



The Personalized Chemical Products Industry in 2040

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A Long Time Ago...

1984-1989: Designing Molecules Possessing Desired Physical Property Values



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A Computer Revolution



**Processing
Intensification**



Next Revolution

In 20 years the way chemical products are made will change dramatically. Comparing the chemical plants of today with those of 2040 will be like comparing a Data General mainframe with a smart phone.

The market for personalized chemical products will be the main driving force for this change.

What are Chemical Products



Gillette Fusion Shaving Gel

Glyceryl acrylate/acrylic acid copolymer

Aloe barbadensis leaf juice

Hydroxyethylcellulose

PVM/MA copolymer

Triethanolamine

Glyceryl oleate

Palmitic acid

Stearic acid

Isopentane

Isobutane

Fragrance

PEG-90M

PEG-23M

Glycerin

Sorbitol

Green 3

Blue 1

Water

Why these ingredients?

Why should chemical engineers be interested?

Viscous Flow



$$Q = \frac{\Delta P \pi r^4}{8 \mu L}$$

$$P_0 = \frac{nRT_0}{V_0}$$

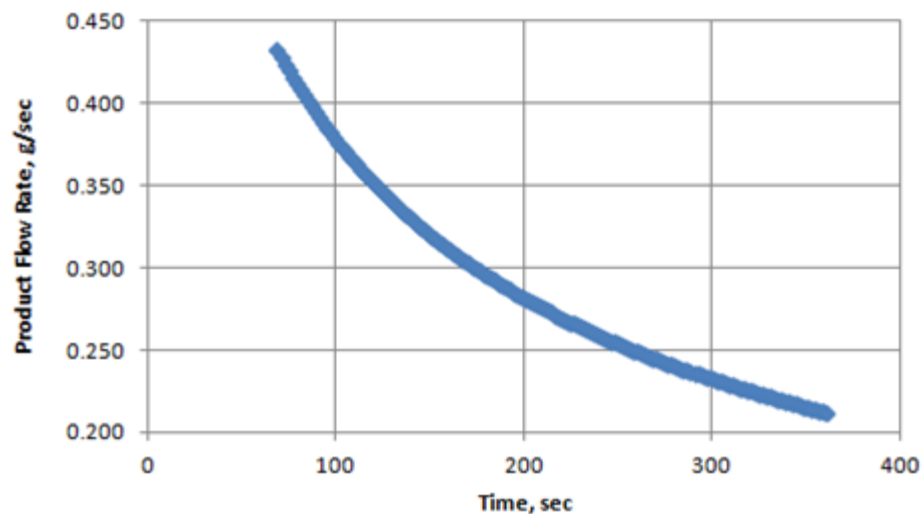
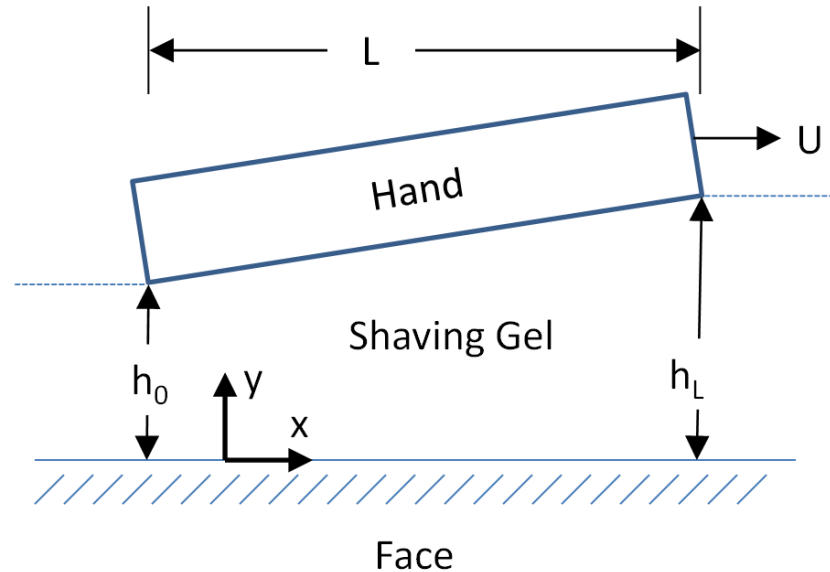


