



Application & Adoption of Rigorous Mixing Discipline into a Pilot Plant Environment

Cliff Kowall, Senior Process Development Engineer
Lubrizol Corporation
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CMK1

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Slide 1

CMK1

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Presentation Outline CMK7

CMK2

- Mixing is important to The Lubrizol Corporation
- Recognized need for and benefit of better mixing CMK3

CMK14 knowledge

- Determined potential tools to meet the need
- Selected tools & developed knowledge base
- Determined potential for creating value
- Searched for applications & successes
- Adoption & general introduction
- Lessons learned

Slide 2

CMK2

Capitalized The

Catherine Kopanski, 16/06/2011

CMK3

Added "for"

Catherine Kopanski, 16/06/2011

CMK7

Deleted underlines on title throughout presentation and standardized on 28 points.

Catherine Kopanski, 16/06/2011

CMK14

Added some wording to make bullet points more parallel.

Catherine Kopanski, 16/06/2011

CMK8

The Lubrizol Corporation

- The Lubrizol Corporation was founded in 1928. CMK4
- We are an innovative specialty chemical company with consolidated revenue of \$5.4 billion for the year ended December 31, 2010.
- We supply technologies and produce additives, ingredients, resins and compounds for the global transportation, industrial and consumer markets CMK5
- Lubrizol's industry-leading technologies in additives, ingredients and compounds enhance the quality, performance and value of customers' products, while reducing their environmental impact.
- Our products are used in a broad range of applications
 - Relatively stable markets such as those for engine oils, specialty driveline lubricants and metalworking fluid
 - Higher-growth markets such as those for personal care and over-the-counter pharmaceutical products, performance coatings, medical products and compressor lubricants.
- We are organized into two operating and reportable segments
 - Lubrizol Additives
 - Lubrizol Advanced Materials

Reference: Lubrizol Corporation SEC 10-K filed 2/25/2011

Slide 3

CMK4

Added " We are" to beginning of sentence

Changed revenue to \$5.4 billion

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CMK5

I broke the second bullet point into two separate bullets.

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CMK8

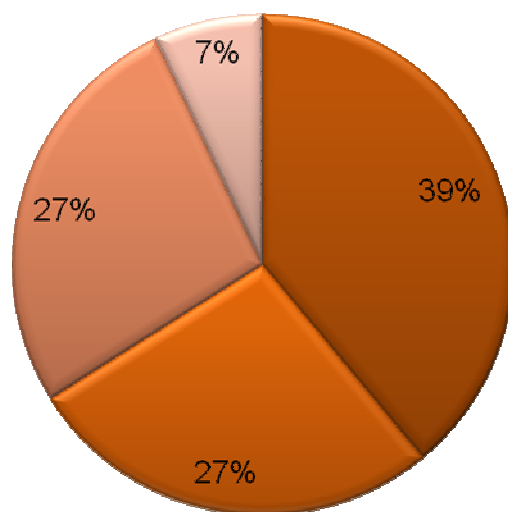
Added "The" in front of Lubrizol Corporation

