Heating and Boiling Wort

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Bell's Brewery Inc.

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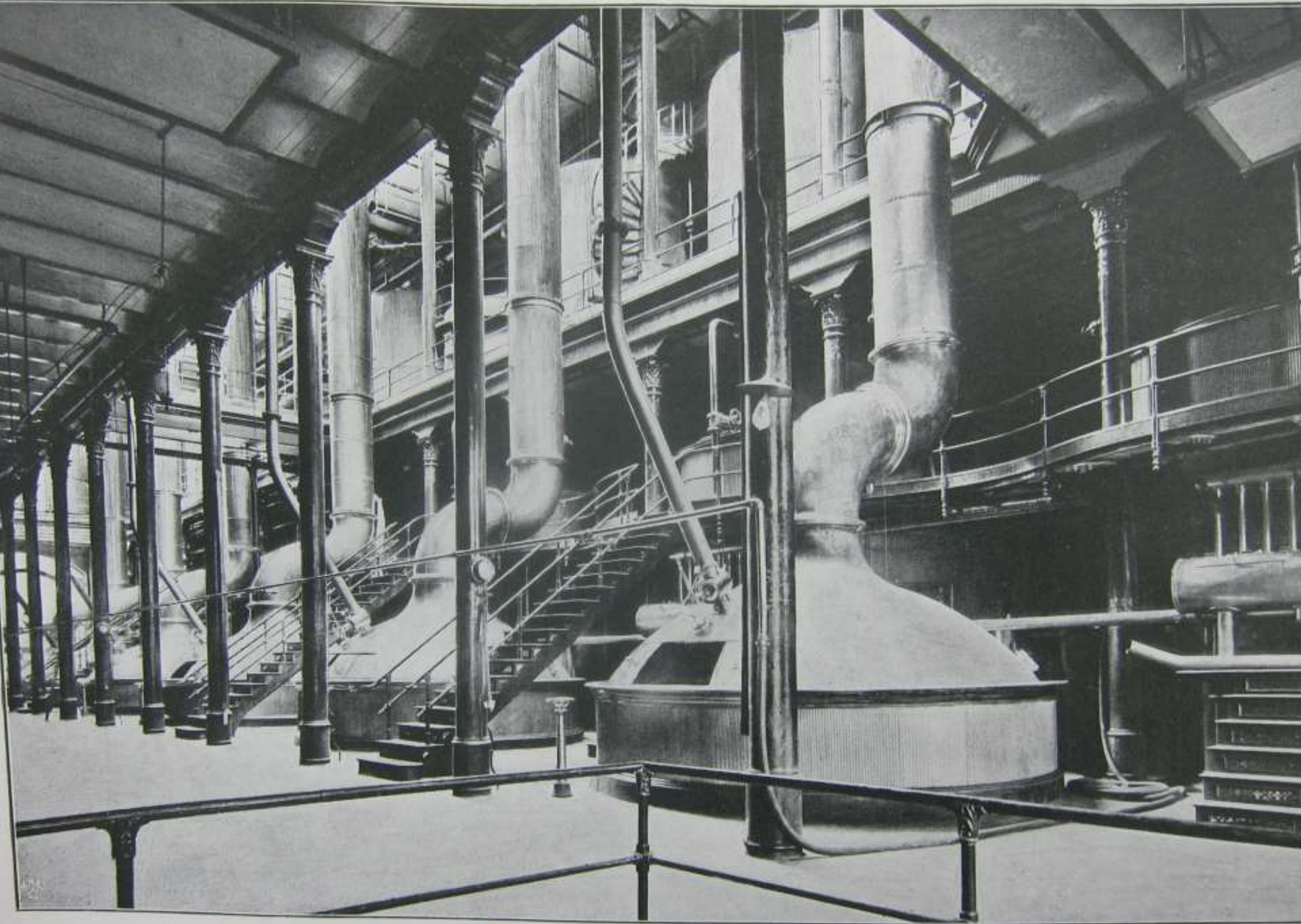
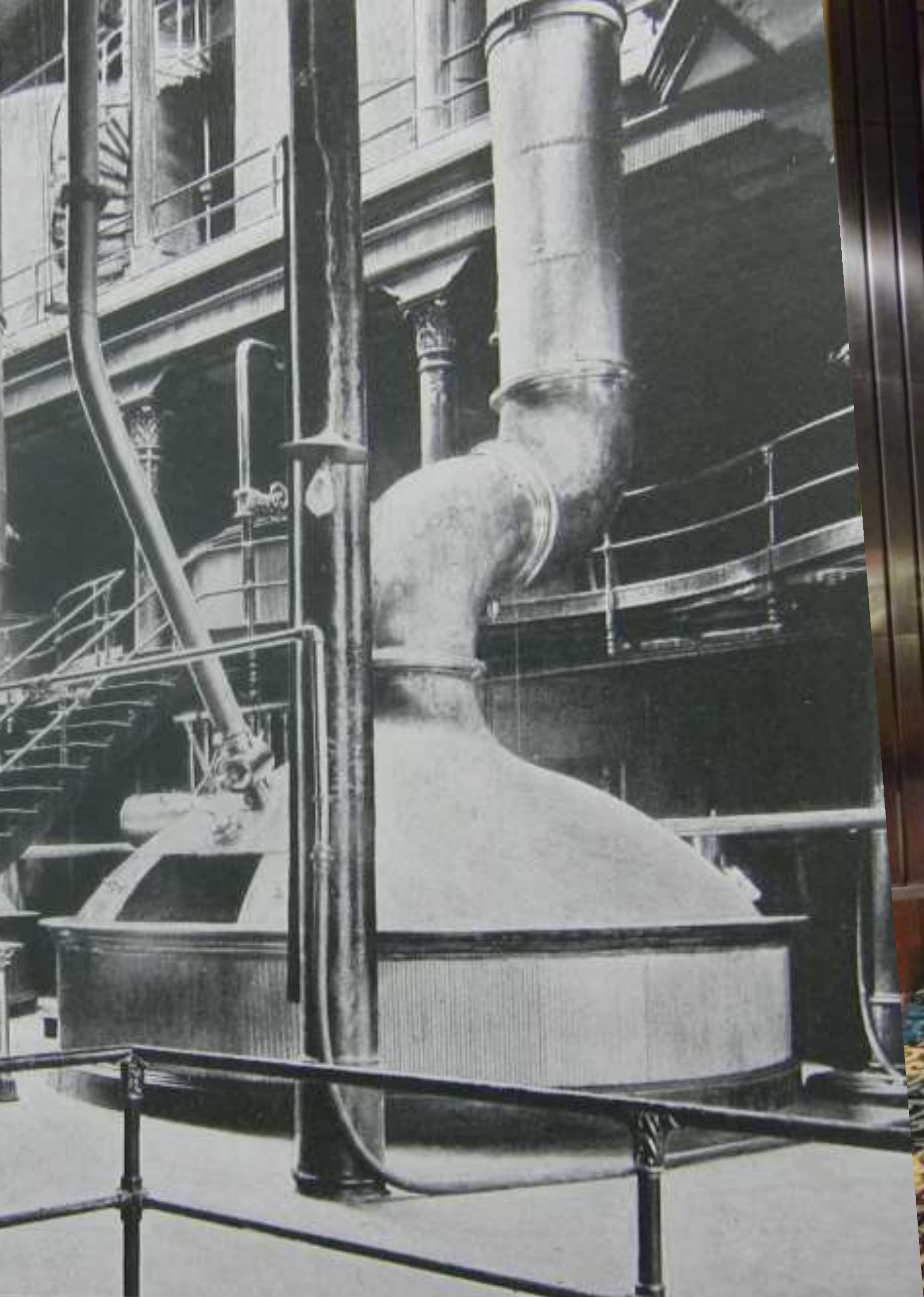
WADWORTH
BREWER
WADWORTH
THE
QUALITY BEER
THE NORTHGATE BREWERY
BEER FESTIVAL
6X


