determine what makes P.U. P.U.**
  - **Worts brewed at Gambrinus fermented at P.U. and vice versa.**
- **OTHER CHANGES AT P.U.**

P.U. INGREDIENTS

- **MORAVIAN BARLEY**
  - **Hanna Kargyn, Hanna Proskowetz..**
    - » **“In fact, the Hanna barleys are considered the finest malting barleys in the world.” deClerk**
  - **Kneifl**
  - **Low protein content**
- **FLOOR MALTED**
- **UNDER MODIFIED**
- **SOFT ARTESIAN WATER.**
  - **TDS: 35 ppm (Noonan) - 51 ppm(deClerk)**
- **Hops from Saaz (Zatec) between Prague (Praha) and Carlsbad (Karlovy Vary)**
  - **Noble variety**
  - **Low alpha; high oils**

P.U. METHODS

- **TRIPLE DECOCTION MASH**
  - **Rests 95°F, 122°F, 149°F, 168°F**
- **LONG BOIL (2 HRS)**
- **3 HOP ADDITIONS**
- **PRIMARY FERMENTATION**
  - **Open wooden casks in atemperated cellars**
  - **Blend of 5 yeast strains**
- **LAGERING**
  - **Large wooden barrels in 1-3° C cellars**
  - **“Forced attenuation”**
  - **3 Months**
  - **Krausening**
- **PASTEURIZATION**

GERMAN PILS
DIFFERENCES

- **HARDER WATERS**
- **STILL ALL MALT (INCLUDING “CHIT”)**
- **OTHER HOP VARIETIES**
  - **Herrsbrucker**
  - **Tettnanger**
  - **Mittelfrüh**
  - **Spalt**
- **LESS MALTY**
- **LIGHTER COLOR**
- **DRIER**
- **LESS CARAMEL**

VG 17

deGroen Pils

- **2 Row North American/ Canadian Barley**
- **Step Infusion Mash**
  - **Dough In at "High" Protein Rest Temperature**
  - **Raise to Glucan Rest Temp - Direct Heat**
  - **Raise to Sachharification Rest Temperature**
- **OG 12.8 °P**
- **2 Hour Boil; 3 Hop Additions**
  - **10 Minutes After Start of Boil (Nugget)**
  - **1 Hour Into Boil (Nugget/Saaz)**
  - **10 Minutes Before Knockout (Saaz)**
  - **> 50 IBU**
- **Chill to 44°F - Cold Trub Removal by Floatation**

VG 18

deGroen Pils II

- **Pitch at 44°F; Allow Temp to Rise to 48°F**
  - **Weihenstephan 3470**
- **Ferment 7 - 10 days**
- **Lower to 39°F Over 3 Days. Blow Down Yeast During This Time**
- **To Lager at 31 - 35 °F (Ambient) When 0.6 - 0.8 °P Left**
- **Lager Tanks 2000 Gal (64 bbl; 76 hl)**
  - **Takes 4 Brews to Fill Lager Tank**
- **Lager 4-6 Weeks**
- **FG 1.9 - 2.0 °P; Apparent Att: 84%; 5.3% ABV**

Thanks to Bill Covaleski

HOMEBREWING PILSNER

- **WHY HOMEBREWERS DON'T BREW PILSNER**
  - **THEY DON'T LIKE IT**
    - » **Too simple i.e. no ester complexity**
    - » **Too bitter**
    - » **Not "big" enough**
  - **IMAGE**
    - » **Association with insipid American "Pilsners"**
  - **THEY ARE LAGERS**
    - » **Kit/Extract Lagers are disappointing**
    - » **Greg Noonan (and others) scare people off**
    - » **Refrigeration/temperature control is required**
    - » **Must wait months to enjoy fruits of labors**
  - **THE SMALLEST FLAW IS EASILY DETECTABLE**

HOMEBREWING PILSNER II

- **WHY SOME HOMEBREWERS (I.E. THIS ONE) BREW PILSNER**
  - **They Like It**
    - **"Hopfen und Malz, Gott erhalts": This beer is about hops and malt. Period.**
    - **It is very refreshing in the warm weather**
    - **Goes well with food**
    - **"Clean" taste**
  - **It's a Challenge**
    - **If you can brew a good Pilsner, you can brew anything**
  - **It Appeals to Traditionalists**
    - **Finest materials**
    - **Reinheitsgebot**
  - **Everybody Has His Favorite**
  - **There Are Ways Around Many of the Difficulties**

WHAT IS pH?

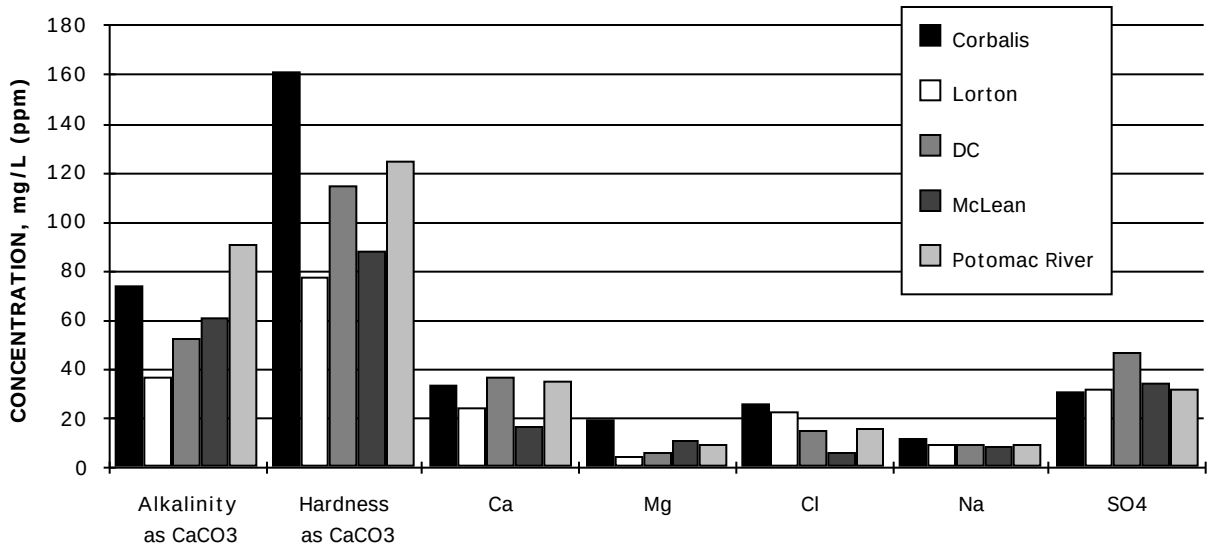
- **SIMPLEST TO THINK OF IT AS ANOTHER PARAMETER (LIKE TEMPERATURE) WHICH NEEDS TO BE CONTROLLED FOR BEST BREWING RESULTS**
  - **MASH ENZYMES PERFORM BEST IN A SPECIFIC RANGE OF TEMPERATURE *AND pH***
  - **BOIL REACTIONS ARE OPTIMIZED WITHIN A CERTAIN RANGE OF pH**
  - **CERTAIN pH CHANGES THROUGHOUT THE PROCESS ARE INDICATIVE OF A NORMAL BREW**
- **STRIKE pH IS THE MOST IMPORTANT pH MEASUREMENT**
  - **pH < 5.8 AT STRIKE USUALLY MEANS pH 5.2-5.4 WILL BE REACHED AT SACCHARIFICATION**