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Lubrizol 2010 Performance

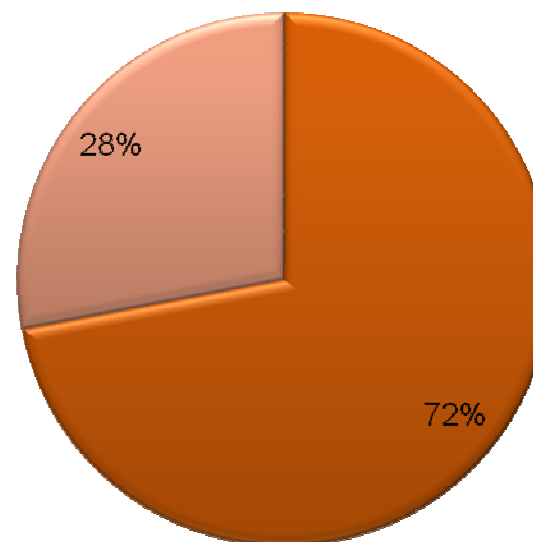
2010 Global Sales Volume %

■ North America
 ■ Europe
 ■ Asia-Pacific/Middle East
 ■ Latin America



2010 Revenues

■ Additives
 ■ Advanced Materials



CMK6
 \$5.4 Billion in Revenue 2010

Slide 4

CMK6

Changed this to 5.4 billion

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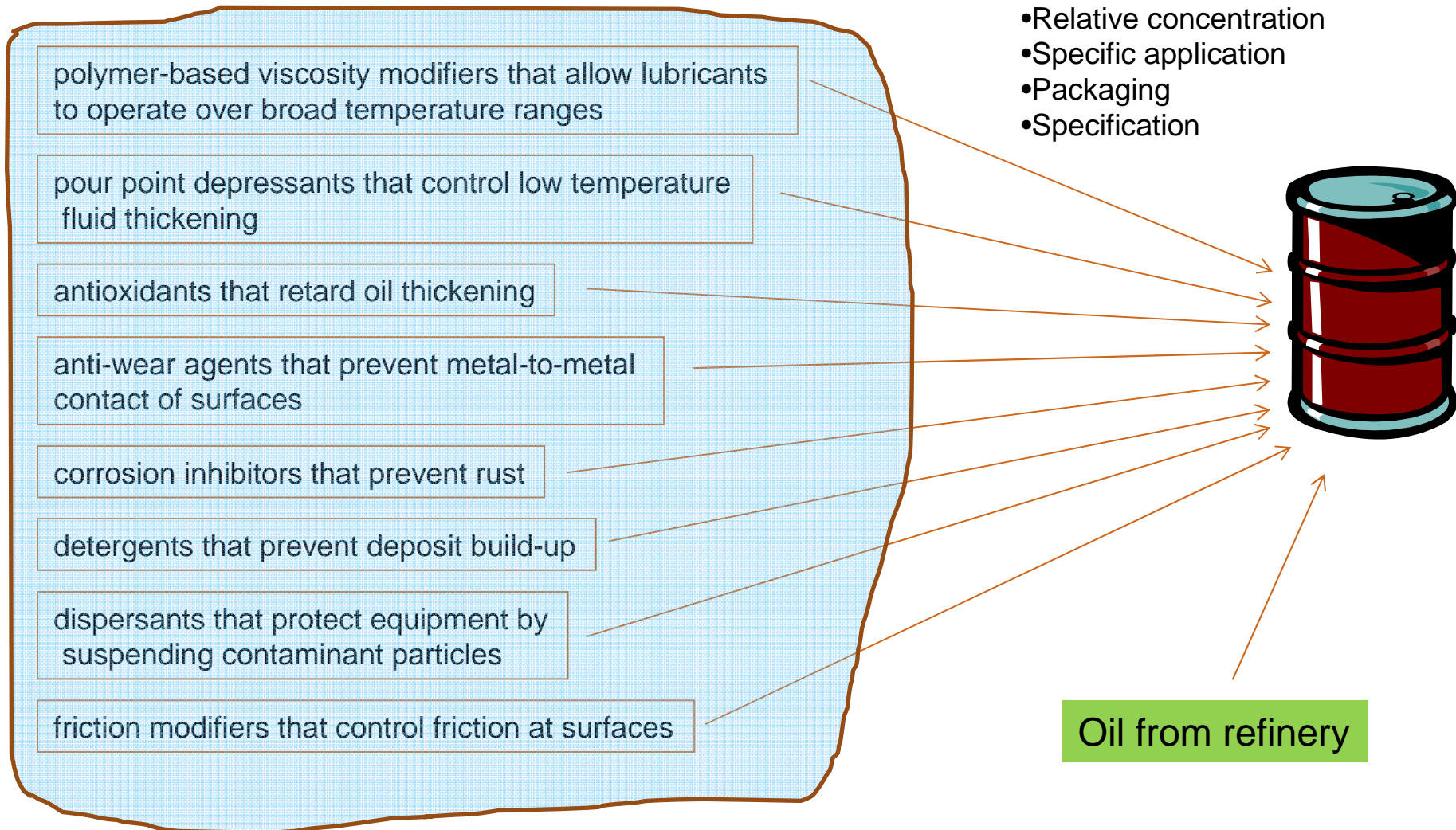
Lubrizol Additives Principal Manufacturing Locations



Blending of a Fully Functional Oil

Other variables:

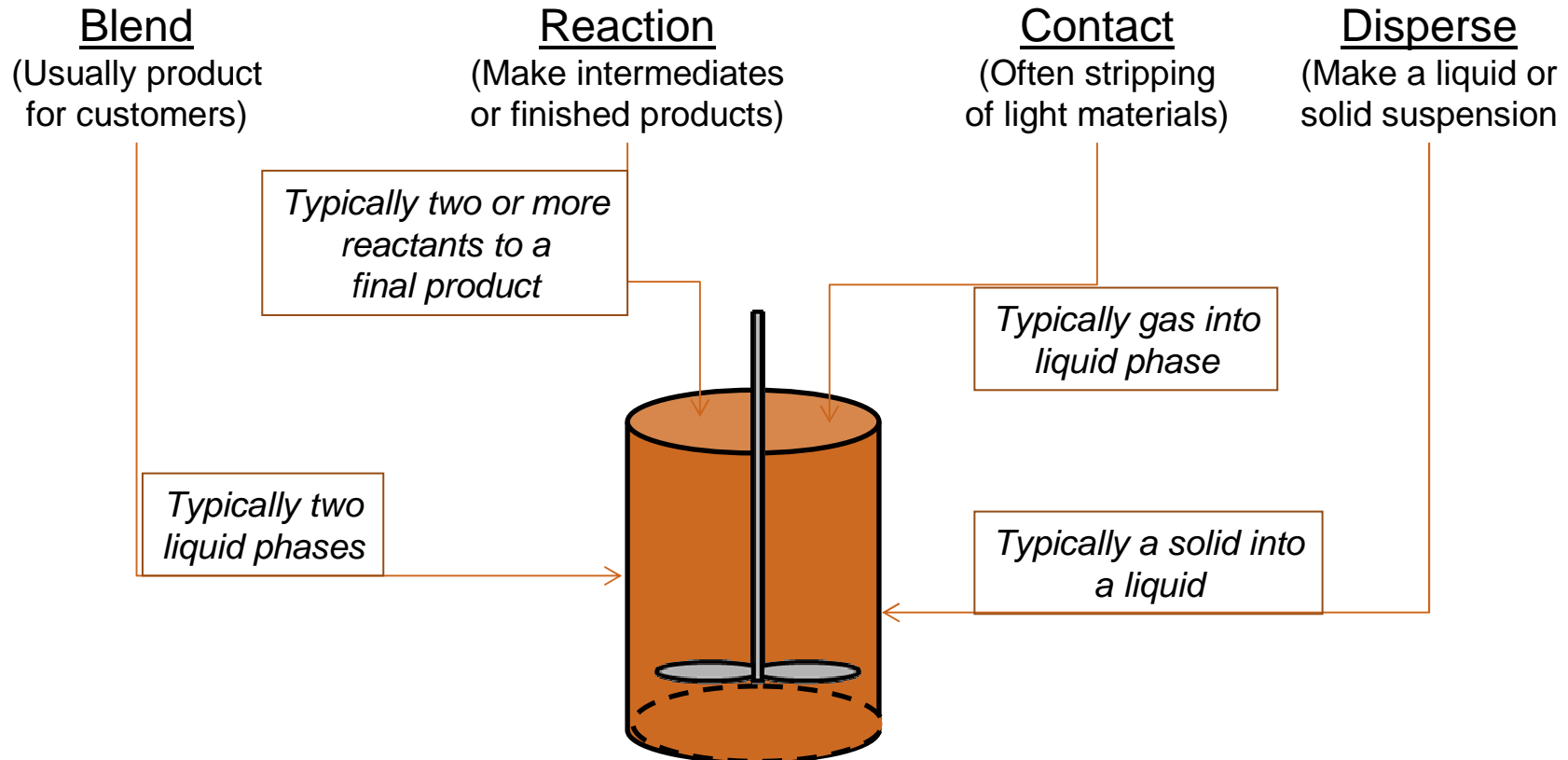
- Relative concentration
- Specific application
- Packaging
- Specification