Figure S1: Shaving Gel Flow Rate as a Function of Time

Fluid Mechanics



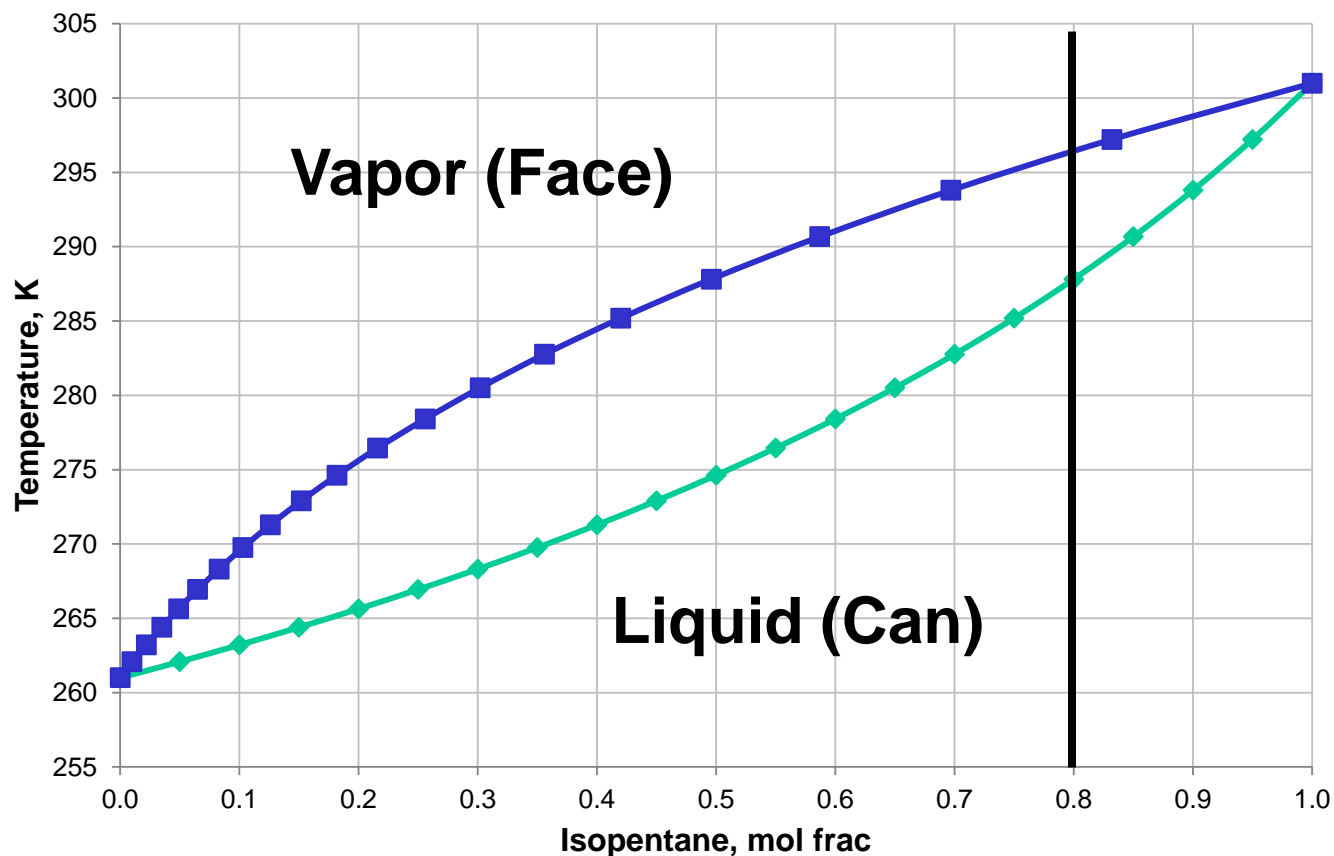
Lubrication Theory



$$F_y = \frac{6\mu UL^2 W}{(h_L - h_0)^2} \left(\ln \frac{h_L}{h_0} - 2 \frac{h_L - h_0}{(h_L + h_0)} \right)$$

