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Heller Industries Technology Review

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Technology Review Topics

- Heller Industries Overview
- MKIII & MK5 Convection Ovens
- 100C Zone Separation in Air and in N2
- Dual Lane, Dual Chamber Ovens
- Vacuum Reflow
- Formic Acid (No Clean)
- Vertical Curing
- Energy Management Cost Reductions
Heller Industries Fact Sheet

- Design, Manufacture Horizontal and Vertical Ovens for Printed Circuit Assembly and Electronic Component Assembly
- Founded 1960, Transition to ovens began 1987
- 1,000-1,250 units/year
- Facilities in New Jersey, USA, Seoul, Korea, Shanghai, PRC, Penang, Malaysia
Heller Industries Philosophy

- Premier Supplier of Soldering and Curing Machines for SMT and Semicon Backend
- Always say “Yes” to our customers
- Be Global and Local or Glocal
- Offer rapid response custom engineering
- Embrace Change, New Technologies
Head Office New Jersey USA
Shanghai Production Floor
1st Floor Production

- Reflow Production; 33 Cells
- 2 Clean room Booths
- Power / Air / Nitrogen supply from earth
- Warehouse
- 7m Elevator

Oven Building Capacity
- 100 Ovens / Month
Production Floor Heller Korea
1st Floor Clean Rooms
755 VERTICAL CURE OVEN
Inline Vacuum Reflow Systems
MKIII & MK5 Series Ovens
MK Series Features

- Green Reflow System – Lead Free / RoHS
- Low Cost of Ownership
  - Low KW – 20-40% reduction in power consumption
  - Low Nitrogen Consumption – Saves 20-40%
  - Reduced Maintenance Intervals – Saves 20-30%
- Superior Thermal Performance
  - Lowest Delta T across the board
  - Cooling rates can be controlled to match Paste Mfr’s specs
MKIII Series
Convection Heater Module
MKIII Oven Module

- 254mm (10”) long heater module (shortest in Industry)
- 127mm (5”) Ø impeller
- Motor with housing
- (Standard) 660mm (26”) wide Module = 460mm Max PCB on Edge-hold conveyor
- (Optional) 762mm (30”) wide Module = 560mm Max PCB on Edge-hold conveyor
MKIII Convection Heat Module

- Return Air Flow returns into module through side suction holes
- Outlet holes in grill are for convection gas flow only
1707 MK3.5 AIR-RETRO/CENTER DRAW

MKIII NITROGEN AND AIR VERSION
BOTH 7 ZONE FULL CONVECTION

Total Length | Heated Length | Typical Belt Speed
---|---|---
3.40m | 1778mm | 50cm/min
Total Length | Heated Length | Typical Belt Speed
---|---|---
4.65m | 2670mm | 85cm/min

MKIII 1809 NITROGEN IS FULL CONVECTION AND HAS OPTIONAL 3RD COOLING ZONE
MKIII 1913 HAS 13 (10") HEAT AND 4 COOLING ZONES WITH FULL CONVECTION

<table>
<thead>
<tr>
<th>Total Length</th>
<th>Heated Length</th>
<th>Typical Belt Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.9m</td>
<td>3650mm</td>
<td>120cm/min</td>
</tr>
</tbody>
</table>
17 Top and Bottom Heating Zones – 10” Zones

<table>
<thead>
<tr>
<th>Total Length</th>
<th>Heated Length</th>
<th>Typical Belt Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.50m (256”)</td>
<td>4320mm (170”)</td>
<td>150cm/min (59”)</td>
</tr>
</tbody>
</table>

MODEL 2017 MKIII

CONFIDENTIAL
MK5 Series

Convection Heater

Module
MK5 Oven Module

- 305mm (12”) long heater module
- 178mm (7”) Backward Wheel Impeller
- No motor housing
- (Standard) 762mm (30”) wide module
  = 560mm Max PCB on Edge-hold conveyor
- (Optional) 864mm (34”) wide module
  = 660mm Max PCB on Edge-hold conveyor
- (Optional) 915mm (36”) wide module
  = 710mm Max PCB on Edge-hold conveyor
MK5 Convection Heat Module

12” wide Heater Module with New Motor & 7” Impeller increase dynamic pressure and improve thermal performance
MODEL 1826MK5

<table>
<thead>
<tr>
<th>Total Length</th>
<th>Heated Length</th>
<th>Typical Belt Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.65m (183&quot;)</td>
<td>2670mm (105&quot;)</td>
<td>85cm/min (33&quot;)</td>
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</tbody>
</table>
MKIII 1936 HAS 10 (12”) HEAT AND 3 COOLING ZONES WITH FULL CONVECTION