WATER

- **WATER IS VERY IMPORTANT (FOR BOHEMIAN PILS IT IS CRITICAL)**
- **KNOW YOUR WATER**
  - **Get city/county report**
  - **Have it tested by a lab**
  - **Test it yourself (even if on city water: chemistry fluctuates)**
- **TREAT IT AS REQUIRED**
  - **Dilute with distilled/RO water**
  - **Supplement with minerals as required**
  - **"Build" from scratch using salt additions**
- **LOCAL (DC AREA) WATER PROBLEMS FOR BOHEMIAN PILS ONLY**
  - **Too alkaline (mash pH doesn't drop enough)**
  - **Too much sulfate (hops too harsh)**

LOCAL WATER

REGIONAL SUPPLIES



WATER-I (BOHEMIAN PILS)

- **WATER MUST BE SOFT (< 50 ppm TDS)**
  - **Sulfate : hops bitterness harsh (but floral char. enhanced)**
    - » **Lots of noble hops are used (3 oz/5 gal or more)**
    - » **Makes beer too dry**
  - **Carbonate/bicarbonate: alkalinity - lots of problems**
    - » **Poor flavor even when neutralized**
  - **Calcium precipitates phosphates (phosphorous essential to fermentation)**
  - **Sodium: disagreeable taste; augments sulfate harshness**
  - **Magnesium. Bitter. Effects some people**
  - **Chloride gives soft, mellow palate. Not objectionable?**
- **BEERS ARE MADE WITH ALL THESE IONS BUT THEY ARE NOT BOHEMIAN PILSNERS**

WATER - II (BOHEMIAN PILS)

- **CHLORINE, IRON, NITRATES MUST BE ABSENT OR REMOVED**
- **BOILING DOES NOT WORK ON LOCAL WATER**
- **MIX DISTILLED /RO OR SPRING WATER WITH TAP WATER TO GET INTO RANGE**
  - **Also dilutes sulfate**
- **TO GET PROPER MASH pH DO NOT ADD GYPSUM (ADDS SULFATE) OR ACID (ADDS ANION). USE:**
  - **Some "caramel" malt**
  - **"Acid rest" (adds lactate)**
  - **Sour mash addition (adds lactate)**
  - **Decoction mashing (may not drop pH enough)**

WATER - III (OTHER STYLES)

- **YOU HAVE MORE LATITUDE WITH OTHER STYLES**
- **LOCAL WATER IS PRETTY GOOD FOR MOST PURPOSES (ONCE CHLORINE IS OUT)**
- **TAILOR ION CONTENT TO STYLE OR TO TASTE AS YOU GET MORE EXPERIENCED**
- **IF A LOT OF DARK MALT IS USED (BOCK) YOU MAY NEED SOME ADDITIONAL CARBONATE**
  - **Note Munich carbonate about twice our local water's**
  - **Use chalk (calcium carbonate)**
    - » **Add to mash in small quantities**
    - » **Mix thoroughly**
    - » **Wait**
    - » **Check pH**

PILS FROM LOCAL WATER

- **DILUTE 1 PART LOCAL WATER WITH 3 PARTS DEIONIZED WATER (EXCHANGE/RO/DISTILLED**

	Alkalinity	Ca	Mg	Cl	Na	SO4
Local Water	70	30	10	10	10	30
Dilute 1 + 3	17.5	7.5	2.5	2.5	2.5	7.5
Pilzen Water	11.7	7	2	5	2	5

MUNICH (Noonan/Richman) FROM LOCAL WATER

- **IMPOSSIBLE TO DO.**
- **COMMON SPECIFICATION FOR MUNICH WATER CAN'T BE REALIZED**
  - **DESCRIBES WATER WITH DISSOLVED CALCIUM CARBONATE AND LITTLE ELSE**
  - **CALCIUM AND CARBONATE ARE NOT IN CORRECT PROPORTION**
- **DILUTE 1 PART LOCAL WATER WITH 2 PARTS D.I. WATER (TO GET Na^{+}, SO_4^{-2}, Cl^{-} DOWN)**
- **ADD 150 mg CHALK PER LITER AND SPARGE WITH CO_2 TO GET IT TO DISSOLVE**
- **RESULT WILL BE LOW IN Ca^{+2} AND HIGH IN HCO_3^{-}**
- **MOOT? HCO_3^{-} MUST BE REMOVED EXCEPT FOR BOCKS.**

MUNICH FROM LOCAL WELL
(Profile: Noonan/Richman)

