CHEMICAL CLARIFICATION – COAGULATION METHODS

Prepared By
Michigan Department of Environmental Quality
Operator Training and Certification Unit

CLARIFICATION

Removal of
Settleable and Floatable Solids

CHEMICAL CLARIFICATION

- **Increase Removal Amount**
  (More Solids Out)

- **Increase Removal Rates**
  (Solids Settle Faster)

CHEMICAL CLARIFICATION

- **Less Solids**
  (in effluent)
- **More Sludge**
  (for disposal)

Stoke's Law

$$VF = \frac{2(p - p_o)g}{9n} (d/2)^2$$

VF = Fall Velocity

$(p - p_o)$ = Density difference between particle and water

n = viscosity of water

g = gravitational acceleration constant

d = diameter of the particle

Stoke's Law

$$VF = \frac{2(p - p_o)g}{9n} (d/2)^2$$

VF = Fall Velocity

$(p - p_o)$ = Density difference between particle and water

n = viscosity of water

g = gravitational acceleration constant

d = diameter of the particle

Stoke's Law

$$VF = \frac{2(p - p_o)g}{9n} (d/2)^2$$

VF = Fall Velocity

$(p - p_o)$ = Density difference between particle and water

n = viscosity of water

g = gravitational acceleration constant

d = diameter of the particle

Stoke's Law

$$VF = \frac{2(p - p_o)g}{9n} (d/2)^2$$

VF = Fall Velocity

$(p - p_o)$ = Density difference between particle and water

n = viscosity of water

g = gravitational acceleration constant

d = diameter of the particle

CHEMICAL CLARIFICATION

- **Increase Particle Size**
  (Average Diameter)

Particle Size versus Settling Time

Particle Size mm	Order of Size	Time to Settle
1.0	Coarse Sand	3 Seconds
0.1	Fine Sand	38 Seconds
0.01	Silt	33 Minutes
0.001	Bacteria	55 Hours
0.0001	Colloidal	230 Days
0.00001	Colloidal	6.3 Years

CHEMICAL CLARIFICATION

- Increase Particle Size
- Encourage Contact

CHEMICAL CLARIFICATION

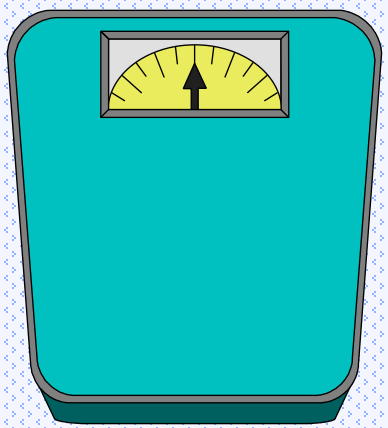
1. Coagulation
2. Flocculation
3. Separation

Coagulation

- Chemical Addition
- Rapid Mixing
- "Pin-point" Floc Formation

Flocculation

- Slow Mixing
- Floc Growth
- Increased Diameter



Solids Separation

- **Clarified Liquid**
- **Concentrated Suspension**

(sludge)

Usually Gravity Settling

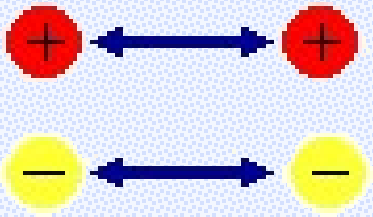
Other Processes

(dissolved air flotation, etc.)

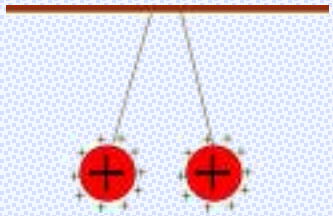
CHEMICAL CLARIFICATION

- Increase Particle Size
- Encourage Contact

* Fine Suspended Particles Have an Electrostatic Charge (Usually +)



Like Charges Repel



Natural Stabilizing Force Keeps Solids Apart

Purpose of Chemical Clarification

* Encourage Contact

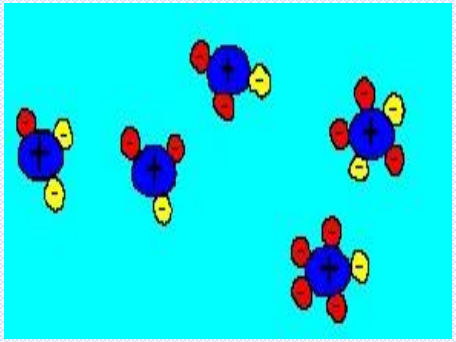
* Destabilize Charges

Mechanisms

- *Electrostatic Charge Reduction*
- *Interparticle Bridging*
- *Physical Enmeshment*

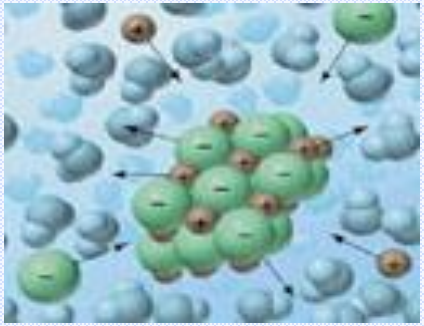
Electrostatic Charge Reduction

- **Solid Particles have an Electrostatic Charge**



usually negative

solids repel one another

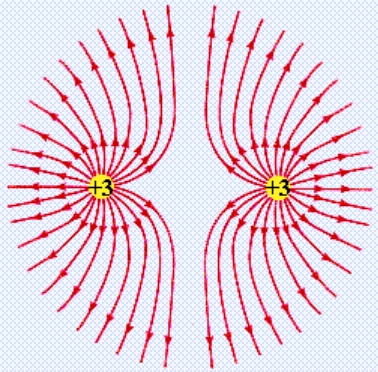


- **Add Chemical to Neutralize Charge**

positive charge (cationic)

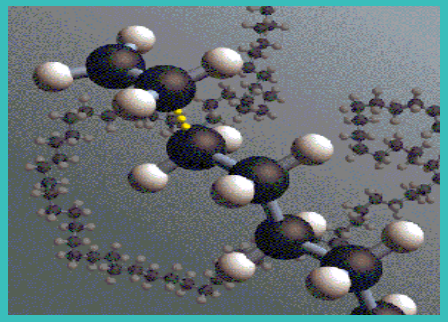
- **Must Not Overdose**

excess positive charge



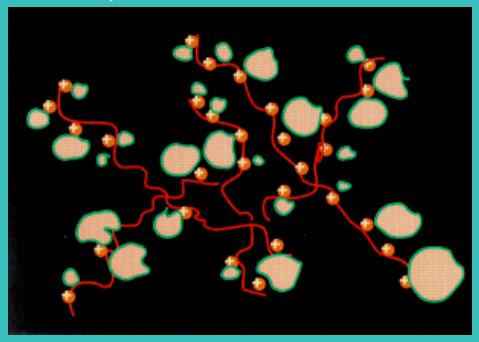
Interparticle Bridging

- **Polyelectrolytes (polymers)**



long chains

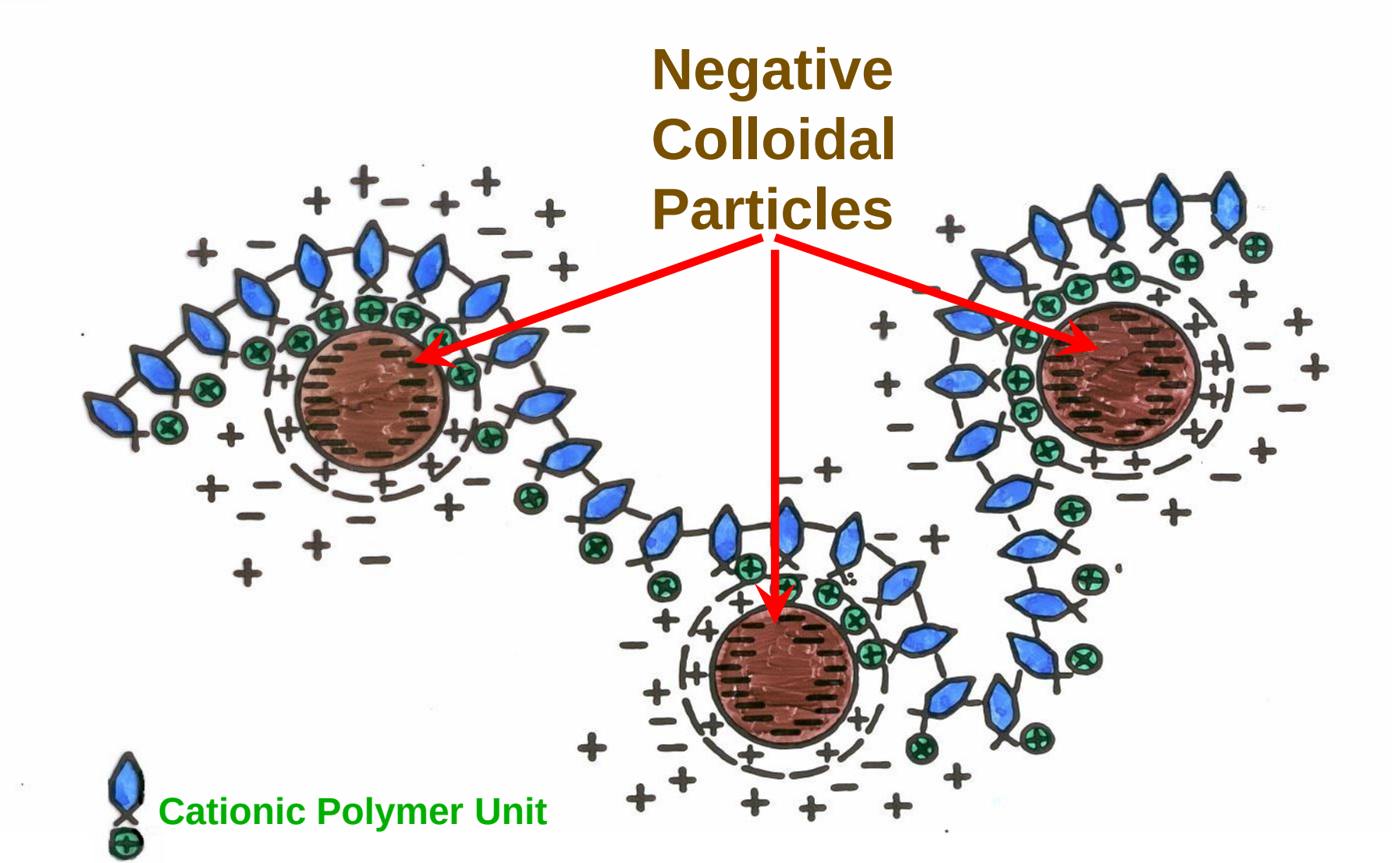
electrostatic charges



- **Adsorb on the Charged Particles**

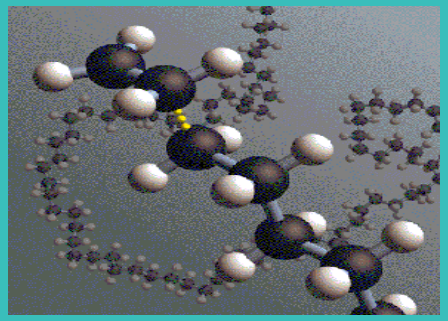
bridges particles together

Interparticle Bridging



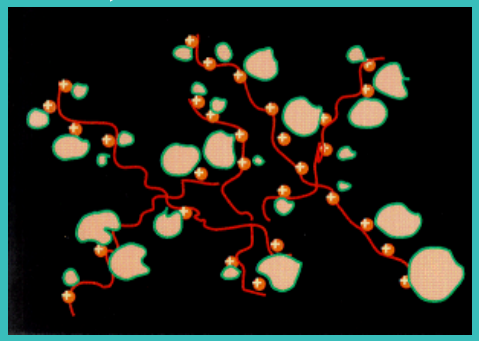
Interparticle Bridging

- **Polyelectrolytes (polymers)**



long chains

electrostatic charges

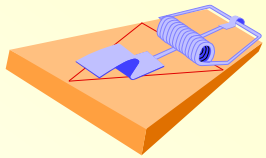


- **Adsorb on the Charged Particles**

bridges particles together

- **Must Not Overdose**

Physical Enmeshment



- Ions Combine with Hydroxyl Ions

  OH^-

- Gelatinous Precipitate Forms

  flakes

  void spaces

- Collects Particles as it Forms

  co-precipitate

  enlarges the floc

Mechanisms

- *Electrostatic Charge Reduction*
- *Interparticle Bridging*
- *Physical Enmeshment*