Performance Additives

Reference: Lubrizol 2009 Annual Report page 2 of part 1

Summary of Typical Mixing Situations CMK9



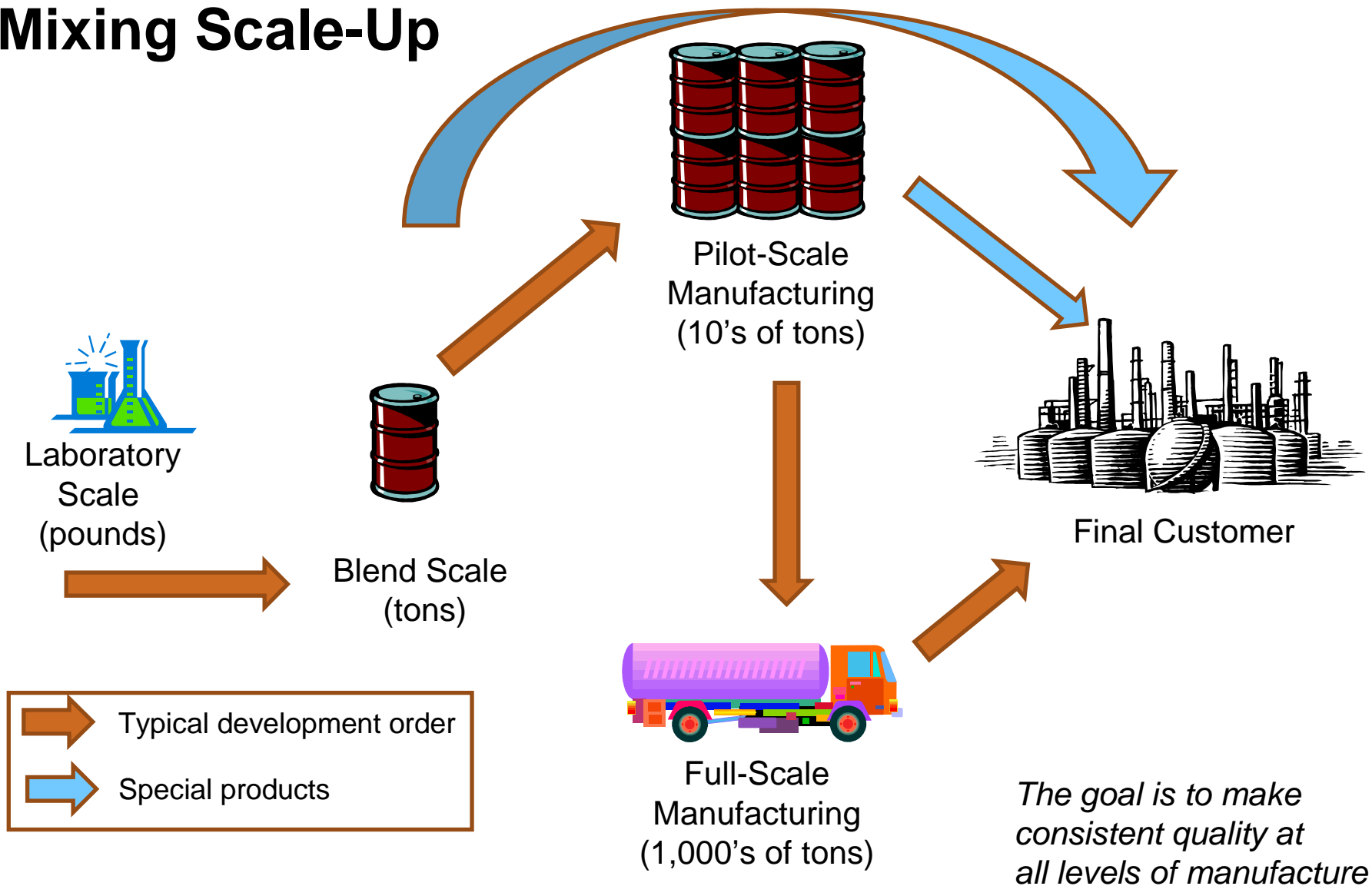
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CMK9

Adjusted capitalization for consistency.