1 Part Well Water + 2 Parts D.I. Water

		r1	r2	f1 = 1/d	f2	f3					
Desired pH	8.30	83.18	0.01	0.0118	0.9804	0.0078					
Alkalinity Defining pH	4.30	0.01	0.00	0.9918	0.0082	0.0000					
Base Water pH	7.00	4.17	0.00	0.1934	0.8063	0.0003					
Salt	**mg/L**	**Ca(mg)**	**Mg(mg)**	**Na(mg)**	**C(mM)**	**CO2(mg)**	**HCO3(mg)**	**CO3(mg)**	**SO4(mg)**	**Cl(mg)**	**City**
Sodium Chloride	0.00			0.00						0.00	
Calcium Sulfate (Gypsum)	0.00	0.00							0.00		
Calcium Carbonate	130.00	52.05			1.30	0.67	77.75	0.61			
Calcium Chloride Dihydrate	0.00	0.00								0.00	
Sodium Bicarbonate	0.00			0.00	0.00	0.00	0.00	0.00			
Magnesium Sulfate (Epsom Salts)	0.00		0.00						0.00		
	mEq/L										
Additional Acid Required*	0.00										
Carbonic Acid	1.18				1.19	0.62	71.41	0.56			
Hydrochloric Acid	0.00									0.00	
Sulfuric Acid	0.00								0.00		
Totals		52.05	0.00	0.00	2.49	1.29	149.16	1.17	0.00	0.00	
pHs (Keep > desired pH)	7.19										
	Alkalin.										
Base Water	24.00	7.70	4.00	2.30	0.60	5.11	29.56	0.01	11.30	2.00	
Shifted to Desired pH	29.68	7.70	4.00	2.30	0.60	0.31	35.94	0.28	11.30	2.00	
Sums	152.86	59.75	4.00	2.30	3.10	1.61	185.10	1.45	11.30	2.00	
Desired	**122.00**	**75.00**	**18.00**	**2.00**	2.47	1.28	147.74	1.15	**10.00**	**2.00**	**Munich**
	Alkalin.	**Ca(mg)**	**Mg(mg)**	**Na(mg)**	**C(mM)**	**CO2(mg)**	**HCO3(mg)**	**CO3(mg)**	**SO4(mg)**	**Cl(mg)**	
p[Ion] Error (Minimize Magnitude)		**-0.10**	**-0.65**	**0.06**	**0.10**				**0.05**	**0.00**	
Weighting		1.00	1.00	1.00	1.00				1.00	1.00	
Weighted Log Error Squared		0.0097	0.4267	0.0037	0.0096				0.0028	0.0000	

MUNICH FROM LOCAL WELL
(Profile: M. M. Moll)

- **INCREASED PERMANENT HARDNESS (SULFATE, CHLORIDE) RE NOONAN SPEC.**
- **CAN BE APPROXIMATED WITHOUT DILUTION**
- **SULFATE QUITE HIGH**
  - **SUITABLE FOR HELLES?**

MUNICH FROM LOCAL WELL
(Profile from Moll)

		r1	r2	f1 = 1/d	f2	f3					
Desired pH	7.60	16.60	0.00	0.0567	0.9418	0.0015					
Alkalinity Defining pH	4.30	0.01	0.00	0.9918	0.0082	0.0000					
Base Water pH	6.50	1.32	0.00	0.4313	0.5686	0.0001					
Salt	**mg/L**	**Ca(mg)**	**Mg(mg)**	**Na(mg)**	**C(mM)**	**CO2(mg)**	**HCO3(mg)**	**CO3(mg)**	**SO4(mg)**	**Cl(mg)**	**City**
Sodium Chloride	0.00			0.00						0.00	
Calcium Sulfate (Gypsum)	70.00	16.30							39.06		
Calcium Carbonate	90.00	36.04			0.90	2.25	51.70	0.08			
Calcium Chloride Dihydrate	62.00	16.93								29.88	
Sodium Bicarbonate	0.00			0.00	0.00	0.00	0.00	0.00			
Magnesium Sulfate (Epsom Salts)	30.00		2.96						11.69		
	mEq/L										
Additional Acid Required*	0.00										
Carbonic Acid	0.00				0.00	0.00	0.00	0.00			
Hydrochloric Acid	0.00									0.00	
Sulfuric Acid	0.00								0.00		
Totals		69.26	2.96	0.00	0.90	2.25	51.70	0.08	50.75	29.88	
pHs (Keep > desired pH)	6.97										
	Alkalin.										
Base Water	71.00	23.00	12.00	7.00	2.53	48.08	87.87	0.01	34.00	6.00	
Shifted to Desired pH	118.63	23.00	12.00	7.00	2.53	6.33	145.54	0.23	34.00	6.00	
Sums	160.77	92.26	14.96	7.00	3.43	8.57	197.24	0.31	84.75	35.88	
Desired	**140.00**	**109.00**	**21.00**	**2.00**	2.99	7.47	171.76	0.27	**79.00**	**36.00**	**Munich**
	Alkalin.	**Ca(mg)**	**Mg(mg)**	**Na(mg)**	**C(mM)**	**CO2(mg)**	**HCO3(mg)**	**CO3(mg)**	**SO4(mg)**	**Cl(mg)**	
p[Ion] Error (Minimize Magnitude)		**-0.07**	**-0.15**	**0.54**	**0.06**				**0.03**	**0.00**	
Weighting		1.00	1.00	1.00	1.00				1.00	1.00	
Weighted Log Error Squared		0.0052	0.0217	0.2960	0.0036				0.0009	0.0000	

MALT - I (BOHEMIAN PILS)

- **FINEST QUALITY MORAVIAN/BOHEMIAN**
  - **2 row Hanna, Kniefl varieties**
- **VERY PALE**
- **LOW PROTEIN CONTENT (2 ROW)**
  - **Chill haze problem**
- **LOW MODIFICATION**
  - **Cold germination**
  - **Short flooring time**
  - **Thorough drying before raising temp to 80°C for 4-5 hr**
- **5 - 10% CARA PILS FOR BODY**
- **5 - 10 % CRYSTAL/BISCUIT FOR CARAMEL FLAVOR**