1885



Sudhaus 1. Stock.



Sudhaus 1. Stock.

What is Wort?

- Water
- Carbohydrates
- Nitrogenous Constituents
- Hop Constituents
- Polyphenols (Tannins)
- Minerals and Salts

Why We Boil

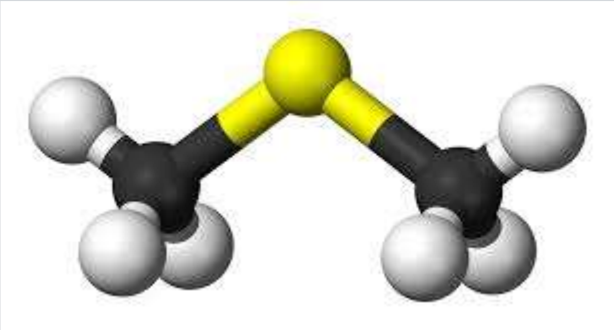
1. Sterilization
2. Concentration (by Evaporation of Water)
3. Distillation of Volatile Substances
4. Denaturation (Enzyme Destruction)
5. Floc & Break Formation (Protein/Tannin Precipitation)
6. Extraction of Soluble Hop Constituents
7. Isomerization of hop $\propto$ -acids
8. Formation of additional Reductive Substances
9. Increase in Color
10. Decrease of pH
11. Decrease of Surface Tension

Sterilization

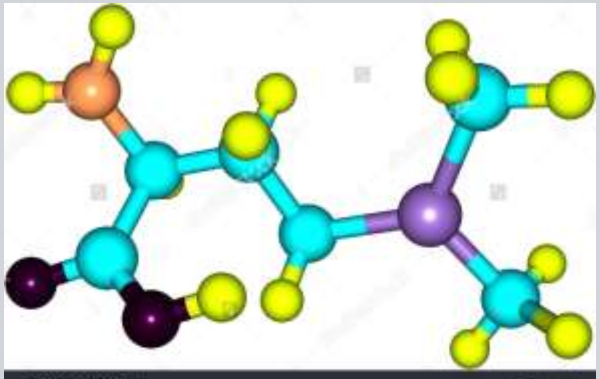
Concentration

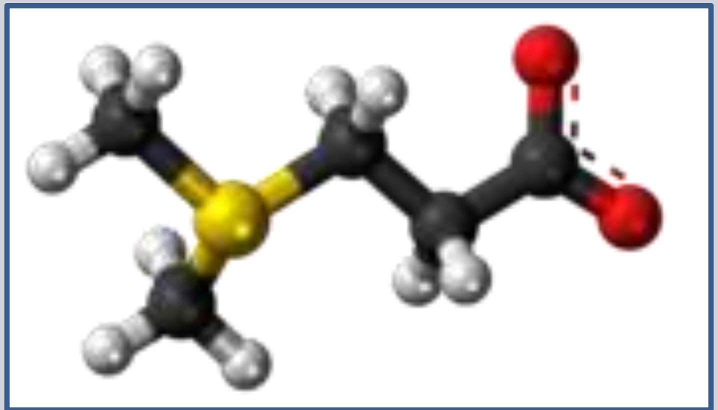
- Evaporation of Water

Distillation of Volatile Substances: DMS



- Dimethyl sulfide (methylthiomethane)
- Highly Volatile; boils at 37 °C (99 °F)
- Formed by thermal degradation of SMM (*S*-Methylmethionine) or DMSP (Dimethylsulfoniopropionate)





Denaturation

Enzyme Destruction

Floc & Break Formation

- Proteins are denatured – helical structures disrupted by: heat, ph change,oxidation/reduction reactions, hydrogen bonding with polyphenols
- Proteins change from hydrophilic to hydrophobic and take positive charge
- Polyphenols have negative charges and combine with positive protein flocs
- Some carbohydrates contribute to aggregation and precipitation