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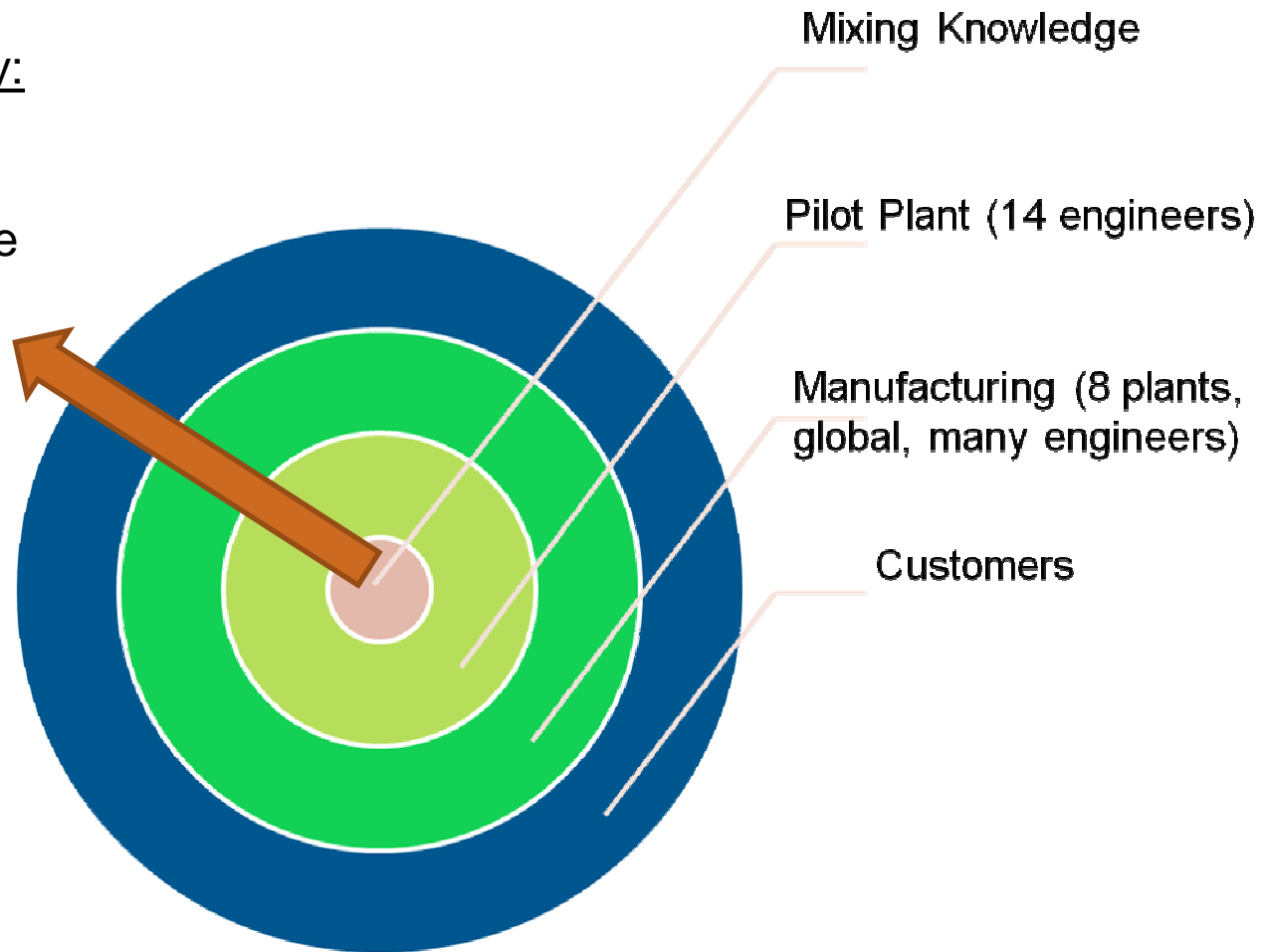
Mixing Scale-Up



