C22_4

< Chemical process improvement>

Product Recovery Techniques

IAMC Toolkit

Innovative approaches for the Sound Management of Chemicals and Chemical Waste

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Introduction

Manufacturers of chemical products often need to clean processing equipment between different batches of products. To do this, they need to remove the existing product from pipelines and vessels. Product loss and waste generation resulting from the cleaning of processing equipment increase production costs and have a negative impact on sustainability. Product recovery is typically done in combination with Clean-in-Place.

This presentation introduces the reader to two techniques for product recovery: pigging and whirlwind systems. Design considerations, advantages & disadvantages as well as case studies are presented for both techniques.

Contents

Product Recovery: The First Step in CIP Systems

- Product recovery
- Fields of application

Motivation for Improving Cleaning Operations

- Manufacturers of chemical products often need to clean processing equipment between different batches of products.

- Customers place smaller orders more frequently and demand higher product quality.

- Product loss and waste generation resulting from the cleaning of processing equipment increase production costs and have a negative impact on sustainability.

Product Recovery: The First Step in Clean-In-Place (CIP) Operations (1)

Clean-in-place (CIP) is a cleaning technique for complete items of plant or pipeline circuits without dismantling or opening of the equipment.

C22_3_Clean-in-place

CIP typically has the following characteristics:

- Cleaning of closed or open circuits
- Semi or fully-automated process with little or no operator involvement

The recovery of valuable product is the first step of an efficient and cost-effective CIP system.

Product Recovery: The First Step in Clean-In-Place (CIP) Operations (2)

The product (e.g. cosmetics, paints, polymers, etc.) remaining in the pipelines and process equipment has economic value and can be recovered using the following techniques:

- Pigging systems
- Whirlwind systems

Both technologies have options to combine product recovery and cleaning of process equipment and pipeline circuits.

CIP System with Product Recovery: Benefits

Material productivity

- Increasing product recovery during filling/emptying of pipeline circuits and process equipment

Environmental impacts during cleaning

- Increasing water, energy and chemicals efficiency
- Reducing process effluent and hazardous waste

Quality control and equipment uptime

- Preventing cross contamination in batch manufacturing processes
- Removing deposits and condensate and increasing equipment uptime

Product Recovery: The First Step in CIP Systems

- Product recovery
- Fields of application

Fields of Application

- Diverse products, such as lubricating oils, paints, polymer dispersions, adhesive dispersions, fragrances, cosmetics and foodstuffs can be handled.
- CIP can be used for:
  - Emptying pipes of product into product tanks
  - Preventing cross-contamination
- It can be used in many continuous and batch process plants.
- It can be used for many transfer process sections, e.g. blending, storage, filling.

Selection of Cleaning Method

The following criteria are important when considering product recovery and cleaning methods:

- What is the substance to be removed (or displaced)?
- Where is the substance located, radially or longitudinally (if known)?
- What is the estimated volume to be removed?
- Does the substance present any hazards?
- How is the pipe system designed (diameters of different parts, length, etc.)?
- What is the viscosity of the product to be removed?

Pigging Systems

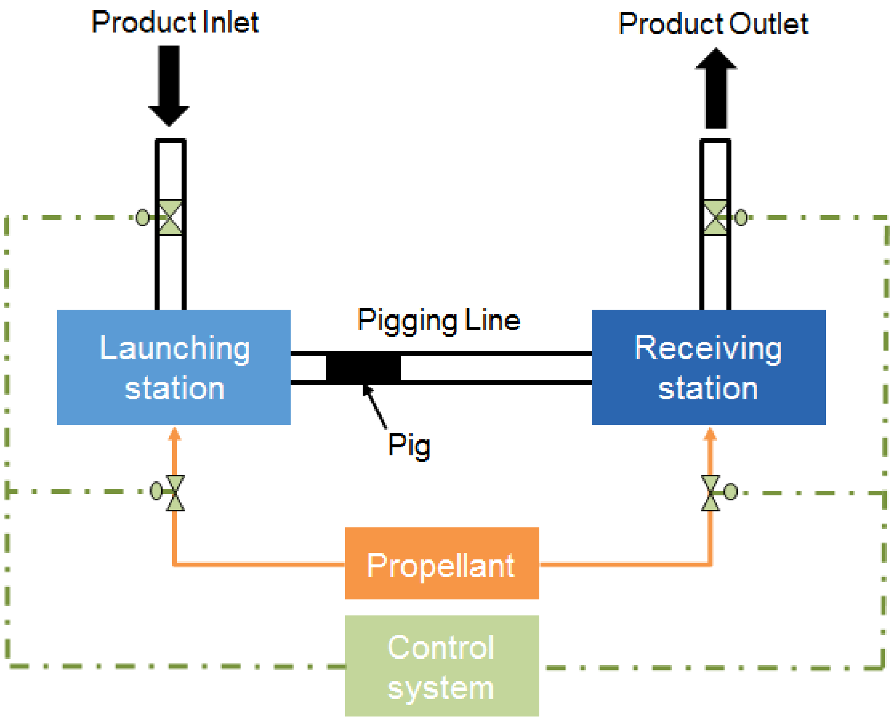
- Technology description
- Benefits and constraints
- Case studies

Technology Description

Components of a pigging system:

- Pig
- Pig loading and receiving station
- Propellant supply
- Control system

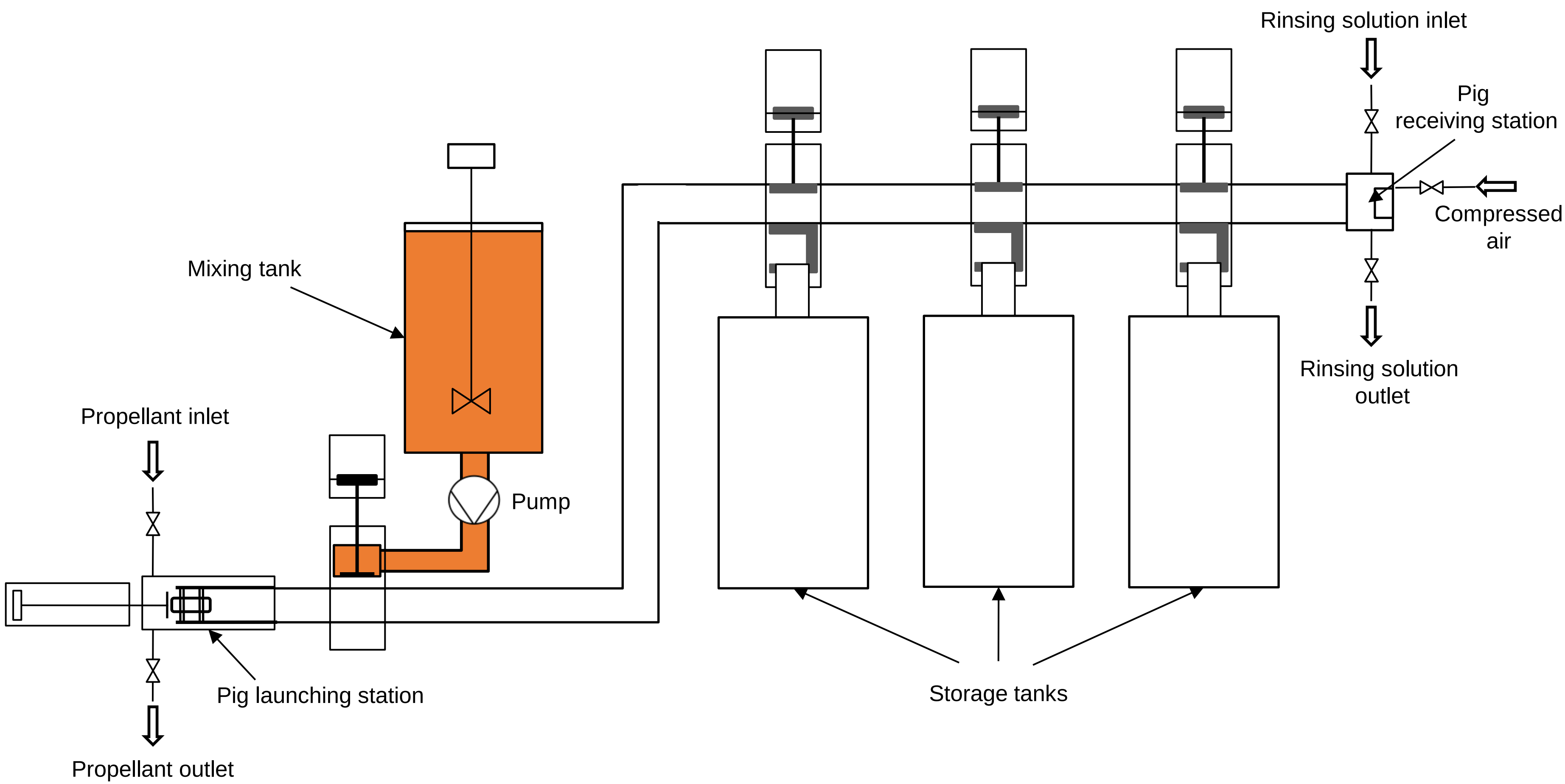
The "pig" is circulated in a pipe to recover the product, clean the pipe and remove deposits.



Source: based on Industrial Pigging Technology

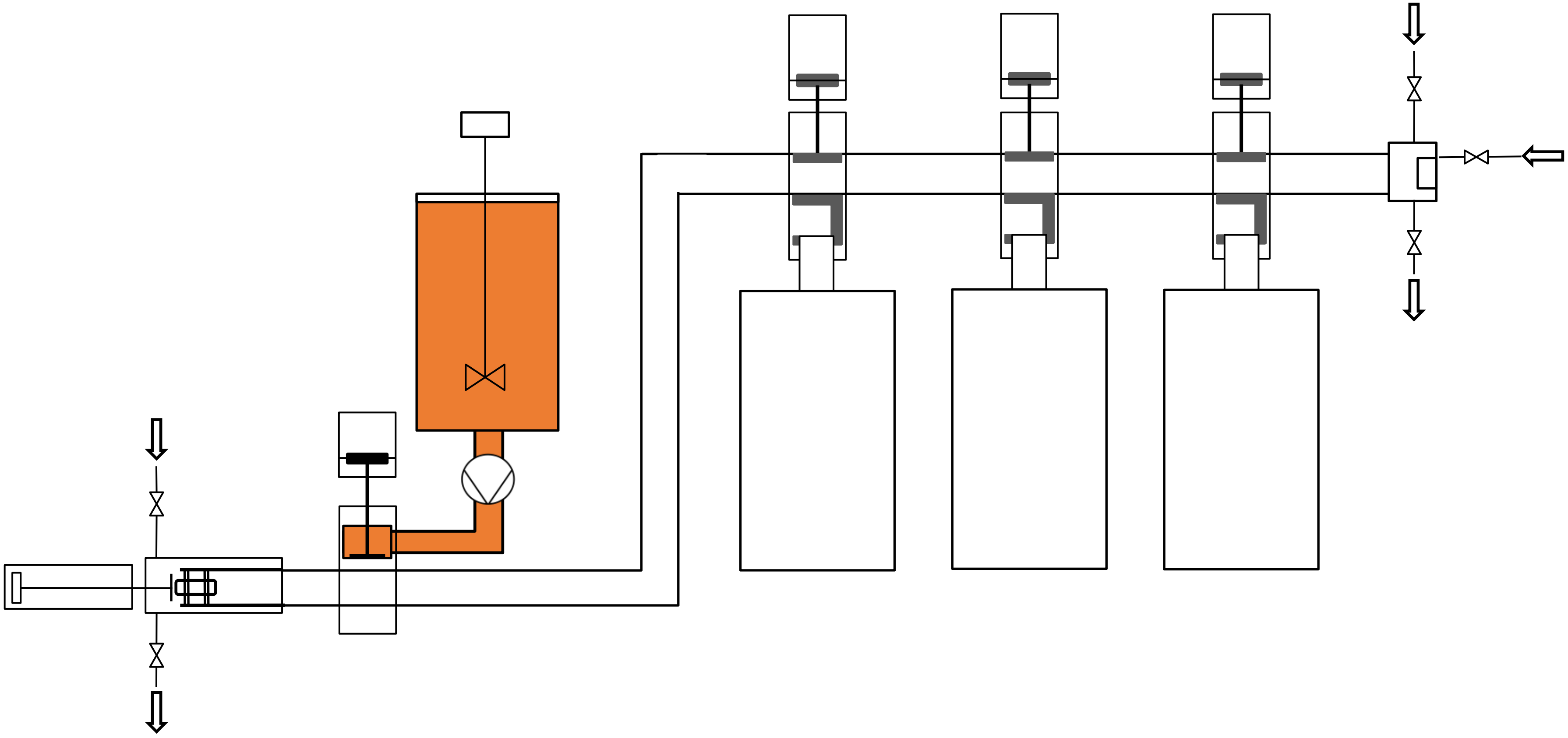
System 1: Single Pig System with Flushing