<table>
<thead>
<tr>
<th>Total Length</th>
<th>Heated Length</th>
<th>Typical Belt Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.9m (232”)</td>
<td>3650mm (140”)</td>
<td>120cm/min (48”)</td>
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</tbody>
</table>
### MODEL 2043MK5

13 Top and Bottom Heating Zones – 12” Zones

<table>
<thead>
<tr>
<th></th>
<th>Total Length</th>
<th>Heated Length</th>
<th>Typical Belt Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.50m (256”)</td>
<td>4320mm (170”)</td>
<td>150cm/min (59”)</td>
</tr>
</tbody>
</table>

![Diagram of heating zones](image-url)
# MODEL 2156MK5

17 Top and Bottom Heating Zones + 5 Cool Zones

<table>
<thead>
<tr>
<th>Total Length</th>
<th>Heated Length</th>
<th>Typical Belt Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.69m (342&quot;)</td>
<td>5.62M (220&quot;)</td>
<td>150 – 170 cm/min (59 - 67”/Min)</td>
</tr>
</tbody>
</table>
100°C Zone Separation
Air and N2
Carburettor's

Allows up to 100 degree C separation between zones when open

Carburetor / Air Intake Open
Carburettor's

Carburetor Air Intake Closed
# Zone Separation

<table>
<thead>
<tr>
<th>Zone</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
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<tbody>
<tr>
<td>SP</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>270</td>
</tr>
<tr>
<td>PV</td>
<td>170</td>
<td>170</td>
<td>172</td>
<td>185</td>
<td>208</td>
<td>270</td>
</tr>
</tbody>
</table>

**Without Radiators**

<table>
<thead>
<tr>
<th>Zone</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>270</td>
</tr>
<tr>
<td>PV</td>
<td>170</td>
<td>170</td>
<td>172</td>
<td>185</td>
<td>210</td>
<td>270</td>
</tr>
</tbody>
</table>

**With Radiators in Upper and Lower 10**

<table>
<thead>
<tr>
<th>Zone</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>270</td>
</tr>
<tr>
<td>PV</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>270</td>
</tr>
</tbody>
</table>

**Note**

100 deg zone separation with Mini cooling coils.
Cool Coils for Enhanced Zone Separation (in heating zones)
MK Series

Dual Lane Options
DUAL EHC – SIAMESE RAILS
EHC and CBS Combination
MK3 Oven – Standard 26” Module

- Standard Rails
- Max / Min Board = 10.75” / 1.75” (273mm / 45mm)
- 18” (457mm) Total Heat
- Center Rails Dist = 5.5” (139.7mm)
- Combinations:
  - Fixed-Moveable-Fixed-Movable
  - Fixed-Moveable-Moveable-Fixed

- Special Order Siamese Center Rails
- Max / Min Board = 13.62” / 3.00” (346mm / 76mm)
- Center Rails Dist = 1.38” (35.05mm)
- Combinations:
  - Fixed-Moveable-Fixed-Movable
  - Fixed-Moveable (both center rails move together) - Fixed
MKIII Oven Special Order 30” Module
30”odule Standard On MK5 Ovens

- Standard Rails
- Max / Min Board = 14.75” / 1.75” (375mm / 45mm)
- Center Rails Dist = 5.5” (139.7mm)
- Combinations:
  Fixed-Moveable-Fixed-Movable
  Fixed-Moveable-Moveable-Fixed

- Special Order Siamese Center Rails
- Max / Min Board = 17.62” / 3.00” (447mm / 76mm)
- Center Rails Dist = 1.38” (35.05mm)
- Combinations:
  Fixed-Moveable-Fixed-Movable
  Fixed-Moveable (both center rails move together) -Fixed
MK5 Oven – Spl Order 34” Module

• Standard Rails
  • Max / Min Board = 18.75” / 1.75” (475mm / 45mm)
  • Center Rails Dist = 5.5” (139.7mm)
  • Combinations: Fixed-Moveable-Fixed-Movable
    Fixed-Moveable-Moveable-Fixed

• Special Order Siamese Center Rails
  • Max / Min Board = 21.62” / 3.00” (548mm / 76mm)
  • Center Rails Dist = 1.38” (35.05mm)
  • Combinations:
    Fixed-Moveable-Fixed-Movable
    Fixed-Moveable (both center rails move together) -Fixed
MK5 Oven – Spl Order 36” Module

- Standard Rails
  - Max / Min Board = 20.67” / 1.75” (525mm / 45mm)
  - Center Rails Dist = 5.5” (139.7mm)
  - Combinations: Fixed-Moveable-Fixed-Movable
    Fixed-Moveable-Moveable-Fixed