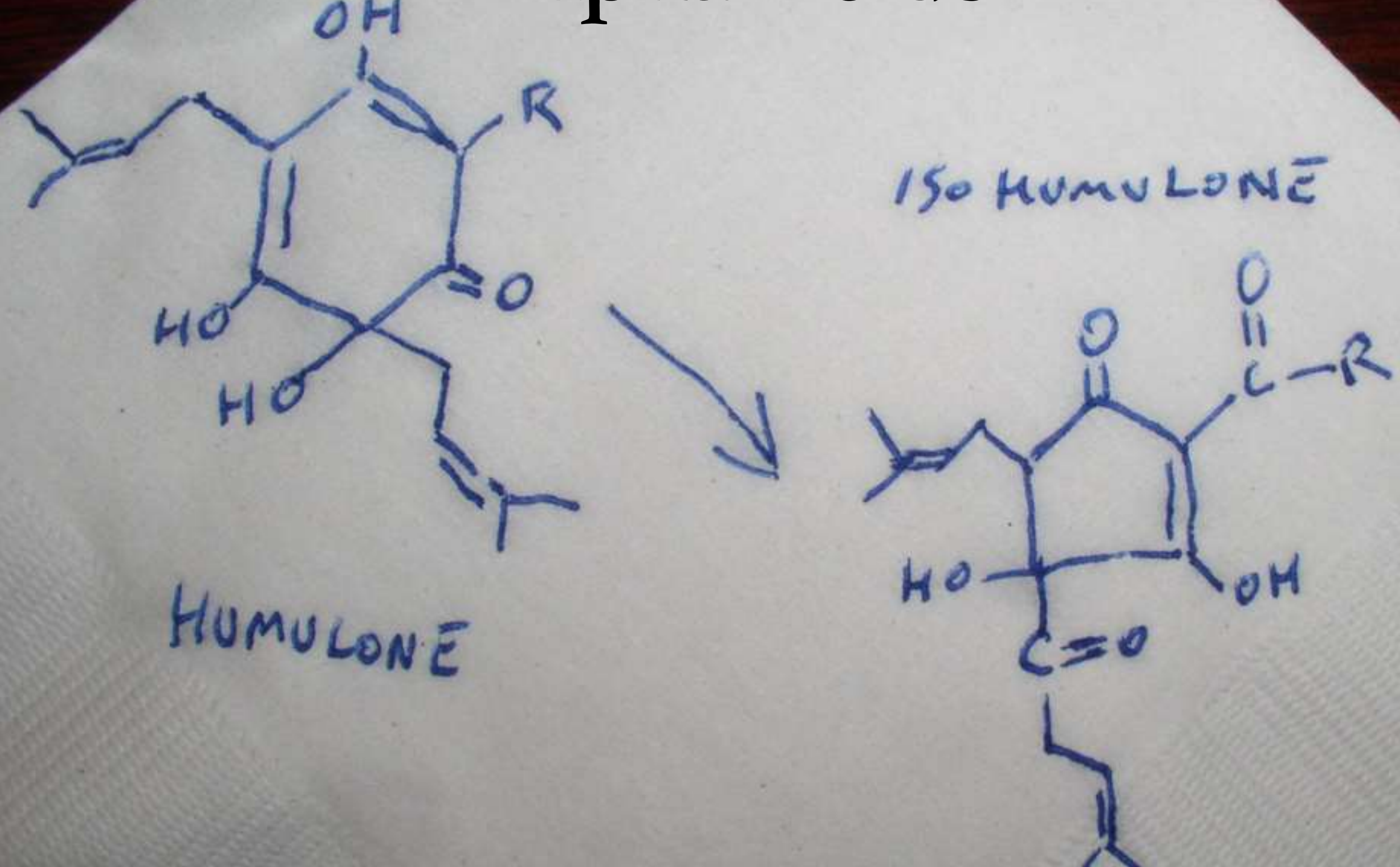
Floc & Break Considerations

- Proteins are enriched on gas/liquid surface leading to greater coagulation
- Shear forces effects on particle size
- Particle size effects on separation

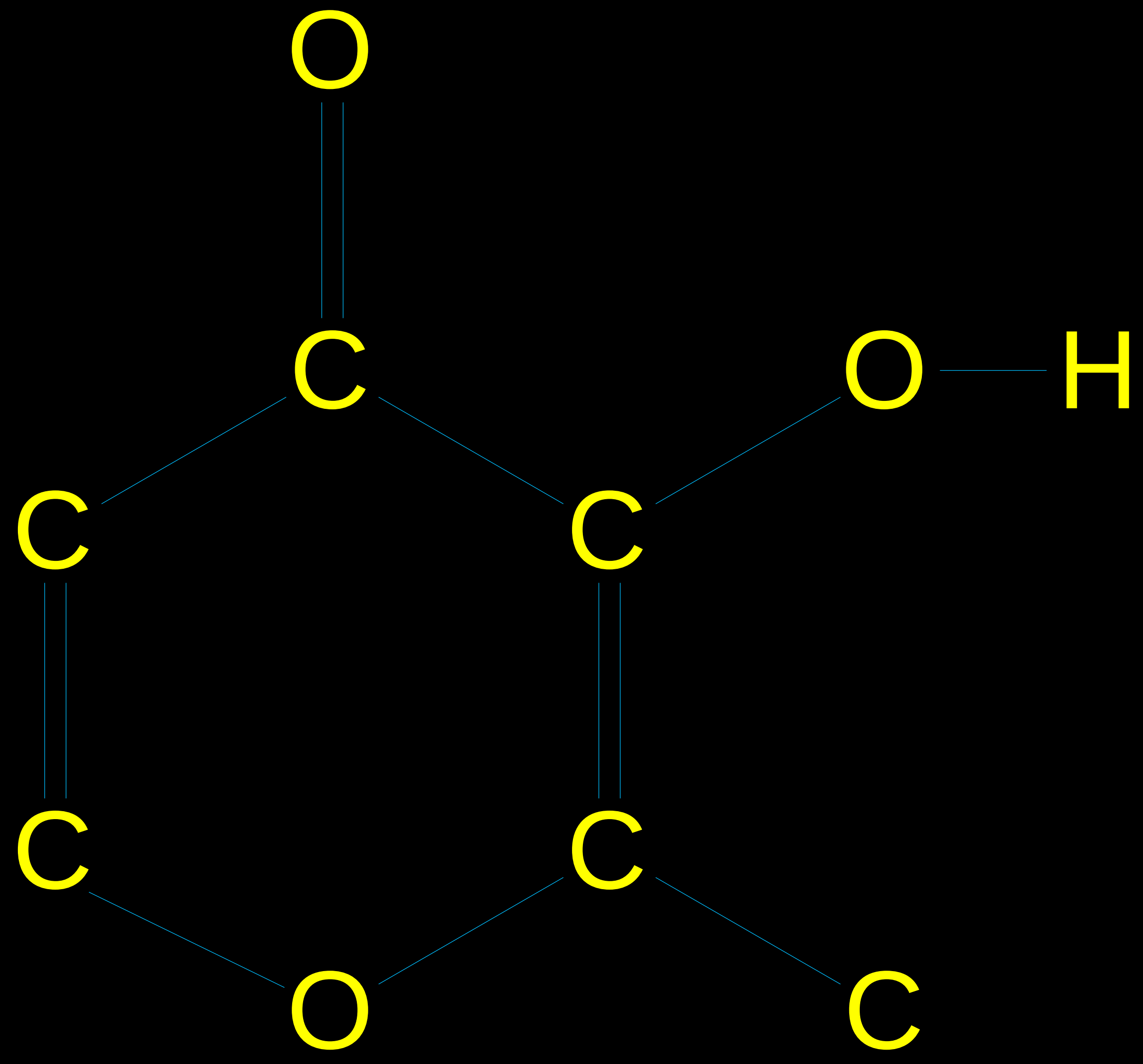
Extraction of Soluble Hop Constituents

- Hop resins are not soluble in cold wort – heat is needed
- Boiling changes the molecular arrangement (isomerization) of the ∝-acids
- These iso-∝-acids are:
  - Much more soluble (change from hydrophobic to partially hydrophilic)
  - Much more bitter and contribute almost all of the bitter taste of beer
- Influenced by:
  - pH
  - Wort Density
  - Time (Duration)
  - Temperature