CHEMICAL CLARIFICATION

1. Coagulation
2. Flocculation
3. Separation

COAGULATION

Rapid Mix

Adequate Contact

FLOCCULATION

Slow Mixing

Increase Floc Size

PROCESS CONTROL

1. **Provide complete mixing.**

2. **Control mixing for floc.**

3. **Control chemical dose.**

Chemical Treatment

Addition of

Positive Ions

(Cations)

or

Polymers

CHEMICAL TREATMENT

Positive Ions Added by Adding Metal Salts

Such As

Aluminum Sulfate (Al^{+3})

Calcium Hydroxide (Ca^{+2})

Ferric (Iron) Chloride (Fe^{+3})

Metal Salts Used

Most Common

Alum (Aluminum Sulfate)
Ferric Chloride
Lime (Calcium Hydroxide)

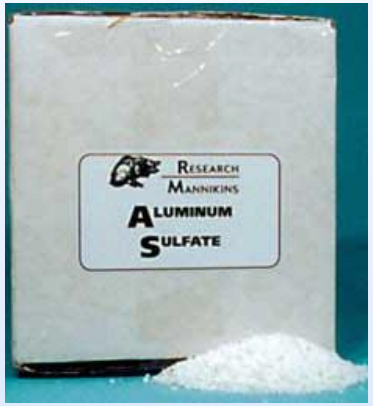
Others

Sodium Aluminate
Ferric Sulfate
Ferrous Sulfate
Ferrous Chloride

Aluminum Sulfate *(Dry)*

$Al_2(SO_4)_3 \cdot 14\ H_2O$

"Alum" or "Filter Alum"



Available in Various Grades

- **Lump (rarely used)**
- **Ground (granulated)**
- **Rice**
- **Powdered**

Feeds Easily

doesn't "bulk"

Aluminum Sulfate *(Dry)*

$Al_2(SO_4)_3 \cdot 14\ H_2O$

Must be kept dry

- cake to solid lump
- corrosive
- equipment must be cleaned

Irritant

- skin
- mucus membranes
- eyes

Dosage Approximately 75 - 250 mg/L

Aluminum Sulfate *(Liquid)*
$Al_2(SO_4)_3$

Approximately 11 pounds / gallon

Approximately 5.4 pounds of "dry"/gal

Ease of Handling vs. Transportation Costs

Corrosive

equipment must be protected

Supports Bacterial Growth / Deposits

Reduces Alkalinity

Ferric Chloride ($FeCl_3$)

Anhydrous

- Absorbs Moisture from the Air
- Corrosive with Water
- Releases Heat as it is Dissolved

Crystal

- Absorbs Moisture
- Releases Less Heat

Liquid

- Lined Containers
- Shipped at 30 - 40 %
- Approximately 12 pounds per gallon

Ferric Chloride ($FeCl_3$)

Corrosive

equipment must be protected

Stains

Safety Concerns

Dosage Approximately 45 - 90 mg/L

LIME

Hydrated Lime

$Ca(OH)_2$

Coagulant

pH Adjustment

Absorbs Moisture

Quicklime (anhydrous)

CaO

Absorbs Moisture

Must be “Slaked”

Heat Generated

Costs vs. Handling

LIME

Erode or Wear Equipment

Scale Build-up

LIME

Erode or Wear Equipment

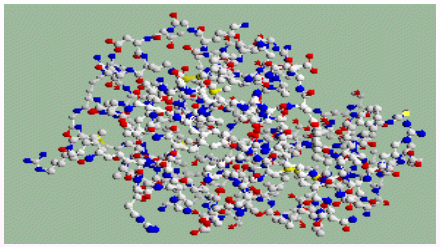
Scale Build-up

Irritant

- **skin**
- **eyes**
- **mucus membranes**
- **lungs**

Dosage Approximately 200 - 400 mg/L

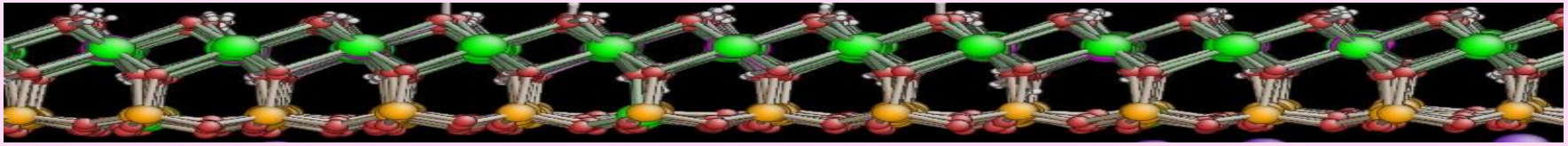
Polymeric Flocculants



“Polyelectrolytes”
“Polymers”

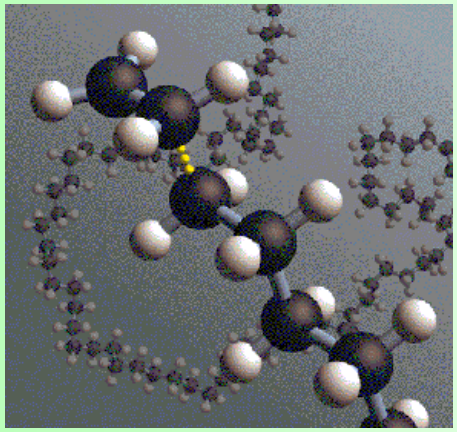
Organic Compounds -
Repeating Units

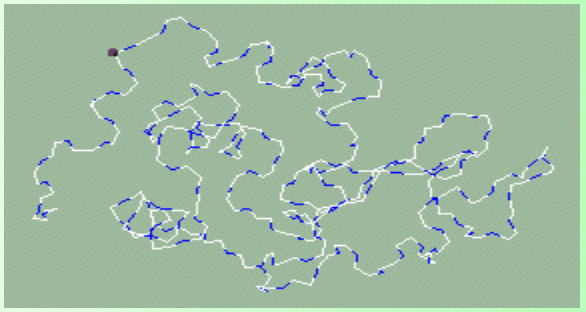
Long Chain -
High Molecular Weight



Polymers

Classified By:





Charge

Charge Density

Size (Length)

Polymers

Charge:

"Cationic" - positive charge

"Anionic" - negative charge

"Nonionic" - no free charge

Polymers

Charge Density:

Relative Number of Locations Along the Chain That Carry a Charge

Percent of Maximum Possible

Low Charge (<25%)
Medium Charge (25 -50%)
High Charge (>50%)

Polymers

Size (Length):

Designated by Molecular Weight

"Low" - <10,000 gm/mole

"Medium" - 10,000 to 100,000 gm/mole

"High" - 100,000 to 1,000,000 gm/mole

"Very High" - 1,000,000 to 10,000,000 gm/mole

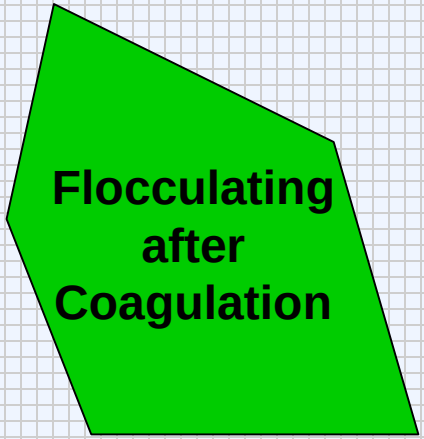
"Ultrahigh" - >10,000,000 gm/mole

POLYMER MAP

Anionic Polymers

Nonionic Polymers

Cationic Polymers



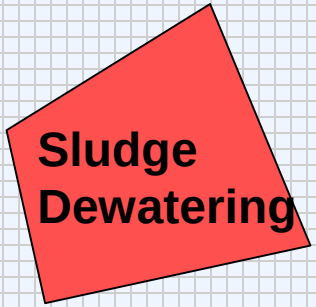
MW > 10^7 gm/mole
Ultrahigh MW

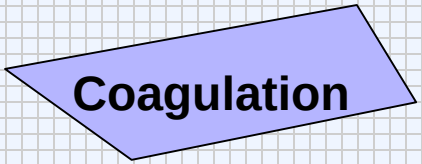
MW = 10^7 gm/mole
Very High MW

MW = 10^6 gm/mole
High MW

MW = 10^5 gm/mole
Medium MW

MW = 10^4 gm/mole
Low MW





-100 % -50 % 0 % +50 % +100 %

Polymers

Available as:

- Liquid
- Dry
- Gel
- Emulsion

Must be Diluted

- usually <1%

Can Be Very Viscous

- may build up in pipes and pumps
- clean regularly
  - salt water - dilute bleach

Polymers

Dry Polymers:

absorb moisture - ineffective

may form “fish-eyes”

aged for maximum efficiency

2 hours minimum

7 days maximum

Polymers

Considered Non-Hazardous

Extremely Slippery

Clean Up Immediately

Salt

Chlorine

Drying Agents

Absorbent Materials

Polymers

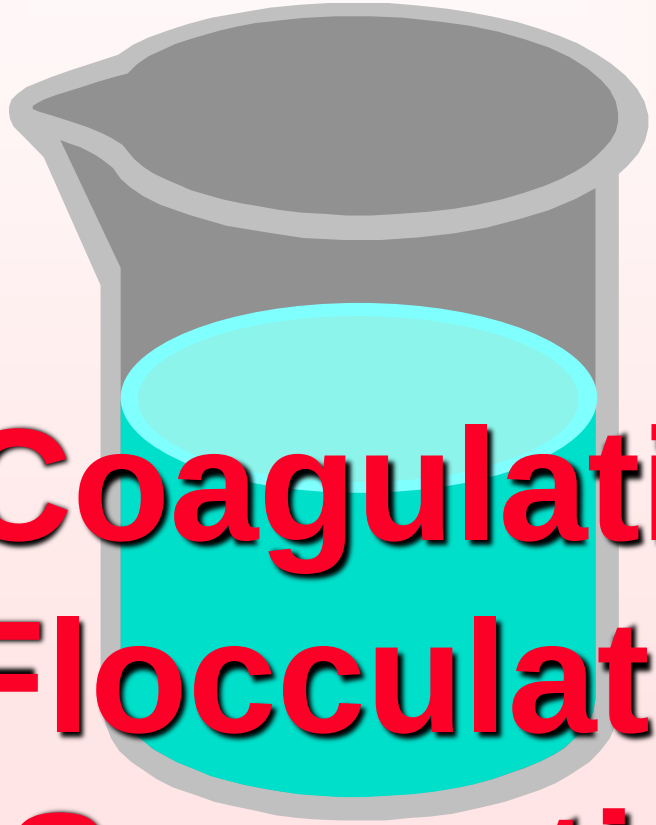
Dosage Rate

usually less than 1 mg/L

(0.25 to 1.5 mg/L)

Overdose Worse Than No Polymer

CHEMICAL CLARIFICATION



1. Coagulation
2. Flocculation
3. Separation

PROCESS CONTROL

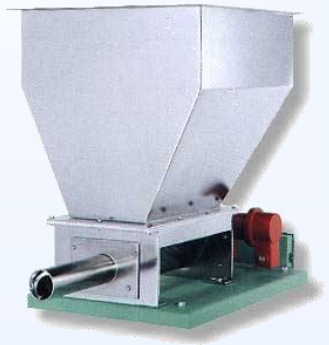
1. Provide complete mixing.

