Gone Fishing!

A CRACKER STORY
1995

7 CRACKER PRODUCTION LINES — 3 PLANTS

20 + SHIFTS /LINE /WEEK

ROOM FOR ONE ADD’TL LINE — $18MM

MAX OUT - PRE PACKAGING

COMPANIES LARGEST SALES SKU’S

‘INTERNAL ONLY’ PROTECTION — NO CO-MNFG

EXPERTS - “LINE SPEED MAXED OUT!”

BUSINESS & TECHNICAL CHALLENGE

DOUBLE BUSINESS BY 2000
GO BACK TO FISH CRACKER SCHOOL
SNACK CRACKER PRODUCTION

Mixing & Fermentation

Sigma Blade Mixer

Portable Dough Trough Fermentation

Flour + Yeast → Ethanol Sugar Alcohols CO₂
Mixing
Stage 1: Incorporation
Stage 2: Uniformity
Stage 3: Development

Energy
Time

Elasticity
Time

Crackers

Mixing - Development

Flour
Water
Cheese
Shortening
Emulsifiers
Yeast
Sugars

A CRACKER STORY
**Snack Cracker Production**

- **Multi Zone Gas Direct Fire Oven**
  - Multiple 50 ft oven sections
  - 1+ Meter width
  - Steel Weave Band
  - 18-20 90,000 - 120,000 BTU
  - Gas burners top and bottom directly firing into oven chamber

- Mixing
- Fermentation
- Dough Sheeting
- Lamination
- Guaging
- Cutting
- Web Separation
- Seasoning
- Topical Oiling
- Cooling
CONVENTIONAL CRACKER BAKING

GDF: GAS DIRECT FIRE

- Ribbon Burners in Product Chamber - Individual Control
- Dense Steel Weave Oven Band
- Multiple Baking Zones
- Humidity Control Exhaust Stacks (fan & damper)
CONVENTIONAL CRACKER BAKING

Tri Zone Gas Mixture Burners

Description
The Flynn Distributor Pipe burner provides lateral flame adjustment to equalize product color and moisture across the band.

Capacity to 4,000 BTU/inch of flame space.
Turn down to 200 BTU/inch of flame space.
Flame space 16 to 215 inches.

Suitable for use with natural gas, propane and butane.
Zone 1

Product
- Internal Temperature and heat increase
- Partial Pressure of Water in dough increases
- Evaporation at Top Surface
- Defusion Reduction at Surface (Skinning)

Oven
- Band Heating
- Humidity Increase - Closed Exhaust Damper

Zone 2

Product
- Internal Temperature and heat increase
- Defusion Reduction at Surface (Skinning) + Trapped steam starts layer separation
- Evaporation continues at Top Surface
  Product bows off band, Evaporation from bottom and sides. Puff begins at Z2.

Oven
- Band Heating - Band Temp Increases
- Humidity Increase - Closed Exhaust Damper
Product
* Primary purpose - Moisture redux (17% to 12%)
* Important to assure that product does not fully skin, and that scorching does not occur.
* Puff levels at maximum by end of Zone

Product
** Primary purpose - Moisture redux (127% to 6%)
* Product Structure set by mid Zone.
* Evaporation continues at Top Surface Product bows off band. Evaporation from bottom and sides.

Oven
* Band Heating
  Heat carried into top of Zone 3 from Band heat in Zone #2.
* Top and Bottom Heat Influx at Maximum
* Humidity Increase - Closed Exhaust Damper

Oven
* Band Heating - Band Temp increased 75 deg
* Humidity decrease - Open Exhaust Damper Pull heat from Z 3, and reduce heat flow into Z5
**Product**
- Primary purpose - Final Moisture redux (6% to 3%)
- Final Toast Flavor and color
- Important to assure that product does not scorch.

**Oven**
- Band Heating
  - Heat carried into top of Zone 3 from Band heat in Zone #4.
- Humidity Decrease - Open Exhaust Damper
Snack Cracker Production

Step #1: Cutter Ring Optimizations

<table>
<thead>
<tr>
<th>Stage</th>
<th>Type</th>
<th>#/Shaft</th>
<th>#/200' Oven @ 30RPM Crackers / Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Start</td>
<td>Plastic Cutters</td>
<td>490</td>
<td>14,700</td>
</tr>
<tr>
<td>Stage 1</td>
<td>Brass Cutters</td>
<td>670</td>
<td>20,100 +37%</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Brass Cutters</td>
<td>873</td>
<td>26,190 +78%</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Brass Cutters</td>
<td>912</td>
<td>27,360 +86%</td>
</tr>
</tbody>
</table>

Same 4.2 min Bake
Snack Cracker Production

Step #2: Bake Optimizations

- Puff Height
  - Shell Break
  - Dense Bite

- Process Capability
- Moisture % 2% - 4%
- Breakage → Stale

- Toasted Bake Color
  - Low taste
  - Scorch
ORIGINAL 5 MIN. BAKE
- FULL PUFF ON 2.2 MIN
- MOISTURE EXIT
  - Z3 12%
  - Z4 6%
  - Z5 3%