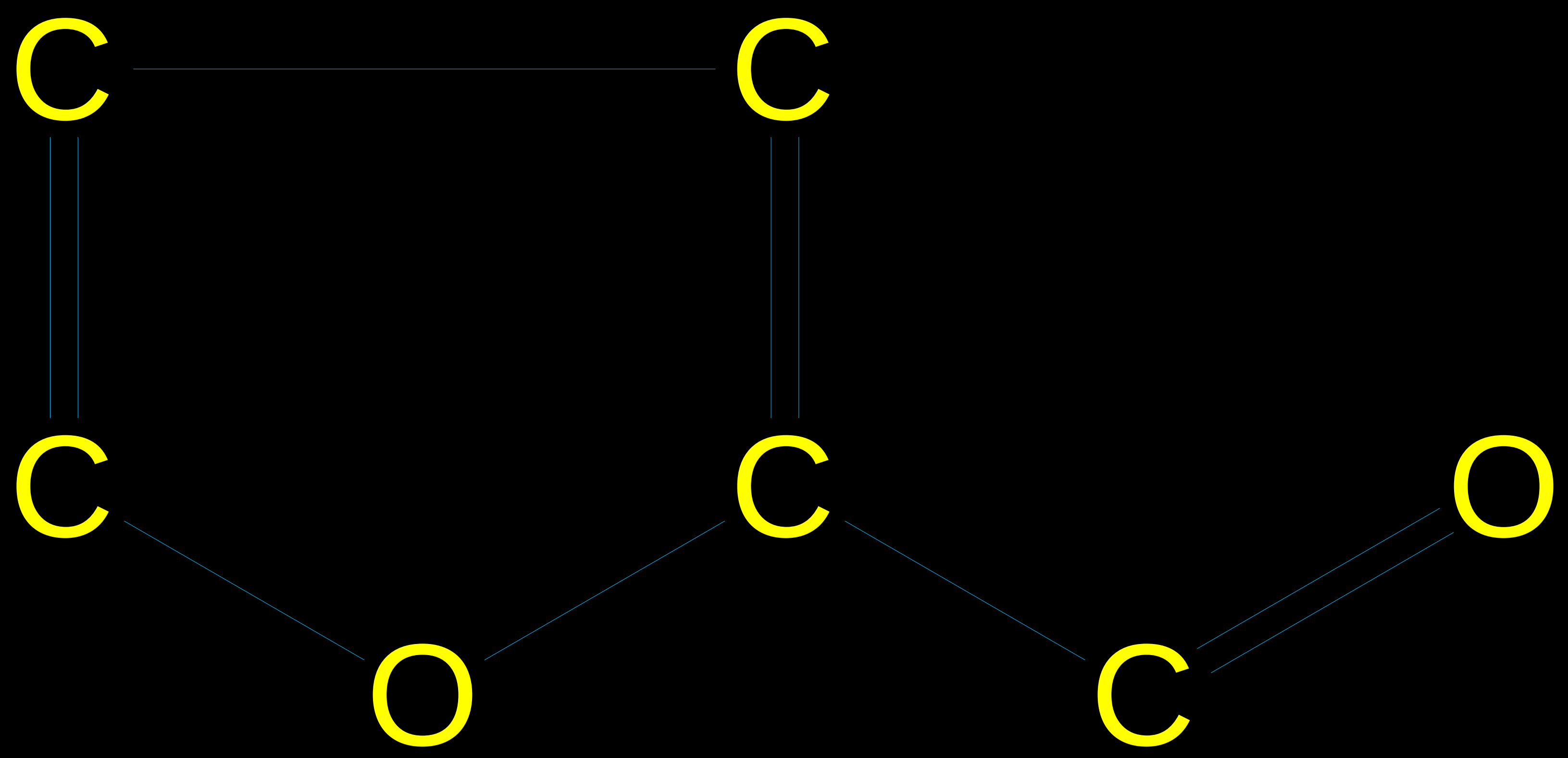
Isomerization of Alpha Acids



Formation of additional Reductive Substances, Flavor Development & Increase in Color



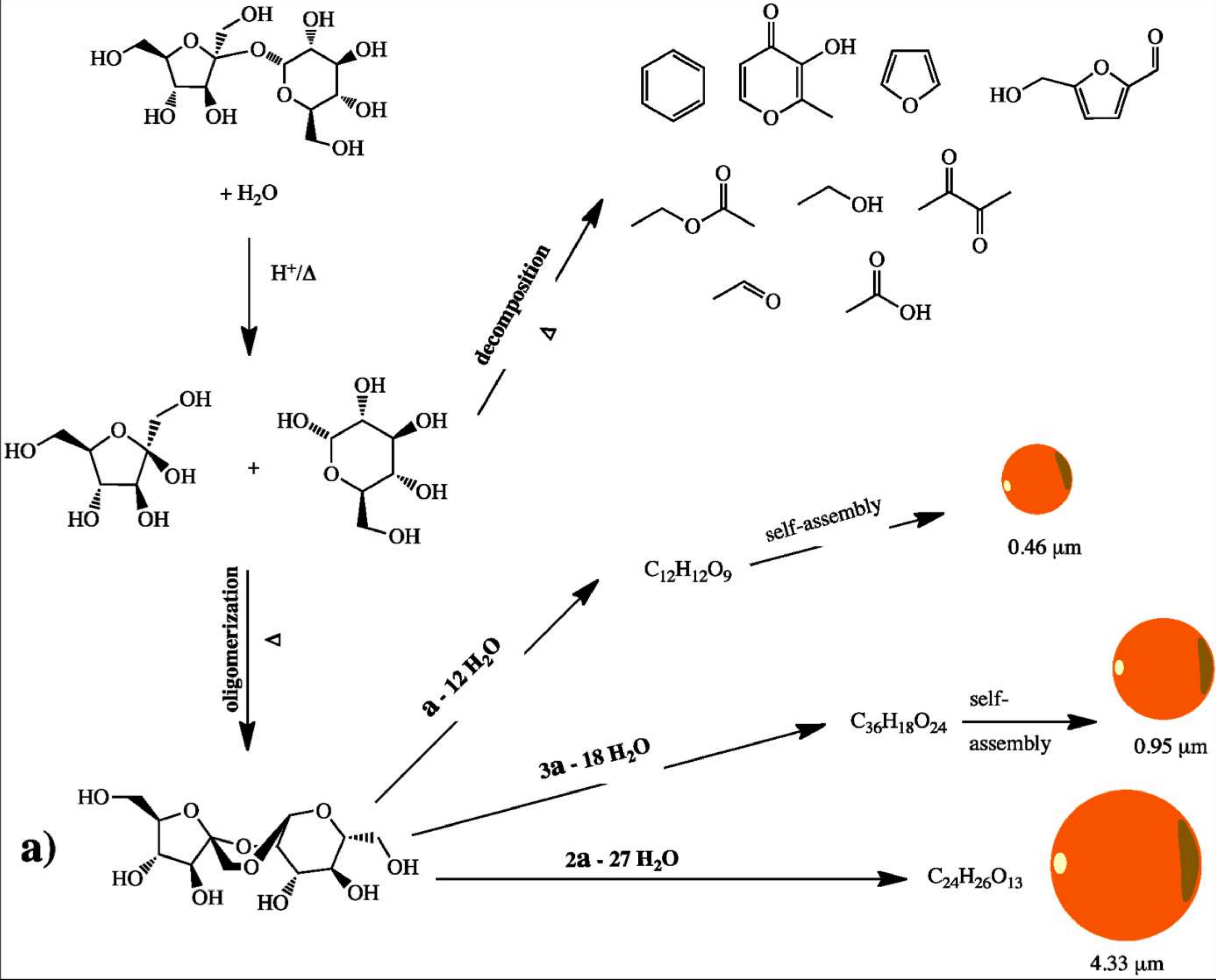
Maltol



Furfural

Maillard reaction

- Non-enzymatic browning
- Involves the reaction of:
  - Simple sugars (carbonyl groups)
  - Amino acids (free amino groups)
  - Heat
- They begin to occur at lower temperatures and at higher dilutions than caramelization.