2. Control mixing for flocculation.

3. Control chemical dose.

CHEMICAL CLARIFICATION

Equipment



Dry Chemical Feeders

VOLUMETRIC

Measures chemical amount by **VOLUME**

GRAVIMETRIC

Measures chemical amount by **WEIGHT**

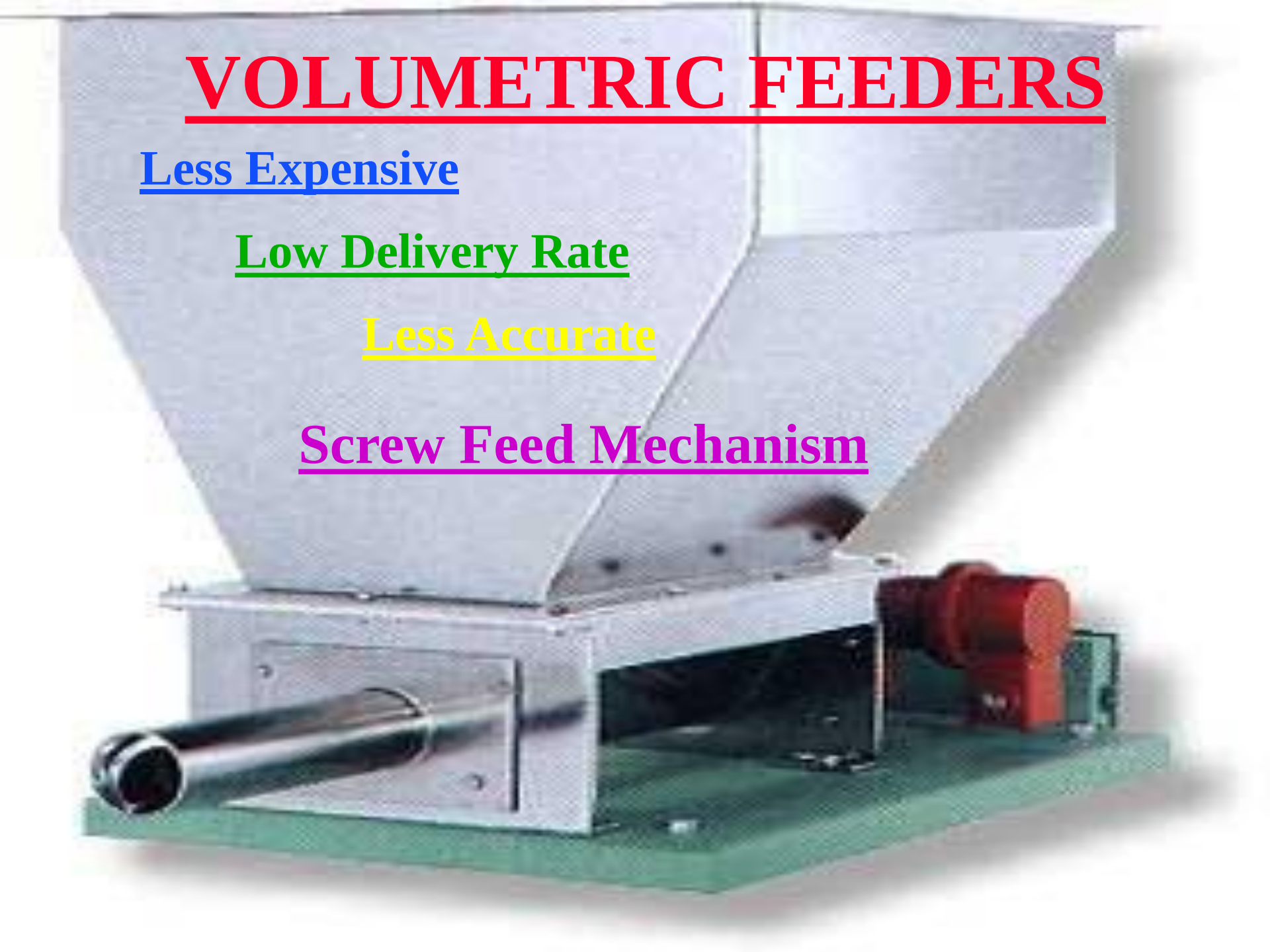
VOLUMETRIC FEEDERS

Less Expensive

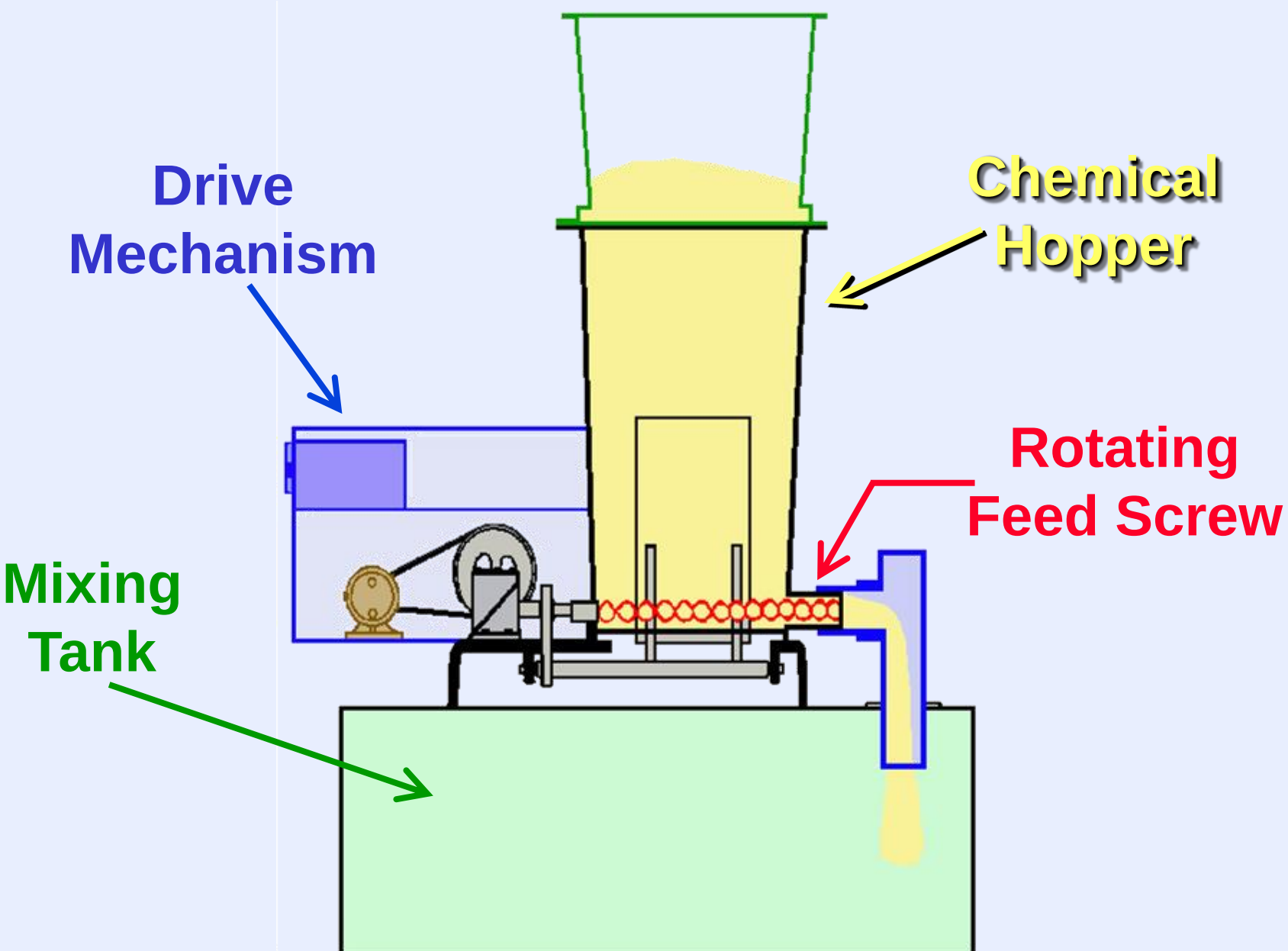
Low Delivery Rate

Less Accurate

Screw Feed Mechanism



Volumetric Screw Feeder



Gravimetric Feeders

Loss-in-Weight Gravimetric Feeders

Highly Accurate

Close Dosage Control