MALT - II (BOHEMIAN PILS)

- **BUY THE BEST QUALITY, LEAST MODIFIED MALT AVAILABLE**
  - **DE WOLF-COSYNS**
    - » **Note: De Clerk claims a lot of Czech production goes to Belgium**
  - **IREKS**
  - **OTHERS...**
- **OTHER PALE 2 ROWS O.K.**
  - **KLAGES**
- **AVOID NORTH AMERICAN (ESP. 6 ROW)**
  - **Too much protein - chill haze problems**
- **BRITISH MALTS TEND TO BE TOO DARK**
- **BLEND MALTS (AVERAGES PROPERTIES)**

MALT - III (OTHER STYLES)

- **MORE LATITUDE BUT STICK WITH HIGHEST QUALITY AVAILABLE**
  - **There are no (or fewer) esters to hide behind with lagers.**
- **IF DECOCTION MASHING, STICK WITH UNDERMODIFIED MALTS**
- **DO NOT USE "PALE" ALE MALTS FOR BASE**
  - **Too highly kilned**

HOPS - I (BOHEMIAN PILS)

- **SAAZ. Period!**
- **“FRESH”**
  - **Oxygen Barrier Packaging**
  - **Cold Storage**
  - **No Cheesy Smell**
- **LEAF, PELLET, HOPLETS**
  - **Type depending on method used in wort separation**
- **3 ADDITIONS**
  - **Early Addition Aids Protein Coagulation**
  - **Last one at or just before end of boil (for aroma)**
  - **Others: suggested times vary**

HOPS - II (OTHER STYLES)

- **ONLY BOHEMIAN PILS IS RESTRICTED IN HOPS CHOICE**
- **AS ALL LAGERS EMPHASIZE MALT AND HOP FLAVORS/AROMAS NOBLE OR CLOSE TO NOBLE (HALLERTAU HERRSBRUCKER) ARE OFTEN CHOSEN**
- **MANY USE NOBLE HOPS FOR ALL ADDITIONS**
  - **PERSONAL OPINION: One of the best ways to ruin a good lager is to use coarse bittering hops.**

MILLING

- **NOTHING SPECIAL HERE**
- **UNDER MODIFIED MALTS ARE "STEELIER" AND REQUIRE A BIT MORE WORK**
- **GOALS THE SAME AS FOR ANY NORMAL BEER**
  - **Grits Small - But Not Too Much Flour**
  - **Husks Intact to Maximum Extent Possible**

MASHING

- **LAGERS TRADITIONALLY MADE BY DECOCTION MASHING**
- **EUROPEAN BREWERIES GENERALLY DO NOT USE IT TODAY**
  - **Is this just a cost saving measure which compromises the quality of the beer?**
- **QUESTIONS AS TO WHETHER THIS IS REQUIRED (OR EVEN DESIREABLE) WITH MODERN MALT**
- **SOME SORT OF STEPPING IS REQUIRED**
  - **Usually can't go all the way to mashout with infusion - too much water required**
- **RIMS ADDS A WHOLE NEW DIMENSION TO THE DEBATE**

MASHING - DECOCTION I

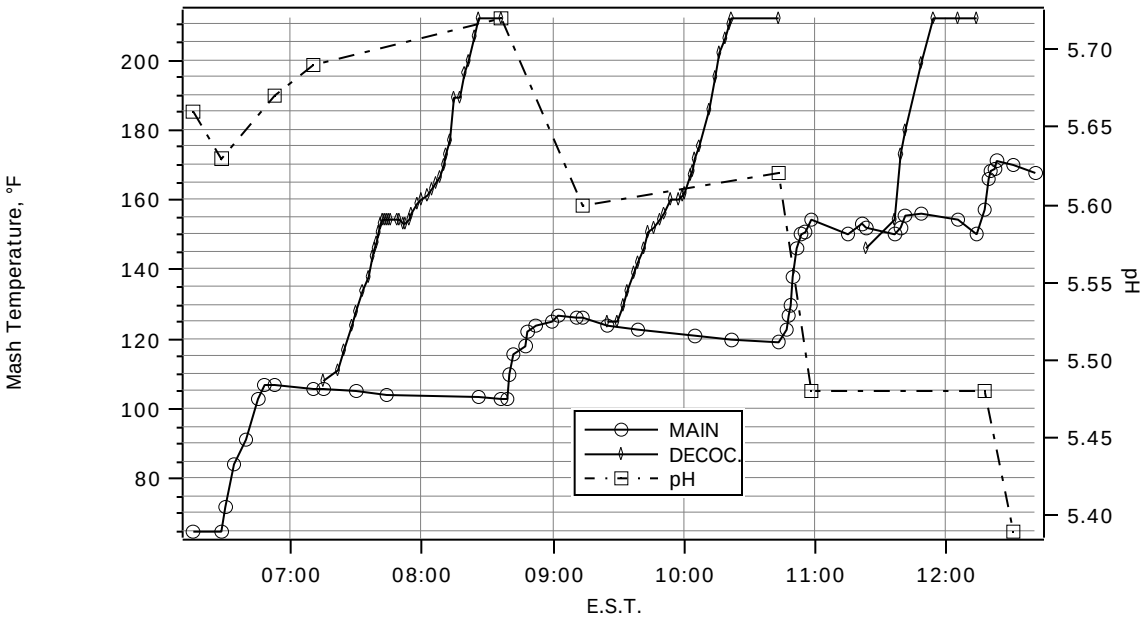
- **ADVANTAGES OF DECOCTION MASHING**
  - **Breaks down protein matrix to free starch**
  - **Gelatinizes starch**
  - **Extract, coagulate and precipitate proteins, tannins, silicates...**
  - **Reduce wort pH**
  - **Less trub formed in main boil**
  - **Less chance of raw starch carry over from lauter/sparge**
  - **Thicker mash**
  - **Traditional**
  - ***Production of flavor and aroma compounds***