+ H_2O
H^+/Δ
decomposition
Δ
oligomerization
Δ
self-assembly
$C_{12}H_{12}O_9$
0.46 μm
a - 12 H_2O
3a - 18 H_2O
$C_{36}H_{18}O_{24}$
self-
assembly
0.95 μm
2a - 27 H_2O
$C_{24}H_{26}O_{13}$
4.33 μm
a)

Increase in Color

- Tannin Oxidation – reaction of anthocyanogens and catechins with oxygen to form reddish/brown compounds

Decrease of pH

- Decrease (0.2 – 0.3) is associated with the precipitation of calcium phosphate
  - $3Ca + 2HPO_4 = Ca_3(PO_4)_2 + 2H$
- $CaSO_4$ or CaCl additions are common
- Other factors in pH reduction may be the addition of hop bitter acids and the formation of acidic Maillard products
- Direct addition of acid to brew kettle
  - -Lactic
  - -Phosphoric

Decrease of pH

- Optimum pH for hot break formation is 5.2.
- Wort drops during boiling from 5.8 -5.9 to 5.2 – 5.4
- Effects of lower pH include:
  - Improved protein coagulation
  - Improved beer flavor, esp. VDK reduction
  - Encourages yeast growth
  - Inhibits many contaminating microorganisms
  - Reduces hop utilization
  - Reduces color formation

Decrease of Surface Tension

- Isohumulone based
- Facilitates the evaporation of volatiles such as DMS
- Reduces chances of over-foaming and over-boiling

Avoiding aeration

- Avoid hot side aeration (HAS) by gentle fills and circulation until vessel is primarily a steam atmosphere
- HSA can create staling compounds in part by activating lipid-oxygenase in the brewkettle
- Oxidation of polyphenols during wort boiling increases wort color and decreases the reducing power of wort and the resultant beer.
- Low oxidation results in lighter colored, more flavor stable beer

Heating of wort

- Gentle steam on jackets & calandria
- Bumping or Surging

- Avoid fouling and heat stress in wort
  - Proteinaceous soils
  - “beer stone” (calcium oxylate) precipitation

How much Boiling?

- How do we define necessary degree of boiling?
  - Sensory considerations
    - DMS/DMS-P levels desired in beer
    - Hop components and the distillation of some and preservation of others
  - Processing considerations
    - Achieving necessary protein break to avoid filtration issues

Too much Boiling:

- Darkening of wort through Maillard reactions
  - simple sugars and amino acids reacting
- Soil build up on heating surface
  - Lowering heat exchange
  - Increasing fouling rates
- Small Heat Transfer Surface Area
- Vapor Boiling Condition
- Superheated Steam

Heat Stress

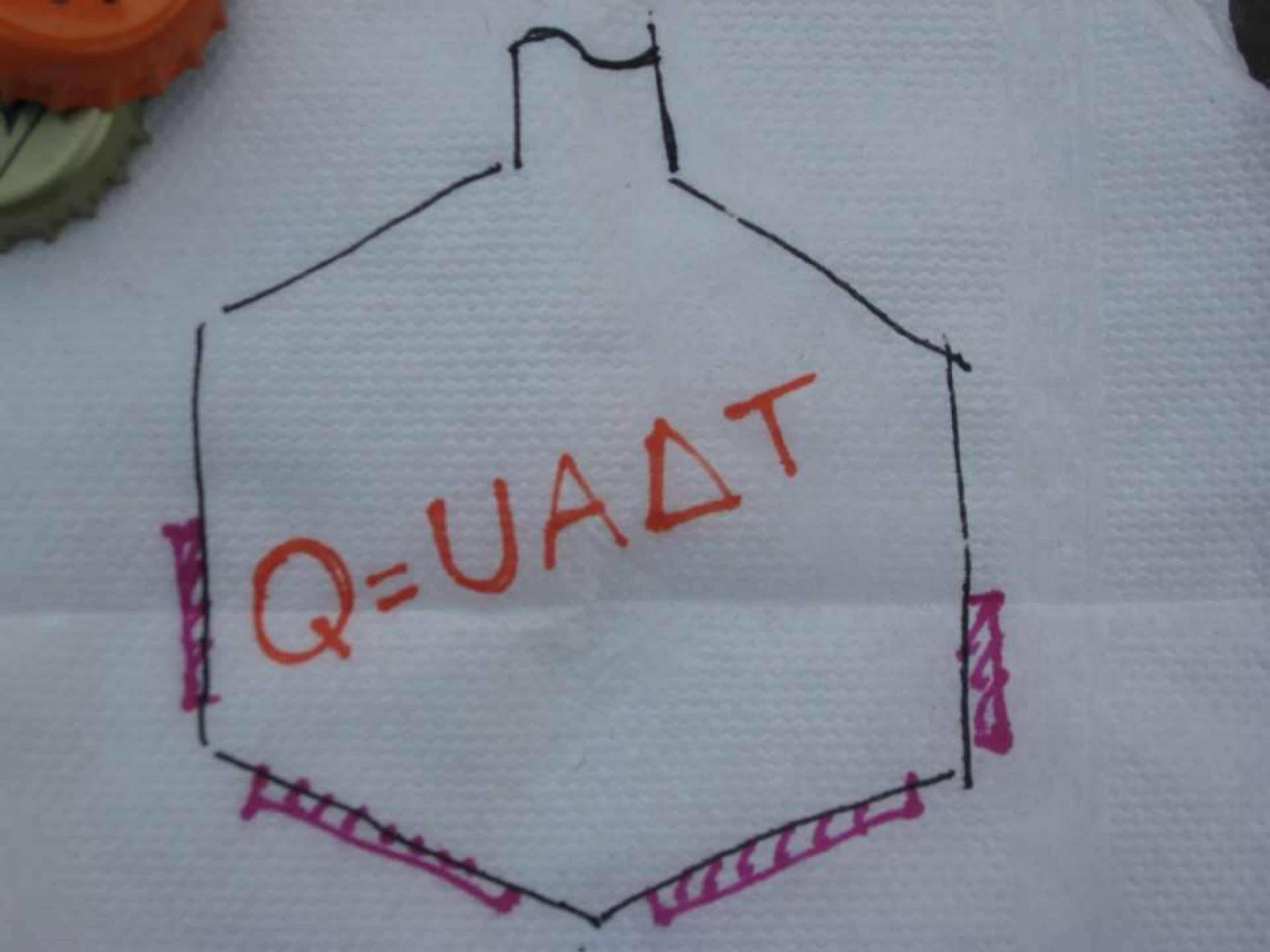
- Formation of compounds
  - Butyric Acid & Hydroxymethylfurfural (HMF)
  - Measured by TBA/TBZ