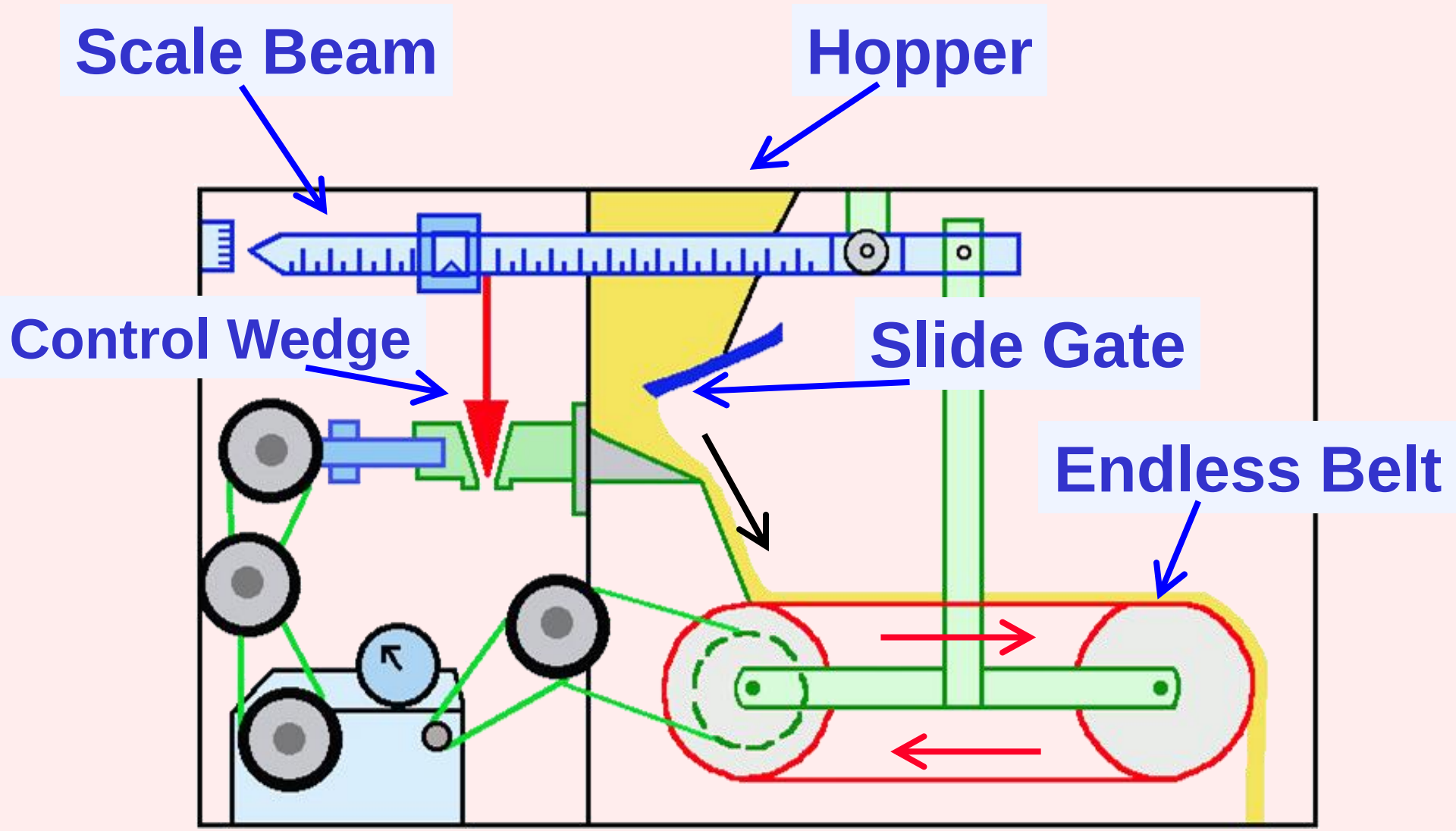
Chemical Cost Savings

Belt Gravimetric Feeders

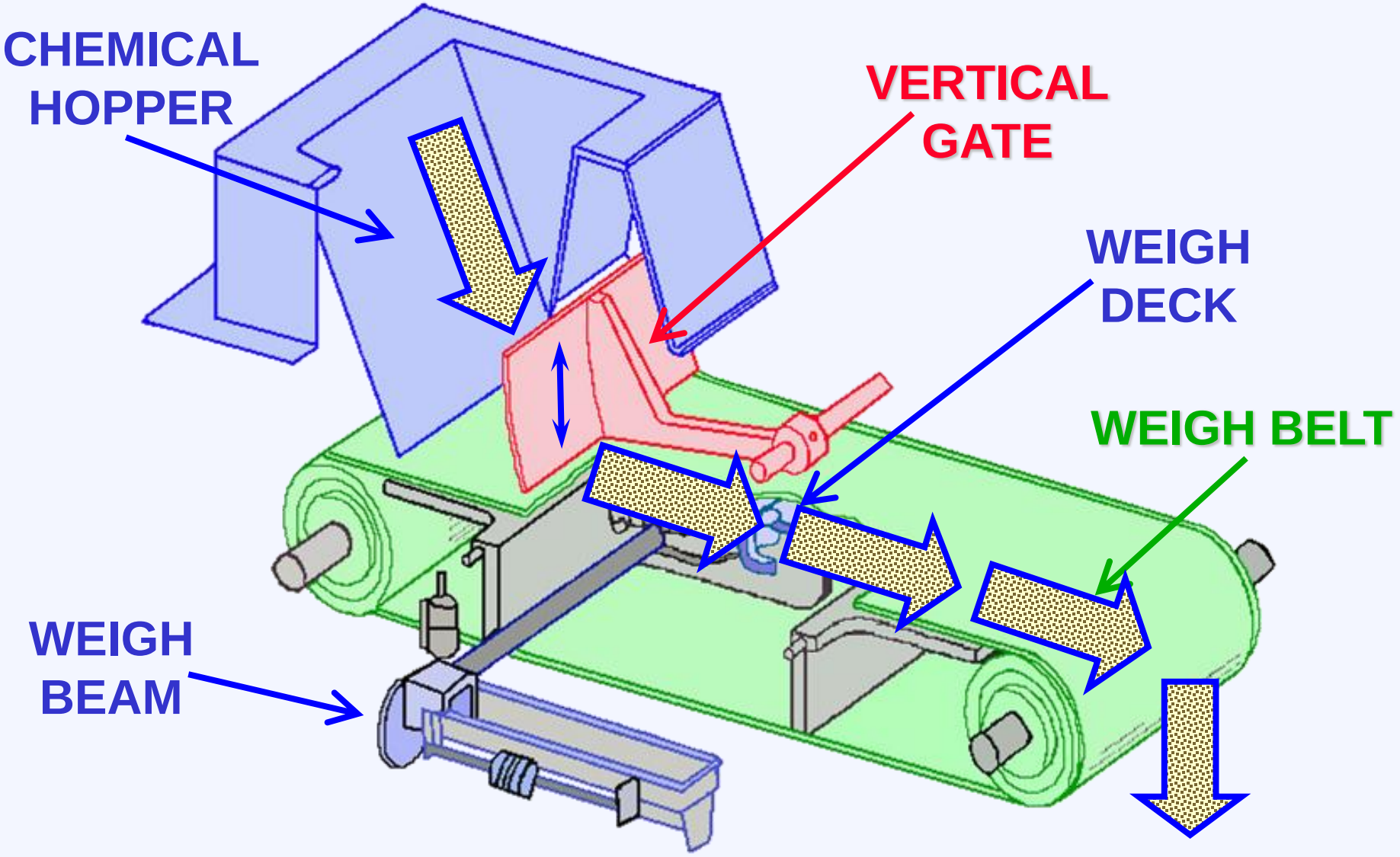
Intermediate Cost

Accurate & Reliable

Gravimetric Feeder



GRAVIMETRIC BELT FEEDER

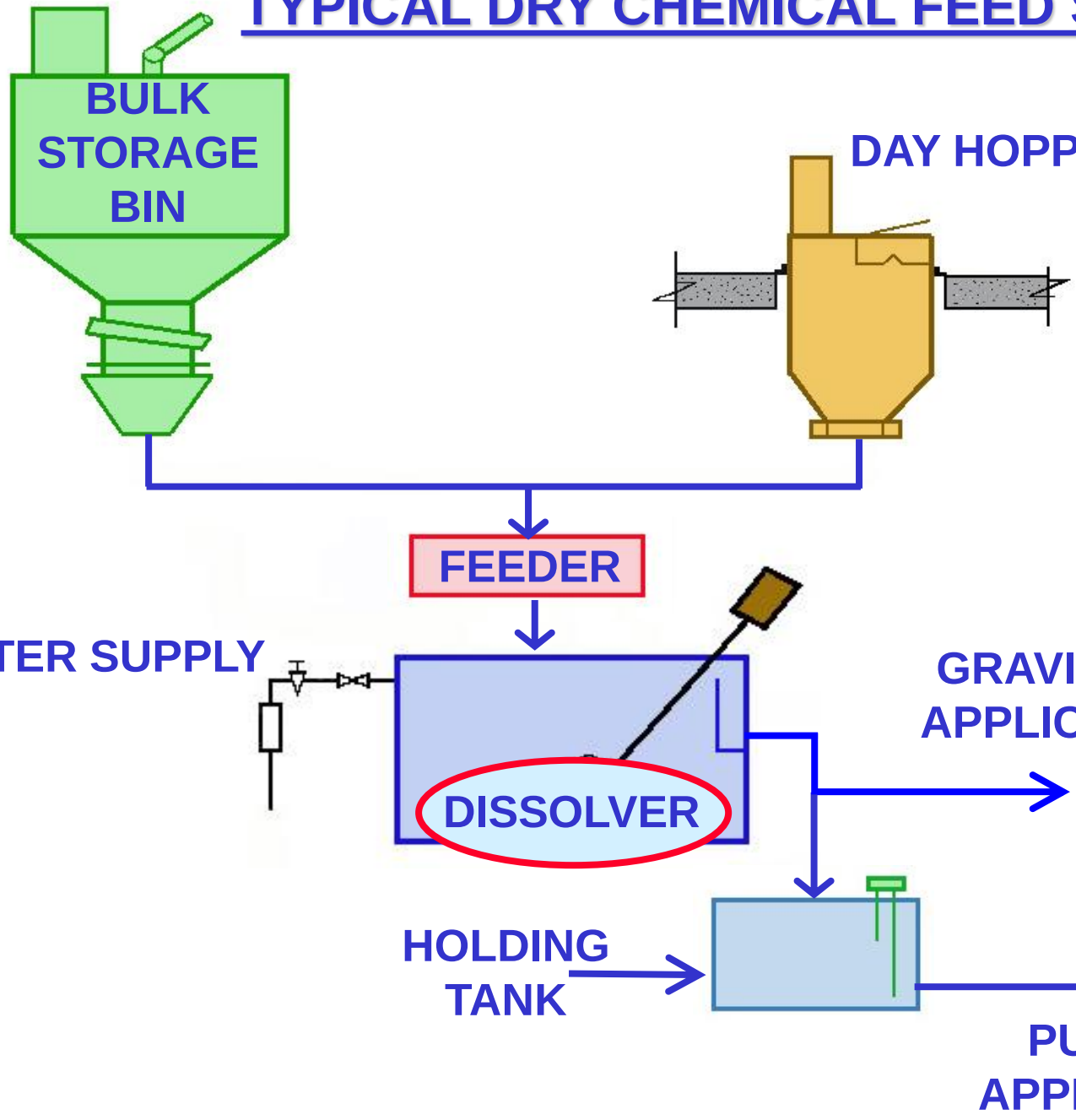


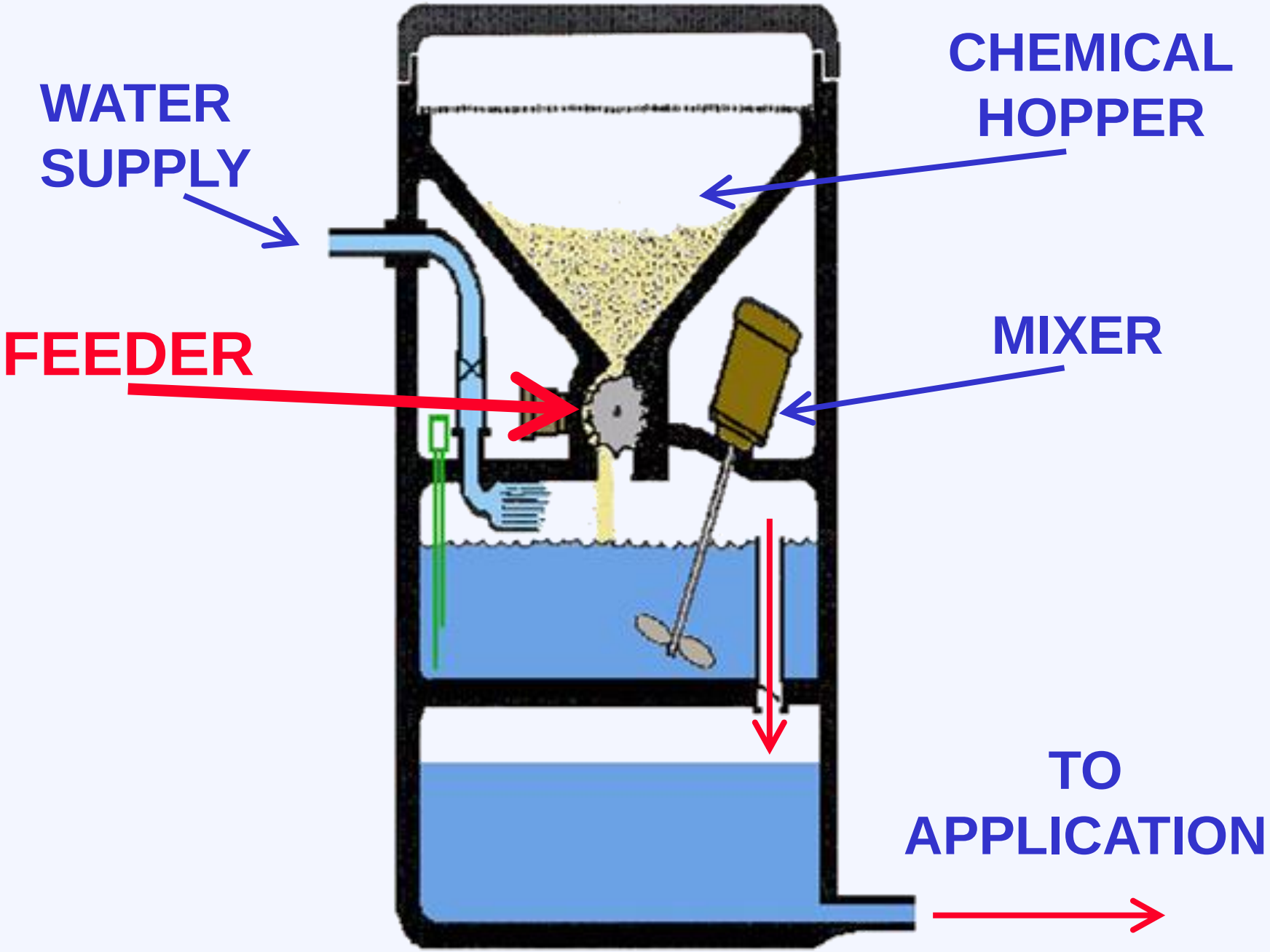
GRAVIMETRIC FEEDERS

ADVANTAGES

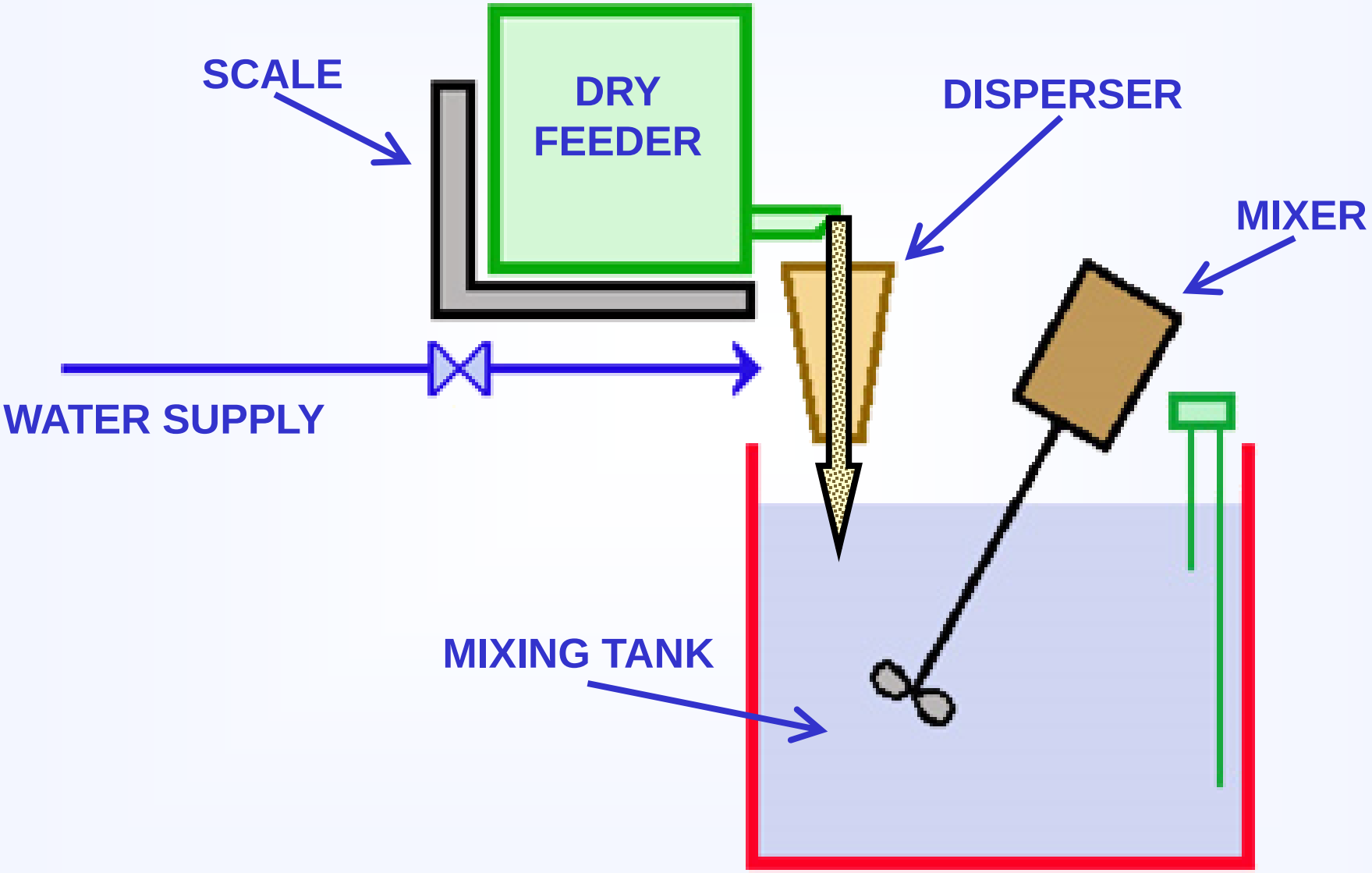
1. Calibration normally not required
2. Greater accuracy and dependability
3. Incorporation of totalizer
4. Automatic proportioning
5. Low maintenance; simple operation