Thermodynamics

Isobutane + Isopentane Foaming Agent



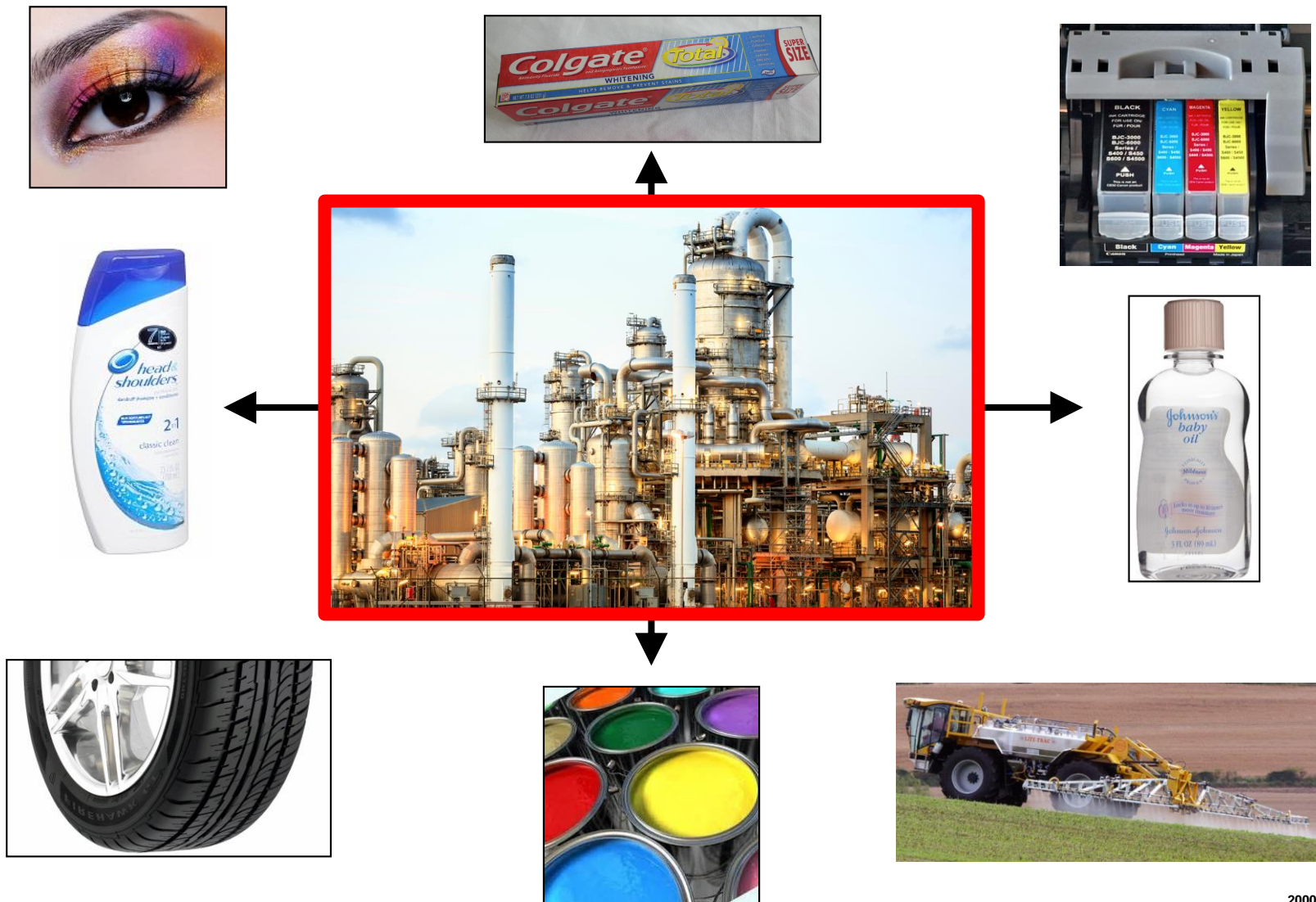
Chemical Products

We are accumulating the knowledge needed to design an enormous variety of chemical products...