- Gas Fired Kettle

  3542 °F (1950 °C)

Saturated Steam Properties

Pressure		Temp		Heat Content		Heat of Vap.
				Liquid	Vapor	
PSIG	bar	F	C	BTU/lb		
0	1.00	212	100	180	1150	970
5	1.34	227	108	195	1156	961
10	1.68	239	115	208	1160	952
15	2.02	250	121	218	1164	946
20	2.36	259	126	227	1166	939
25	2.70	267	131	236	1169	933
30	3.04	274	134	243	1171	928
35	3.38	281	138	250	1173	923
40	3.72	287	142	256	1175	919
45	4.06	293	145	262	1177	915
50	4.40	298	148	267	1178	911


Q=UAΔT

Wort Boiling

1 bbl of wort evaporating at a rate of 5%/hr.

The latent heat of vaporization for water at 1 atmosphere of pressure is 970 BTU/lb.

1 bbl wort
X 31 gal/bbl
X 8.34 lbs/gal (259 lbs)
X .05 evaporation/hr
X 970 BTU/lb

= 12,539 BTU/hr.

Wort Heating

1 bbl of wort (259 lbs) warming 36 F (from 176 F to 212 F) in 45 minutes

1 BTU=1 lb water 1 degree F.

259 X 36 = 9324 BTU

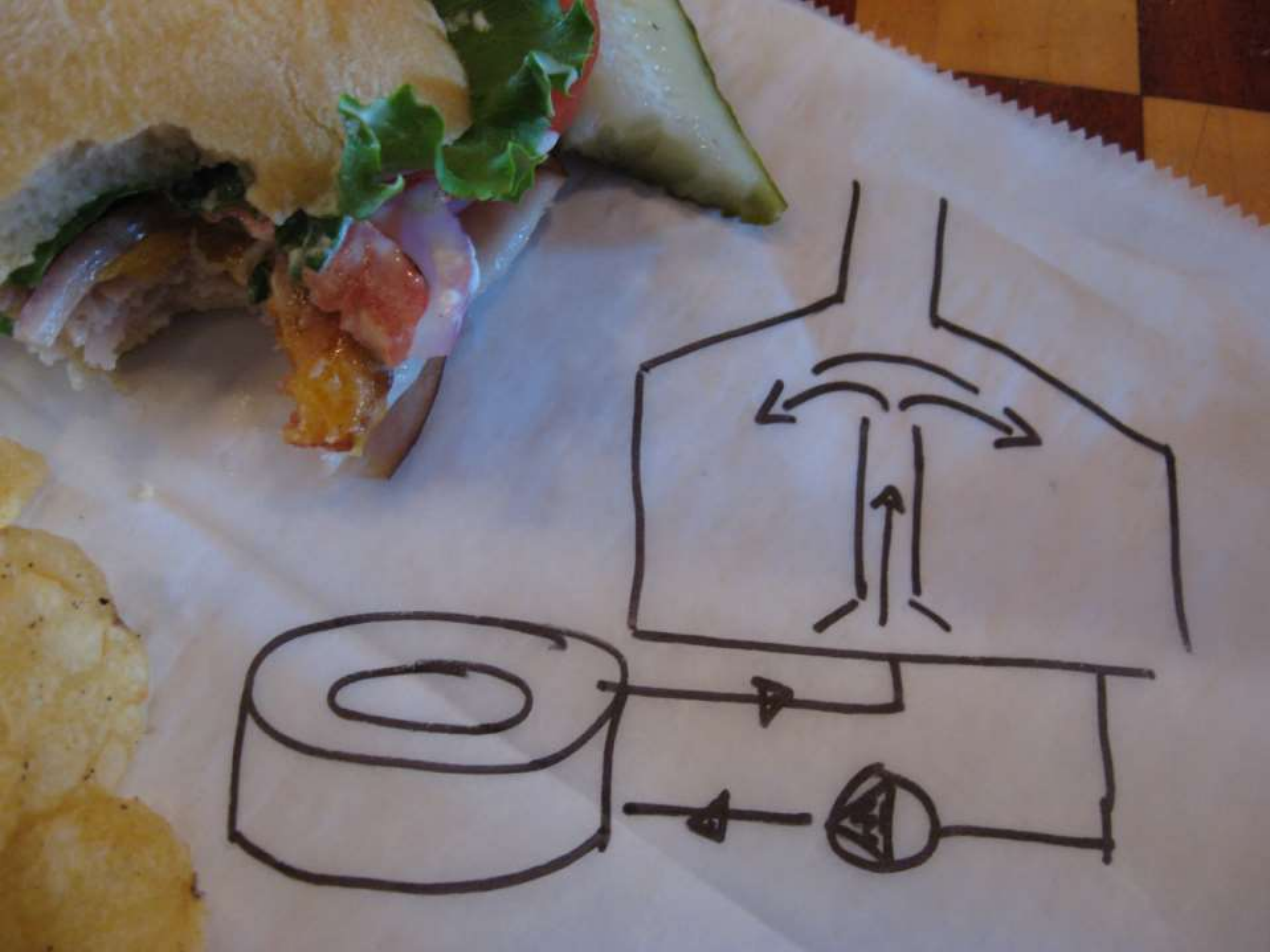
/ .75 Hour

=12,432 BTU/hr. to heat wort

= 12,539 BTU/hr. to boil wort

Wort pre-heaters

- Designs
- Role in heat recovery
- “Fouled” vapor flow



Coming to full boil

- Avoiding foam
  - Wort spreaders
  - Hops timing
  - Closed door timing
  - Antifoams
  - The trusty spray hose