Source: based on Kiesel



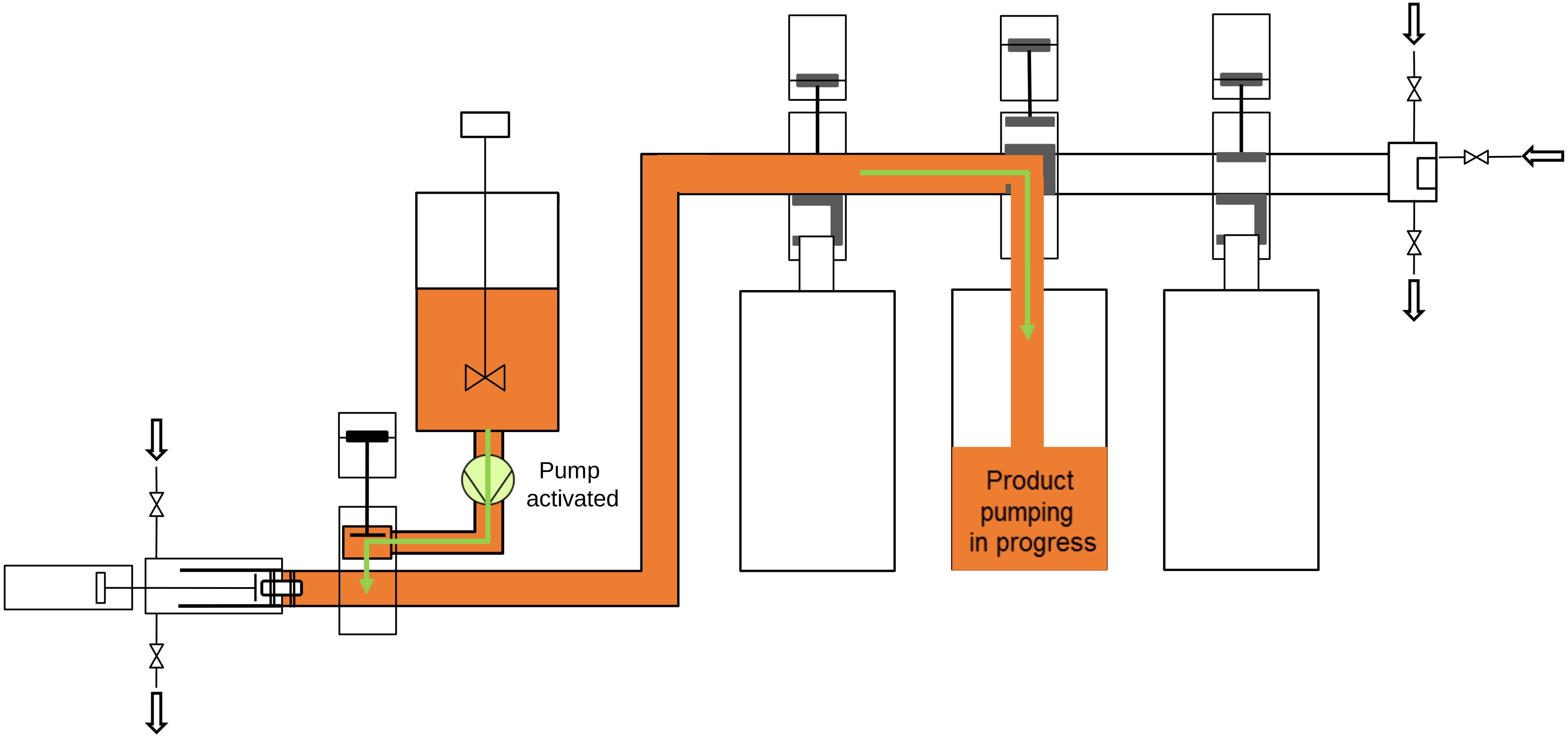
Initial Position

Source: based on Kiesel



Step 1: Start of Product Pumping

Source: based on Kiesel



Step 2: Pumping Finished

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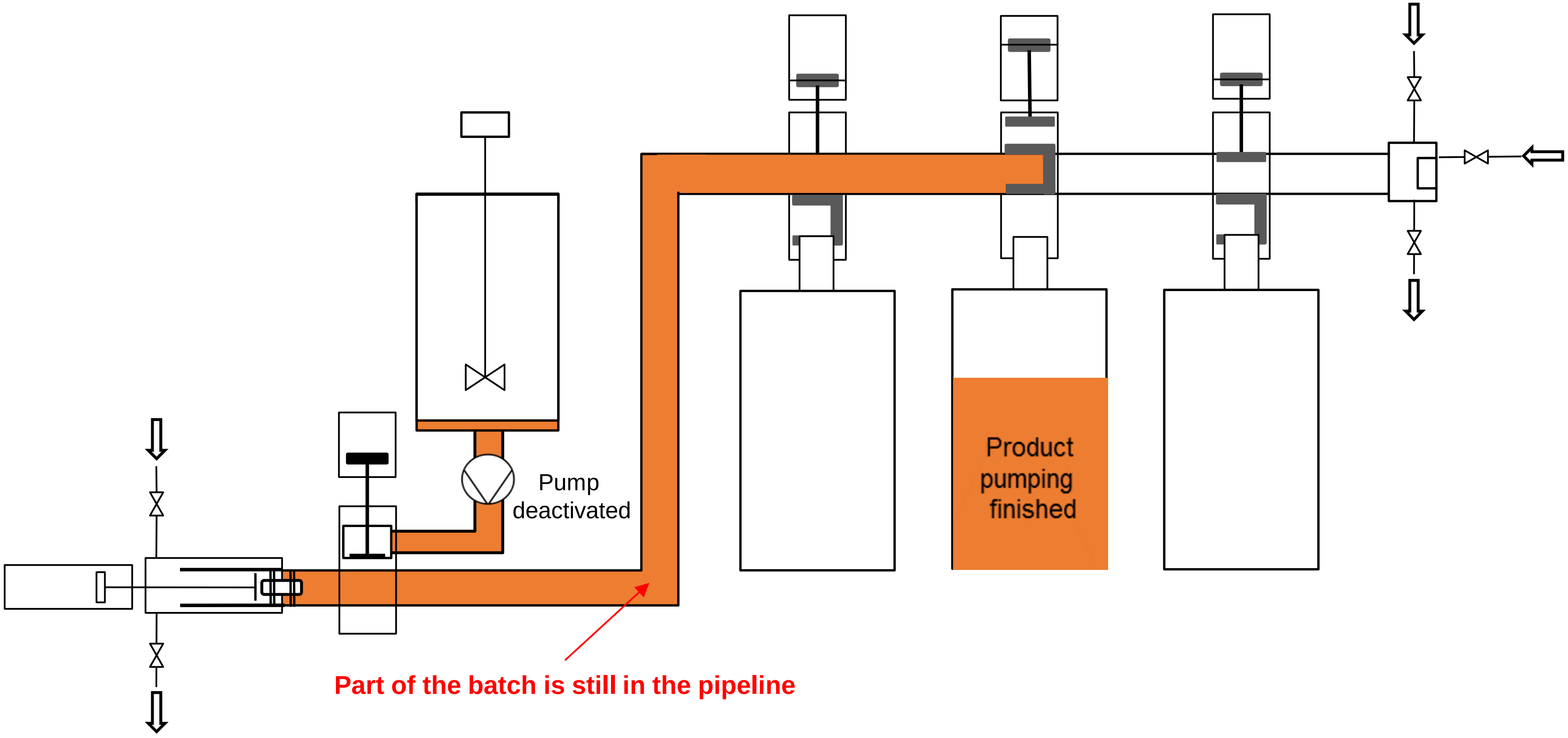
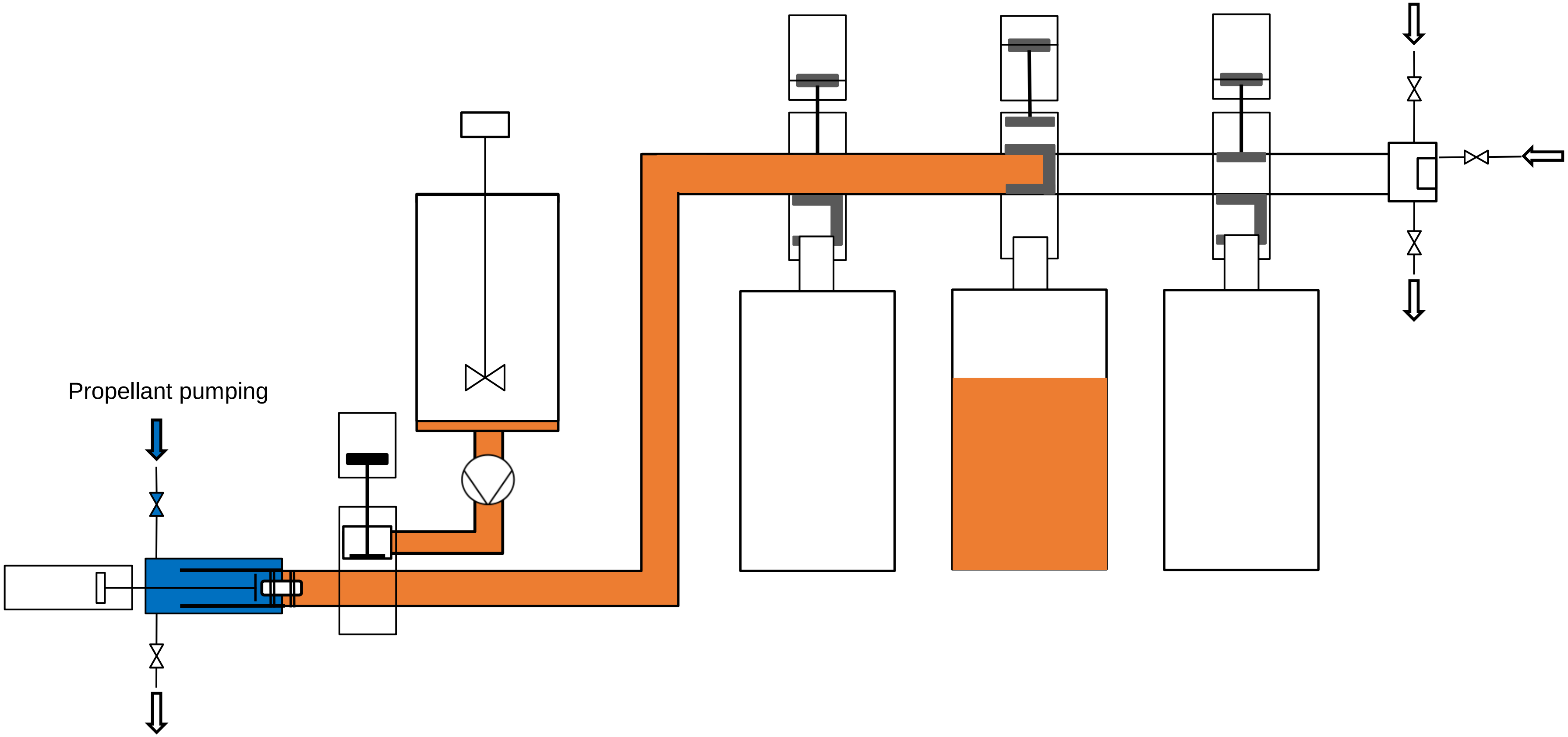


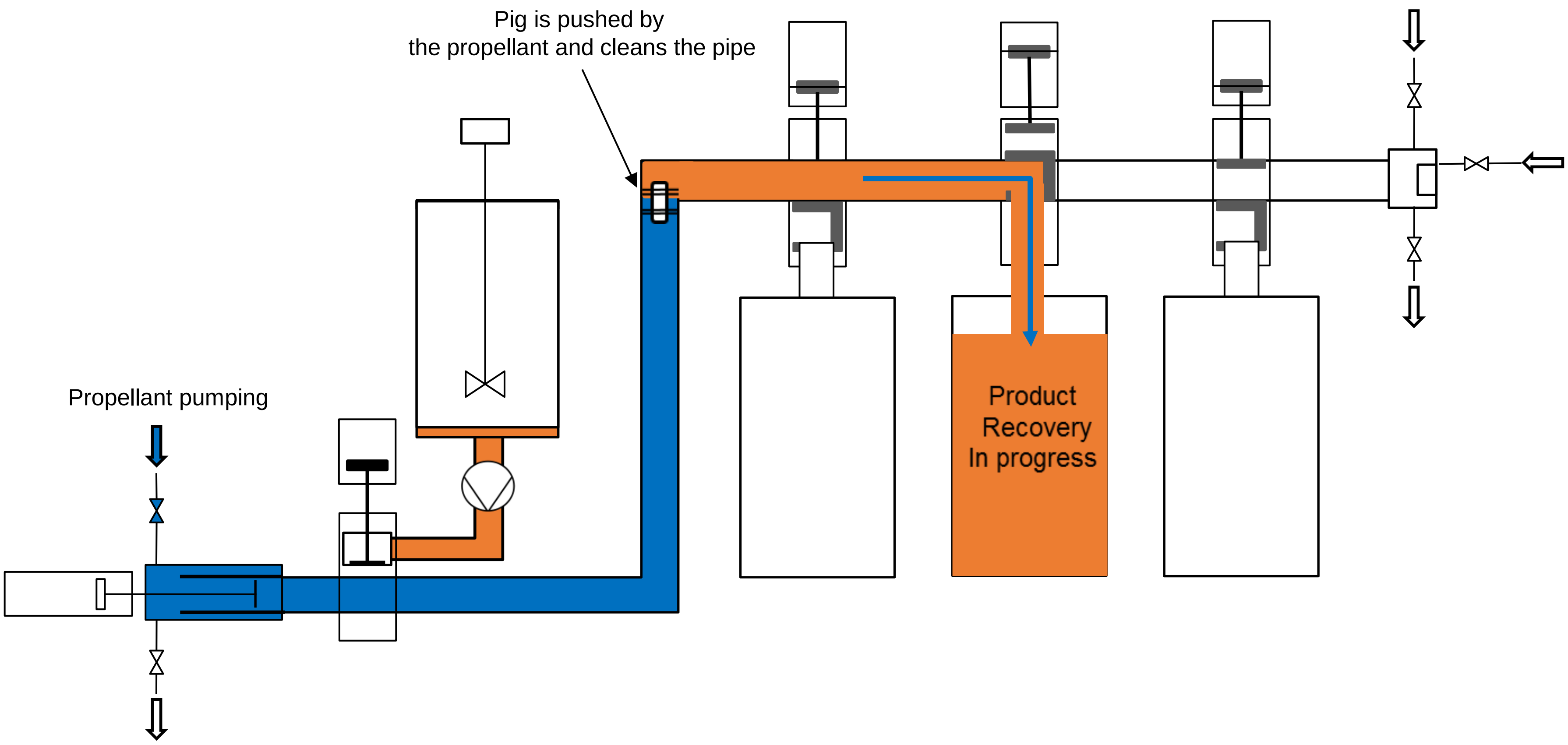
Step 3: Propellant Pumping

Source: based on Kiesel



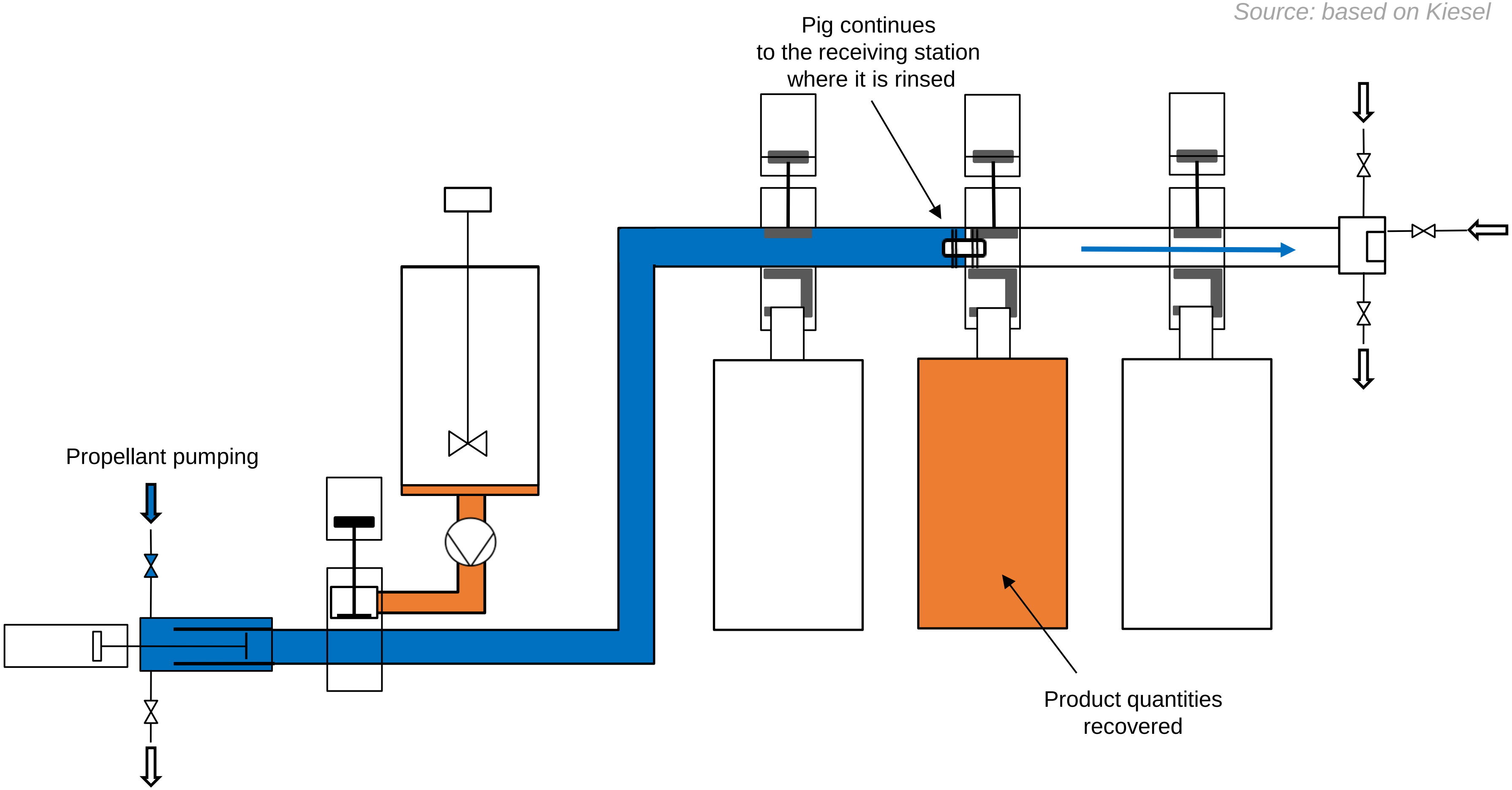
Step 3: Propellant Pumping (Continued)

Source: based on Kiesel



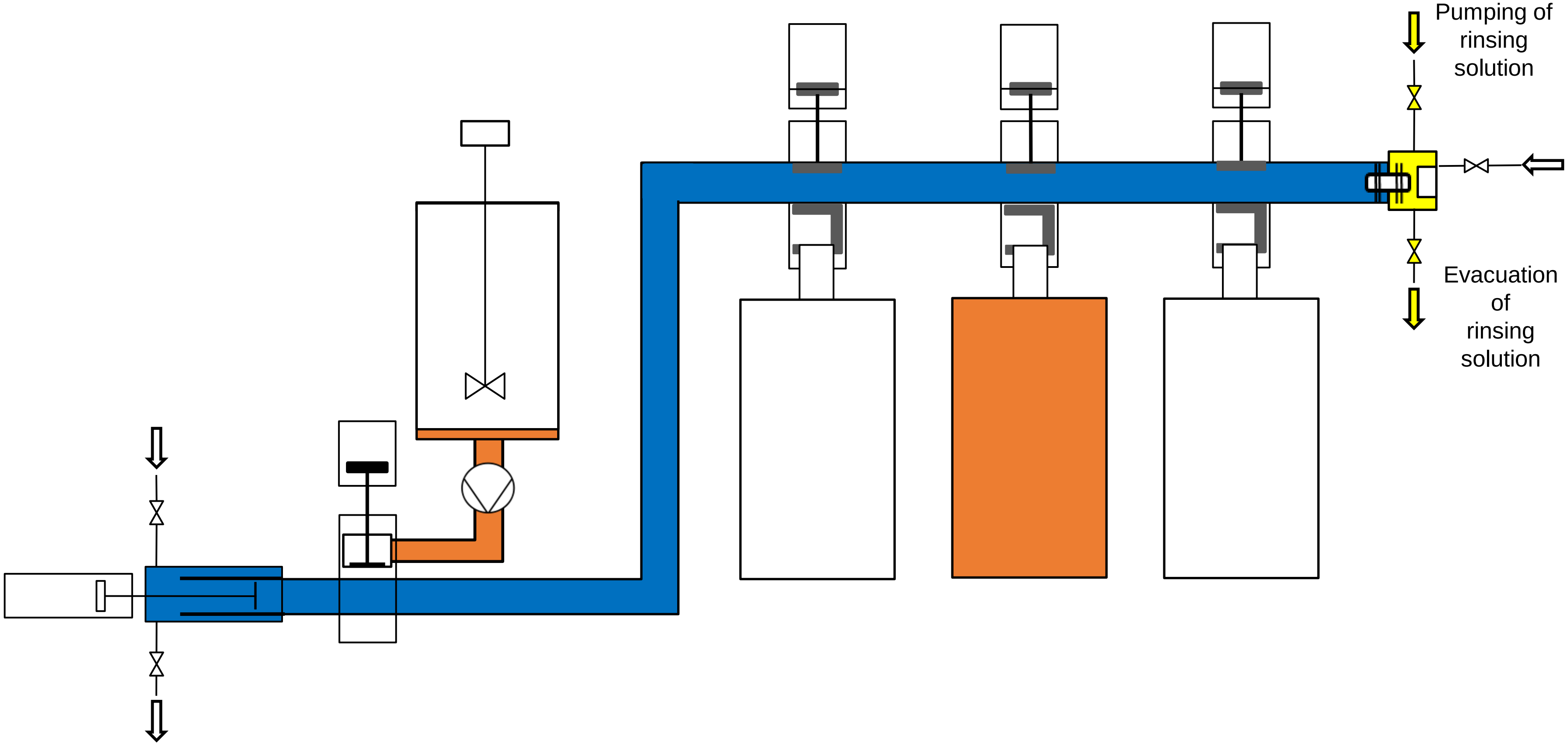
Step 3: Propellant Pumping (Product Fully Recovered)