MASHING - DECOCTION II

- **DISADVANTAGES OF DECOCTION MASHING**
  - **Complicated - intimidating**
  - **Additional equipment required (capital)**
  - **Time consuming (labor costs)**
  - **Darkens beer**
  - **Tannin extraction (grains boiled)**
  - **Danger of scorching**
  - **Higher energy utilization (costs)**
  - **Starch released in 2d decoction may not convert if this is the final decoction**
  - **"**The classical three-mash system is a long-drawn-out affair and the chief criticism which has been leveled against it is, that mashing is too intensive**"** Jan deClerk [*intensive* refers to dissolution of too much protein "at the expense of the stability of the beer"]

MASHING - TRIPLE DECOCTION I

- **TRIPLE DECOCTION (DREIMAISCHVERFARHEN)**



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MASHING - TRIPLE DECOCTION II

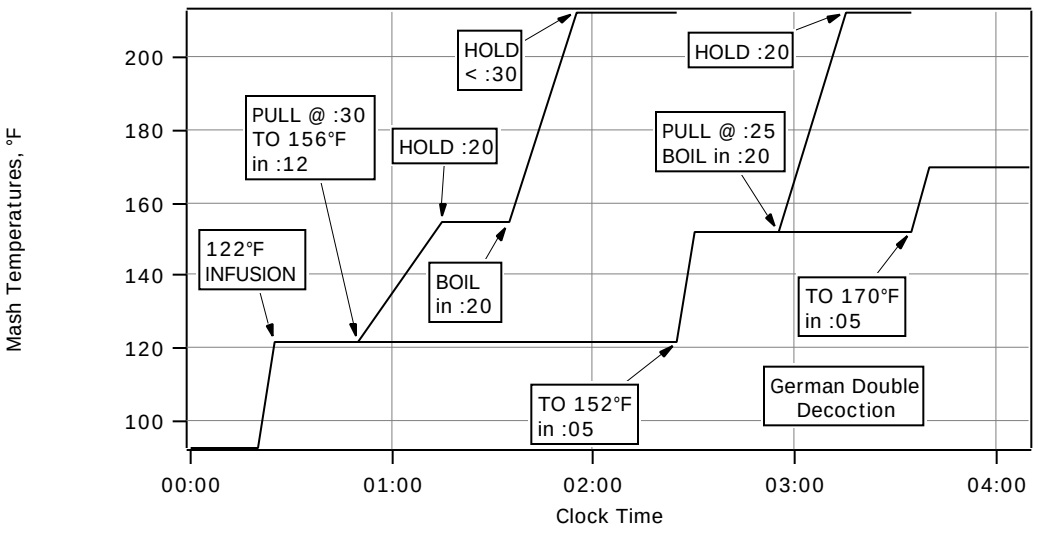
- **DOUGH-IN COLD WITH APPROX. 1 QT/LB**
- **RAISE TO ACID REST TEMPERATURE (105 °F) WITH INFUSION (< 1.3 QTS/LB)**
- **OTHER STEPS SET BY DECOCTION RATIOS**
  - **1st: 30-40% Thickest Part**
    - » **Rest at 122 and 152°F if Desired**
    - » **Return to Hit 118 - 128°F**
  - **2nd: 35 - 45% Thickest Part**
    - » **Rest at 152° if Desired or Go Through Enzyme Activity Range (145 - 167°) Slowly**
    - » **Return to Hit 148° - 154°**
  - **3rd (Lauter Decoction): 40-50% Thinnest Part**
    - » **Return to Hit 167 - 172°**

MASHING - TRIPLE DECOCTION III

- **MASHOUT 5-10 MINUTES AT (167-172°F)**
  - **Just Long Enough to Inactivate Enzymes**
- **ROUSE (TO GET HUSKS UNIFORMLY DISTRIBUTED) AND TRANSFER TO LAUTER TUN (IF TRANSFERRING)**

MASHING - DOUBLE DECOCTION

- **ZWEIMAISCHVERFAHREN**
  - **Saves Time, Labor, Energy**



MASHING - INFUSION

- **WELL MODIFIED MALT**
  - **Single Step ~150°F**
  - **Mashout Rest (170°F) For Better Lautering/Sparging**
- **LESS FULLY MODIFIED MALT**
  - **Acid Rest (95 - 105°F)**
  - **Protein Rest (118 - 128 °F)**
  - **Saccharification Rest (149 - 154°F)**
- **USE COMBINATION OF METHODS**
  - **All Steps by Infusion Leads To Too Thin A Mash**
  - **Use Infusions At Start, Direct Heat or Recirculation For Later Steps**

MASHING - MIXED (ADJUNCT)

- **USUALLY LIMITED TO LIGHTER LAGERS**
- **“MEGASWILL” MADE THIS WAY**
- **METHOD**
  - **Adjunct and some malt (10%) or enzymes heated in separate “cooker” to saccharification temperature and then boiled.**
  - **Boiling bursts granules and frees starches**
  - **Main Mash Stepped to Protein Rest Temperature**
  - **Boiling Adjunct Added to Raise to Saccharification Temperature**
  - **Mashout Temperature by Infusion or Direct Heat**

ADJUNCTS (ADD JUNK)

- **USED TO DILUTE:**
  - **The Color**
  - **The Flavor**
  - **The Body**
  - **The Nitrogen (Haze)**
- **ADJUNCT MATERIALS**
  - **Rice**
  - **Corn**
  - **Unmalted Barley**
  - **Chit Malt (Barley)**
  - **Sugar (Australian Lagers)**
- **MALTS**
  - **High Protein/Nitrogen Content 6- Row O.K.**
  - **Must Have High Diastatic Power**

EXTRACT

- **“PILSNER IS ONE OF THE MOST DIFFICULT STYLES OF BEER TO BREW FROM MALT EXTRACT.” Dave Miller**
  - **Caramelization In Processing**
  - **“Tang” Very Apparent**
  - **Corn Syrups Frequently Added**