TYPICAL DRY CHEMICAL FEED SYSTEM

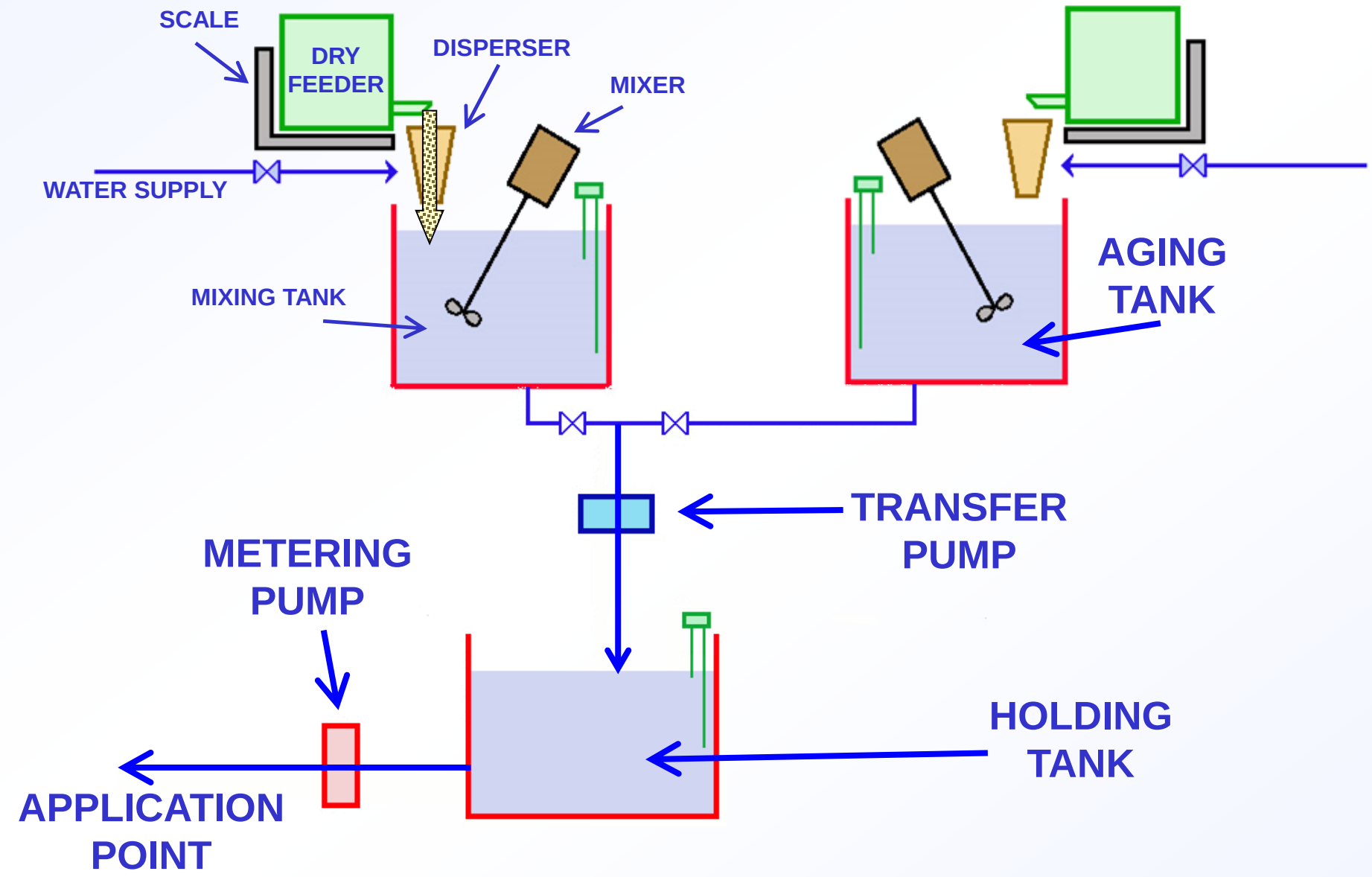



WATER SUPPLY
CHEMICAL HOPPER
FEEDER
MIXER
TO APPLICATION

Loss-in-weight Gravimetric Feeder



POLYMER FEED SYSTEM



Liquid Feeders

Rotary Dippers

Rotometers

Metering Pumps

METERING PUMPS

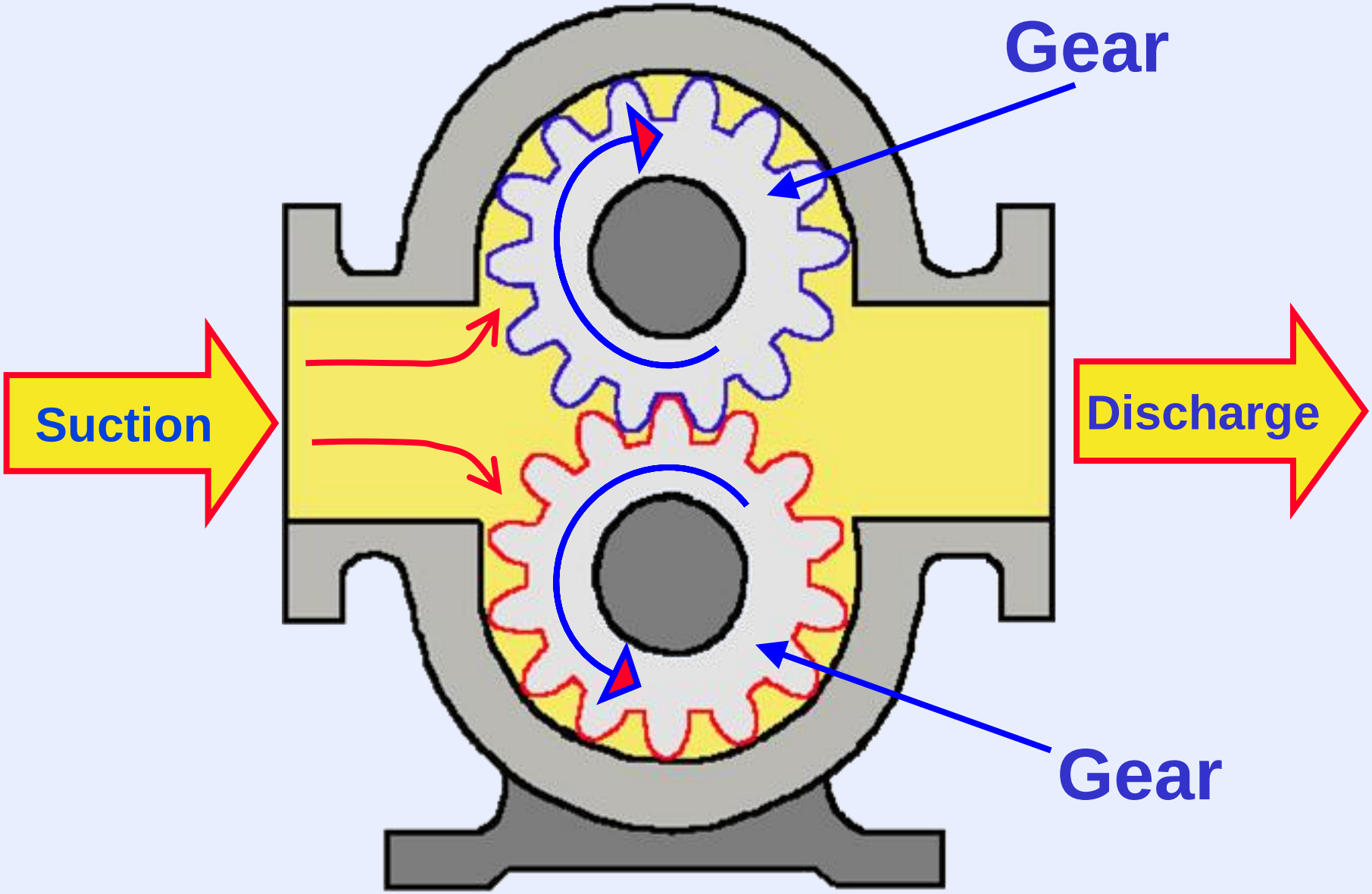
POSITIVE DISPLACEMENT

Gear

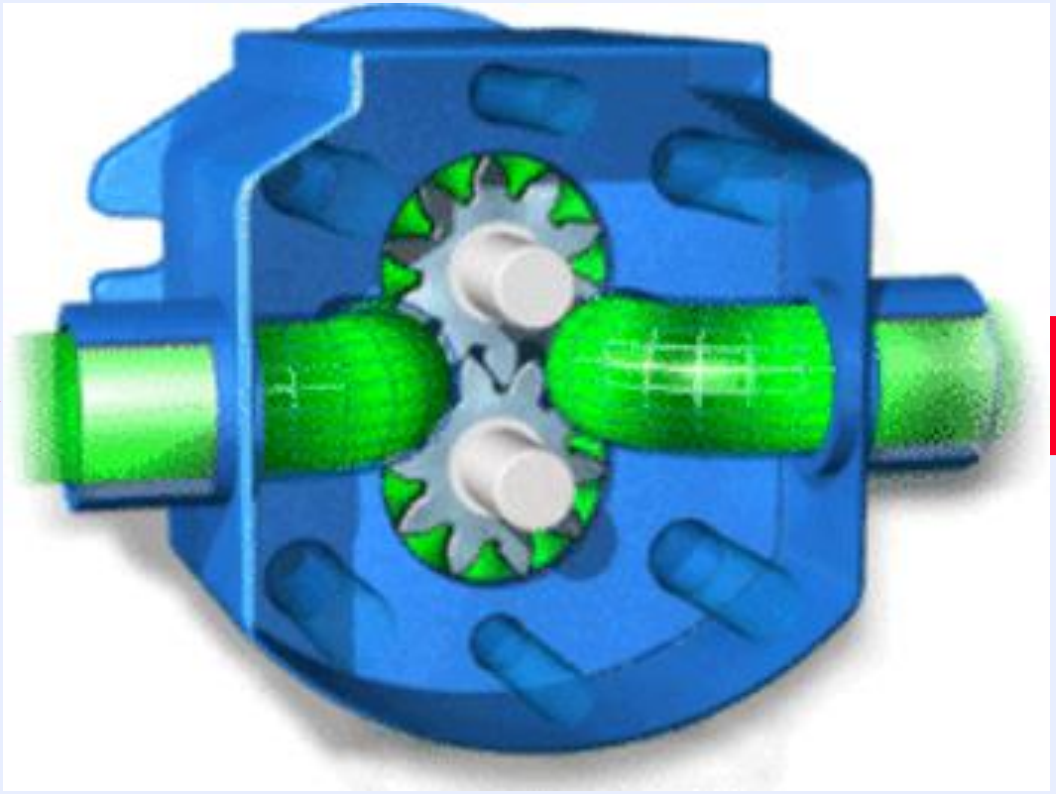
Plunger

Diaphragm