ORIGINAL TARGET 2.5 MIN. BAKE
- FULL PUFF ON 1.2 MIN
- MOISTURE EXIT
  - Z3 12%
  - Z4 6%
  - Z5 3%

ALL HEATING VIA THERMAL GRADIENTS

GREATER HEAT TRANSFER RATES REQ. HIGHER TEMP &/OR HIGHER HUMIDITY

SCORCH + HIGH MOISTURE

CHALLENGES TO DOUBLE
Snack Cracker Production

- Dense Bite
- Scorch
- Moisture
- Puff Height
- Speed
- Process Capability
- Toasted Bake Color
- Low taste
- Breakage → Stale
- 2% - 4%

GARY ISRAEL
PROCESS SOLUTIONS OF NY LLC
SEPTEMBER 19, 2008
RADIO FREQUENCY DRYING

The Microwave™ Advantage
RADIO FREQUENCY DRYING

Response of Polar Molecules In An Electric Field

40 MHz Alternating Electric Field

TARGETING POLAR (H₂O) MOLECULES
RADIO FREQUENCY DRYING

Dielectric Materials + Electromagnetic Field = HEAT

Some portion of the electromagnetic energy will go through a change of state and be dissipated as heat with the dielectric.

Conversion of energy = F (atomic and molecular structure of the material, frequency, field strength)

Alternating electromagnetic field

• Displacement of the polarized components as re-alignment with the positive and negative oscillations occurs.
• Friction on an atomic or molecular level = Heat generated in the dielectric.

Heat generated in a dielectric

\[ P = 0.555 \times f \times E^2 \times e' \times (\tan \delta \times 10^{-6}) \]

- \( P \) = Heat generated in watts/cm³
- \( f \) = Frequency of the electromagnetic field MHz/sec
- \( E \) = Field strength in Volts/cm
- \( e' \) = Dielectric constant of the material
- \( \tan \delta \) = Loss tangent, \( le/lc \)
RADIO FREQUENCY DRYING

Heat generated in a dielectric

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- **e'** = Dielectric constant of the material
- **tan δ** = Loss tangent, \( \frac{I_e}{I_c} \)

Materials with higher "loss tangents" and higher "dielectric constants" heat more readily. (Multiply the (loss tangent) by the (dielectric constant) we obtain by definition the "loss factor".)

The higher the loss factor of any specific material, the more efficiently it will heat in an alternating RF field.

Materials with loss factors of
- .3 or greater are considered excellent candidates for RF heating,
- between .2 and .3 good candidates,
- <.2 but > .1 fair to poor.

Raw Dough - Bound Water ------ Poor
Dough > 180 F Good!
**RADIO FREQUENCY DRYING**

**Typical Dielectric Heating Frequencies Reserved For Industrial Use (ISM)**

- 13.56MHz + 0.05%
- 27.12MHz + 0.50%
- 40.68MHz + 0.05%
RADIO FREQUENCY DRYING

RF Power Versus Product Load

"No Load"

RF Power

Frequency

40.68 MHz

RF Power

Frequency

40.68 MHz

"Partial Load"

RF Power

Frequency

40.68 MHz

"Full Load"

RF Power

Frequency

40.68 MHz
RADIO FREQUENCY DRYING

Advantages of Macrowave™ Heating

- Automatic Response to Product Load
- Power Consumed Proportionate to Product Load
- Unlike Microwave, there is no need for Energy Wasting Dummy Loads to Accommodate Gaps in Production
- Inherent Versatility for Multiple Product Lines

- Uniform Application of Heat to the Product Load
- Longer Wavelength Eliminates Preferential Surface Heating
- Energy is Applied Uniformly Across Product Width

$\text{CAPITOL ADVANTAGES}$
RADIO FREQUENCY DRYING

75kW Continuous Wet Granulation Drying System

300kW Catalytic Converter Substrate Drying System
ALTERNATE BAKING OPPORTUNITIES

STANDARD: GDF THERMAL

EXTERNAL HEAT

RADIO FREQUENCY

INTERNAL HEAT

HYBRID OVEN BAKE

NO SCORCH + MOISTURE CONTROL
INCREASE SPEED WITH

NO SCORCH + MOISTURE CONTROL
<table>
<thead>
<tr>
<th>Stage</th>
<th>Cutters</th>
<th>RPM</th>
<th>Bake-Min</th>
<th>Crackers / min.</th>
<th>Percentage Increase</th>
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<tr>
<td>Project Start</td>
<td>Plastic Cutters</td>
<td>490</td>
<td>30</td>
<td>4.25</td>
<td>14,700</td>
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<td>Brass Cutters</td>
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<td>4.25</td>
<td>27,360</td>
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<td>3.11</td>
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<td>912</td>
<td>49</td>
<td>2.6</td>
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</table>
“Today, however, the plant uses radio frequency drying equipment that has doubled the line’s throughput.”