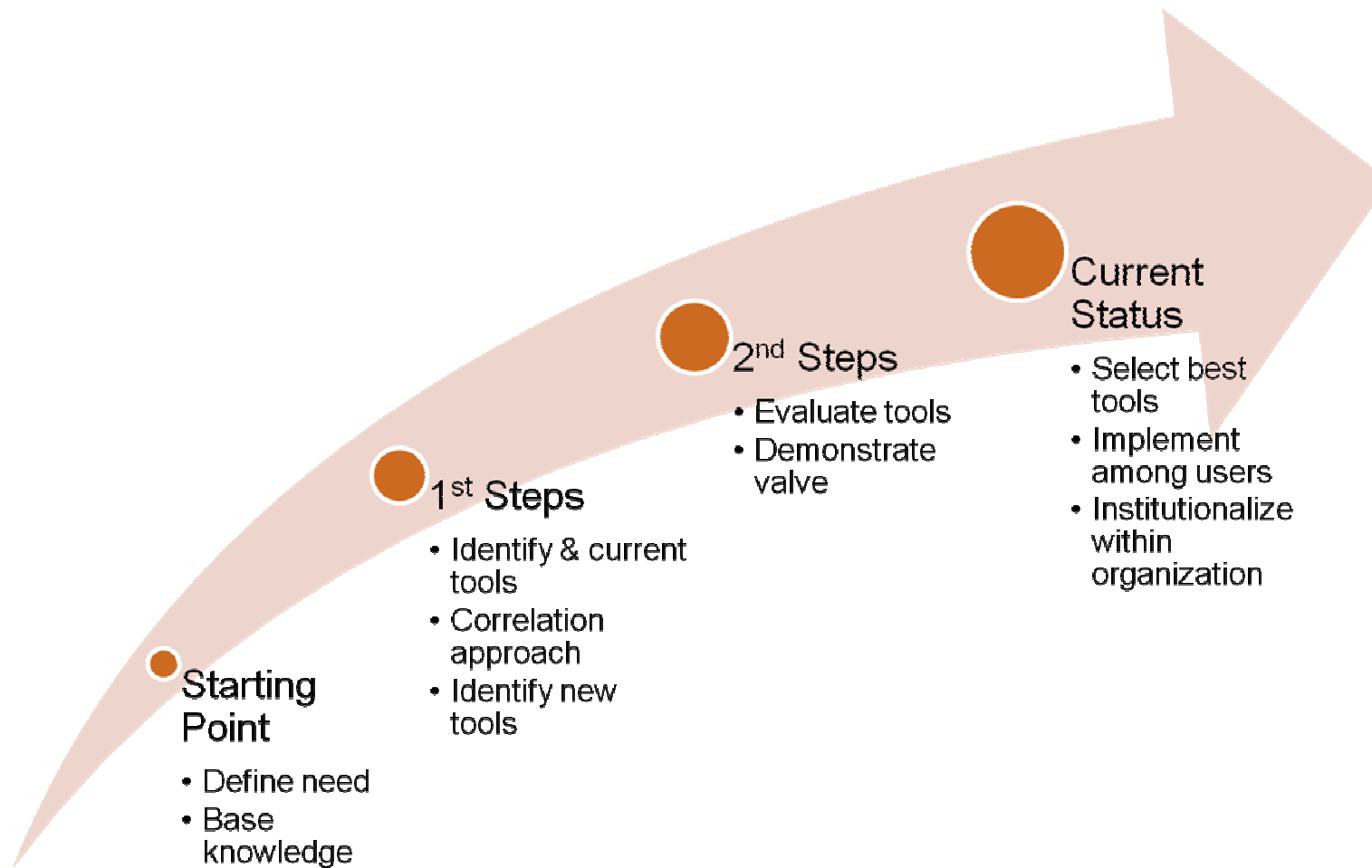
Objective of Mixing Knowledge Center

Generate Value by:

- Better quality
- Higher yield
- Shorter cycle time
- Consistency
- Greater volume