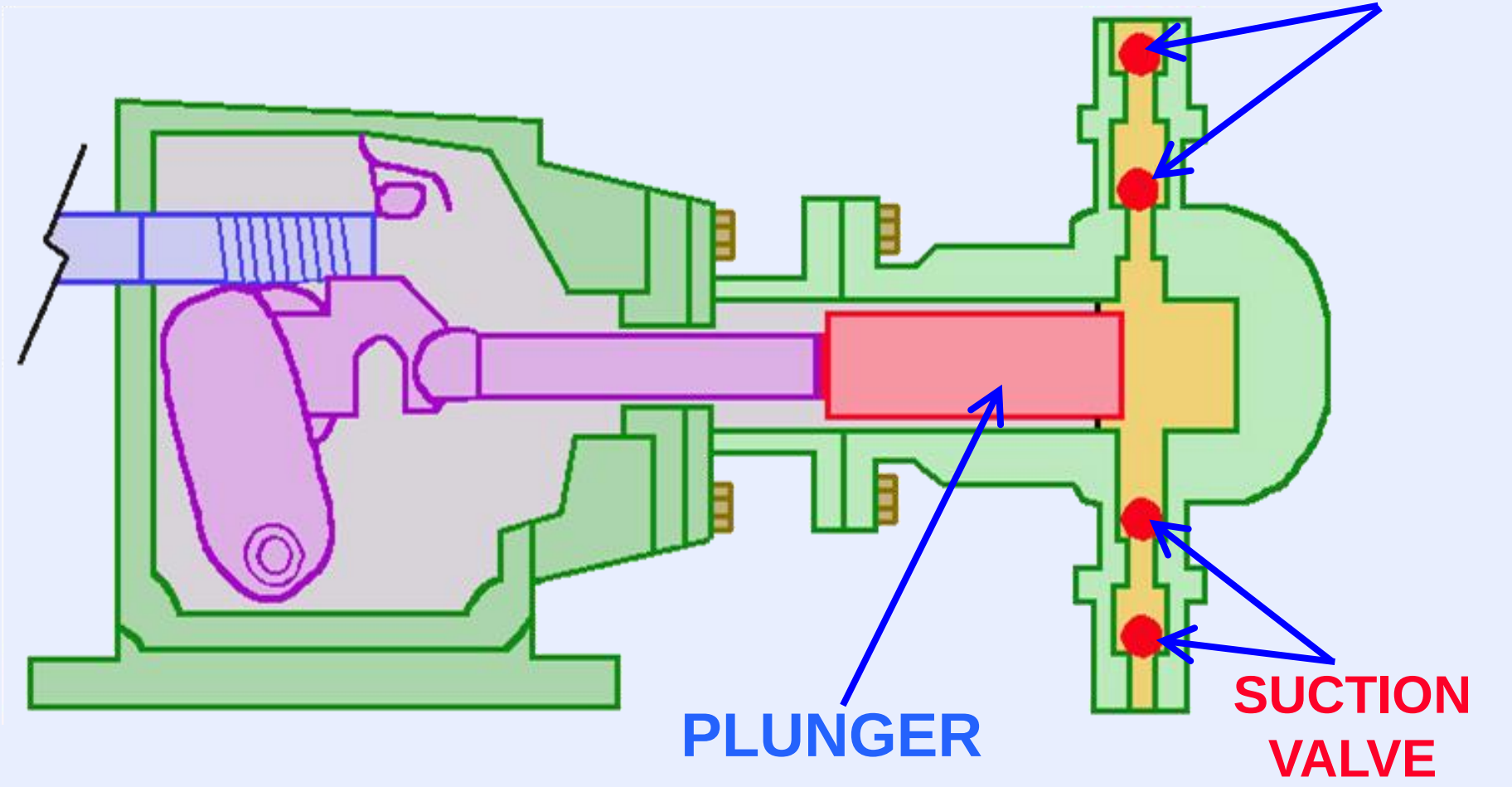
GEAR PUMP



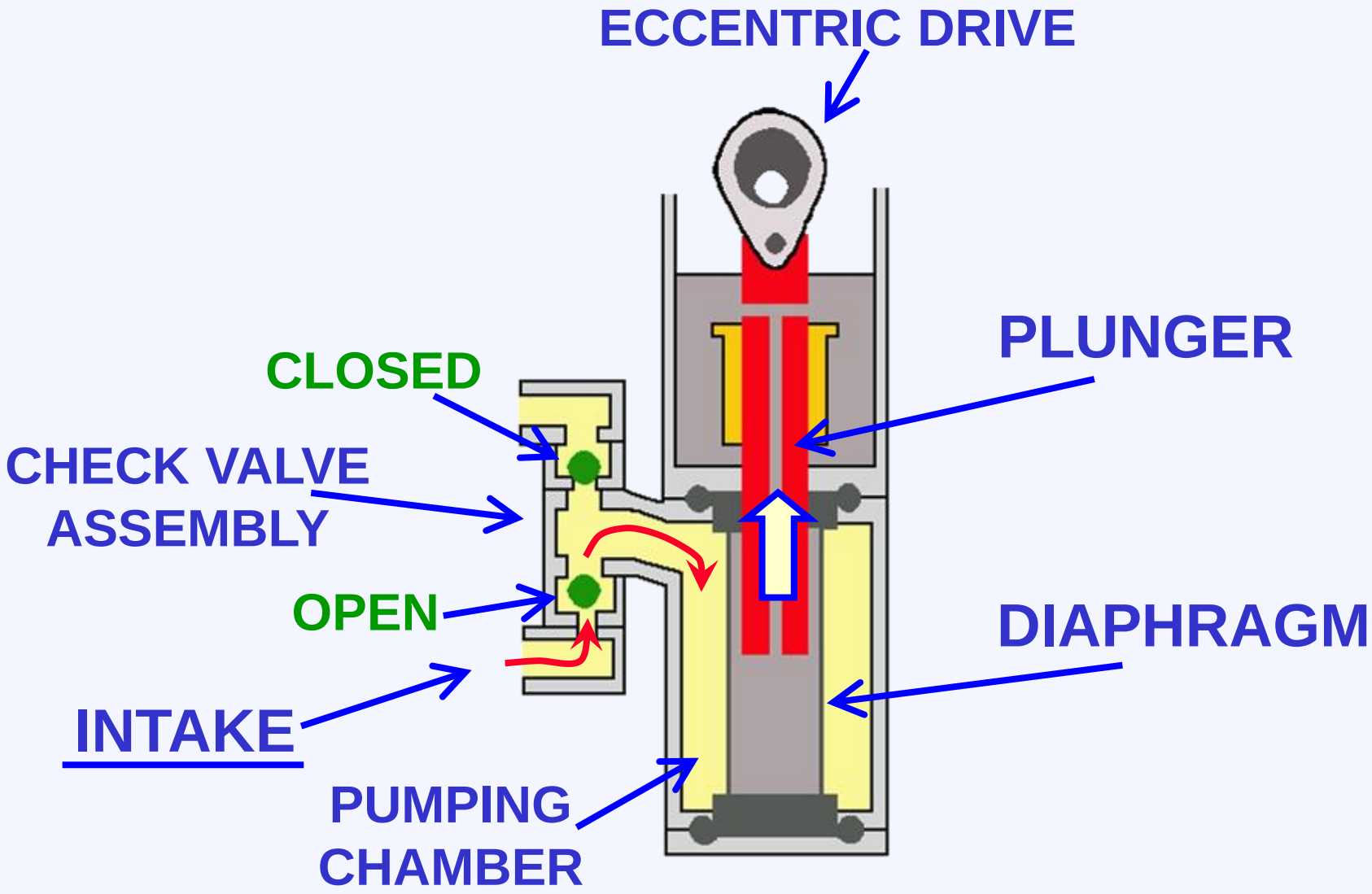
GEAR PUMP



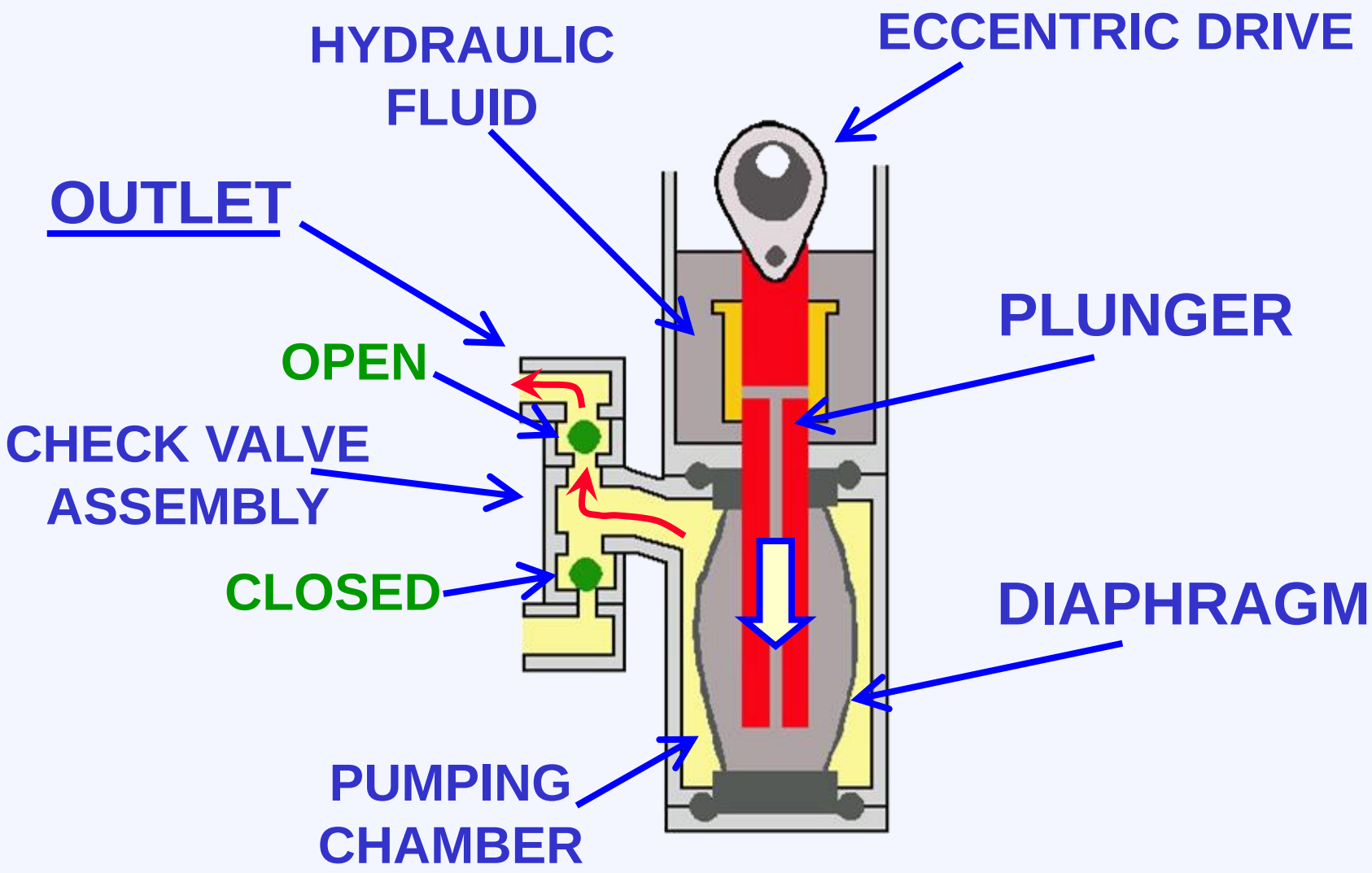
PLUNGER PUMP



DIAPHRAGM METERING PUMP

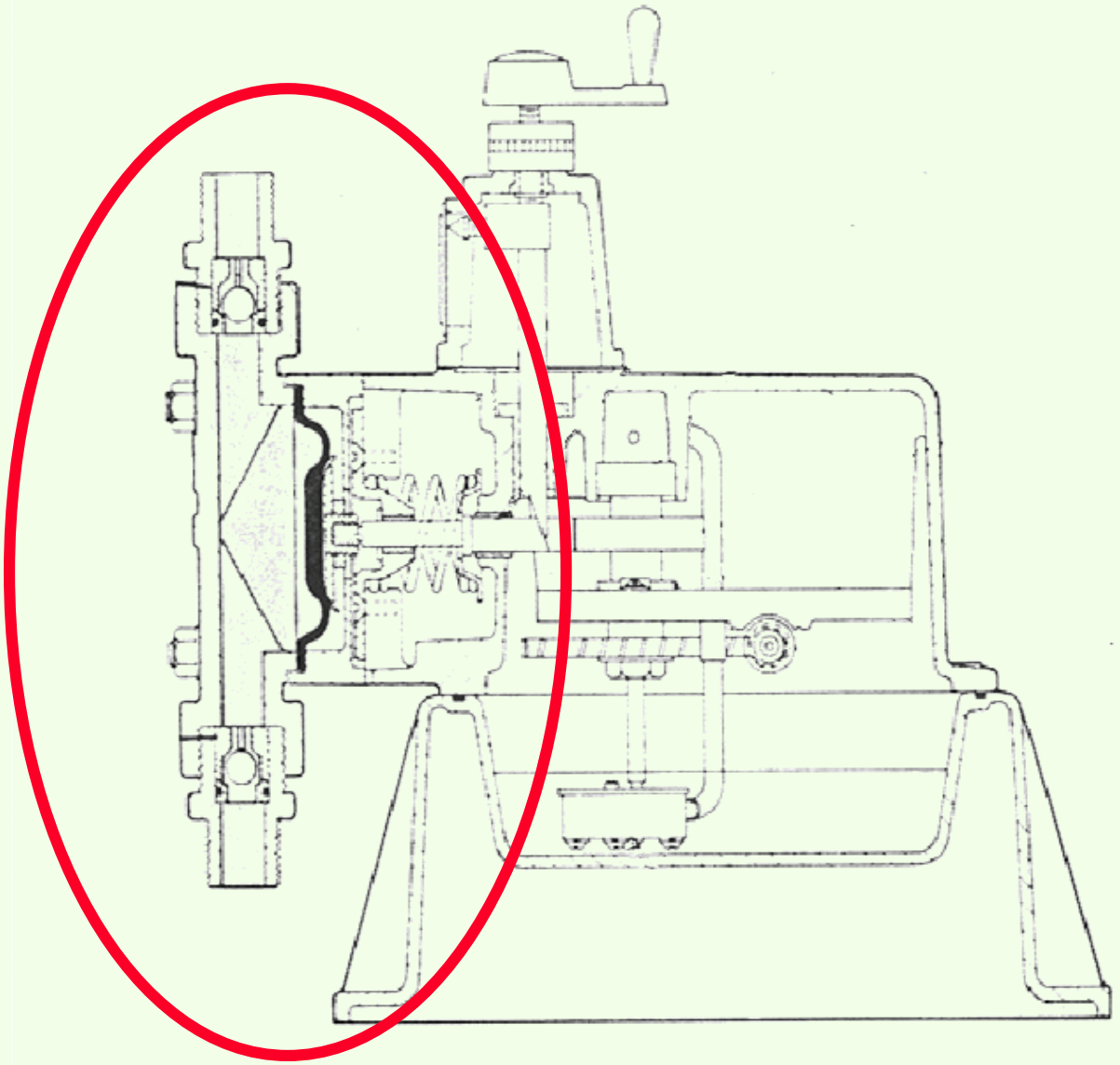


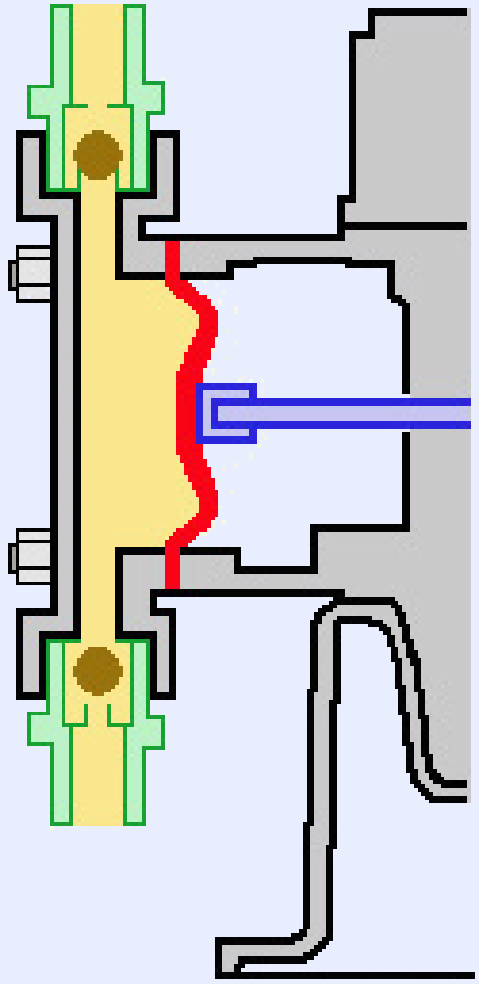
DIAPHRAGM METERING PUMP

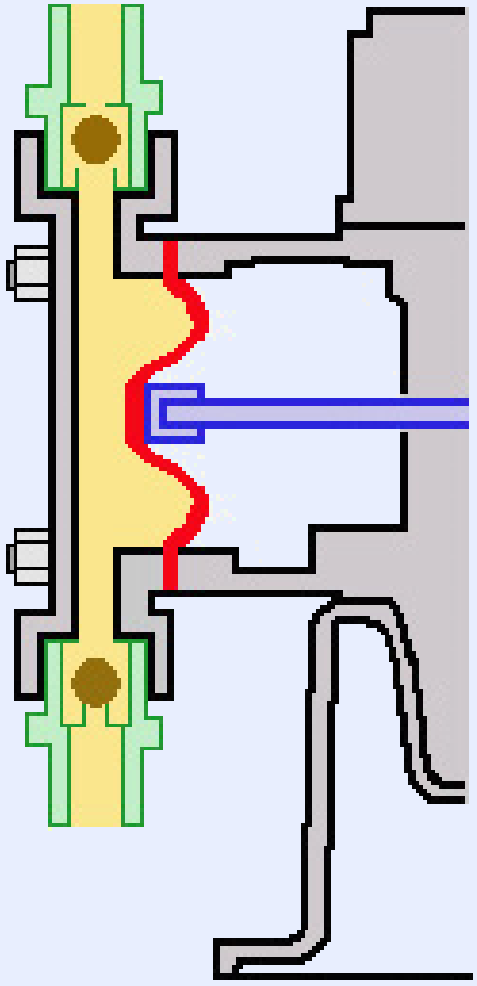


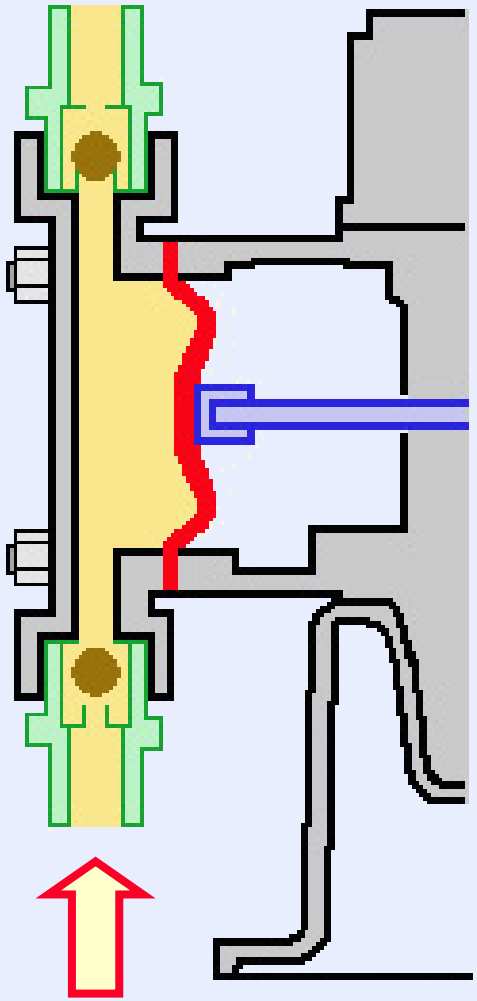
DISCHARGE STROKE

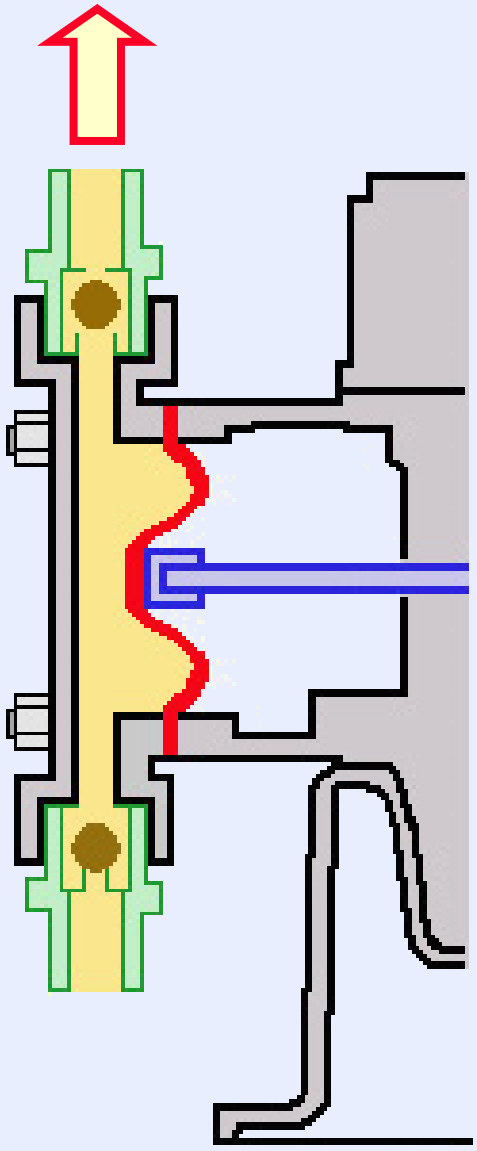