- Special Order Siamese Center Rails
  - Max / Min Board = 23.54” / 3.00” (598mm / 76mm)
  - Center Rails Dist = 1.38” (35.05mm)
  - Combinations:
    Fixed-Moveable-Fixed-Movable
    Fixed-Moveable (both center rails move together) -Fixed
MK5 Series Air and N2

Dual Chamber

Reflow oven
MK5series - Bifurcated (Dual Chamber) Feature

Dual Chamber Module
- Dual Chambers + Dual Blowers + Dual Heaters + Dual T/Cs
Dual Lane
Dual EHC & Thin Sled CBS
Dual Conveyor Speed
Dual 300mm Extension for exit
Dual Computers & Monitors
Dual Controllers
Dual Inverter Fan Speed Control

Separation Wall

Insulation in the middle between two chambers
MK5 series –
1.1m (44”) & 1.3m (42”) Bifurcated (Dual) Chamber Module

BW Dual Chamber Module Structure and Air Flow
--- Dual Chambers + Dual Blowers + Dual Heaters + Dual T/Cs

Insulation in the middle between two chambers
1936MK5 4-Lane Bifurcated Chamber Machine

Dual Chamber Module; 4 Lane
Front side of oven
Rear side of oven
Model 1910 TCO-N

Front open

Rear open

Both side open / close Top shell
Horizontal Convection Vacuum Assisted Reflow Oven

SOLDER JOINT VOID REDUCTION
Inline Vacuum Reflow Systems
Eliminate Voids
Improve Performance

- Improve heat dissipation of components or solder joint structures (i.e., current density increases with voiding)
- Improve long-term stability and reliability of solder joint against heat dissipation and vibration/shock
- Improve chip performance in high frequency applications
- Maintain impedances within spec for components (i.e. power modules)
- Mitigate or eliminate solder problems (bridging, solder splashes, i.e. at μBGAs)
Vacuum Assisted Reflow

- Vacuum-assisted reflow has been shown to reduce the voids in a solder joint by 99%.
- Pressure is dropped to 1-10 Torr during liquidus of the soldering process.
- Existing voids escape externally through the solder when vacuum is applied.
  - Trapped gas bubbles increase in size as pressure is reduced.
  - Larger bubbles are more likely to collide with other bubbles and ultimately collide with the edge of liquid solder to escape.
  - Larger bubbles are accelerated by stronger buoyancy forces making them more likely to escape.
Vacuum Assisted Reflow

- Pressure inside trapped gas bubble changes according to Young-Laplace Equation
  \[ P_{\text{bubble}} = P_{\text{ambient}} + \frac{2\gamma}{r} \]  
  (where \( \gamma \) is surface tension and \( r \) is the radius of the bubble)

- Bubble size is then determined by ideal gas law using \( P_{\text{bubble}} \)
Convection Reflow with Vacuum Module

- Heller Industries has developed a vacuum module that inserts directly in its reflow oven line.
- Vacuum module is inserted in zone directly after reflow peak (liquidus) has occurred.
- Convection reflow with vacuum module is continuous and allows thermal profiles to be directly ported from non-vacuum reflow applications.
- Continuous operation facilitates low COO and high UPH.
Vacuum System with Multiple Vacuum Stations for Additional Control
### Multi-Chamber Vacuum Assisted Reflow

**Single Vacuum Chamber**
- Trapped gas must move through coalesced solder and join with solder surface to escape.
- Surface tension of bubbles releases energy during escape resulting in “splat”.

**Multi-Vacuum Chamber**
- Applying vacuum prior to reflow can remove trapped gas from liquified solder paste resins.
- Minimizing trapped gas in solder will significantly reduce the tendency for solder “splat”.
Heller 1936 Mark V Vacuum Oven
Solder Paste Thermal Profiles

Examples of solder paste thermal profile specification from solder paste suppliers. All illustrate a wide process tolerance.
Profile-20sec Vacuum

---

**Table: Profile Details**

<table>
<thead>
<tr>
<th>TCs</th>
<th>Preheat 160-200°C</th>
<th>Peak Temp</th>
<th>Total Time 240°C</th>
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</thead>
<tbody>
<tr>
<td>&lt;TC2&gt;</td>
<td>61.69</td>
<td>-264%</td>
<td>252.26</td>
</tr>
<tr>
<td>&lt;TC3&gt;</td>
<td>57.35</td>
<td>-326%</td>
<td>255.11</td>
</tr>
<tr>
<td>&lt;TC4&gt;</td>
<td>55.25</td>
<td>37%</td>
<td>251.00</td>
</tr>
<tr>
<td>Delta</td>
<td>5.34</td>
<td>4.11</td>
<td>12.14</td>
</tr>
</tbody>
</table>