Source: based on Kiesel



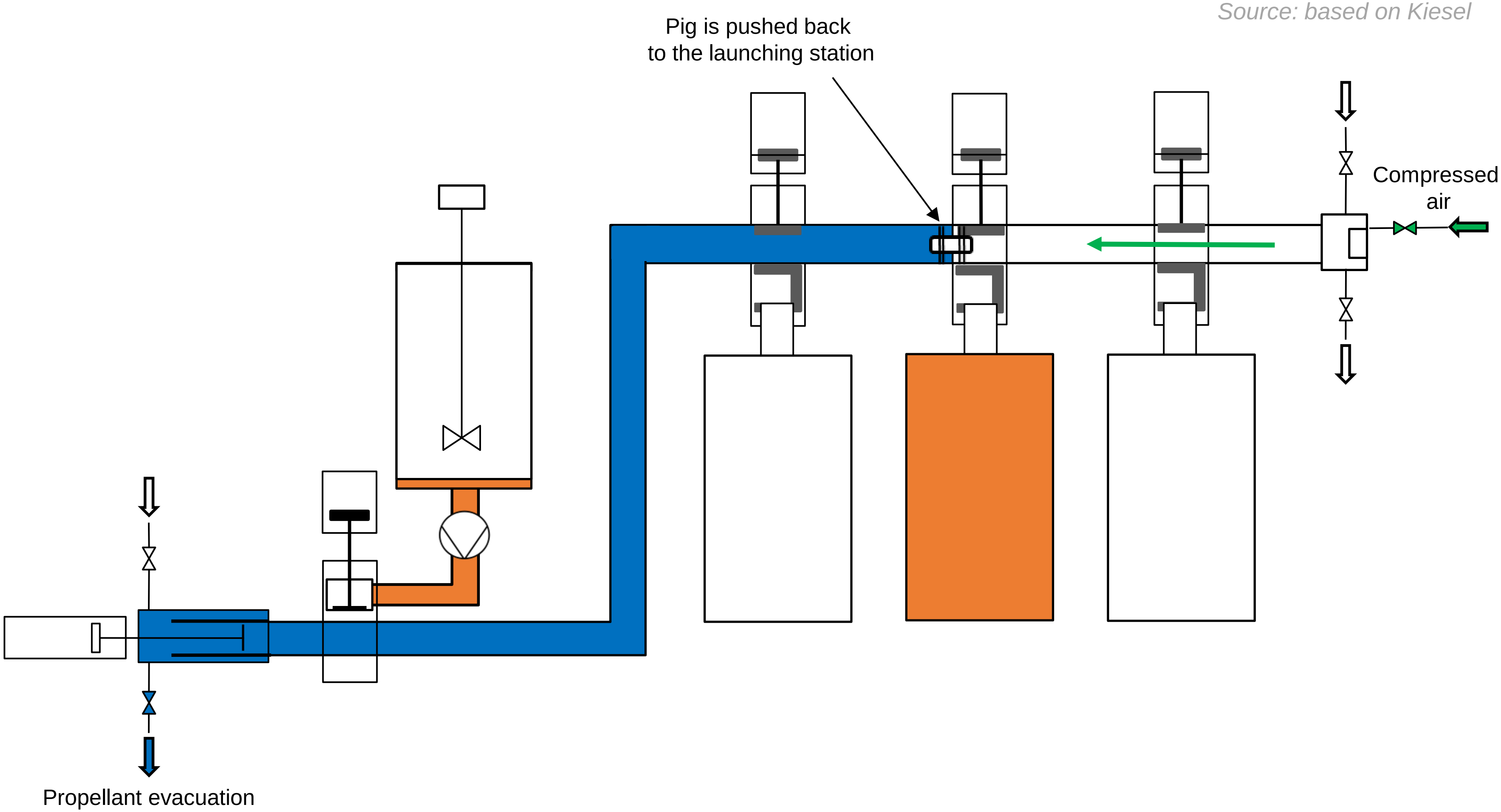
Step 4: Pig Rinsing

Source: based on Kiesel



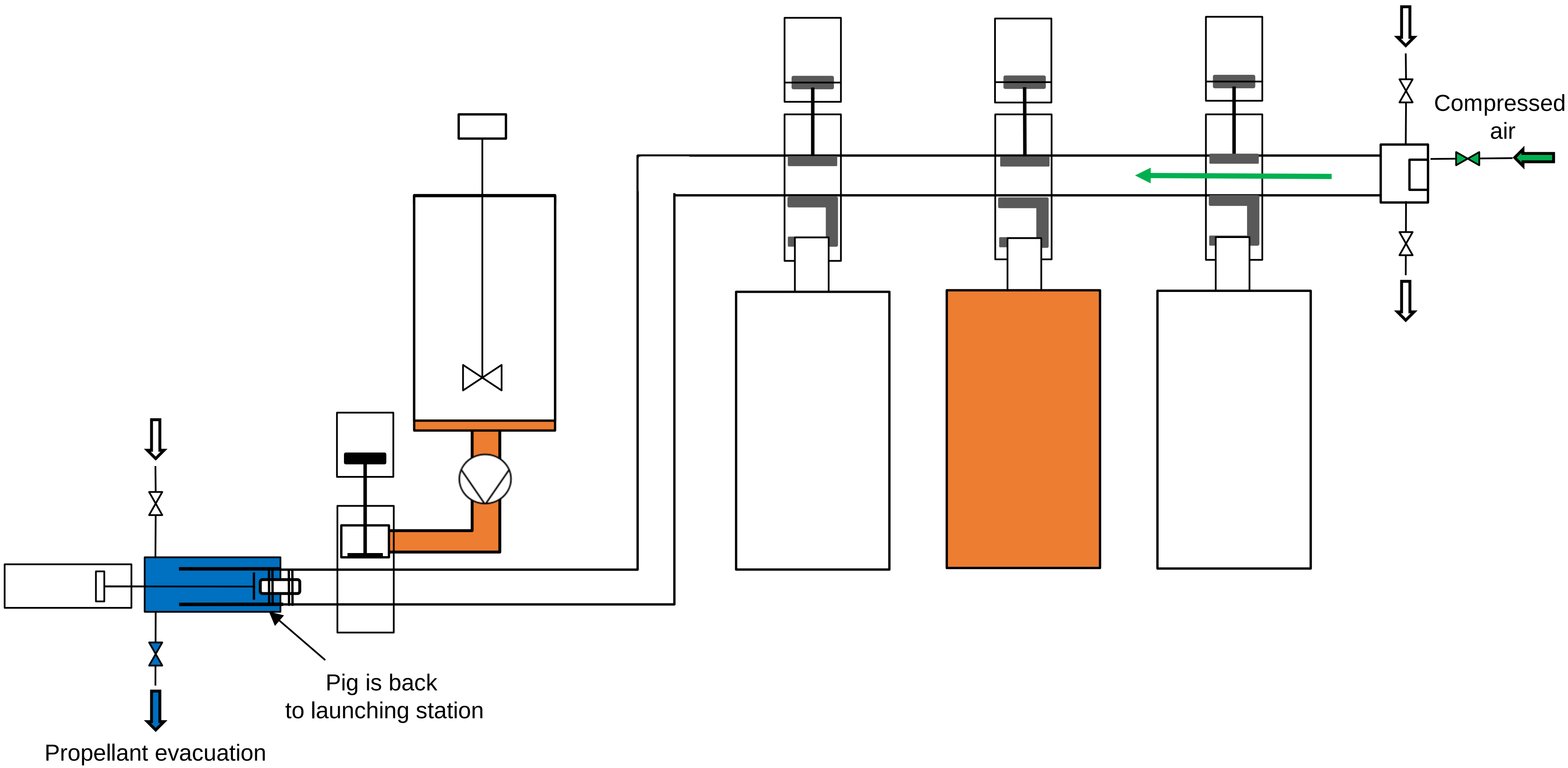
Step 5: Evacuation of Propellant

Source: based on Kiesel



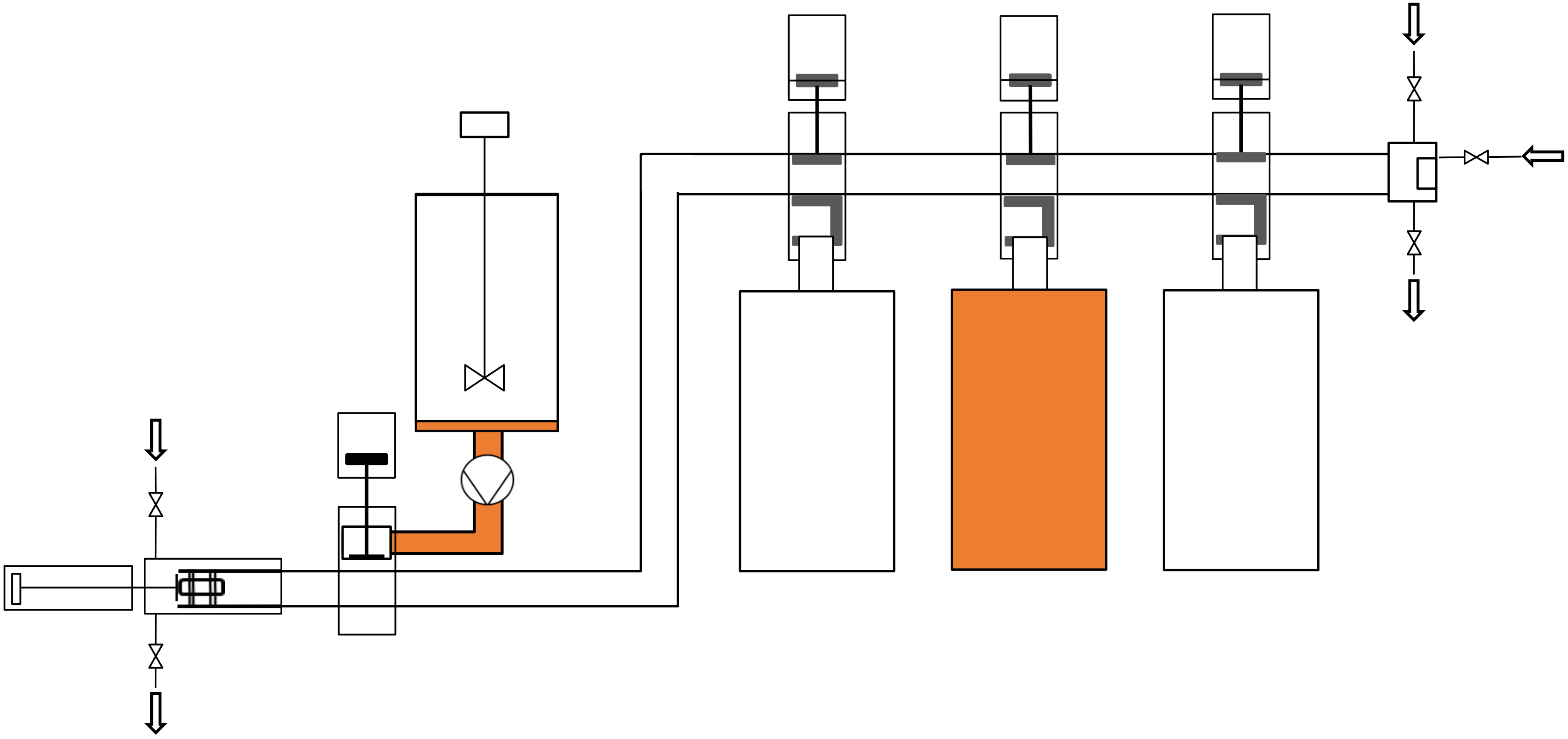
Step 5: Evacuation of Propellant (Continued)

Source: based on Kiesel



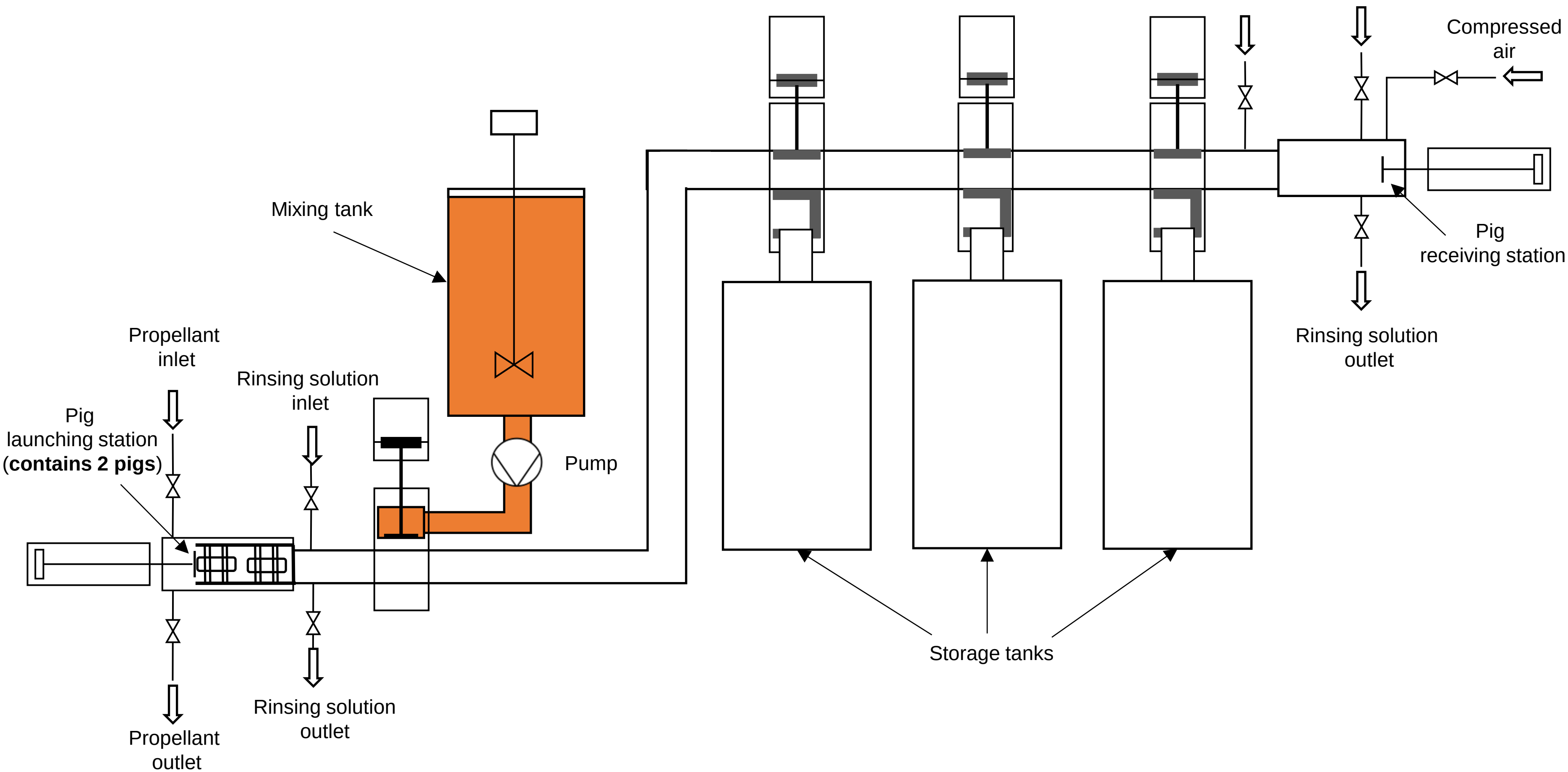
Step 6: Return to Initial Position

Source: based on Kiesel



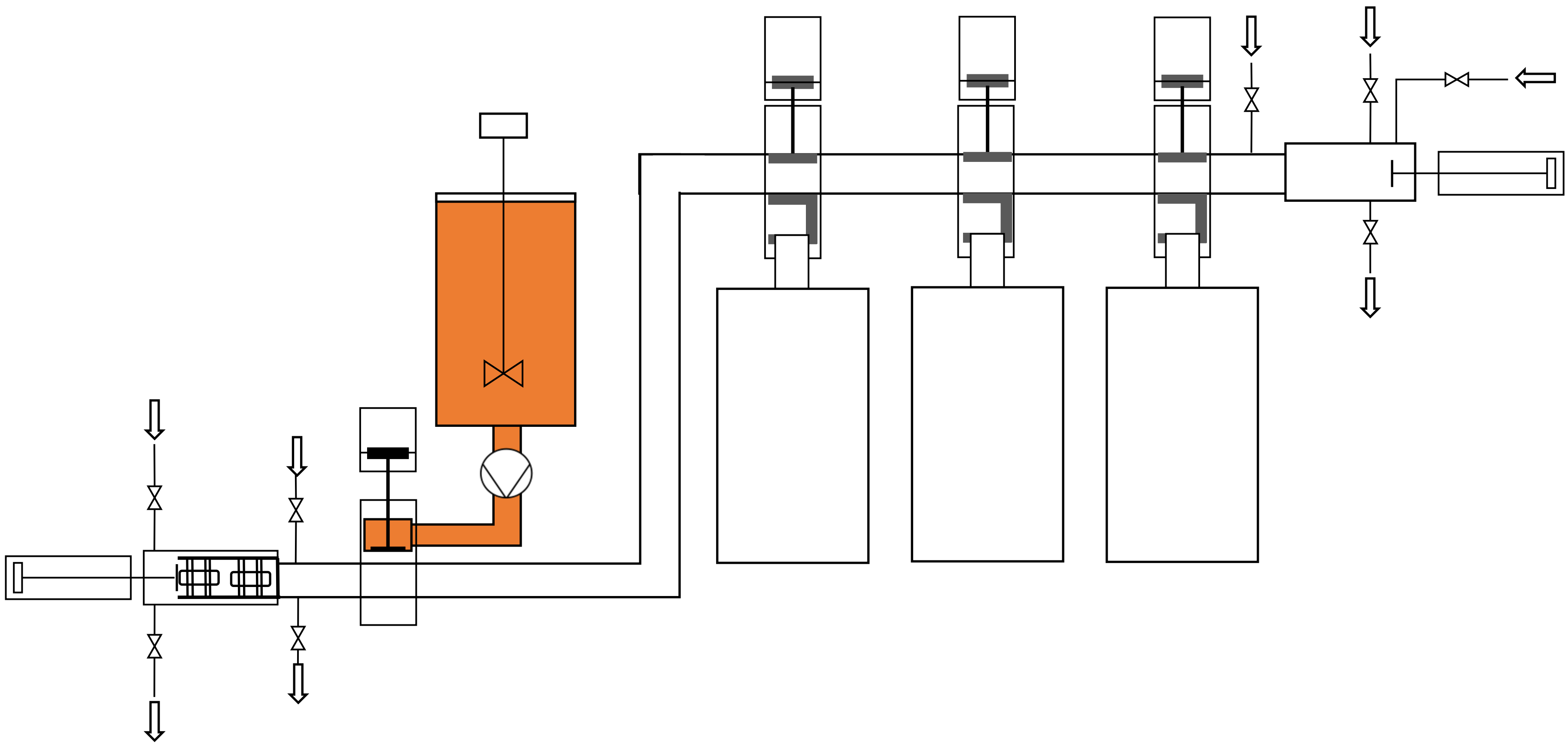
System 2: Dual Pig System with Intermediate Clamping Liquid and Rinse