Trajectory for Development of Mixing Activity

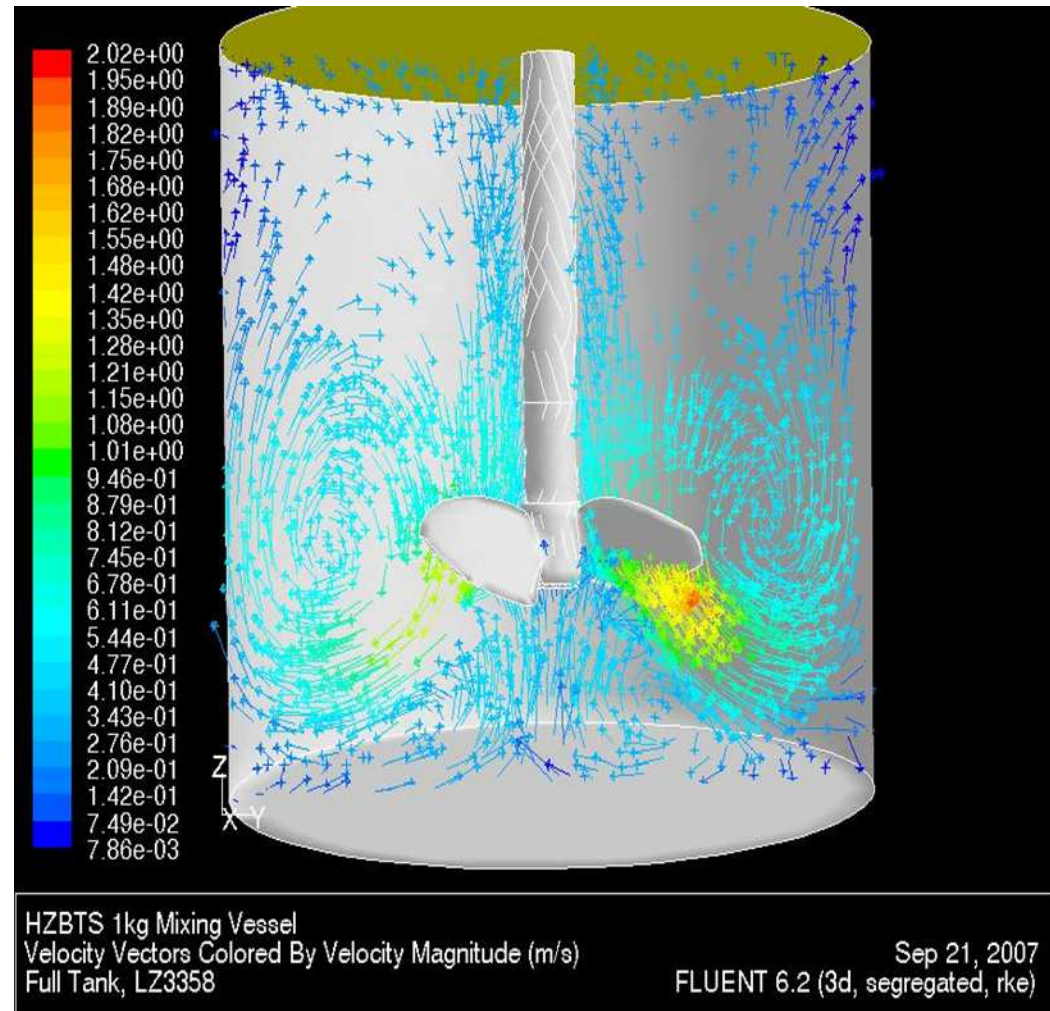


1st Step Results

- Value based on better consistency & optimized equipment use
- Resources need to be expanded
 - Usual modeling software does not handle mixing
 - CFD is good but impractical for current situation
 - University support is limited
 - Timeliness
 - Academic vs industrial approach
 - Continuity of graduate students
 - Intellectual property and knowledge protection
 - External consultants
 - Expensive
 - Long company learning curve
 - Difficult to engage fully
 - Variable knowledge base
- Concluded that internal expertise is preferred

Computational Fluid Dynamics Tools

- CFD is traditional tool
- Advantages:
 - Visually appealing
 - Multiple variables
 - Multiple visual feedback
- Disadvantages:
 - Expensive software
 - Special computers
 - Computationally intensive
 - Validation against data
 - Highly trained users
 - Not plant friendly
- Conclusion:
 - CFD may have niche applications but is not suitable for general use



2nd Step Results

- Developed knowledge of correlation-based approaches CMK10
- Searched for non-CFD based mixing programs
- Found VisiMix™ software being used in other parts of company
- Established contact with VisiMix™ company
 - Trial copy for evaluation
 - Validation
 - Tracer work in lab CMK11
 - Compared with correlations
 - Visual work was useful for communication to uninitiated
 - Justified one license
- Applied to larger applications outside of the lab
- Realized the need for better archive data on mixing vessels