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**Graph: Temperature Over Time**

- **X-axis:** Seconds (0-400)
- **Y-axis:** Temperature (0-250 Celsius)
- Key points: 200 200 180 180 200 240 300 340/360
- High blower speed: 63rpm, 30rpm, 38rpm, 30rpm/sec, dwell time: 20sec with 10rpm
Inline Vacuum Reflow System - Layout

- Heat Zones
- Staging Conveyors
- Vacuum Chamber
- Cooling Zones
Inline Vacuum Reflow System - Zones

Heating Zones:
- Top – 10 Convection Heat Zones
- Bottom – 8 Convection Heat Zones & 1 IR Panel
- 283 cm Total Length

Cooling Zones:
- Top – 4 Convection Cool Zones
- Bottom – 2 Convection Cool Zones & 1 Chill Plate
- 109 cm Total Length
Inline Vacuum Reflow System - Conveyors

- Entrance Conveyor: 297 cm
- Vacuum Conveyor: 50 cm
- Exit Conveyor: 117 cm
- Staging Conveyors: 40 cm (each)
Inline Vacuum Reflow System - Sensors

- Entrance Sensor
- Loading - Oven

- Handoff Sensor #1
- Heating - Staging

- Handoff Sensor #2
- Staging - Chamber

- Handoff Sensor #3
- Chamber - Staging

- In-Vacuum Sensor
- IR Panel Aligned

- Handoff Sensor #4
- Staging - Cooling
Vacuum & Conveyor System Details

- Vacuum Pump
- Entrance Staging Conveyor
- Vacuum Chamber
- Exit Staging Conveyor
Vacuum Cycle Step-by-Step

Time = 0 seconds
- Board is fully on entrance side staging conveyor
- Door Opens
- Will be accelerated into chamber at high speed

Time = 15 seconds
- Door closes
- Vacuum cycle begins
- Upstream board transfers onto staging conveyor
Vacuum Cycle Step-by-Step

**Time = 30 seconds**
- Vacuum at full level
- Upstream board almost completely on entrance staging conveyor

**Time = 45 seconds**
- Vacuum cycle complete
- Board transported out of chamber at high speed
- Upstream board transported into chamber at high speed
Vacuum Cycle – Set Values & Variables

**Variables**
- **Transport Time**
  - Depends on product & final system dimensions
  - Variable speed conveyor
- **Pump-down Time**
  - Slowed to reduce solder splatter
  - PLC adjustable
    - Torr / second Value
- **Dwell Time**
  - Process dependent
  - PLC adjustable

**Set Values**
- **Doors Opening & Closing**
  - ~ 2 Seconds
  - Slow speed to reduce vibration
  - Manually adjustable
- **Repressurize**
  - ~ 5 Seconds
  - Slow speed to reduce chance of disturbing components
  - Manually adjustable
Vacuum Chamber Details

- **Width**
  - Chamber Internal: 63 cm
  - Max. EHC: 45 cm
  - Min. EHC: 5 cm
  - Max. Effective: 35 cm

- **Length:**
  - Chamber Internal: 59 cm
  - Max. Effective: 35 cm

- **Notes:**
  - Effective dimensions are based on effective area of IR panel inside chamber.
  - Images show model with side-chain mesh belt conveyor. Final product will be with EHC.
Vacuum Source Details

- Precision Vacuum Level Control
- Pump-down Rate Precisely Controllable
- Vacuum Level Attainable in as Little as 5 Seconds
- Excellent Flux Handling Ability
Heller Advanced Vacuum Pump

- Clean oil-free design
- Compact footprint
- Internally heated to avoid flux condensation
- High capacity: 650m$^3$/hr
Vacuum Assisted Reflow
Customer Test

March 2013
## Test Conditions

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
<td>5</td>
<td>120</td>
<td>400</td>
<td>**</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>30</td>
<td>400</td>
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<td>4</td>
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<td>400</td>
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<tr>
<td>6</td>
<td>20</td>
<td>60</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Atmospheric</td>
<td>-</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>15</td>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>