LAUTER/SPARGE

- **USE FOUNDATION WATER IF FALSE BOTTOM LAUTER TUN**
- **ALLOW GRAIN BED TO SETTLE**
- **LAUTER UNTIL RUNOFF FREE OF ALL PARTICULATE MATTER**
  - **Remember, this is a CLEAN beer**
- **SPARGE WATER TEMP CAN BE HIGHER THAN USUAL**
  - **Tannins Have Been Extracted**
  - **BUT don't let sparge water pH get over 6.**
  - **This should coincide with runoff of 2-3°P**

BOIL

- **APPLY HEAT DURING WORT COLLECTION**
  - **Initial Runoff Should Not Be > 3-4°P Above Design Gravity or Excess Caramelization May Occur**
    - » **You may want this to happen!**
  - **If Done Right Wort Will Boil At Completion of Collection**
- **BOIL FOR 2 HOURS**
- **BOIL VIGOROUSLY**
  - **Mechanical Action Aids Coagulation**
- **BOIL UNCOVERED**
  - **Allow DMS to Escape**
- **AT LEAST 20% VOLUME WILL BE LOST**
  - **Make Up With Boiling Liquor**

WORT SEPARATION

- **TRUB REMOVAL NOT SO CRITICAL IN DECOCTION MASHING**
  - **Much trub is precipitated by decoctions and left in lauter tun.**
- **SEPARATION FROM HOPS**
  - **VARIOUS METHODS WORKABLE FOR HOMEBREWER**
    - » **HOP-BACK**
      - **Integral With Boiler**
      - **Separate Unit**
    - » **WHIRLPOOL**
      - **Transfer Wort To A Separate Vessel**
      - **Swirl (Don't Oxygenate)**
      - **Siphon After Cone Of Trub/Hops Residue Forms**

CHILLING

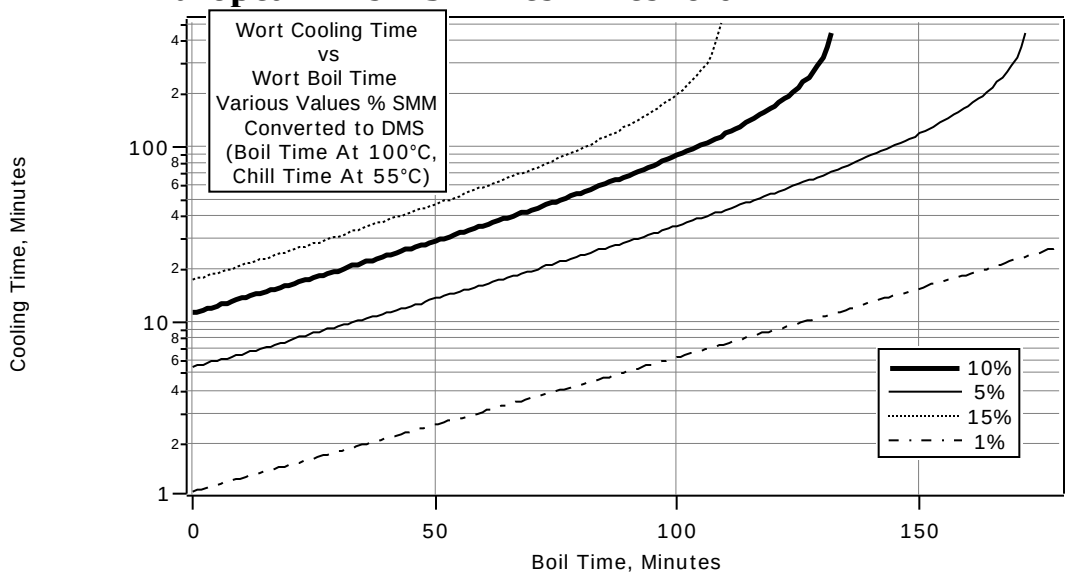
- **COOL RAPIDLY**
  - **Stop DMS Formation**
  - **Aid In Cold Break Formation**
  - **Reduce Chances of HSA**
  - **Get Inoculated ASAP (Reduce Infection Possibility)**

AERATION

- **NOT NECESSARY IF ENOUGH YEAST ARE PITCHED BUT PITCHING ENOUGH YEAST IS IMPOSSIBLE**
- **YEAST REQUIRE OXYGEN TO REPRODUCE**
  - **Used to form sterols and lipids**
- **IMPROPER LEVEL (HI OR LO) RESULTS IN ESTER/ACID FORMATION**
  - **Make a starter. Aerate/oxygenate for maximum cell production. Taste the supernatant!**
- **PROPER LEVEL DEPENDS ON YEAST STRAIN.**
- **GENERAL ADVICE: PITCH 1E6/Cells/mL/°P AND OXYGENATE TO AIR SATURATION (~8.5 mg/L)**
  - **Injected air must be sterile**
  - **Medical oxygen effective but how do you know when correct level has been reached?**

DMS CONTROL

- **SMM IN MALT**
  - **1 - 10 μgm SMM/gm => 20 - 2000 μgm/litre**
  - **Converts to DMS When Wort Hot (40 min t_{50} @ 100°C)**
  - **Taste Threshold ~ 30 μgm/litre**
  - **European Pils ~ 3 Times Threshold**



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PITCHING

- **PITCH 1-2 x 10^6 CELLS/mL/°P @ 43°F**
  - **0.4 - 1.3 Fl Oz Paste Per Gallon (4 Oz /5 Gallon)**
- **THAT'S A LOT OF YEAST**
  - **Coordinate Your Brewing With A Friend. Use His Crop.**
  - **Krausen 10% (No Lag Phase)**
  - **Snuggle Up To A Brewery**
  - **Use Randy Mosher's Method**
    - **Make a 1 Liter Starter.**
    - **Amplify To 1 Gal.**
    - **Decant Supernatant and Feed Back Up To 1 Gal.**
    - **Repeat**
    - **Oxygenate/Aerate At Each Feeding**
- **PROBLEM: YEAST DOES NOT HIT ITS STRIDE FOR SEVERAL BATCHES**