Boil outs

- Safety considerations
- Engineering control


708

Hop & process aid additions

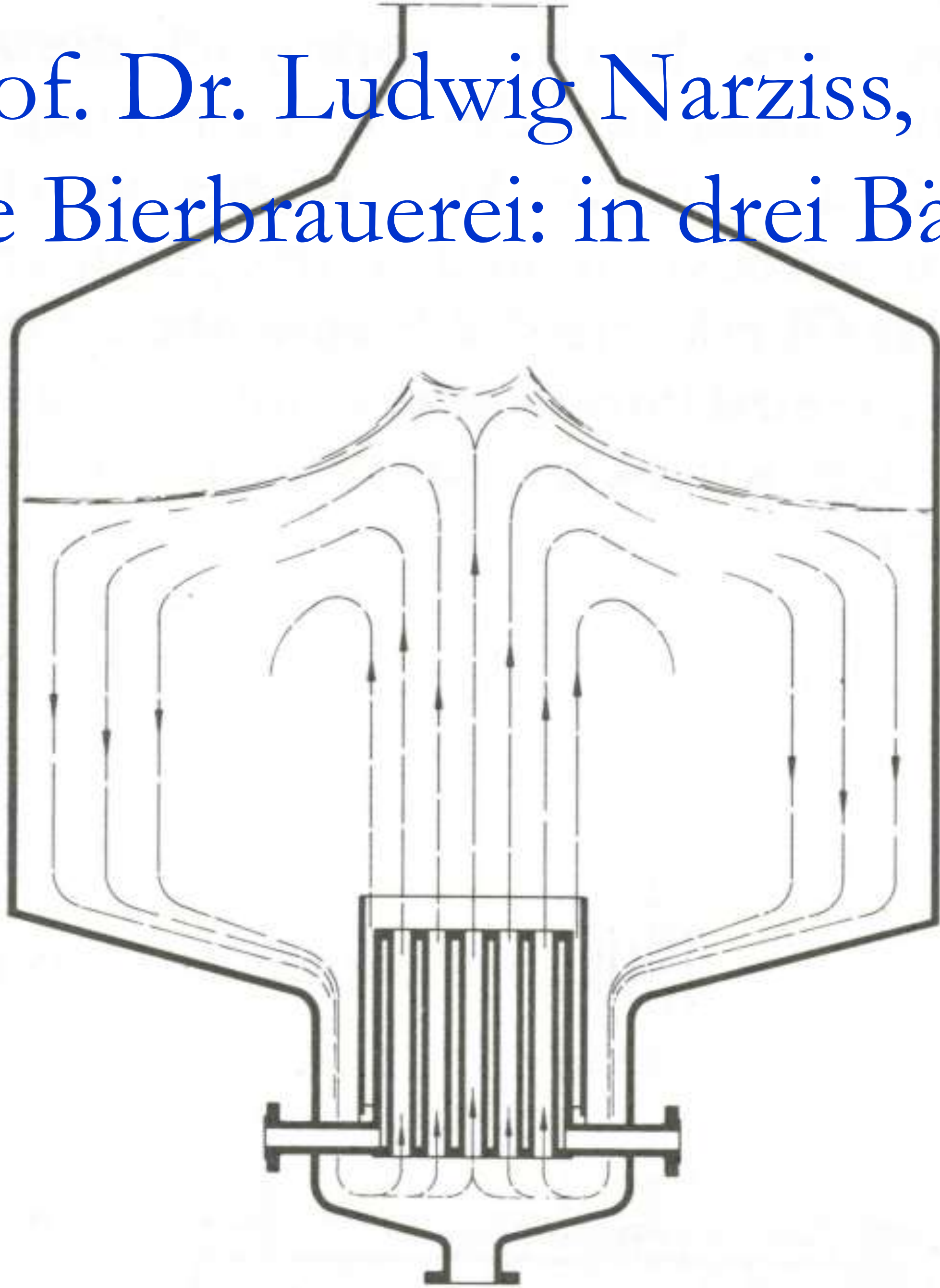
- Manual dosing considerations
  - Turn off heat before adding hops
- Automated dosing equipment


DANGER

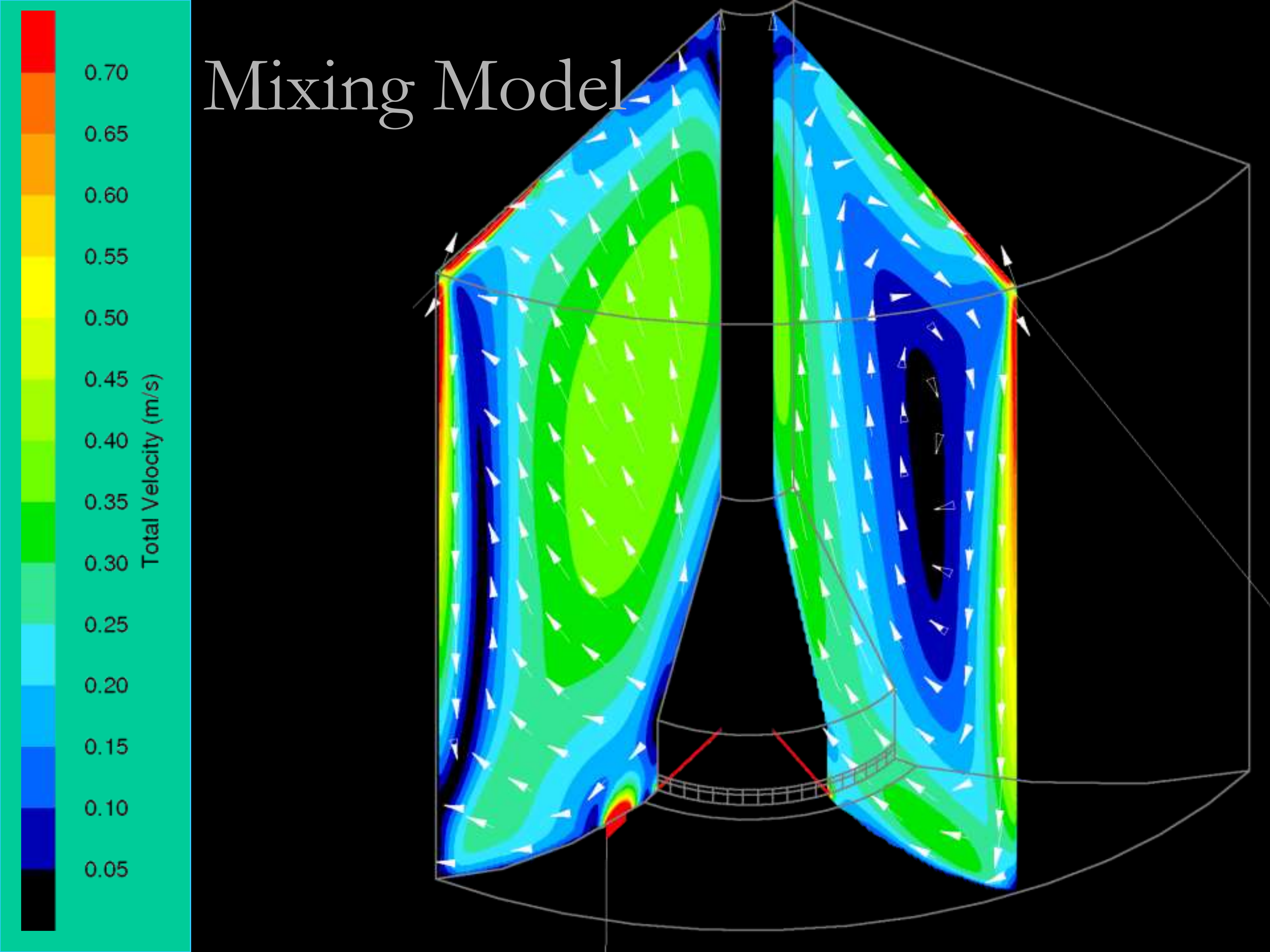
Boiling strategy

- Variable heating
- “Simmer boil”