** Should be 60 seconds but mistakenly set to 120 seconds.**

- Die size = 7.5 x 6, 3mm square
- Liquidus peak = 250°C
- Alloy type SAC 305 (217°C Melt Point)
## Test Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Vacuum Level [torr]</th>
<th>Dwell Time [sec]</th>
<th>Worst Case [%]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>30</td>
<td>0.21</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>120</td>
<td>0.39</td>
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<tr>
<td>3</td>
<td>10</td>
<td>30</td>
<td>0.36</td>
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<tr>
<td>4</td>
<td>10</td>
<td>60</td>
<td>0.26</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>30</td>
<td>0.20</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
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<td>0.47</td>
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<td>7.64</td>
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<tr>
<td>8</td>
<td>5</td>
<td>15</td>
<td>0.48</td>
</tr>
</tbody>
</table>
Test #7 Details-No Vacuum
Test #1 w/ 5 Torr for 30 seconds

0.21% worst case voids
Horizontal Convection Fluxless Reflow Oven

FORMIC ACID VAPOR DELIVERY
Reflow in Formic Acid Vapor

- Fluxless reflow utilizes gas phase Formic Acid to replace standard fluxing agents
- Eliminates the need for pre-reflow fluxing and post-reflow flux cleanup steps
- Feasibility has been demonstrated with production grade oven
  - Extensive engineering efforts in safe, precision delivery of formic acid and abatement.
Fluxless Reflow
Model 1809MKIII Oven Schematic

Formic Acid soak in first six zones of Model 1809 Mark III Oven (equivalent to Flux Activation Time (FAT))
Formic Acid Delivery System
Formic Acid Safety Monitoring System

Top View of Heller 1809 Mark III Oven with Gas Safety Sensor shown…
Catalytic Reactor Boxes at each end of the oven remove all unused formic acid and carbon monoxide produced in the fluxless reflow process…
Formic Demo Machine
Inside Class 10K Clean Room
Florham Park, New Jersey
Heller Flux-less Reflow Summary

- Publicly announced Joint Development Agreement (JDA) with IBM to commercialize high end fluxless reflow
- Formic Acid has been shown to be an effective reducing agent in fluxless solder reflow
- Heller has designed and built a production ready horizontal reflow oven for this application.
- This new oven has been designed to meet Semi S2/S8 safety standards (including toxic gases).
- The Heller Oven is available for testing and development activities in Florham Park, New Jersey.
Inline Vertical Epoxy Cure Oven
Heller 788
Large Vertical Curing Oven
Custom built to meet product size and curing requirements
Heller 788 VCO Substrate Flow

- 4 individually controlled Heat zones
- 2 zones up, 2 zones down
- Max Cure temperature 200°C
Four Zone Heating with 788 VCO

- Four-zone heating
- Independent time and temperature controls for single and double step profiling
755 VERTICAL CURE OVEN
## Specification Review

<table>
<thead>
<tr>
<th>Dimension</th>
<th>755 Specification</th>
<th>Remark</th>
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<tbody>
<tr>
<td>Height (mm)</td>
<td>1670±30</td>
<td></td>
</tr>
<tr>
<td>Length (mm)</td>
<td>1850</td>
<td></td>
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<tr>
<td>Width (mm)</td>
<td>1500</td>
<td></td>
</tr>
<tr>
<td>Vertical Pitch (mm)</td>
<td>19.05</td>
<td></td>
</tr>
<tr>
<td>Edge width clearance (mm)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Max board width (mm)</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Min board width (mm)</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Max board length (mm)</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Maximum Board weight</td>
<td>.15 Kg (.33 lb)</td>
<td></td>
</tr>
<tr>
<td>Cycle Time (sec)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Process Time (min)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Temperature Settable range</td>
<td>125~150 C</td>
<td></td>
</tr>
<tr>
<td>Up/Down Conveyor (Boards)</td>
<td>25(24 Step)</td>
<td>Total 50 Boards.(Up;25 , Down;25)</td>
</tr>
</tbody>
</table>
## Specification Review

<table>
<thead>
<tr>
<th>Miscellaneous</th>
<th>755 Specification</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows on Shed</td>
<td>Applied Top side and Front side</td>
<td></td>
</tr>
<tr>
<td>Entrance/Exit Conveyor</td>
<td>Applied</td>
<td></td>
</tr>
<tr>
<td>Autolube on EHC</td>
<td>Applied</td>
<td></td>
</tr>
<tr>
<td>Top Cam &amp; Entrance Black Box</td>
<td>Option</td>
<td></td>
</tr>
</tbody>
</table>
Overall Dimensions

Basic Dimensions
- Height: 1670 ± 30mm
- Width: 1500mm
- Length: 1850mm
- Conveying Height: 900mm
Thermal Flow
2 Heat Zones Upper and Lower
Boards Flow