YEAST

- **OBVIOUSLY, LAGER YEAST (S. UVARUM)**
- **FREE FROM CONTAMINATION**
- **WYEAST**
  - **#2007 Pilsner**
  - **#2278 Czech Pils**
  - **#2124 Bohemian (Saaz) (WS 3470?)**
  - **#2308 Weihenstephan 308 - Unpredictable**
- **OTHER**
  - **Weihenstephan #3470 from a local brewpub/micro**
  - **Various other suppliers of slants/cultures**
- **STARTER OR PASTE REQUIRED**

COLD TRUB REMOVAL

- **SOME CONTROVERSY AS TO WHETHER IT SHOULD BE DONE**
  - **Generally thought to be desirable for Pils**
  - **Cold Trub Contains Materials (Lipids) That Are Required For Cell Membrane Formation**
- **NOT MUCH MATERIAL IN DECOCTION MASHING**
- **METHODS**
  - **Floatation During Aeration/Oxygenation**
  - **Settlement**
    - » **Racking**
    - » **Blow-down**
  - **Before or After Pitching?**

FERMENTATION

- **ALLOW TEMPERATURE TO RISE TO 45-50°F**
- **DON'T LET TEMPERATURE GO MUCH ABOVE 50°F**
- **GRAVITY DROP ~ 1°P (.004 SG) PER DAY**
- **pH SHOULD DROP**
- **GET A TERMINAL GRAVITY ESTIMATE**
- **REMOVE SCUM**
- **WHEN ~2-3° P ABOVE TERMINAL:**
  - **Raise Temperature To 55°F For A Day Or Two (Diacetyl Rest) If Diacetyl Is A Bete Noir For You**
  - **Seal**
  - **Gradually Lower Temperature To ~ 40°F**
  - **Transfer to Lagering Container**

LAGERING

- **REASONS FOR LAGERING**
  - **Secondary Fermentation**
  - **Conditioning**
  - **Clarification (Precipitation of Yeast, Protein-Tannin Complexes)**
  - **Flavor Maturation**
  - **Scrub out *Jungbukett* (green beer "stench" largely sulfur compounds)**
- **LAGER AS COLD AS POSSIBLE**
  - **But Approach Lagering Temperature Gradually**
- **PROVIDE LOTS OF SURFACE FOR YEAST**
  - **Horizontal Tank (Cornelius)**
  - **Beechwood/Aluminum Chips**

SPEEDING UP LAGERING

- **PITCH AT 46-50°F**
- **ALLOW TEMPERATURE TO RISE AS HIGH AS 61-64°F**
- **HOLD UNTIL FERMENTATION COMPLETE**
  - **Will Be Largely Free of Diacetyl, Hydrogen Sulfide and Acetaldehyde**
- **DROP TEMPERATURE TO 32°F**
- **LAGER A FEW DAYS (Clarification)**
- **FINE OR FILTER**
- **CARBONATE BY INJECTION**

HAZE

- **VERY UNDESIRABLE IN A PILS**
- **CAUSES**
  - **Protein**
  - **Polyphenols**
  - **Protein-Polyphenol Complexes**
  - **Trace Metals (Copper, Aluminum, esp. Tin)**
  - **Carbohydrates**
  - **Oxalic Acid**
- **REMEDIES**
  - **Low Protein Malts**
  - **Proper Protein Rests**
  - **Decoction Mashing**
  - **Trub Removal (Hot and Cold)**
  - **Long, Cold Lagering**
  - **Fining/Filtering/Centrifugation**

OXIDATION

- **MELANOIDEN OXIDATION OF FUSEL ALCOHOLS**
  - **Oxidized-state Melanoiden Steals 2 Hydrogens From Alcohol Resulting In Long Aldehyde (trans -2- nonenal)**
- **OXIDATION OF ISO -α-ACIDS**
  - **Donation of Electrons to Oxidized Melanoidens Can Help Prevent Oxidation of Fusels**
  - **Further Oxidation to Fatty Acids - Stale, Cheesy**
  - **Loss of Bitterness**
- **OXIDATION OF LONG CHAIN FATTY ACIDS**
  - **Soapy/Goaty**
- **OXIDIZED PHENOLS**
  - **Polymerize**
  - **Condense With Aldehydes**
  - **Haze; Harsh Flavors**

OXIDATION II

- **Strecker Reaction**
  - **Dicarbonyl Compounds React With Amino Acid to Produce Aldehyde and CO_2**
- **Aldol Condensation**
  - **Short Aldehydes Condense to Form Long, Unsaturated Aldehydes (e.g. trans-2-nonenal)**
- **CONCLUSION:**
  - **Shoot For Reduced State Melanoidens in Wort**
    - » **Exclude Air During Hot Phases of Mash, Lauter, Sparge, Collection, Trub Separation**
  - **Exclude Air During Lagering, Packaging, Storage**

EQUIPMENT

- **EQUIPMENT CAN BE EXPENSIVE**
  - **Definitely an area for the innovation for which homebrewers are famous**
- **ESSENTIALLY THE SAME AS FOR ALE BREWING PLUS:**
  - **Equipment for decoction mashing (Optional)**
  - **Refrigeration (Not Optional)**
  - **Wort Chiller**
  - **Lagering vessels (Cornelius kegs...)**
  - **Equipment for better process control**
    - » **pH Measurement**
    - » **Water Testing Kits**
    - » **Microscope/ Hemacytometer**
    - » **D.O. Meter**
    - » **Temperature Controllers (ON/OFF; PID)**