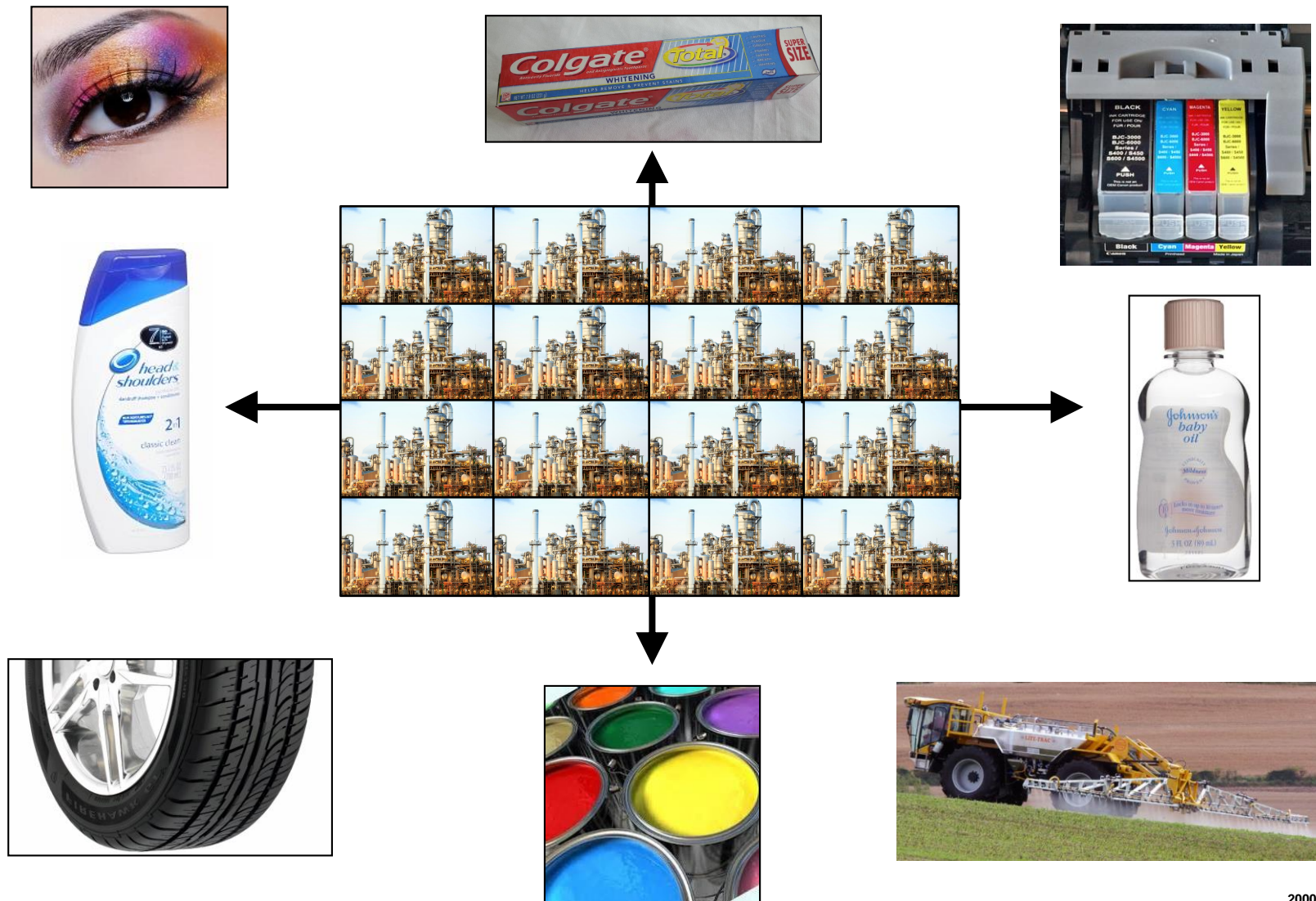
... but how will we produce them?

Chemical Process Industries



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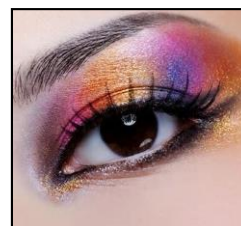
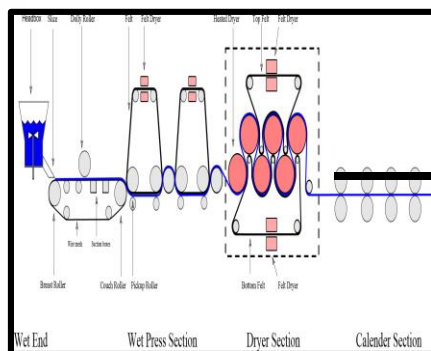
Process Intensification



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Millions of Chemical Plants

The same trend as computers:
Personalized Chemical Plants



How might we get there? Killer Apps?

3D and Inkjet Printing



Personalized Cosmetics

Cosmetic Foundation



The most sophisticated and unique service in cosmetics. To protect against oxidation and maintain color accuracy, the custom made technology is equipped with eight peristaltic heart pumps for an airtight blending and dispensing process. The innovative technology allows for customized coverage, finish and moisturizing.



Personalized Biofuel

Chemical Reactor

Triglycerides

+

Strong base

+

Methanol



Today: Used vegetable oil
Tomorrow: Leaves and grass?

Impact on PSE

- ☐ **Instead of a chemical plant making a commodity, the chemical plant will be the commodity**
- ☐ **Think in terms of appliances: ovens, refrigerators, washing machines**
- ☐ **Inherent environmental compatibility**
- ☐ **Control of very small quantities**
- ☐ **Different design objectives**
- ☐ **Low maintenance**
- ☐ **Robust operation**
- ☐ **Inherent safety**

An Exciting Path

Process systems engineers have an opportunity to design a new generation of chemical plants that will produce numerous personalized chemical products.

I have greatly enjoyed the computer revolution. I am looking forward to the chemical product revolution. It is an exciting path. A path George helped me set out on, a long time ago.

George, Thank You