Top Transfer Flow – Top Shuttle

- Up Flow
  - Up Conveyor

- Entrance Flow
  - Entrance Conveyor
  - Bottom Shuttle-Entrance

- Down Flow
  - Down Conveyor

- Exit Flow
  - Exit Conveyor
  - Bottom Shuttle-Exit

Boards Flow
Energy Management

REDUCING ELECTRICAL AND NITROGEN COSTS
Areas to Consider for Cost Reduction

1. Oven Skin Temperature and Air-Con Load
2. Too Much Exhaust?
3. Effect of the Mesh belt (It’s a heat pump
4. Effect of PPM level on Nitrogen cost
5. Standby mode—reducing power and N2 when the oven is idle
6. Multiple Lanes can save money
EFFECT OF OVEN SKIN TEMPERATURE
BASELINE TEMPERATURE READING ON
EXISTING OVEN

Baseline Temperature:
Reading on skin of existing oven using Infra – Red camera. Average 37.3°C

M1: 37.8c
M2: 38.4c
M3: 43.2c
M4: 34.2c
M5: 33.1c
Average: 37.3c
EFFECT OF OVEN SKIN TEMPERATURE
TEMPERATURE READINGS AFTER
MODIFICATION

IR Camera results AFTER modifications to the oven
Average of the skin temperature is 30.6°C

Average Reduction in Skin Temperature = 6.7°C
Reduction in Electricity = 1.21 KW
Using engineering formulas, we can calculate to show that the change in skin temperature of 6.7°C results in a savings of 1.3 KW!

(Actual was 1.2KW)

That is 8790 RMB per year!

Most Existing Reflow ovens CAN have insulation added to them to reduce skin temperature and save Energy and Money!
EFFECT OF TOO MUCH EXHAUST ON ENERGY--BASELINE MEASUREMENT

Recommended Exhaust-120 CFM

Baseline Power Consumption Data: Average 11.41KWH
EFFECT OF TOO MUCH EXHAUST ON ENERGY--
HIGH EXHAUST DATA

With exhaust that is only 40 CFM higher, the idle power consumption increases by .47 KWH!

9.77m/s = 160 CFM

Power Consumption Idle (11.88kwh average)
## COST IMPACT OF TOO MUCH EXHAUST

### Power Consumption Idle (11.41kwh)

<table>
<thead>
<tr>
<th>Time</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:17:49</td>
<td>0,00</td>
</tr>
<tr>
<td>14:19:12</td>
<td>5000,00</td>
</tr>
<tr>
<td>14:20:35</td>
<td>10000,00</td>
</tr>
<tr>
<td>14:21:58</td>
<td>15000,00</td>
</tr>
<tr>
<td>14:23:21</td>
<td>20000,00</td>
</tr>
<tr>
<td>14:24:44</td>
<td>25000,00</td>
</tr>
</tbody>
</table>

### Recommended Exhaust (120 CFM)

- **Power Consumption**: 11.41 KW/H

### Excessive Exhaust (160 CFM)

- **Power Consumption**: 11.88 KW/H

### Savings per Year

- **Savings**: 2978.79 RMB

Savings based on: .47KW/Hr saving X 24 hrs/day x 365 days/yr x .7235 RMB/KWH (Actual savings may vary based on actual exhaust and local costs)

### Note

- **$ Note**: Even a small change in exhaust can waste electricity!
- **All existing Ovens** can have the Exhaust calibrated to ensure proper levels and optimize cost.
TOO MUCH EXHAUST CAN WASTE NITROGEN

BASELINE DATA:
N2 oven running 1000 PPM at 700 SCFH (19.8M/3hr) with recommended exhaust requirement of 120 CFM
When running at 160 CFM:
Nitrogen consumption increases by 50 SCFH to 750 SCFH (21.2 M3/Hr) @1000 PPM

A 50 SCFH (1.4 M3/Hr) increase can have a BIG Cost impact....
COST IMPACT OF TOO MUCH EXHAUST ON N2

$$\text{Note: Even a small change in exhaust can cost money!}$$

All existing Ovens can have the Exhaust calibrated to ensure proper levels and optimize cost

<table>
<thead>
<tr>
<th>Nitrogen Consumption when using recommended exhaust (120 CFM)</th>
<th>700 SCFH (19.8 M$^3$/Hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Consumption when exhaust is too high (160 CFM)</td>
<td>750 SCFH (21.23 M$^3$/Hr)</td>
</tr>
<tr>
<td>Saving per hour in Nitrogen Consumption</td>
<td>50 SCFH (1.43 M$^3$)</td>
</tr>
<tr>
<td>Saving per year in Nitrogen Cost</td>
<td>11,274 RMB/Year</td>
</tr>
</tbody>
</table>

Calculations based on: 1.4M$^3$ / Hr X 24 hrs/day X 365 days/yr X .9 RMB/M3 = 11,274 RMB/Yr (Actual savings may vary based on usage and local N2 cost)
Effect of Exhaust on Air Conditioning Load

Exhausted air needs to be “replaced” by outside air. The outside air needs to be air conditioned and in many parts of Asia that means: Cooled AND De-Humidified. Here we can calculate the AirCon load and potential savings associated with improper exhaust levels.