Source: based on Kiesel



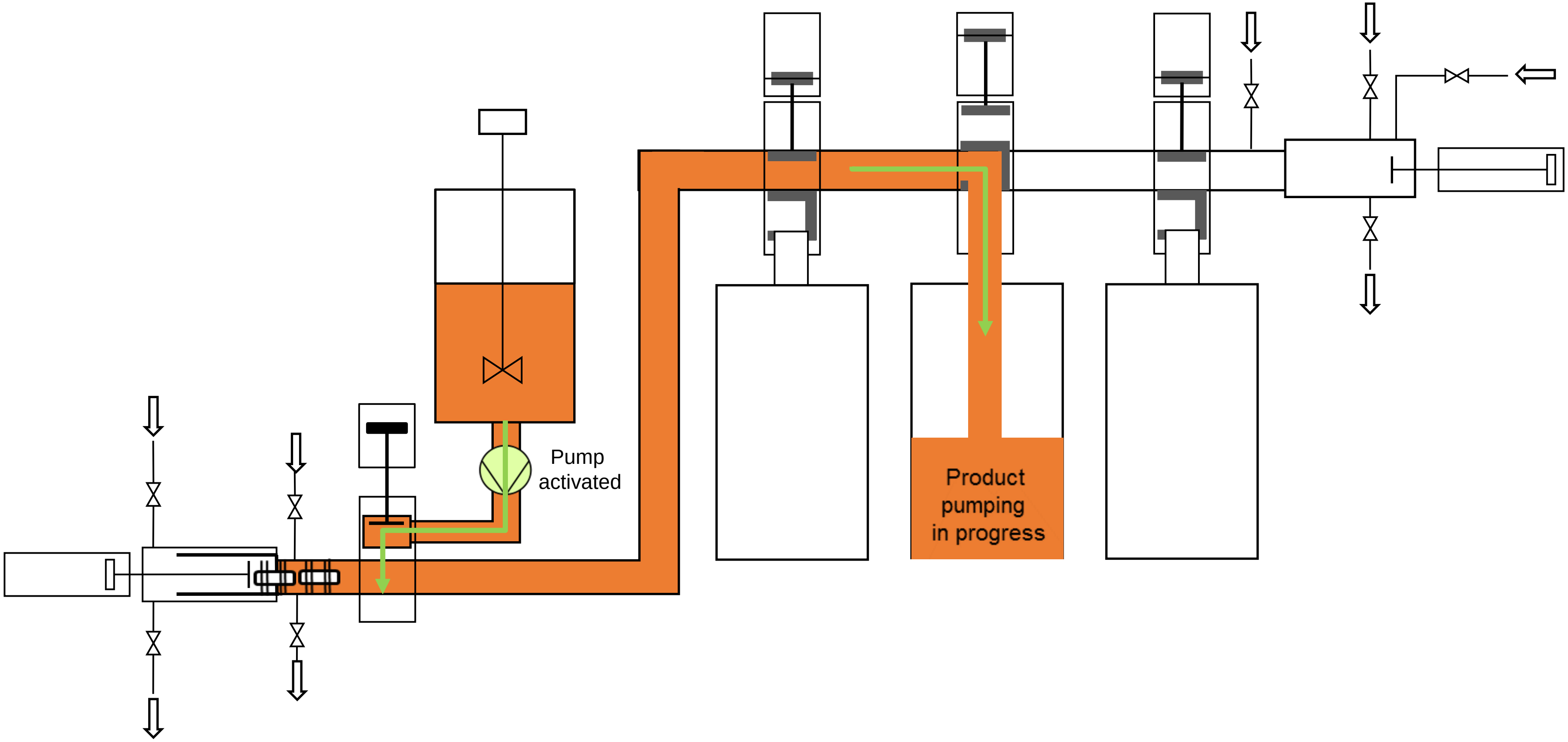
Initial Position

Source: based on Kiesel



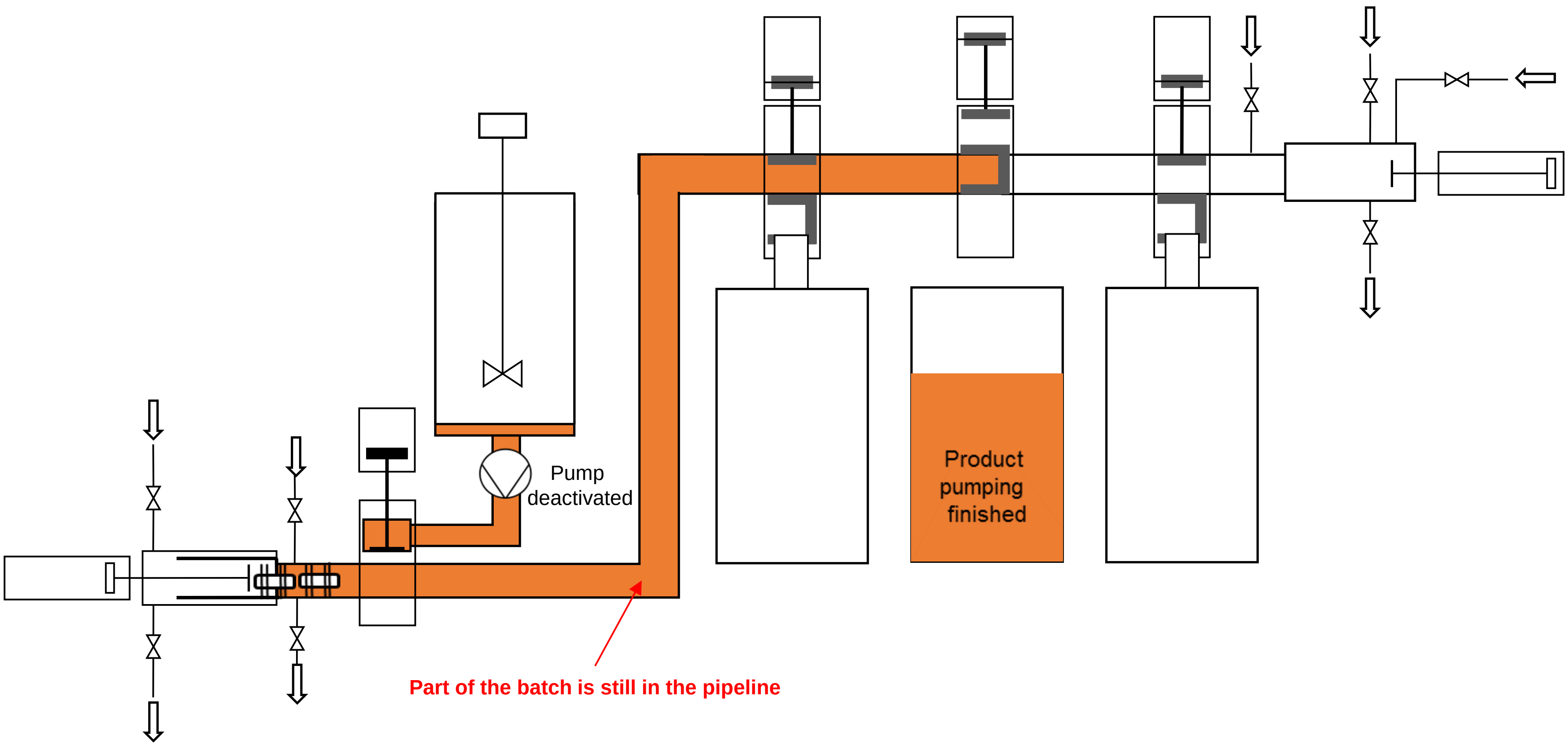
Step 1: Start of Product Pumping

Source: based on Kiesel



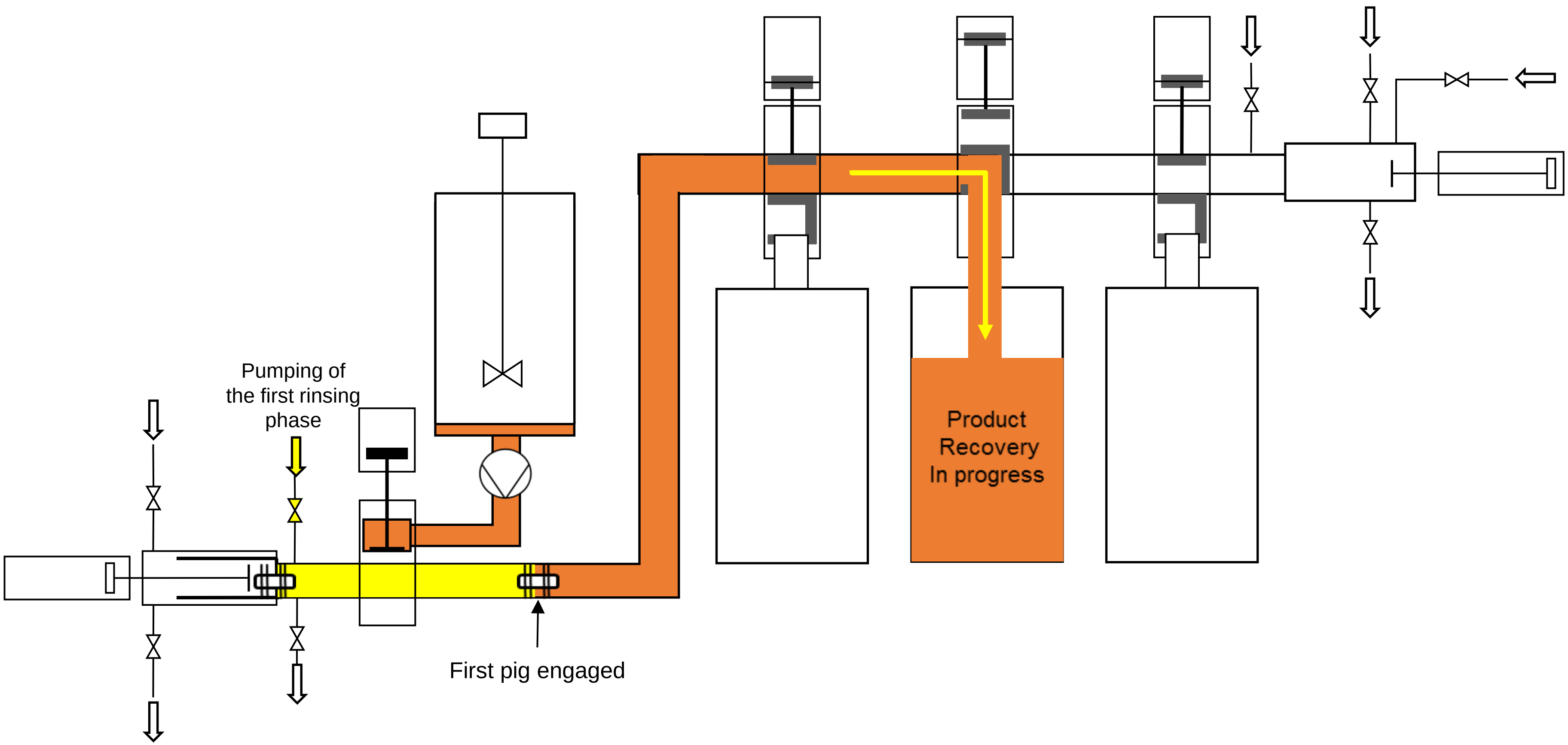
Step 2: Pumping Finished

Source: based on Kiesel



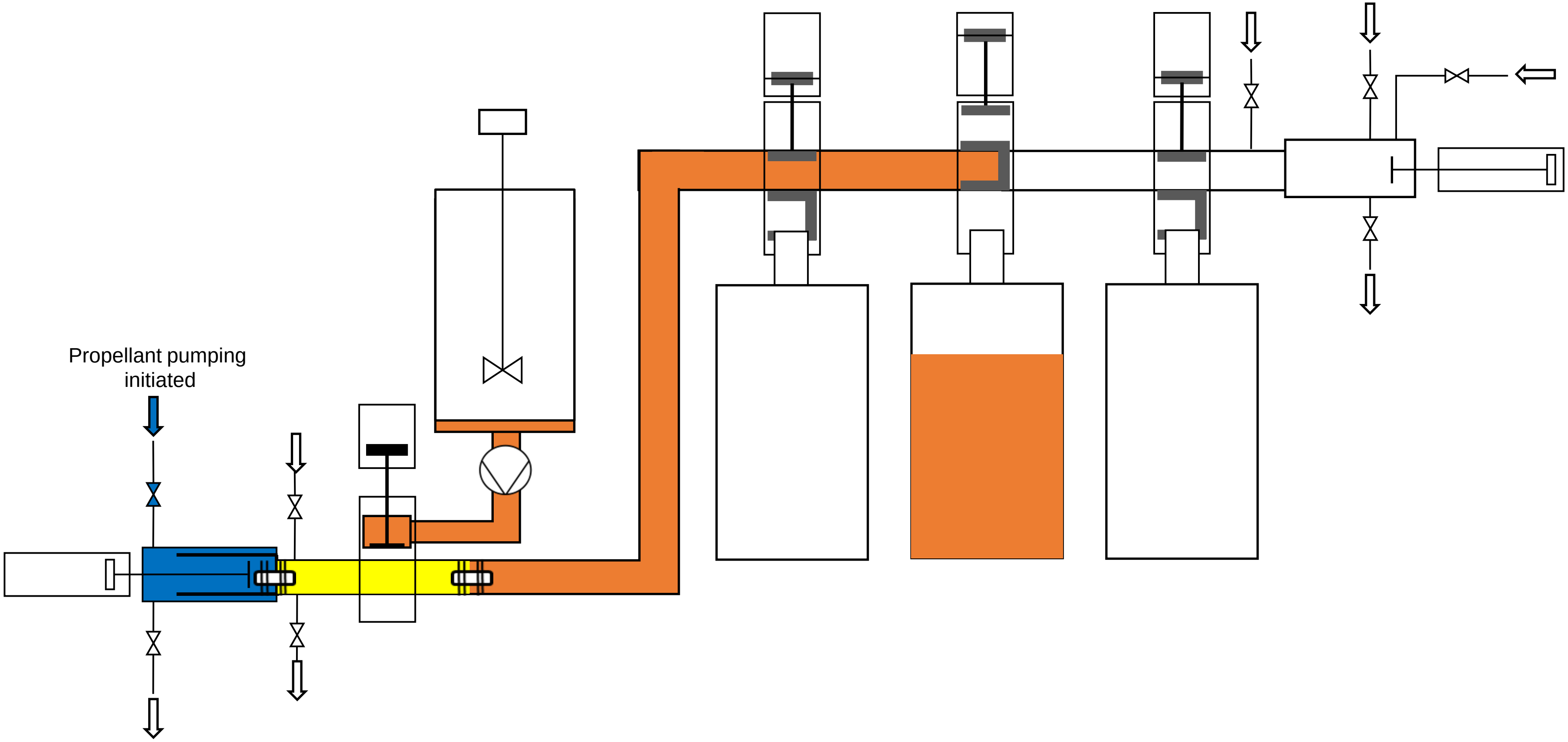
Step 3: Start of Rinsing Phase

Source: based on Kiesel



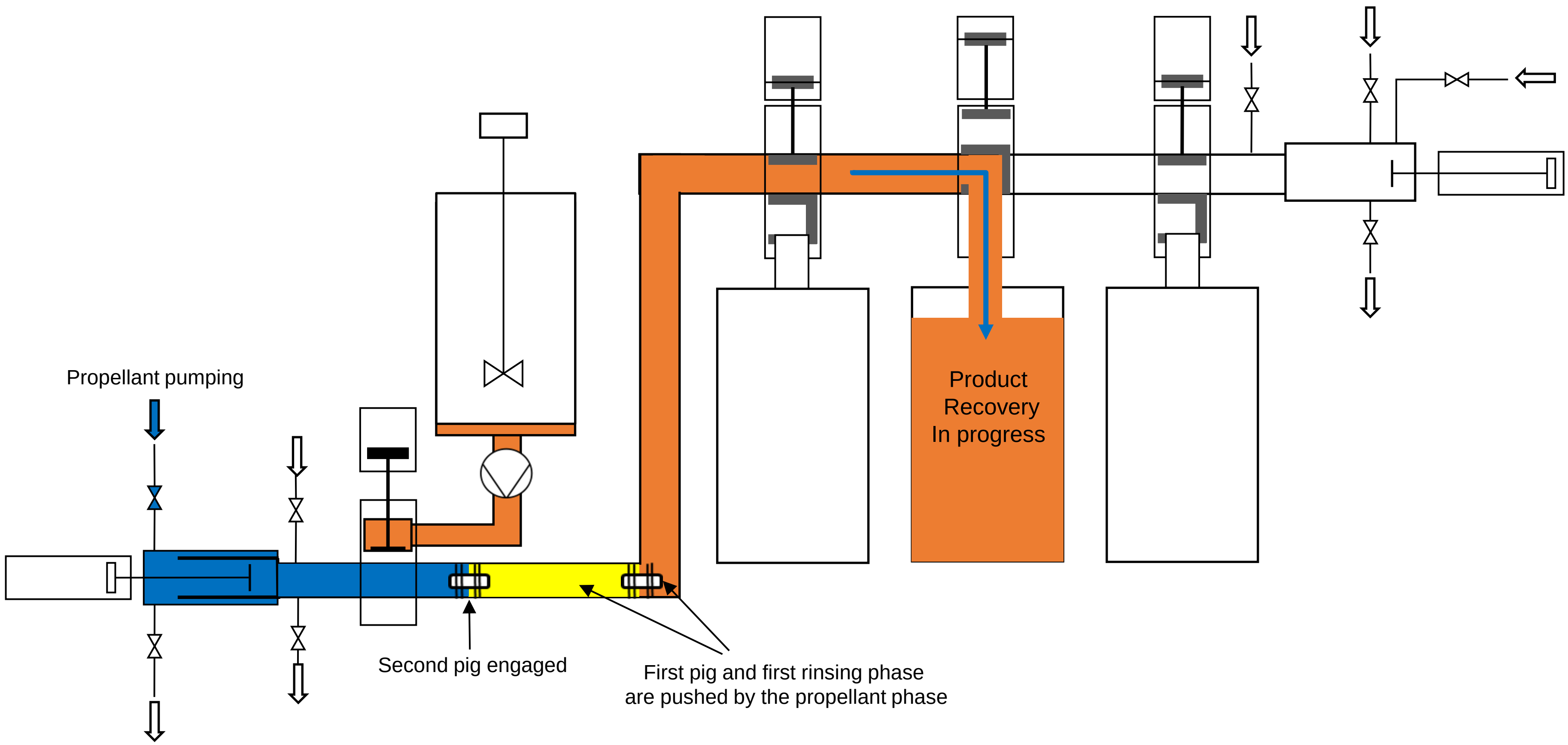
Step 4: Propellant Pumping