MASH/LAUTER TUNS

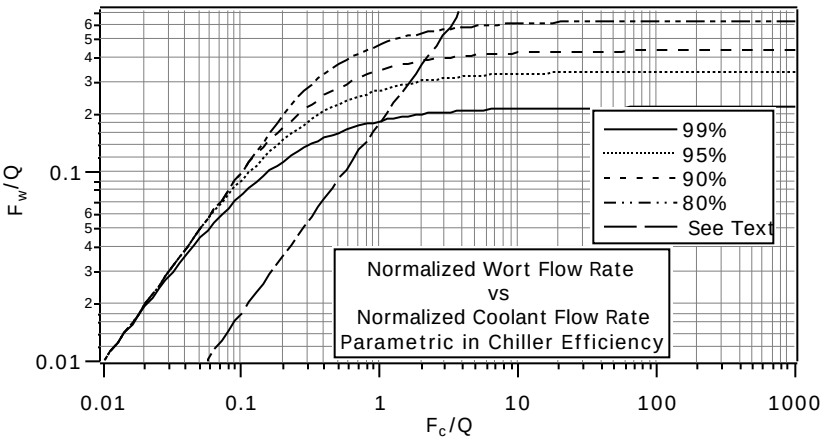
- **A VARIETY OF HEAT RETAINING CONTAINERS WILL DO**
  - **Pots Wrapped In Blankets, Quilts Etc**
  - **Coleman/Gott Coolers**
- **TRICK IS TO GET/KEEP HEAT IN...**
  - **Burners (possibly w/Automatic control)**
  - **Electric Heating Elements (possibly w/Automatic control)**
  - **Steam through "Easy Masher"**
  - **RIMS (probably w/Automatic control)**
- **...AND GET CLEAR WORT OUT**
  - **False Bottoms**
  - **Manifolds**
  - **Easy Mashers**
- **BURP WORKSHOP**

WORT CHILLERS

- **IMMERSION**
  - **Coolant Circulated Through Coil Immersed In Wort**
  - **Simpler/Less Expensive**
  - **Easier To Clean, Sanitize and Inspect**
  - **Slower**
  - **Increase Risks of Infection, Aeration. Wort Exposed**
- **COUNTERFLOW**
  - **Heat Exchanger. Wort Flows Against Coolant.**
  - **More Complicated/Expensive**
  - **Closed System Prevents Exposure to Air, Organisms**
  - **Required for Larger Brew Lengths**
  - **Harder to Clean, Sanitize and Inspect**

COUNTERFLOW CHILLERS

- **SOME CHILLER CAPACITIES (Q, gph)**
  - **50’ 1/2” Copper Tube in 1” HOSE: 215**
  - **Stoelting: 68**
  - **25’ 3/8” Copper Tube Coiled in 4.5” PVC Pipe: 65**



Efficiency =100 (Drop in Wort Temp)/(Wort Temp In - Coolant Temp In)

Use Coolant Flow of Q, Wort Flow Q/5

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REFRIGERATION

- **MUST HAVE FOR LAGER BREWING**
- **CONTROLLING AMBIENT ADEQUATE**
- **SOLUTIONS**
  - **Used Refrigerators Freezers**
    - » **No matter how cheap they are they take up space**
  - **External Controllers**
    - » **Hunter Air Stat**
      - **Modify Series Resistor for Lower Temperatures**
    - » **Honeywell Capillary**
      - **3° Differential**
      - **Can Put Bulb in Beer**
    - » **Honeywell Electronic**
      - **Expensive**
      - **1° Differential**
      - **Multi Channel Units**

REFRIGERATION - II

- **INNOVATIVE BREWERS HAVE LOT'S OF OPPORTUNITIES**
  - **Junked/Surplus Industrial Chillers**
    - » **Blood Analyzers/Hypothermia Machines**
    - » **Lasers**
    - » **Photo Processors**
    - » **Brine Chillers**
    - » **...**
  - **Air Conditioners**
  - **Dehumidifiers**
- **INVENT ACCORDING TO WHAT YOU CAN FIND**

KLUGE CHILLER

- **SMALL CHEST FREEZER**
  - **10 Gallon Cornelius Keg Full of 50% Propylene Glycol**
  - **Set Freezer Thermostat to Near 0°F**
  - **Small Pump Circulates Glycol Through Copper Tubing:**
    - » **In the Fermenter**
    - » **Around the Fermenter**
  - **Pump Controlled By Thermostat With Sensor In the Beer**

FERMENTERS

- **FERMENT IN ANY CONTAINER WHICH:**
  - **Can Be Cleaned/Sanitized**
  - **Is Compatible With Your Refrigeration System**
  - **Can Exclude* Air and Contaminants**
  - **Allow CO_2 to Escape**
- **PRIMARY FERMENTERS**
  - **Carboys**
  - **Plastic (Food Grade) Pails, bins...**
  - **Pots**
  - **Uni-Tanks**
- **SECONDARY/LAGERING**
  - **Carboys**
  - **Cornelius Kegs**

***Exclusion may mean no more than a blanketing with CO_2**

READING LIST

- **LAGER Brewing**
  - **Noonan, "Brewing Lager Beer"; Brewers Pubs.**
  - **Miller, "Continental Pilsner"; Brewers Publications**
  - **Fix, G&L, "Marzen, Oktoberfest,Vienna"; Brewers Pubs**
  - **Richman, "Bock", Brewers Publications**
- **GENERAL**
  - **Brewing Techniques Magazine**
  - **Randy Mosher, "Brewers Companion"; Alephenalia Pubs.**
  - **Jean DeClerk, "Textbook of Brewing"; Siebel Inst.**
  - **MBAA, "The Practical Brewer"**
  - **J.S. Hough et al., "Malting and Brewing Science"; Chapman and Hall**
  - **George Fix, "Principals of Brewing Science"; Brewers Pubs.**
  - **Hardwick (ed.),"Hanbook of Brewing", Dekker**

COLD STRIKE pH

- 50 Grams Crushed Malt with 100 Grams Water
- All measurements at ~ 22 °C
- Measurement within minutes of strike

Water	Alk. (mg/L as CaCO3)	Calcium (mg/L)	Chloride (mg/L)	pH; DWC Pils	pH; DWC Munich
D.I.	0	0	0	5.75	5.17
Low Alk.	0	60	106	5.52	5.14
Munich	149	60	0	6.02	5.54

-Low Kilned Malt : Lo acid but phytase intact
-High Kilend Malt: Acidic but less phytase