Assume:
--Air exhausted from oven must be replenished with outside air.
--Factory climate control system must condition incoming air to room state.
--Humid locations will have considerably higher loads.

\[ Q_3 = \text{Energy to bring outside air to room state} = \text{Mass flow} \times (\Delta h \text{ enthalpy}) \]
Effect of Exhaust on Air Conditioning Load

$$\text{Q3} = \text{Energy to bring outside air to room state} = \text{Mass flow} \times (\Delta h \text{ enthalpy})$$

Mass flow = Exhaust Flow rate * Density
Density of air = 1.15 kg/M^3 (@35c, 0 elevation above sea level)
conversion factor: 1 M^3/sec = 2119 cfm

$$\Delta h \text{ enthalpy} = (h \text{ outside} - h \text{ inside})$$

h is a function of temperature and relative humidity
h is found using a psychrometric chart
psychrometric chart data has been provided in attached table

<table>
<thead>
<tr>
<th>Q3 CALCULATOR</th>
<th>Considering Recommended Exhaust of 500 CFM</th>
<th>With 550 CFM Exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Temperature</td>
<td>22.5 deg c</td>
<td>Inside Temp.</td>
</tr>
<tr>
<td>Inside Relative Humidity</td>
<td>40 %</td>
<td>Inside Rel. Humid.</td>
</tr>
<tr>
<td>Outside Temperature</td>
<td>27.5 deg c</td>
<td>Outside Temp.</td>
</tr>
<tr>
<td>Outside Relative Humidity</td>
<td>60 %</td>
<td>Outside Rel. Humid.</td>
</tr>
<tr>
<td>Oven Exhaust</td>
<td>500 cfm</td>
<td>Oven Exhaust</td>
</tr>
<tr>
<td>Density</td>
<td>1.15 kg/M^3</td>
<td>Density</td>
</tr>
<tr>
<td>Inside Enthalpy</td>
<td>57.68 (KJ/Kg)</td>
<td>Inside Enthalpy</td>
</tr>
<tr>
<td>Outside Enthalpy</td>
<td>80.71 (KJ/Kg)</td>
<td>Outside Enthalpy</td>
</tr>
<tr>
<td>Q3</td>
<td>6249 Watts</td>
<td>Q3</td>
</tr>
</tbody>
</table>

**Note:** AirCon Costing is not usually considered in Energy Saving calculations BUT reducing exhaust can have a big cost impact. In this case, a 50 cfm change yields .624 KW

That is 3954 RMB per Year!
EFFECT OF MESH BELT ON ENERGY CONSUMPTION

The Mesh belt is a big “heat pump” as seen in this IR photo

Baseline Data:
Average 11.94 KW when running the oven Mesh / Edge Conveyor Belt at 100 CM/Min
EFFECT OF MESH BELT ON ENERGY CONSUMPTION

With Mesh Turned OFF:
Average KW DROPS from 11.94 to 9.87KW when running the oven Mesh Belt turned OFF.

The belt is a HUGE Heat Pump that wastes 1.5KW – 2KW of electricity!

This is 9506 RMB saved per year!

$$ NOTE
You can remove the mesh belt right now and save money instantly!
YOU CAN REDUCE NITROGEN COST BY INCREASING PPM

<table>
<thead>
<tr>
<th>Item</th>
<th>N2</th>
<th>Cost Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000ppm</td>
<td>640scfh</td>
<td>13,528 RMB /Yr</td>
</tr>
<tr>
<td>1500ppm</td>
<td>660scfh</td>
<td>8,995 RMB /Yr</td>
</tr>
<tr>
<td>1000ppm</td>
<td>700scfh</td>
<td>Baseline</td>
</tr>
</tbody>
</table>

$$ Note: Most processes CAN run at higher PPM levels with NO CHANGE TO PRODUCT QUALITY. However, a large savings in nitrogen cost can easily be achieved!
Energy Management System During production

Under Production Loads the Heat & Cool Modules & Exhaust Operate at 100%
Energy Management System In Standby Mode