Source: based on Kiesel



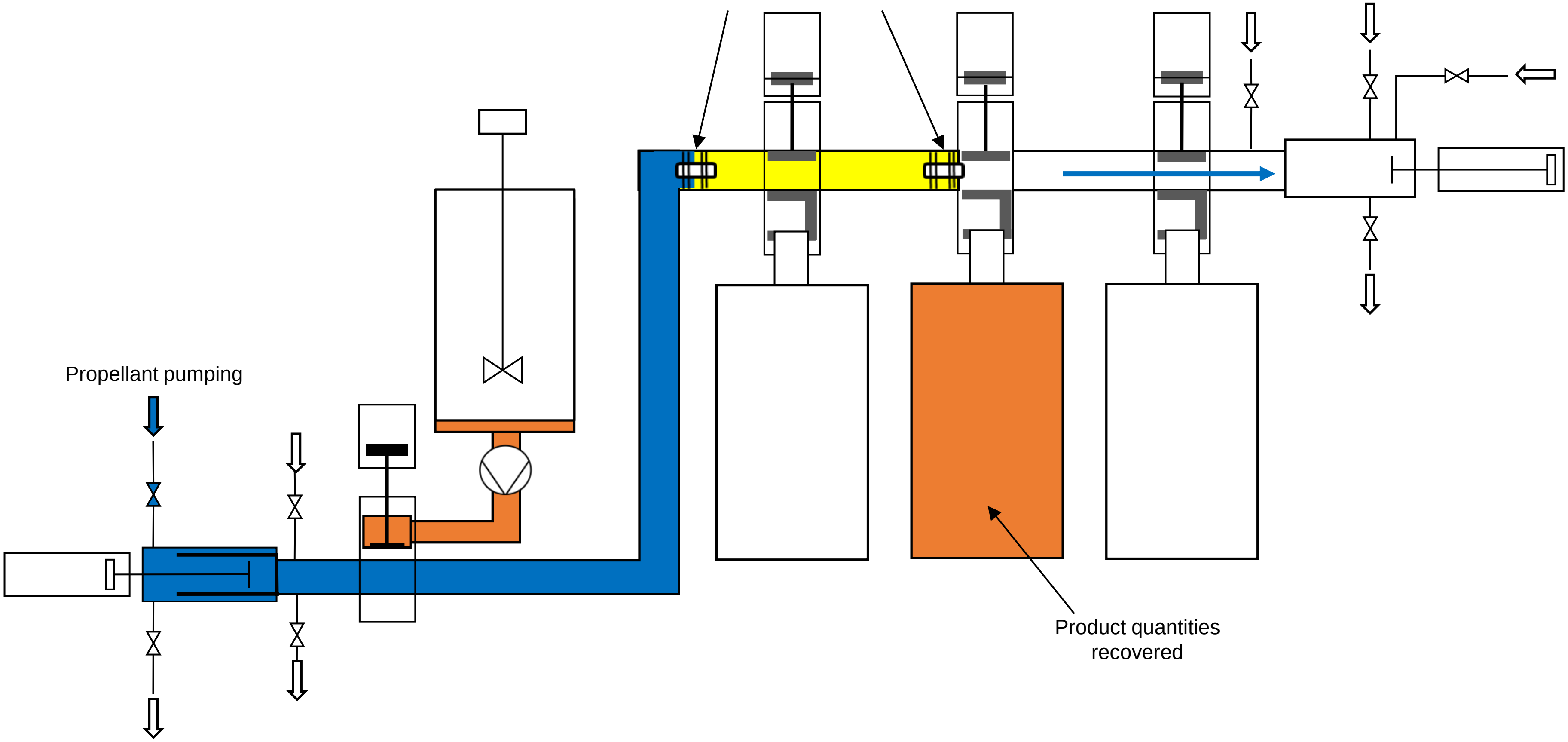
Step 4: Propellant Pumping (Continued)

Source: based on Kiesel



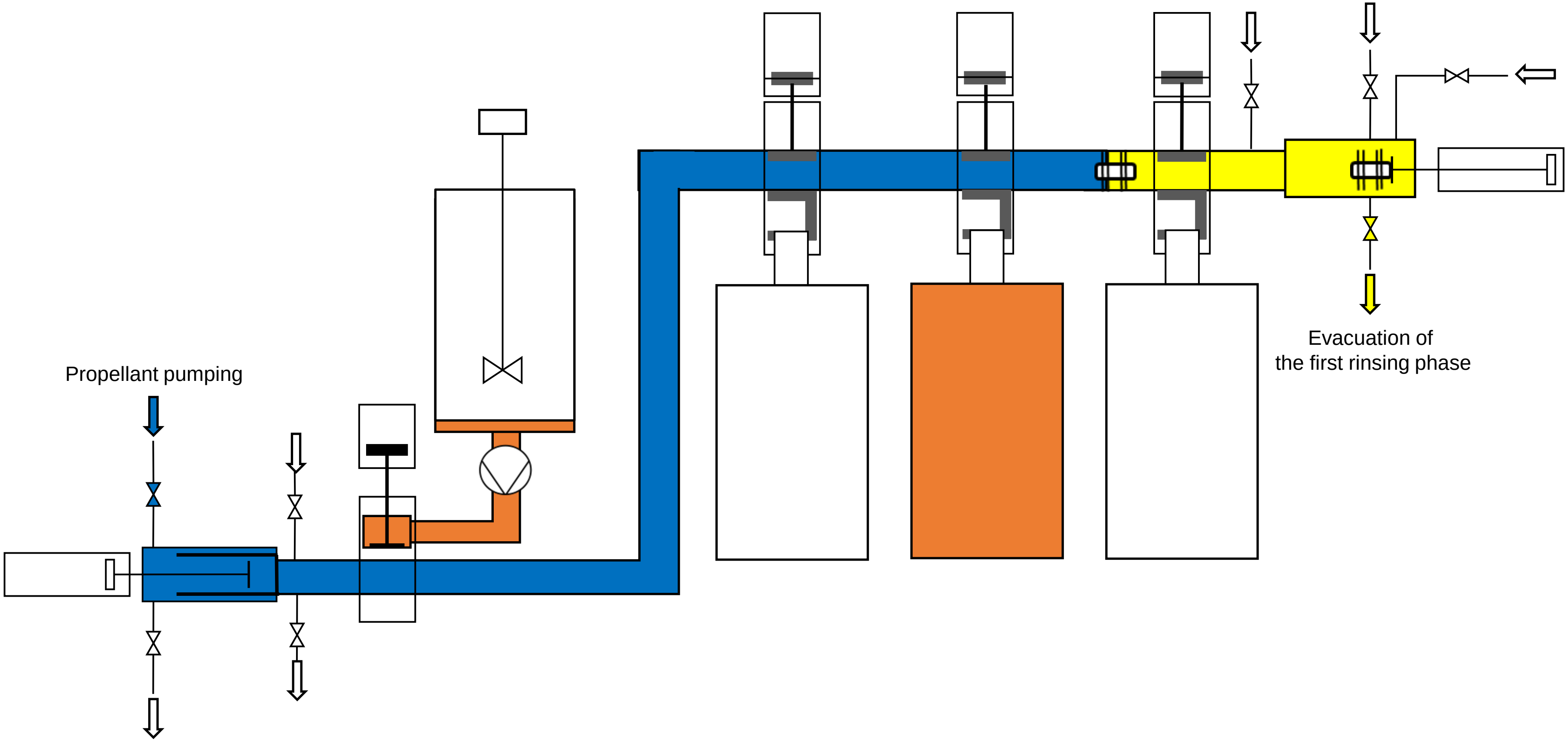
Step 4: Propellant Pumping (Product Fully Recovered)

Source: based on Kiesel



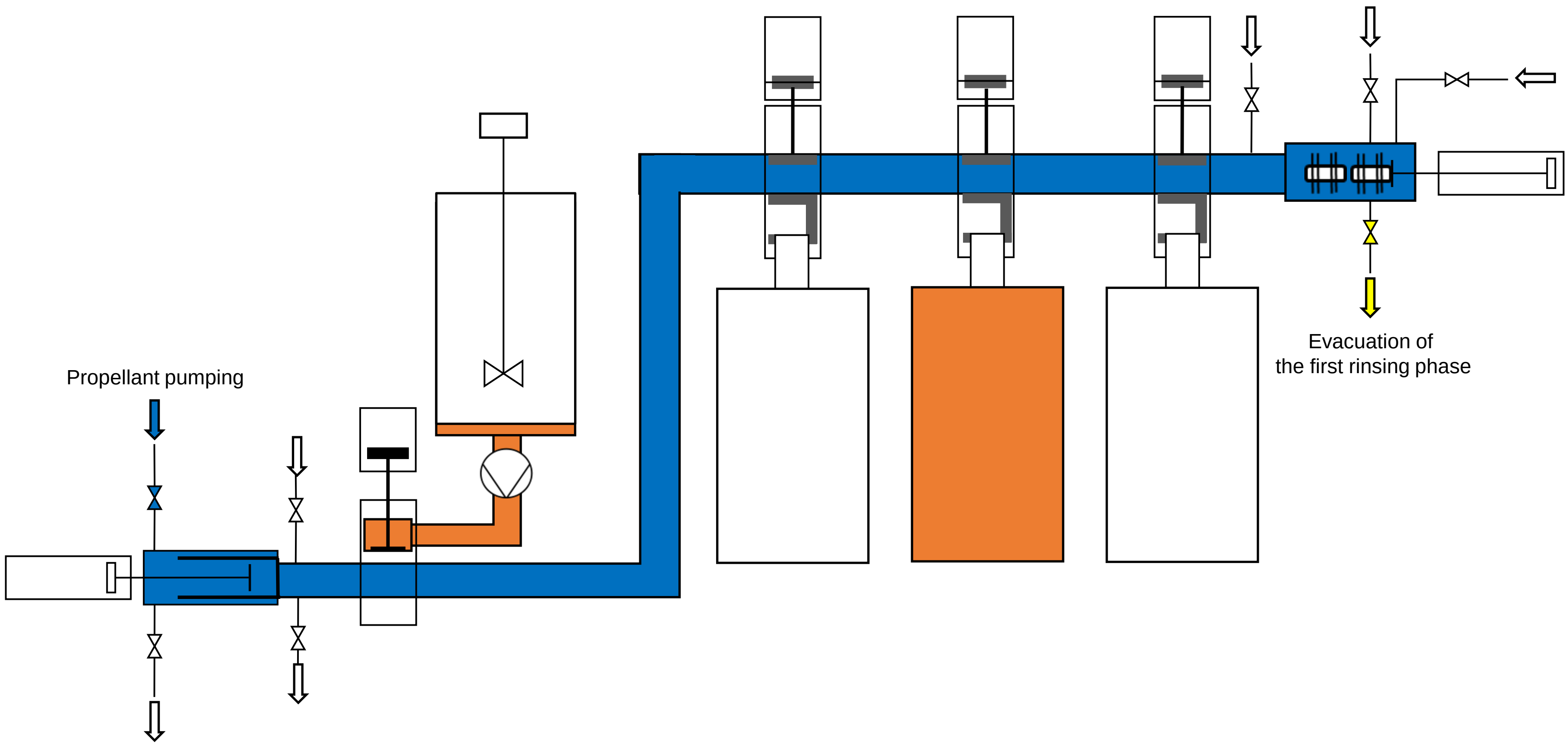
Step 5: Evacuation of the Rinsing Phase

Source: based on Kiesel



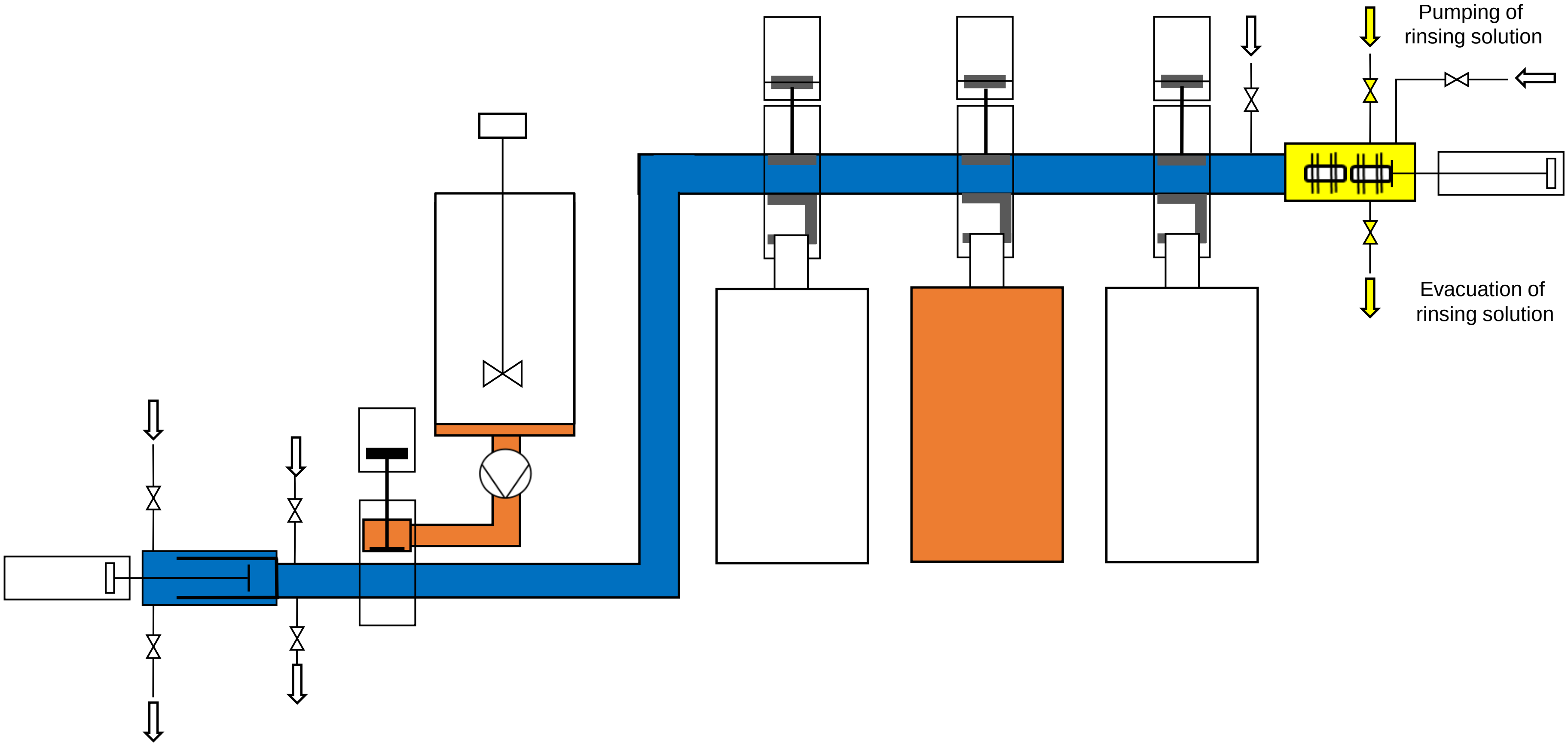
Step 5: Evacuation of the Rinsing Phase (Continued)