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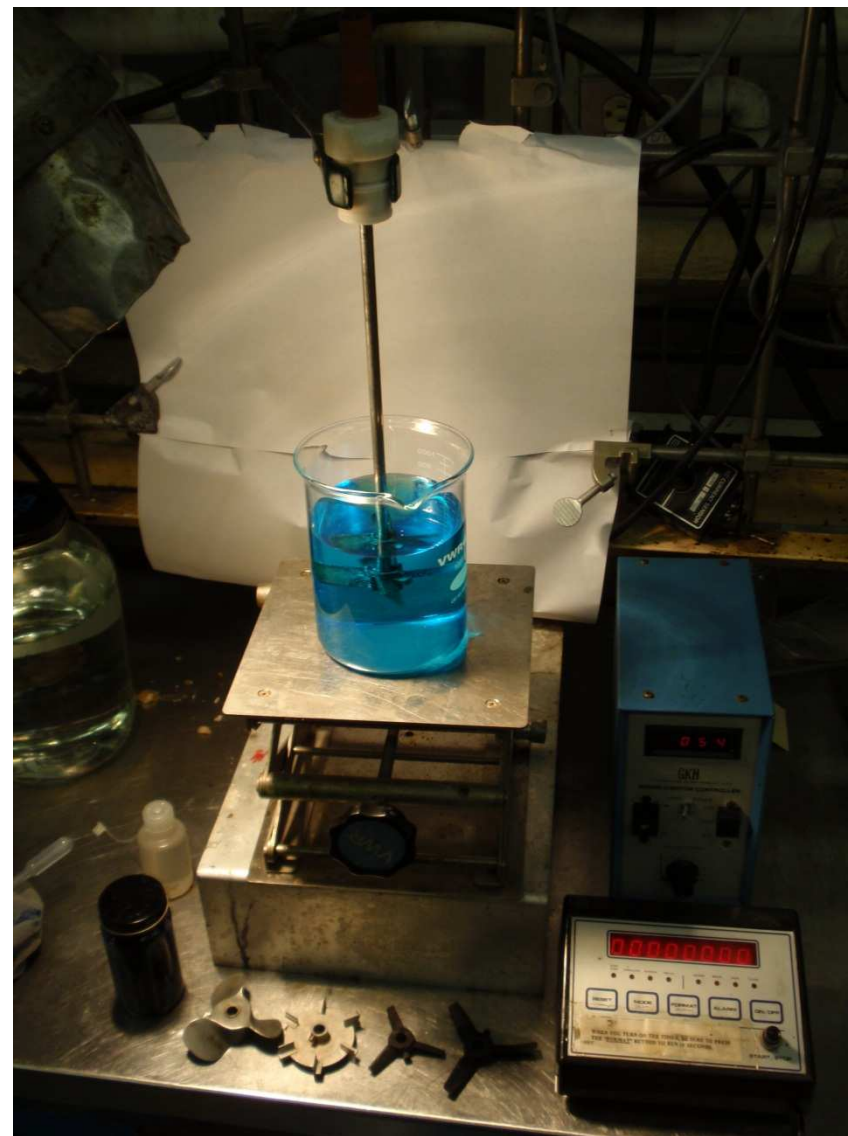
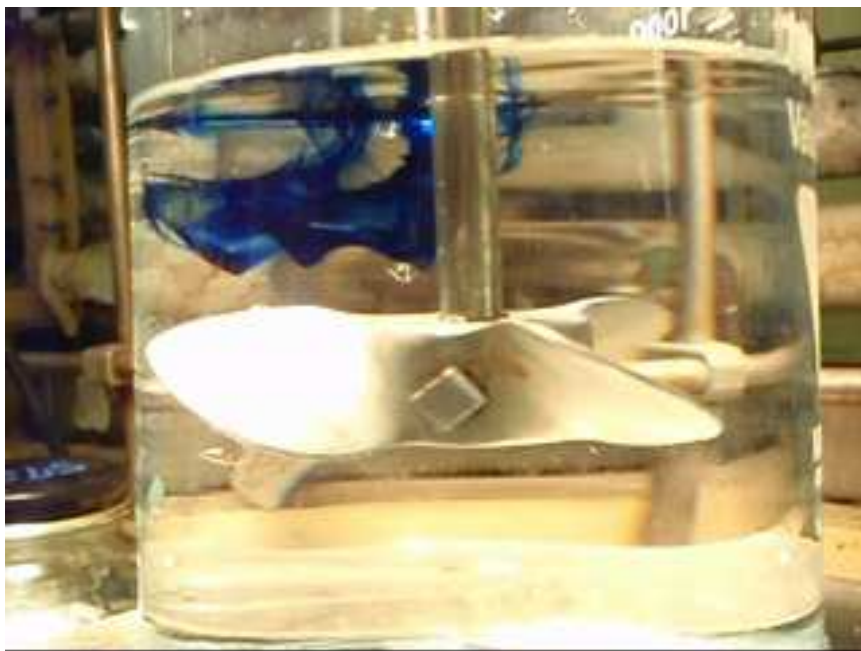
CMK10 Changed Develop to Developed
Catherine Kopanski, 16/06/2011

CMK11 Change compared to compared
Catherine Kopanski, 16/06/2011

Simple Correlation Computation Tools

- Based on flow number and power number
- Easy to use for approximate results
- Power number: $N_P = 1.37 \left(\frac{W_b}{0.2D} \right)^{0.8} \left(\frac{N_b}{4} \right)^{0.6} \left(\frac{\sin \theta_b}{\sin 45} \right)^3$ for a axial impeller
- Computed power: $P = N_P \rho N^3 D^5$
- Flow number: $N_Q = 0.77 N_P^{0.33}$
- Pumping rate: $Q = N_Q N D^3$
- Blend time: $t = \frac{4.605}{0.641 N \left(\frac{D}{T} \right)^{2.19} \left(\frac{T}{Z} \right)^{0.5}}$

Laboratory Work to Validate Tools



Comparative Results on Lab Bench

| Method Employed | Mixing Time | Comments |
|-----------------|-------------|---------------------------------------|
| Observed | 44 sec | Still some trace of dye near agitator |
| Correlative | 28 sec | Observably too short |
| VisiMix™ | 60 sec | |

Based on laboratory observations in glass vessel using water, dye tracer and an axial impeller

Conclusions:

CMK12

- Given observational variation the VisiMix™ results were generally considered more reasonable
- A standardized program is preferred over the correlative approach for use beyond pilot plant and for knowledge transfer

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CMK12

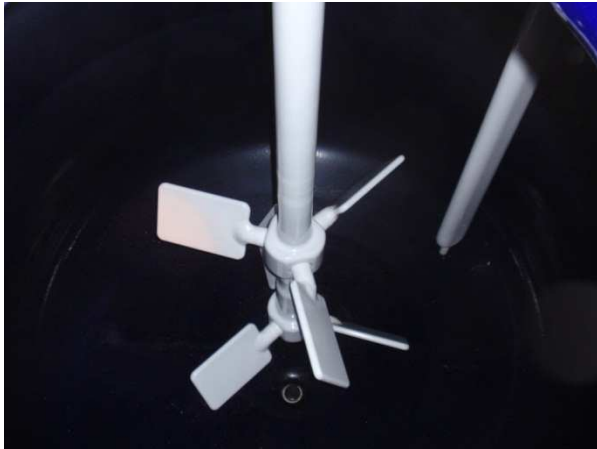
Deleted periods in bullet points.