Under Zero Production Load the Heat & Cool Modules & Exhaust Idle at 20hz Saving Power & N2 Consumption!
EFFECT OF "STANDBY" FEATURE ON ENERGY

BASELINE TEST—Fully Loaded production test
--Board size 250x250mm
--1000ppm@750scfh
--Board Loading 1 pcb / 20 sec
--Power Consumption 13.07KW
WHEN OPERATORS GO TO LUNCH, YOU CAN SAVE ENERGY AND NITROGEN

STANDBY MODE OPERATION:
--When production stops, the oven can reduce blower motor speed and Exhaust from 50HZ to 20 HZ --- but zone temperatures stay the same.
This keeps the heat inside the oven and reduces Electrical consumption by 45%!!!
## Electrical Cost Savings Using Standby Mode

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power When Running at Full Production</td>
<td>13.07kwh</td>
</tr>
<tr>
<td>Power When Running Standby for 30 minutes</td>
<td>7.23kwh</td>
</tr>
<tr>
<td>Net change in power consumption</td>
<td>5.84KW</td>
</tr>
<tr>
<td>Actual Power Saved power during 30 minutes</td>
<td>2.92 KW</td>
</tr>
<tr>
<td>Power saved per day for 3 meal breaks</td>
<td>8.76 KW</td>
</tr>
<tr>
<td>Power saved per year using Standby Feature</td>
<td>3,197 KW</td>
</tr>
</tbody>
</table>

| Savings per Year                                      | 2,313 RMB |
STANDBY MODE OPERATION:
--When production stops, the oven can reduce blower motor speed and Exhaust from 50HZ to 20 HZ

This keeps the nitrogen inside the oven and reduces nitrogen loss through exhaust by 60%!!!
## NITROGEN COST SAVINGS WHEN USING STANDBY MODE

<table>
<thead>
<tr>
<th>Item</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Consumption at Full Production</td>
<td>750 SCFH</td>
</tr>
<tr>
<td>Nitrogen Consumption in Standby Mode</td>
<td>300 SCFH</td>
</tr>
<tr>
<td>Nitrogen Savings During 30 Minute Standby</td>
<td>450 SCFH</td>
</tr>
<tr>
<td>Nitrogen Savings per Day with 3 Meal Breaks</td>
<td>1350 SCFH</td>
</tr>
<tr>
<td>Nitrogen Savings per Year Using Standby</td>
<td>492,750 SCFH</td>
</tr>
<tr>
<td></td>
<td>(13,923 M³)</td>
</tr>
<tr>
<td>Cost Savings per Year</td>
<td>12,531 RMB</td>
</tr>
</tbody>
</table>

Standby Mode is typically an automatic feature based in Software with links to fan speed controls but manual fan speed controls can be field retrofitted in most machines. In either case, the investment is small and ROI is big!

Calculations based on: 13,923 RMB/Yr \( \times .9 \) RMB/M3 = 12,531 RMB/Yr

(Actual savings may vary based on usage and local N2 cost)
EFFECT OF DUAL LANE ON ENERGY

Single Lane Loading Power Consumption (12.66 kWh)
Most Existing Reflow ovens CAN be field retrofitted for Dual Lane processing. Dual Lanes provides 100% production increase with only a 10% (1.27KW/Hr) increase in electrical consumption!
### EFFECT OF DUAL LANE ON ENERGY

<table>
<thead>
<tr>
<th>Item</th>
<th>Power</th>
<th>Floorspace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single lane</td>
<td>12.66kwh</td>
<td>8.07m² (5.89x1.37m)</td>
</tr>
<tr>
<td>Two single oven</td>
<td>25.32kwh</td>
<td>16.14m² (5.89x1.37m^2)</td>
</tr>
<tr>
<td>Dual lane</td>
<td>13.93kwh</td>
<td>8.07m² (5.89x1.37m)</td>
</tr>
<tr>
<td>Savings (Dual Lane vs. 2 Ovens)</td>
<td>-11.39kwh</td>
<td>8.07m² (5.89x1.37m)</td>
</tr>
<tr>
<td>Savings per year</td>
<td>72,138 RMB</td>
<td>Saves 1 Entire oven!</td>
</tr>
</tbody>
</table>

The best way to save on energy is with Dual Lane processing. The cost savings is huge!

And most existing ovens can have the dual lane retrofitted so in many cases you DON’T need to buy a new oven!
Energy Management Summary

- Most existing ovens can save Energy and Nitrogen
- In many cases, there is little or no cost:
  - Removing Mesh belt
  - Calibrating Exhaust
  - Increasing Nitrogen PPM
Thank You