Source: based on Kiesel



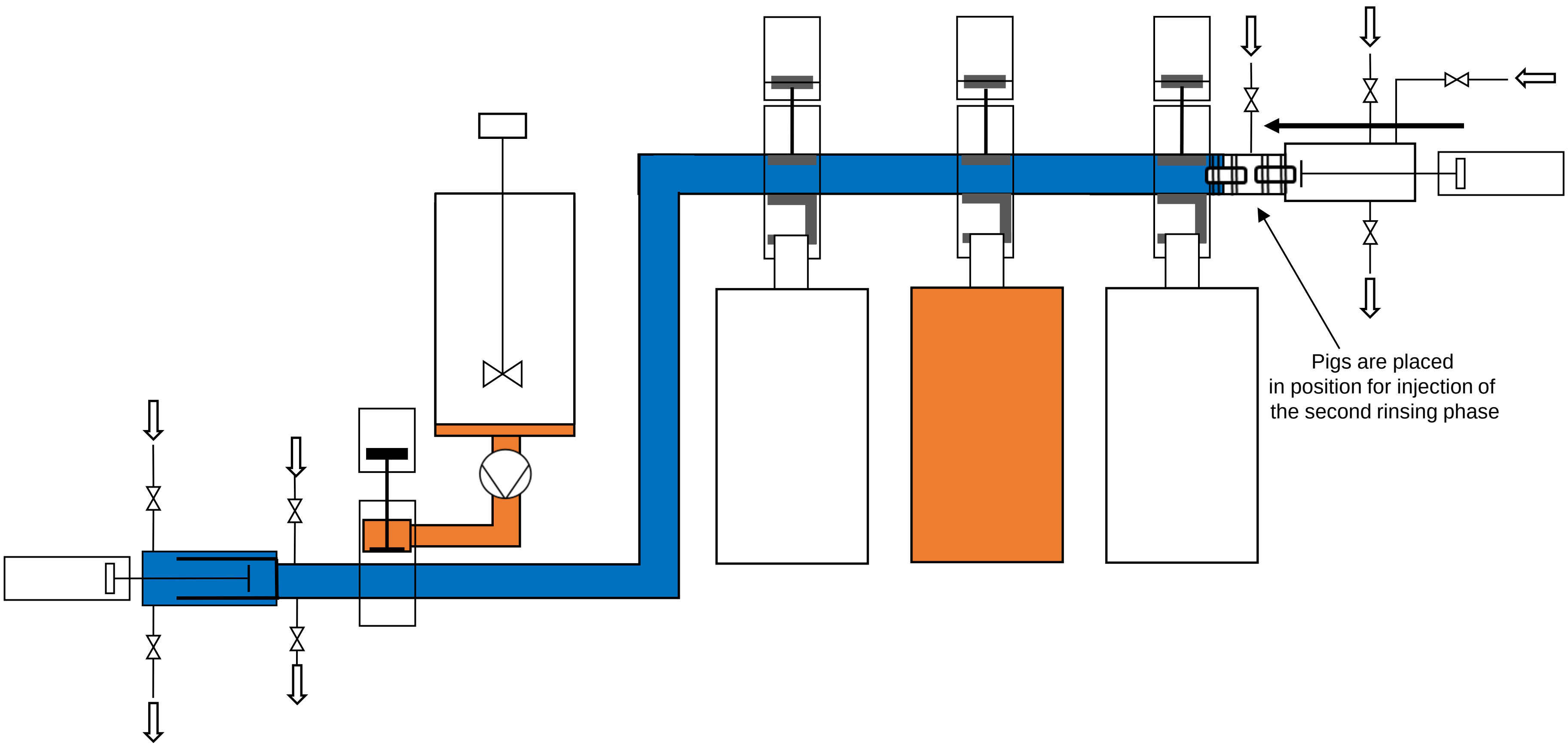
Step 6: Rinse in the Receiving Station

Source: based on Kiesel



Step 7: Return to Launching Station (Placing Pigs in Position)

Source: based on Kiesel



Step 7: Return to Launching Station (Pumping of the Second Rinsing Phase)

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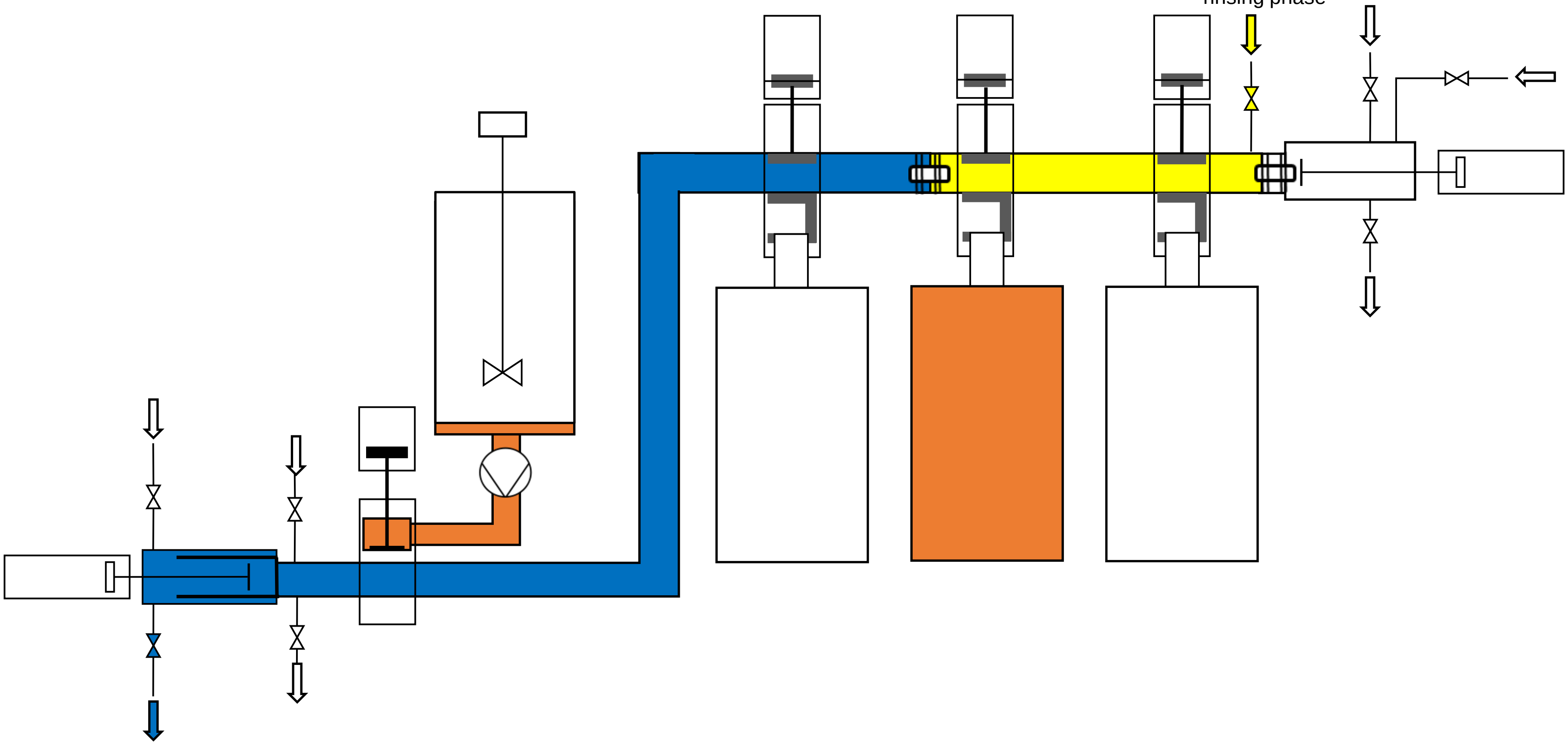
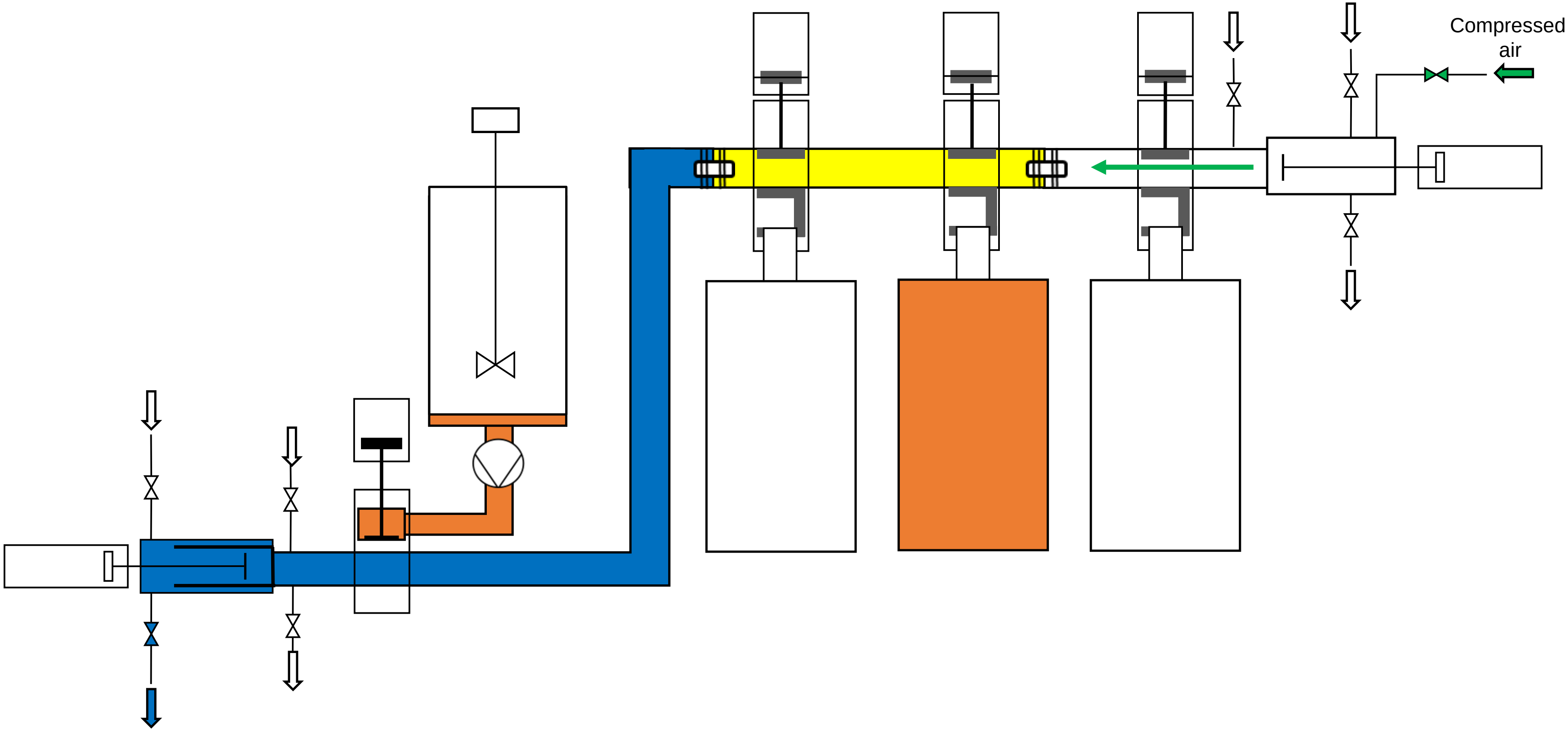


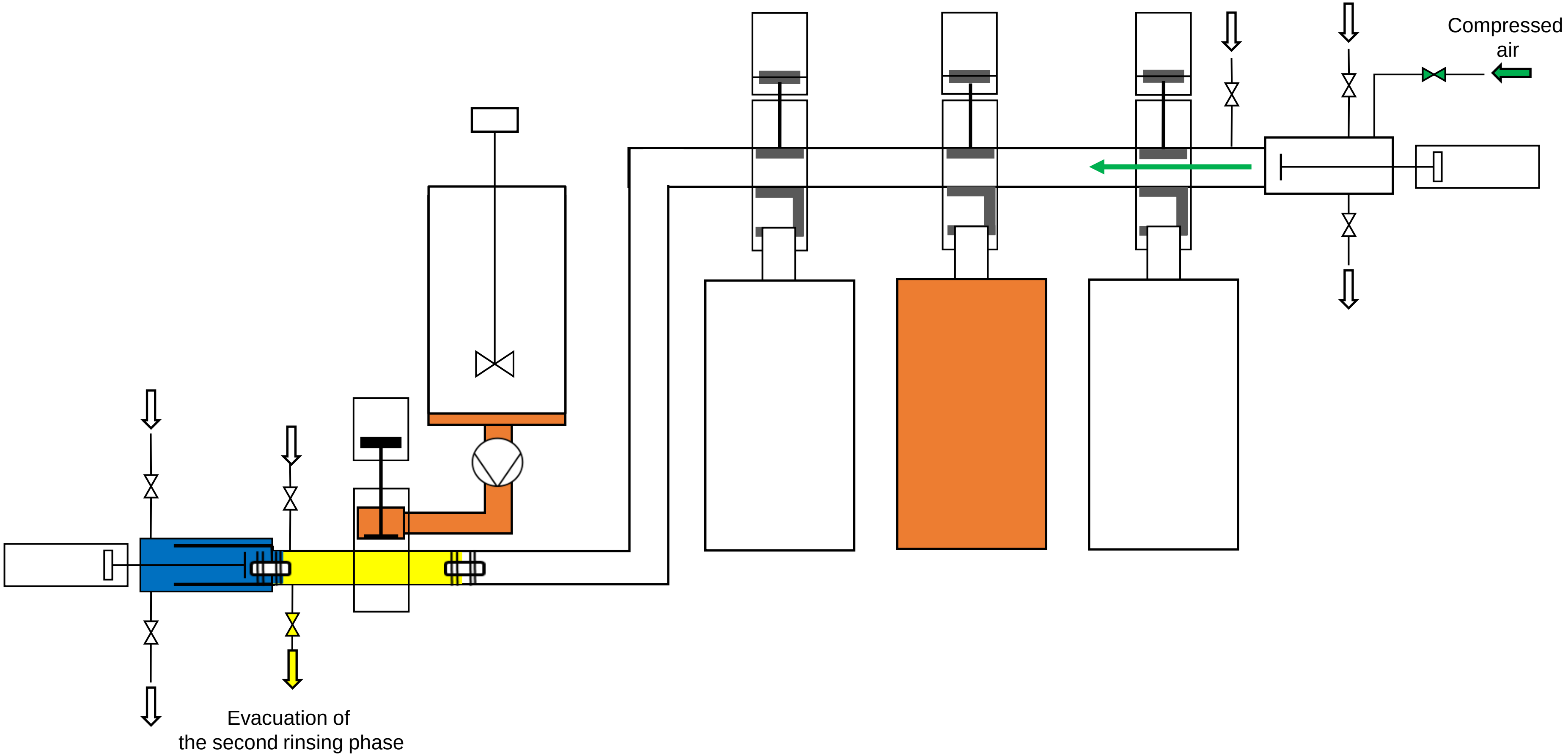
Step 7: Return to Launching Station (Start of Propellant Evacuation)

Source: based on Kiesel



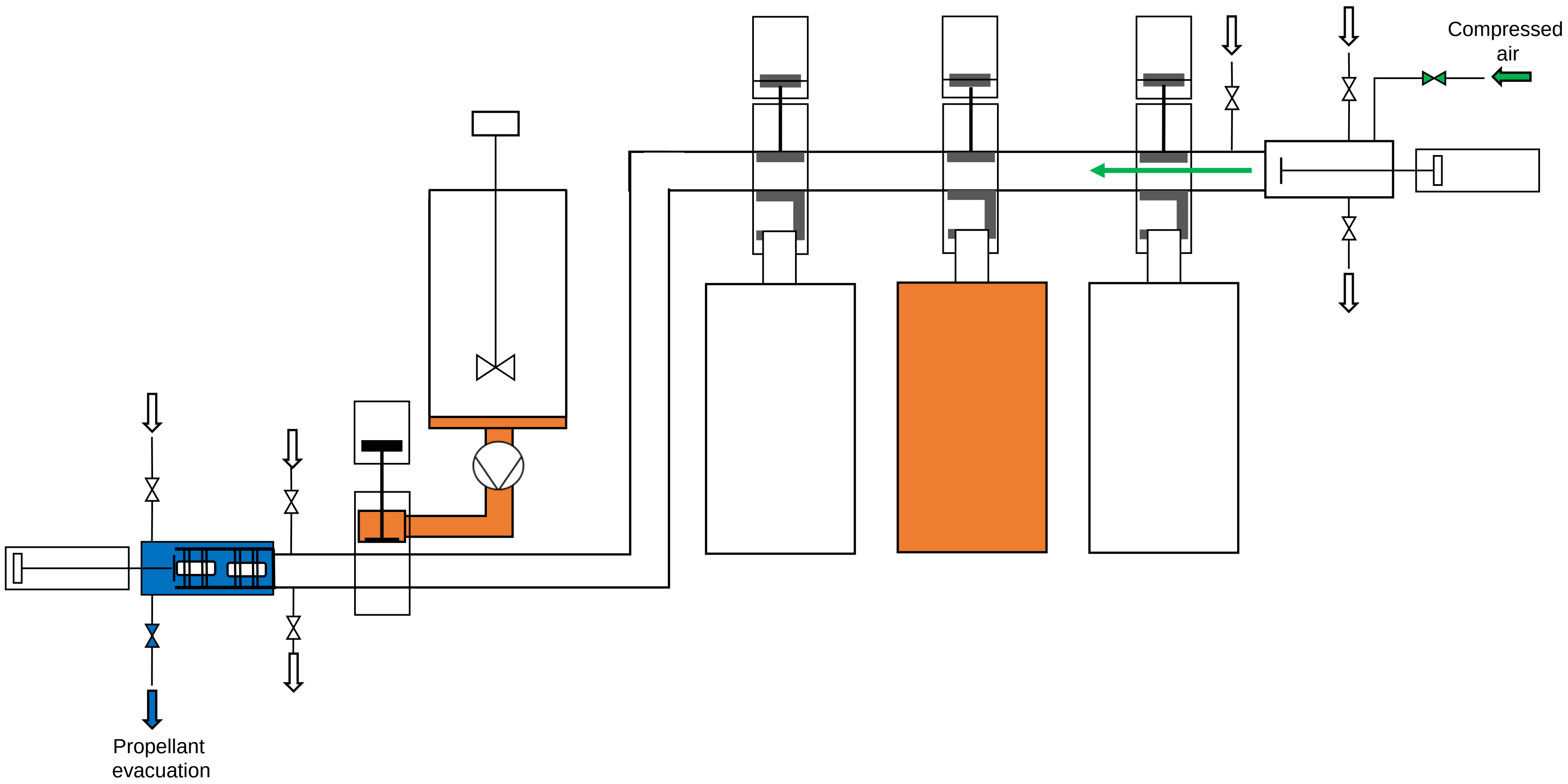
Step 7: Return to Launching Station (Evacuation of the Second Rinsing Phase)