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Current Status

- Wide adoption of VisiMix™ software
 - Network licenses
 - Training for all engineers
 - Identified both an operational and a computational focus person
 - Communicated need for better data
 - Began more formal archiving of key design information
 - Vessel characteristics
 - Internals
 - Materials of construction
- Use as a daily tool for operational work as well as design of new equipment

Example: Placement of Dual Agitators in Reactor

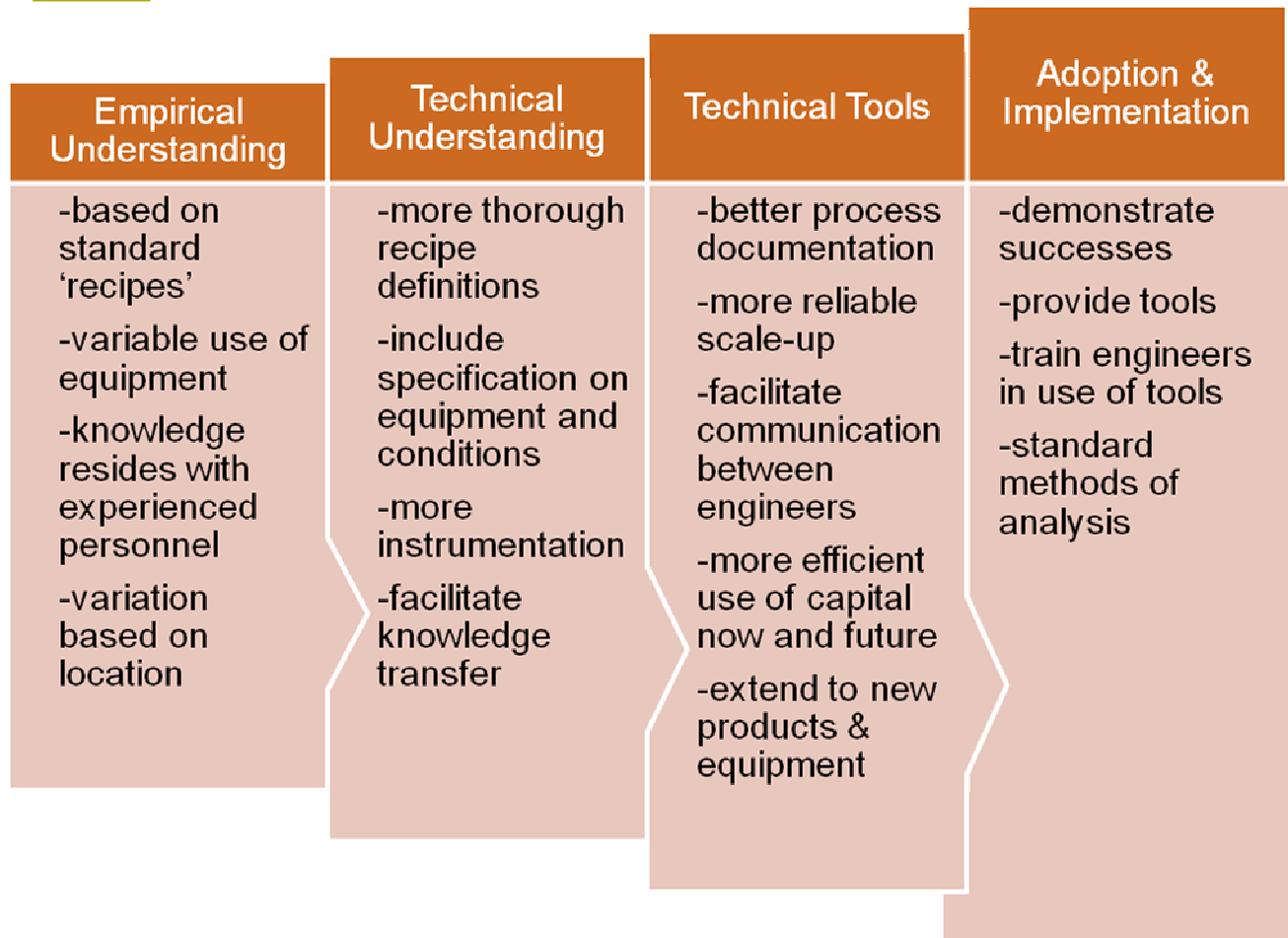


Application to position agitator in reactor

- Key was to maximize pumping to surface
- Existing reactor but adjustable impeller
- Quick study showed:
 - Height from bottom had minimal effect
 - Distance between impellers has minimal effect
 - Pitch of the blades had significant effect
- Net result:
 - Adjusted impellers before start-up
 - Increase in circulation flow by 18%
 - Cost was power increase of 27%
 - Benefit was better contacting & higher conversion

Goals & Progression of Mixing Knowledge

CMK13



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CMK13

Capitalization is inconsistent

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Lessons Learned & Conclusions

- Mixing had been a neglected area of technical attention within our company
- Value can best be generated by actual application in plants
- Value will be maximized by distributed knowledge among the plants and technical areas
- Outside resources are useful but internal expertise is more timely for actual applications
- Central expertise should be available for interpretation and deeper study
- VisiMix™ software is a simple & effective tool which is easily used by all engineers