Prof. Dr. Ludwig Narziss, 1956
Die Bierbrauerei: in drei Bänden

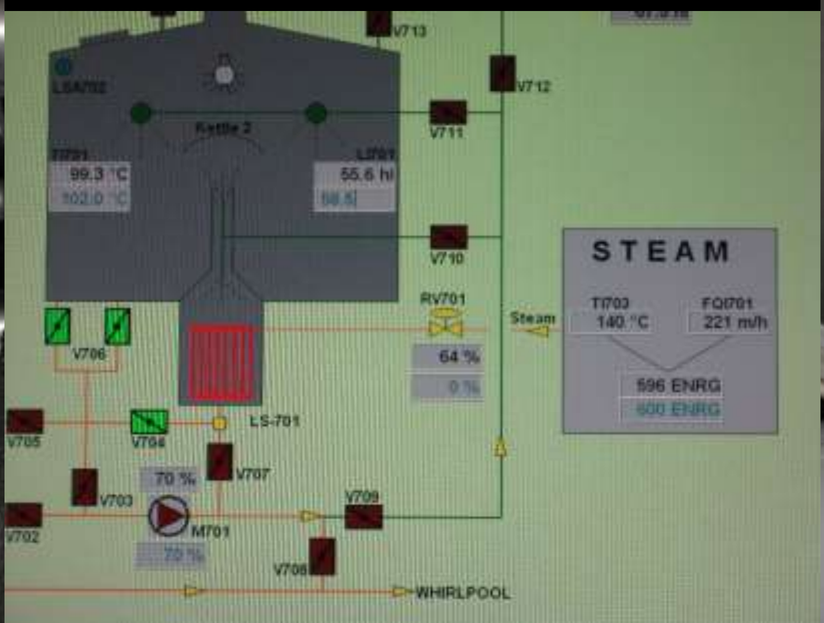


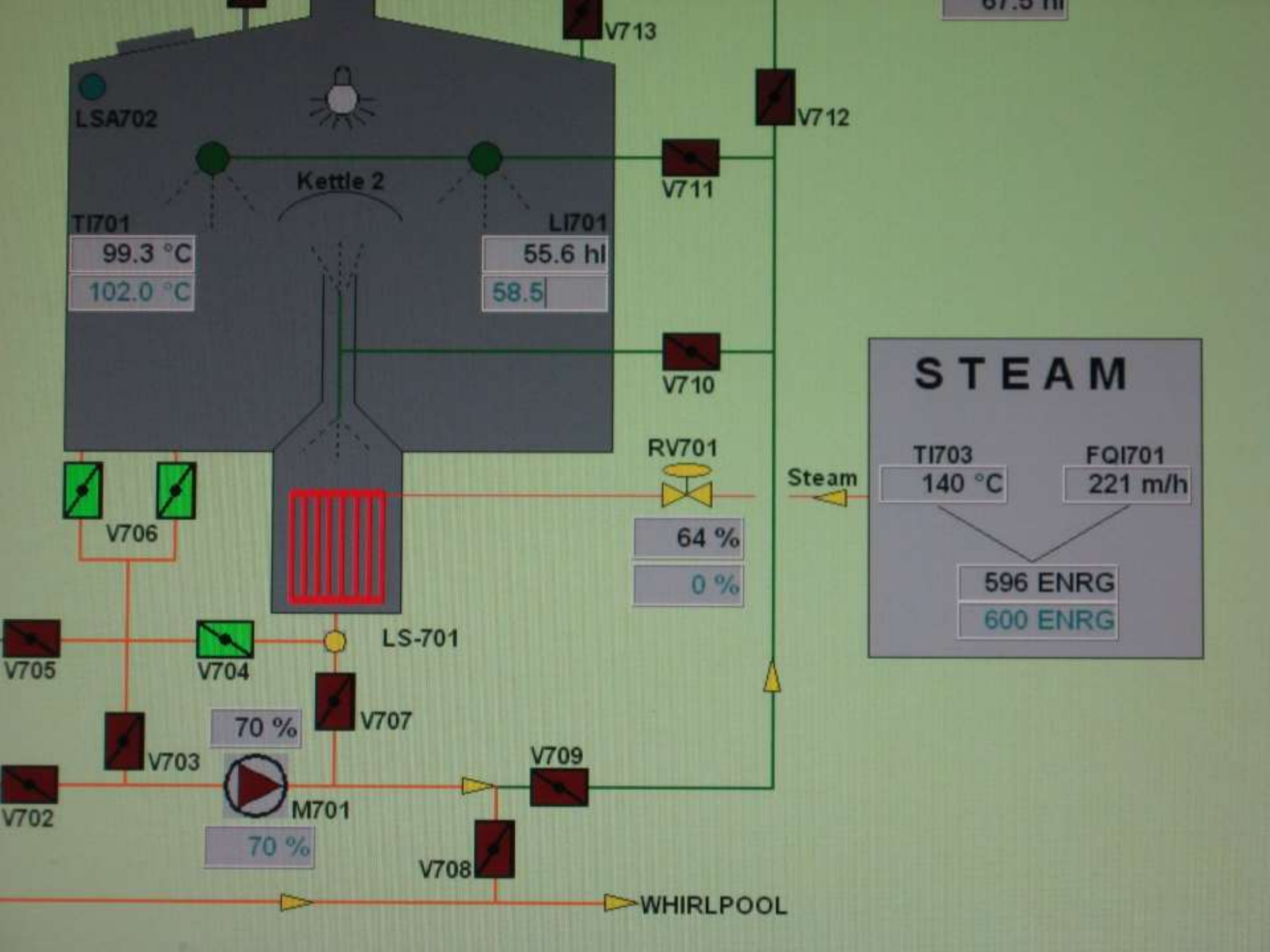
Mixing Model



Controls:

- Vortex Flow Meter reads steam flow
- Therms read into controls software
- Steam control by Vee-Ball valve





67.5 hl
V713
LSA702
V712
V711
Kettle 2
TI701
99.3 °C
102.0 °C
LI701
55.6 hl
58.5
V710
STEAM
RV701
Steam
TI703
140 °C
FQI701
221 m/h
V706
64 %
0 %
596 ENRG
600 ENRG
V705
V704
LS-701
V707
70 %
V703
V709
V702
M701
70 %
V708
WHIRLPOOL

Kettle end considerations

- Transfer to Whirlpool
- Rinsing

Strategies for State-of-the-Art Wort Boiling

- Low TBI values
  - < Time + < Heat
- Lowest Boundry Temps
  - >Foam values
- Greater Volatilization with < Evap.

Common Sense Kettle Rules:

- Do not turn on boiling system until heating surfaces are covered
- Do not overfill kettle
- Turn off steam before adding hops (manual addition through door)
- Make sure there is a 'rolling boil'
- Clean heating surfaces before they are fouled
- Keep stack condensate rings clear
- *Never turn your back on an open boiling kettle!*


BELL'S
Inspired Brewing
Thank You!