Source: based on Kiesel



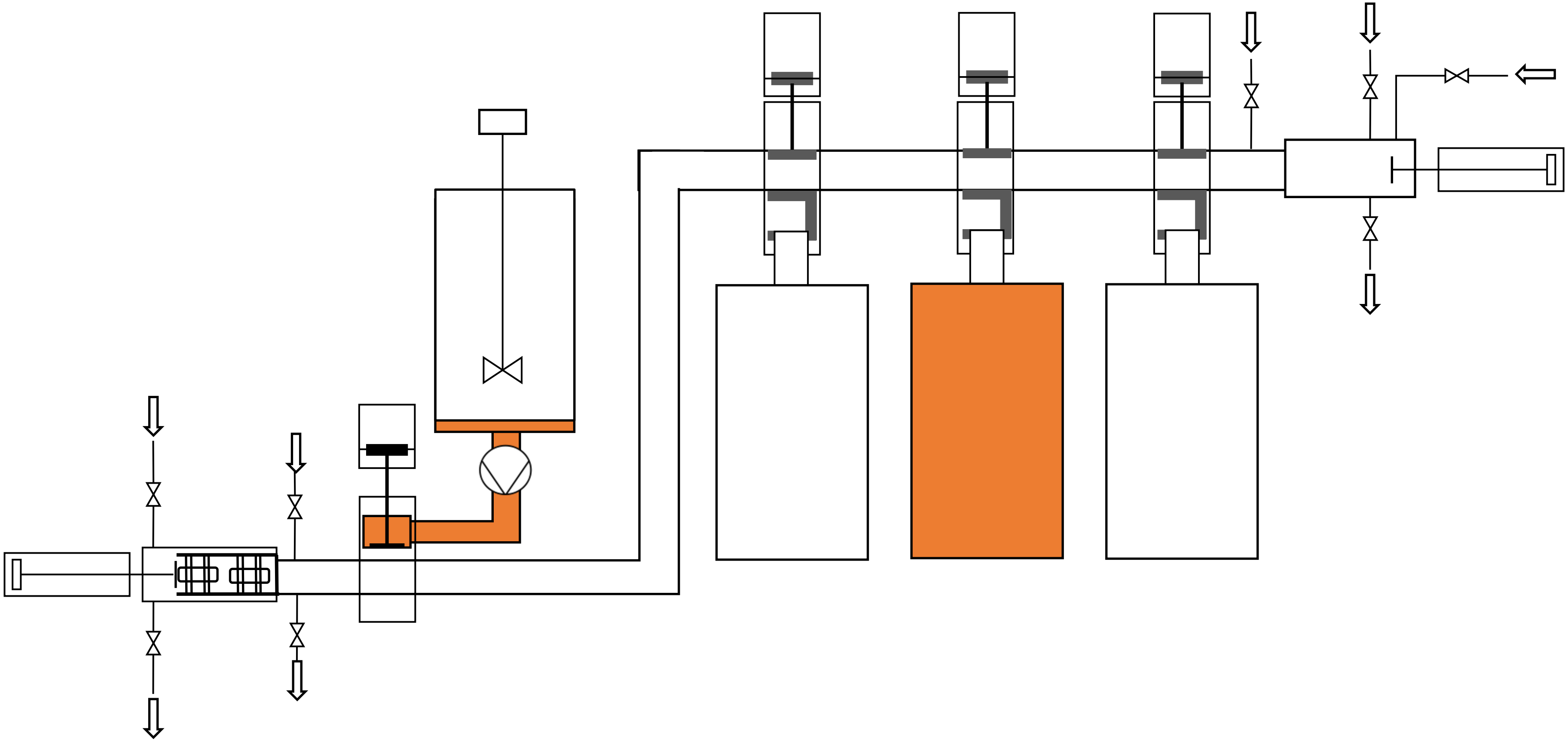
Step 7: Return to Launching Station (Evacuation of the Remaining Propellant)

Source: based on Kiesel



Step 8: Return to Initial Position

Source: based on Kiesel



Pigging Systems

- Technology description
- Benefits and constraints
- Case studies

Constraints and Challenges of Pigging Systems

Aspects to consider when choosing the pipes:

- Pipe must be supplied in accordance with its specifications
- Pipeline cannot be pigged if it contains butterfly valves
- Diameters of pipe and piggable valve must be the same

Aspects to consider when choosing the valves:

- Gaskets should be resistant to the product and swell
- With sticky or polymerizable products, hardened product residues remain
- Outward leakage through the valve possible if gasket material with the wrong specifications is used

Constraints and Challenges of Pigging Systems

Possible problems regarding pigs include:

- Pipes have to be examined before inserting a pig
- Pigs show their strengths and weaknesses only after a longer period of operation. Frequent defects include:
  - Running time too short
  - Insufficient resistance to the product
  - Destruction by an obstacle projecting into the pipeline

Possible problems regarding the control system include:

- Errors in the logic diagrams occurred during programming
- Errors in signal processing preventing the system from proceeding to the next phase
- Wrongly adjusted response times in the sequence control leading to malfunctions (e.g. pig does not return to its end position)

Pigging Systems

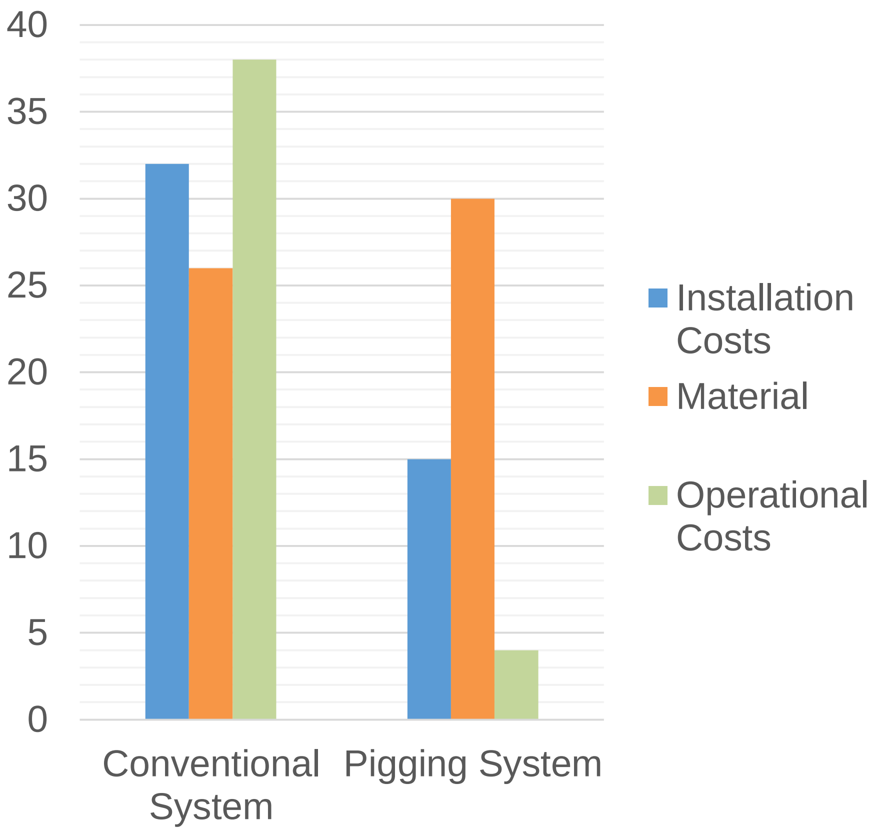
- Technology description
- Benefits and constraints
- Case studies

Case Study 1: Infrastructure and Operational Cost Advantages of Pigging Systems

- Cost comparison between a conventional pipeline system with 10 pipelines and a pigging system with only one pipeline

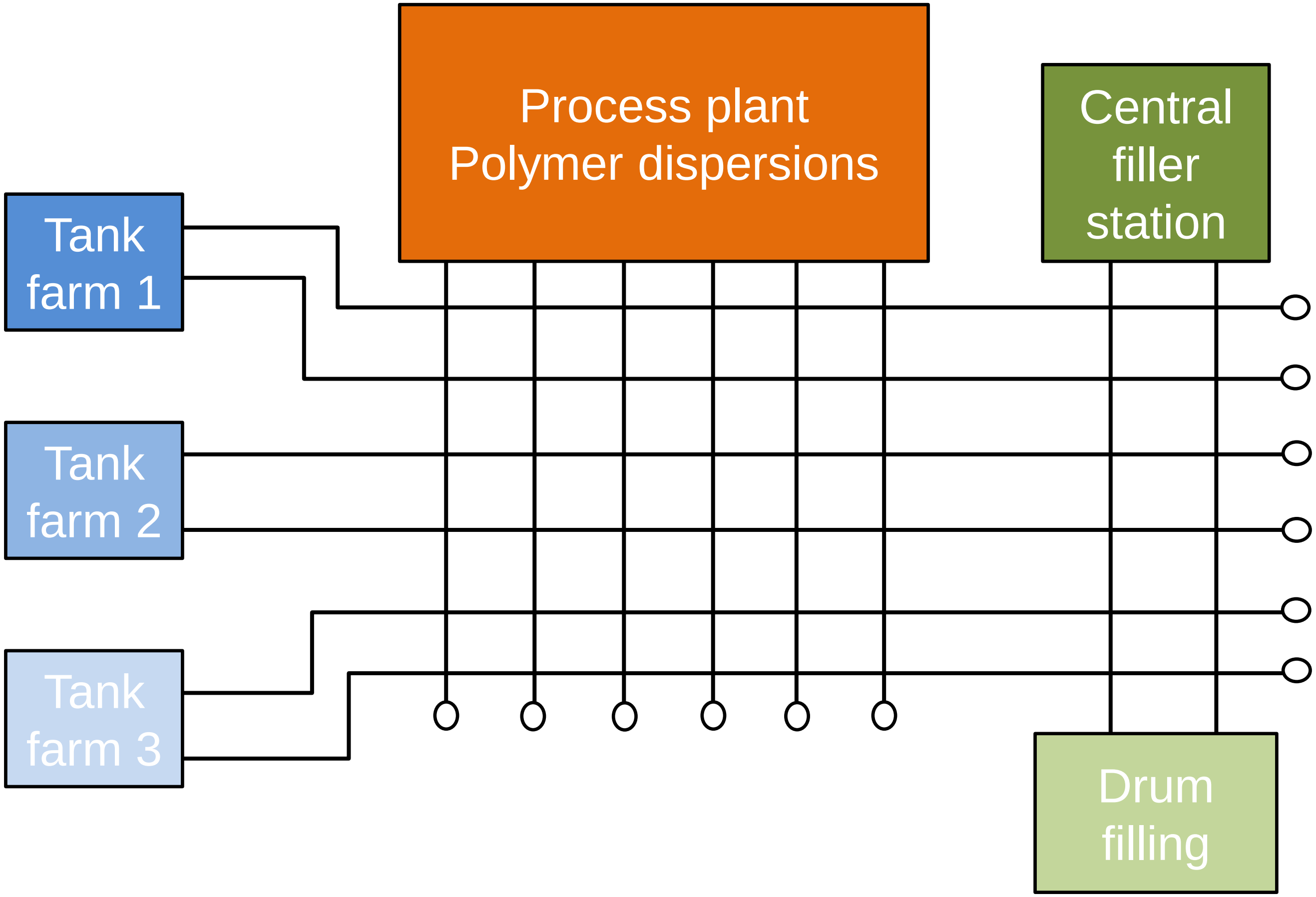
- Comparison of the regular costs referring to rinsing costs and product losses in relation to the wear costs for the pigs

Example from a chemical plant



Case Study 2: Polymer Dispersions

Overview of the pigging lines in a dispersion plant



Case Study 2: Polymer Dispersions

At a production plant, the following pigging lines are installed:

- Between storage tanks and heat exchangers
- Between vessels and deodorization columns
- Between conditioning tanks and filters

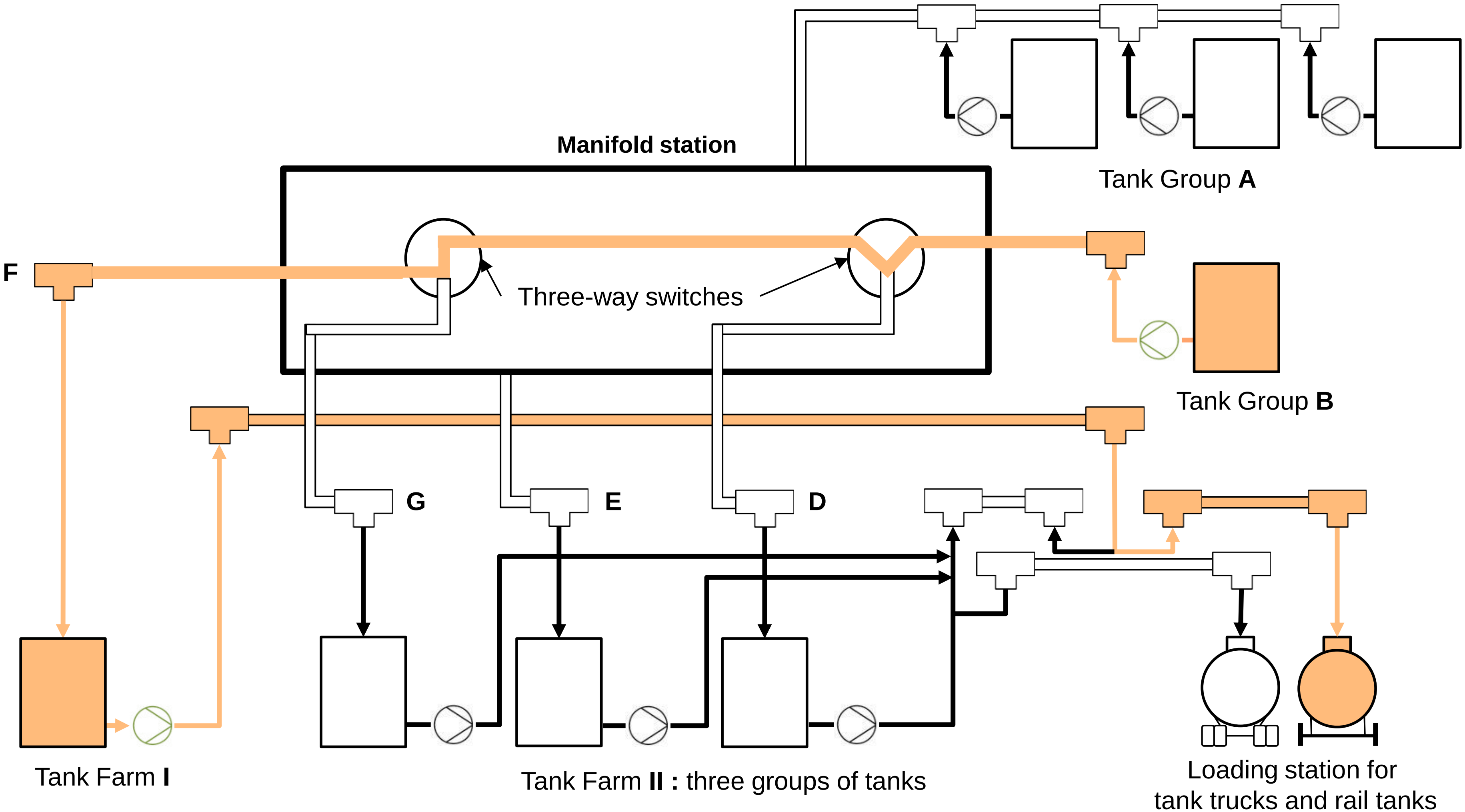
The storage tanks and the loading facilities are connected by the following pigging lines:

- To all storage tanks in three tank farms
- To the tank truck filling station
- To the drum filling station

Case Study 2: Polymer Dispersions

Production plant	After batch production, the products are stored in finished-product tanks for the filling process. The total production plant includes a raw-materials tank farm, several production buildings, a large storage tank farm for the finished products and a dispatch building. All buildings are connected by pipelines. All products are liquid and are filled into tank trucks, rail tanks, or containers.
Benefits	• Use of a single pipe for several products • Pipe cleaning by removal of the product • Pipes that were not used for product feeding had to be constantly filled with demineralized water • Flexibility with a large number of products, free allocation of the products to storage tanks, flexible use of the existing production lines • Substantial savings in wastewater costs • Recovery of valuable products

Case Study 3: Pigging Lines in a Urea Formaldehyde Plant



Case Study 3: Urea Formaldehyde

Production plant	The total plant consists of: i) A production plant (with production-intermediate vessels and a distribution station) ii) Two large tank farms, which are connected to the processing building by pipes (connecting pipelines between the production plant and the tank farms are up to 300 metres long) iii) Loading stations for tank trucks and rail tanks supplied with products from the tank farms. The aqueous urea formaldehyde condensation products are continuously produced and stored in the finished-product tanks in the tank farms and, after an inspection, are held for dispatch.
Benefits	• Using one pipeline for several products of a product family • Emptying and cleaning of the pipeline by almost complete removal of the product • Rapid product change by complete separation of the products • Avoidance of product losses by cleaning • Preventing the clogging of pipes due to product condensation • Substantial savings in wastewater costs • Achieving uniformly high product quality

Case Study 3: Urea Formaldehyde

At the production plant, the following pigging lines are installed:

- From Tank Group A to the manifold station (10 three-way switches)
- From Tank Group B to the manifold station
- From the manifold station to Tank Farms I and II

The storage and filling facilities are connected by the following pigging lines:

- From Tank Farm I to Tank Farm II
- From three groups of tanks to the tank truck loading facility
- From three groups of tanks to the rail tank loading facility

Whirlwind Systems

- Technology description
- Benefits and constraints
- Case studies

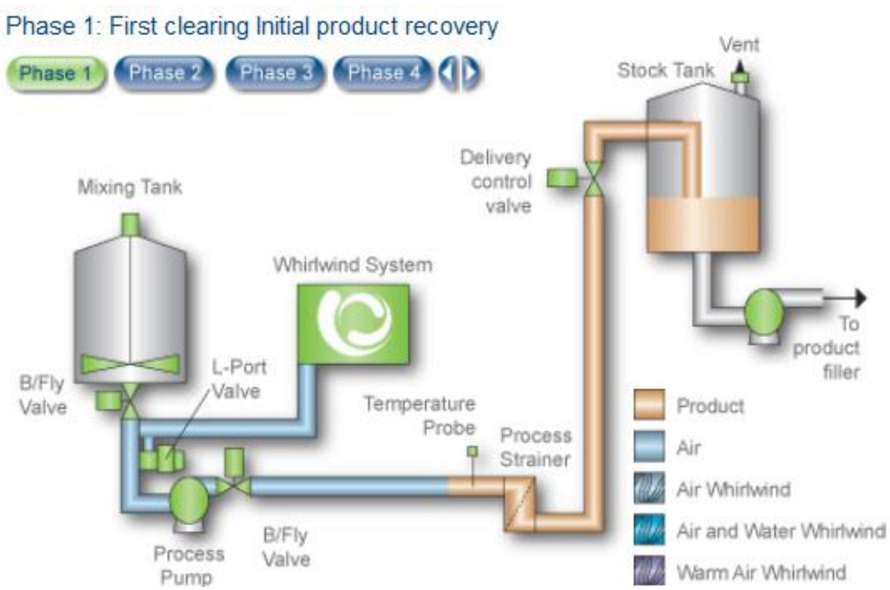
Technology Description

Can be used to clean:

- Pipes (as with pigging)
- Valves, pumps, filters, heat exchangers

Components:

- Pipe clearing unit
- Pipe cleaning unit
- Extra valves for flow path control (if necessary)
- Gas scrubber (if necessary)
- Cyclone (if necessary)



Source: Rulandec

Whirlwind Cleaning Cycle

Cleaning with whirlwind technology includes the following steps:

1. A laminar airstream is blown through processing pipework (60-80% of the product will be recovered).
2. A whirlwind is generated within the airstream which clears the remaining product (less than 5% of the product remains on the inner surface).
3. Droplets of water or cleaning agent (2-10 l/min) are introduced into the airflow (after this step the inner surface is 100% clean).
4. The air is heated and the pipework is completely dried.