DIAPHRAGM PUMP





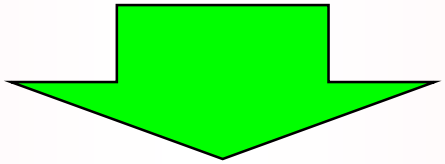




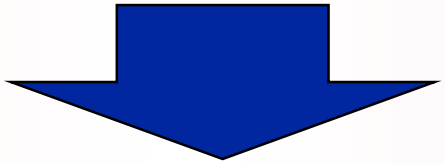


Treatment Process

Coagulation



Flocculation



Separation

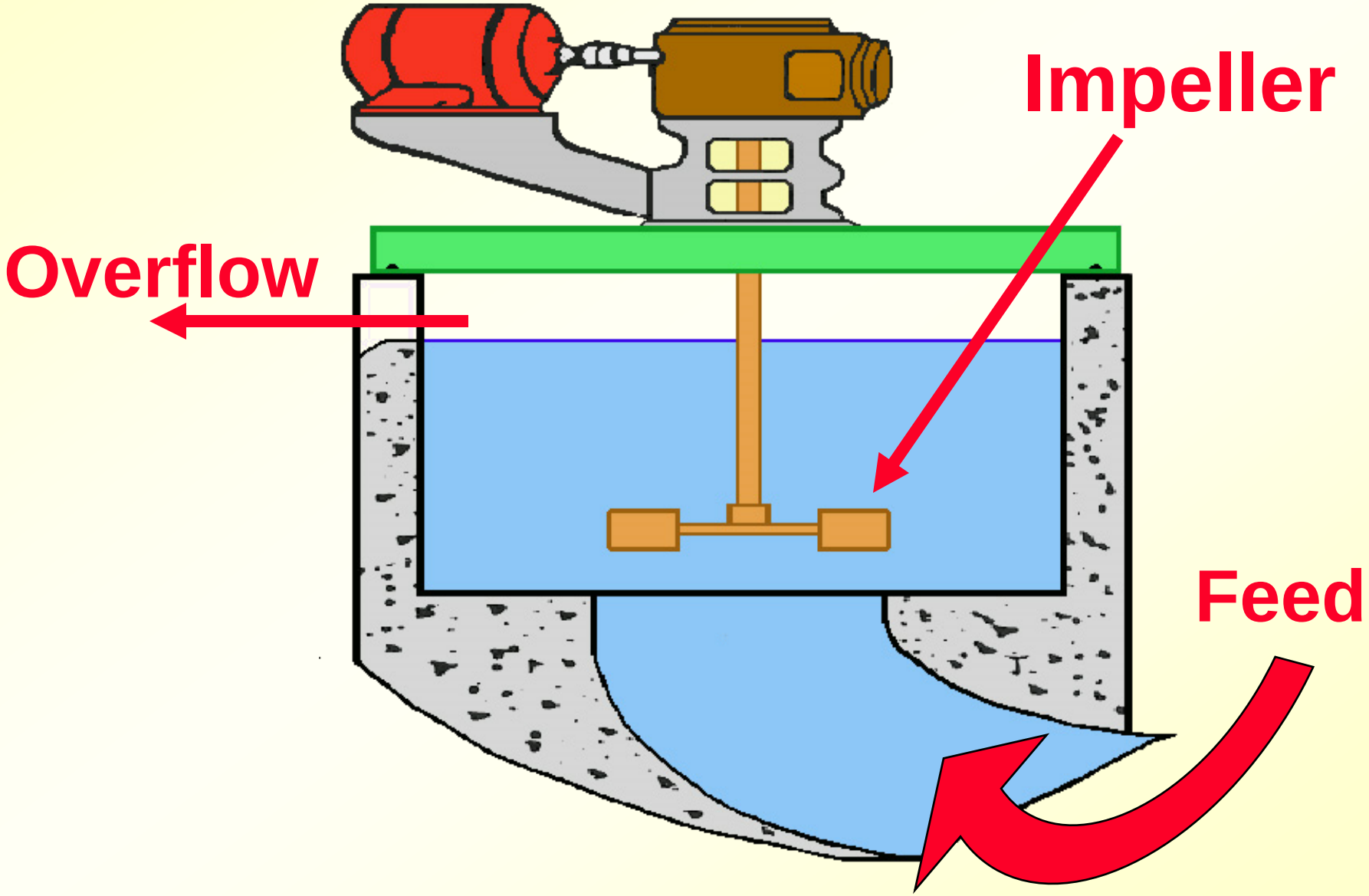
MIXING

Initial Rapid Mixing

Uniform Dispersion

Efficient Application

FLASH MIX TANK



FLASH MIX TANK

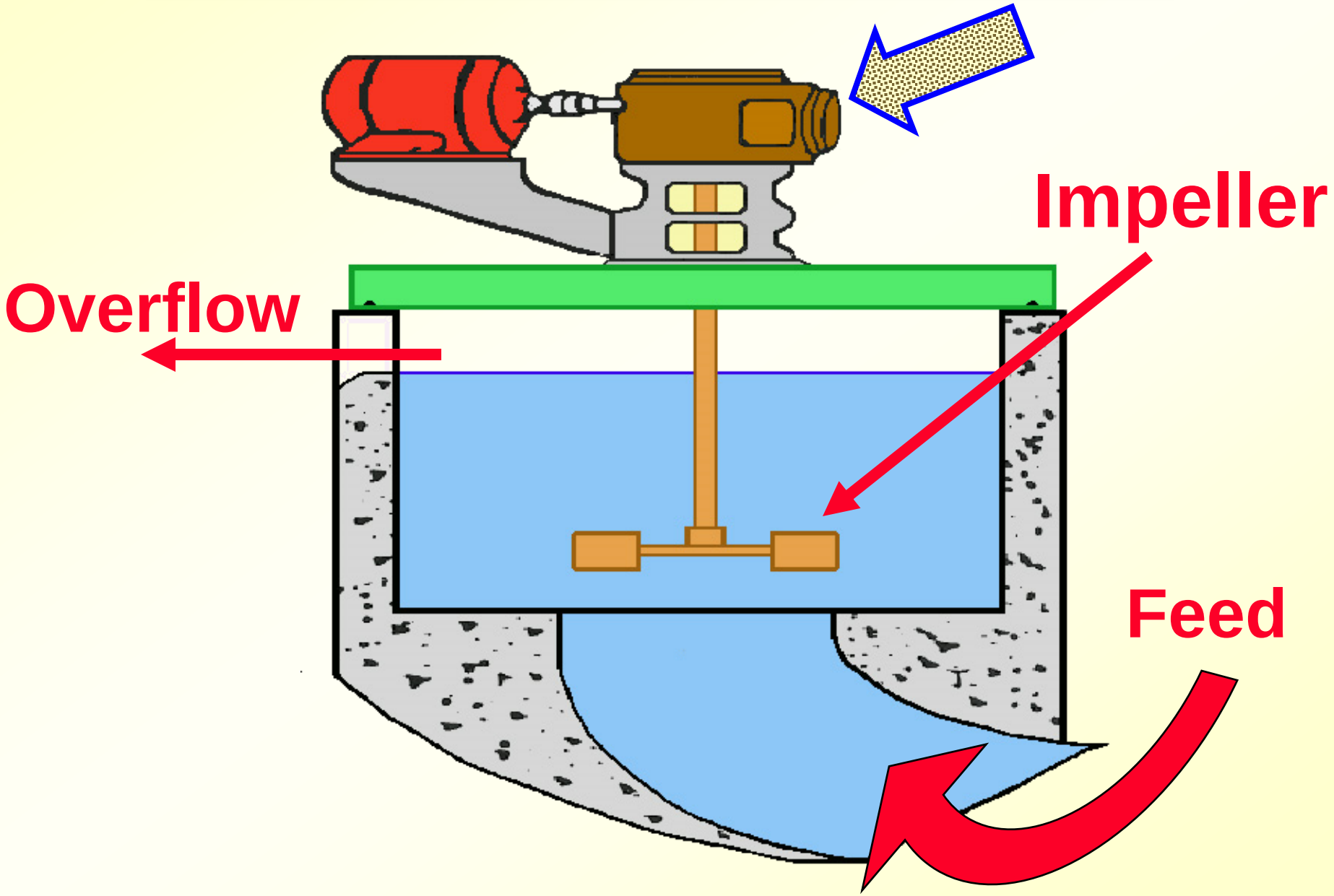
FLOCCULATION

Gentle Mixing

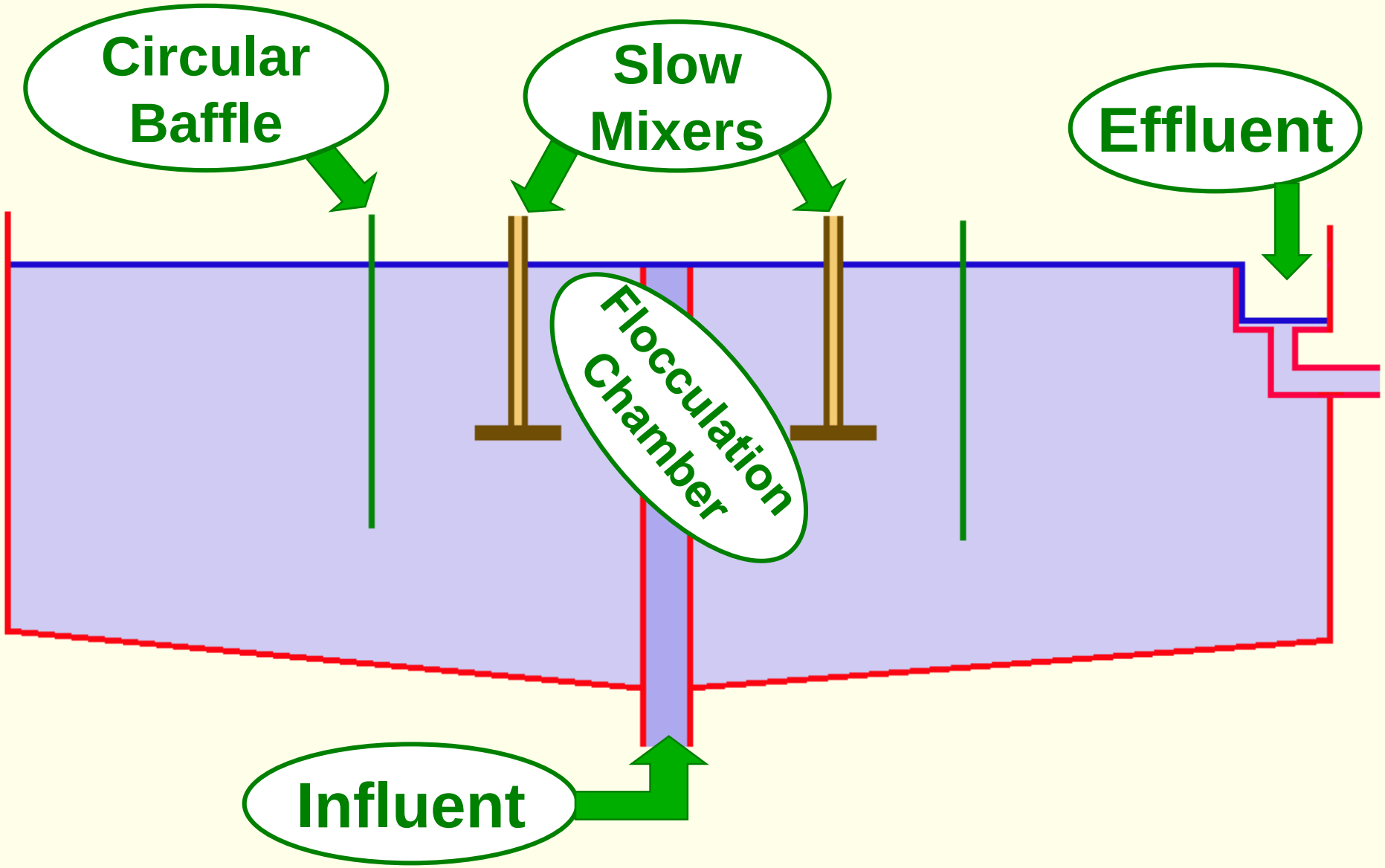
Particle Contact

In Biological Process

FLOCCULATION TANK

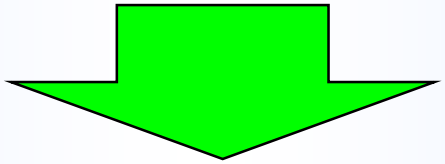


Typical Mechanically Mixed Flocculating Clarifier

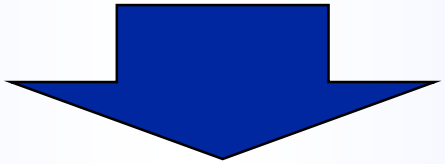


Treatment Process

Coagulation



Flocculation



Separation

CHEMICAL CLARIFICATION – COAGULATION METHODS

Prepared By
Michigan Department of Environmental Quality
Operator Training and Certification Unit