Whirlwind Systems

- Technology description
- Benefits and constraints
- Case studies

General Constraints

- Shut-off elements within a pipeline have to be removed and cleaned separately.
- Whirlwind ineffective if change in diameters of a pipeline is too great (i.e. > twice the initial diameter).

➔ Special bypasses have to be installed to use the technology.

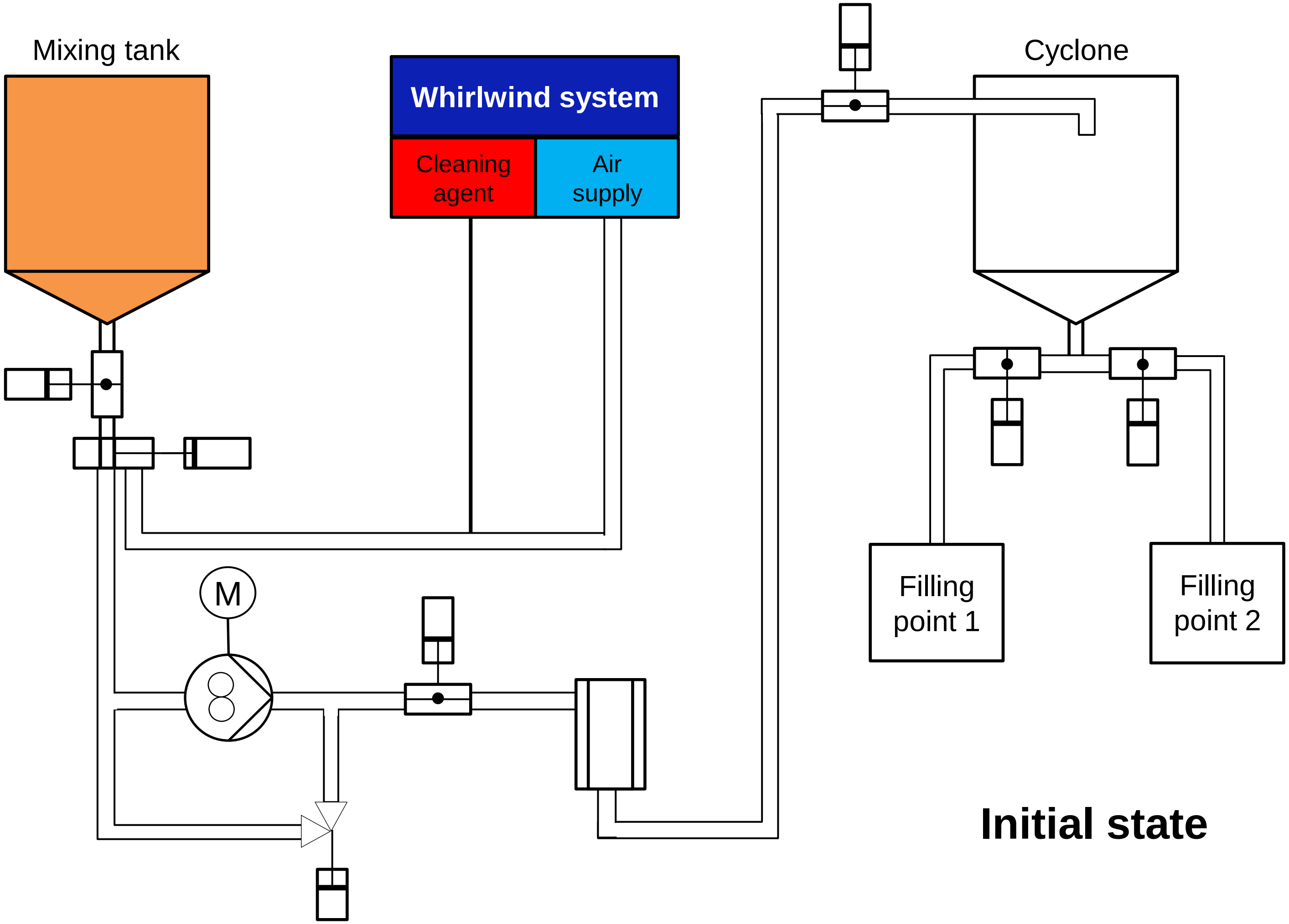
Whirlwind Systems

- Technology description
- Benefits and constraints
- Case studies

Case Study 4: Pipeline Cleaning I

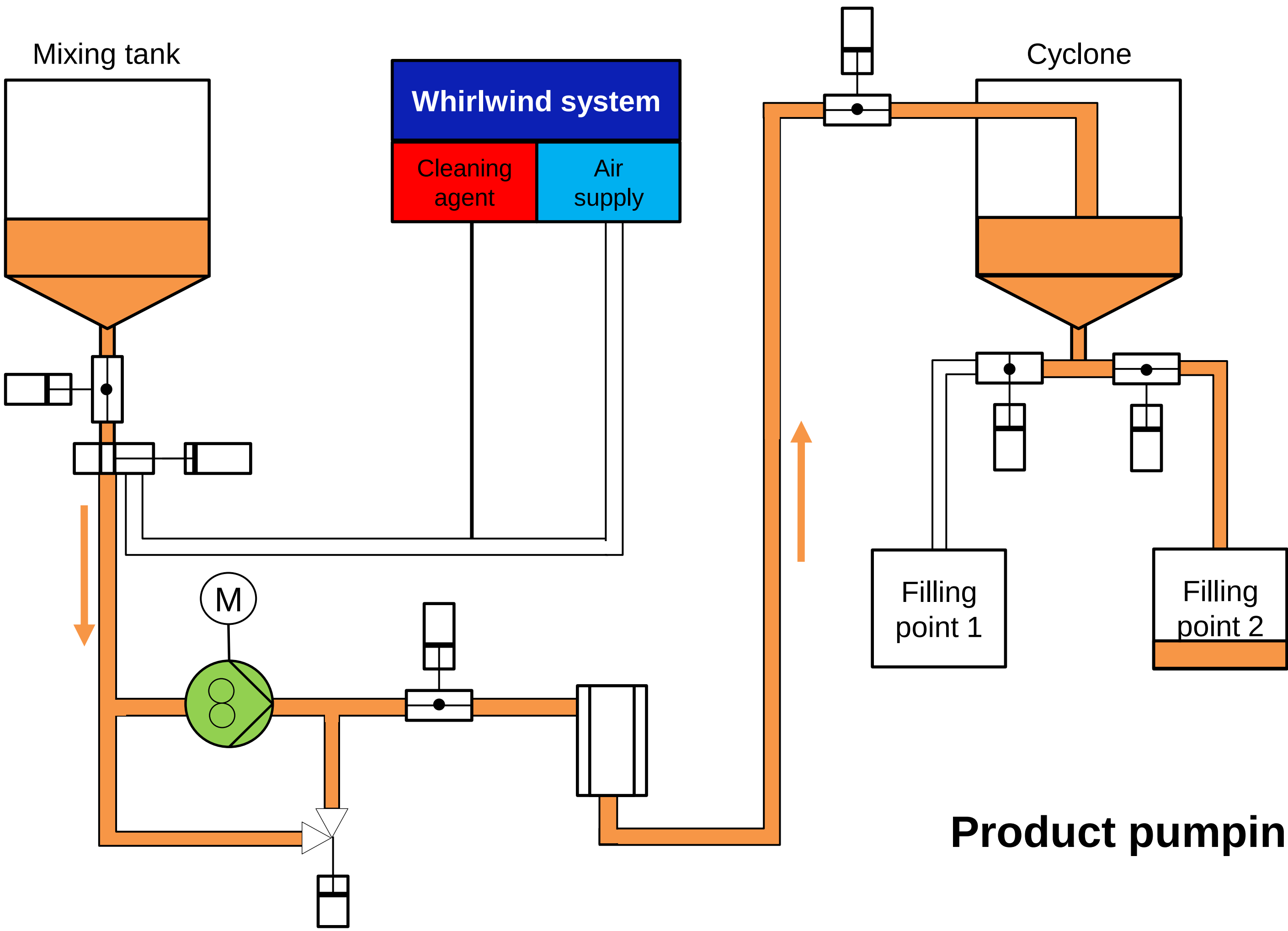
Procedure	A paint production company manufactures paints in discontinuous batch mode. Between each production process, the extensive pipeline network for paint transport is emptied and cleaned with water. Whirlwind technology is installed to optimize the process. In a multi-stage procedure, an airflow is generated that clears and cleans the pipelines.
Benefits	• Product yield increased by approx. 16% to an overall 90-95% • Reduction in water and cleaning agent consumption by 70% to 100 litres per cleaning procedure • Intensification of the cleaning procedure and minimization of product residues

Case Study 4: Pipeline Cleaning I



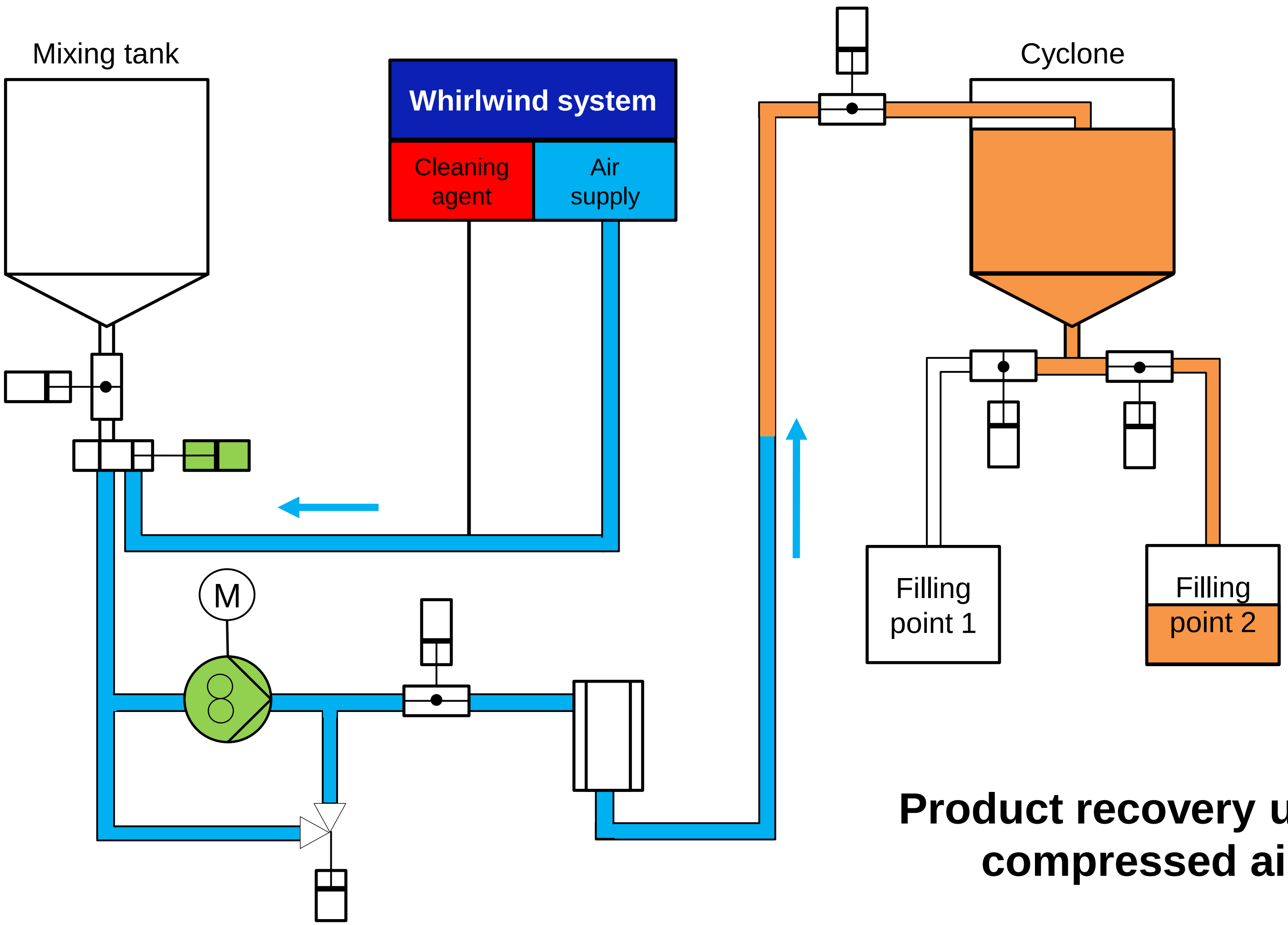
Initial state

Case Study 4: Pipeline Cleaning I



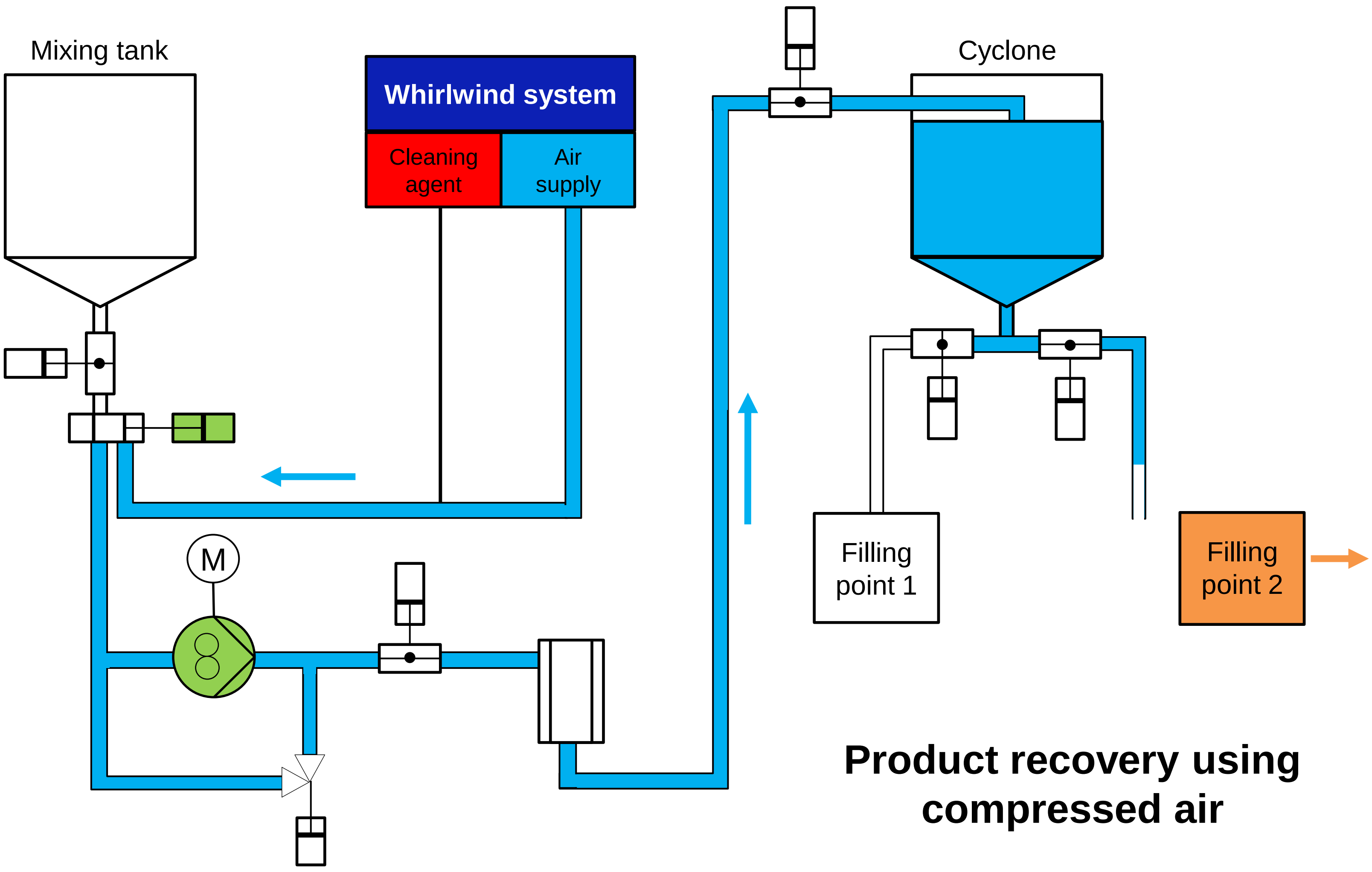
Product pumping

Case Study 4: Pipeline Cleaning I



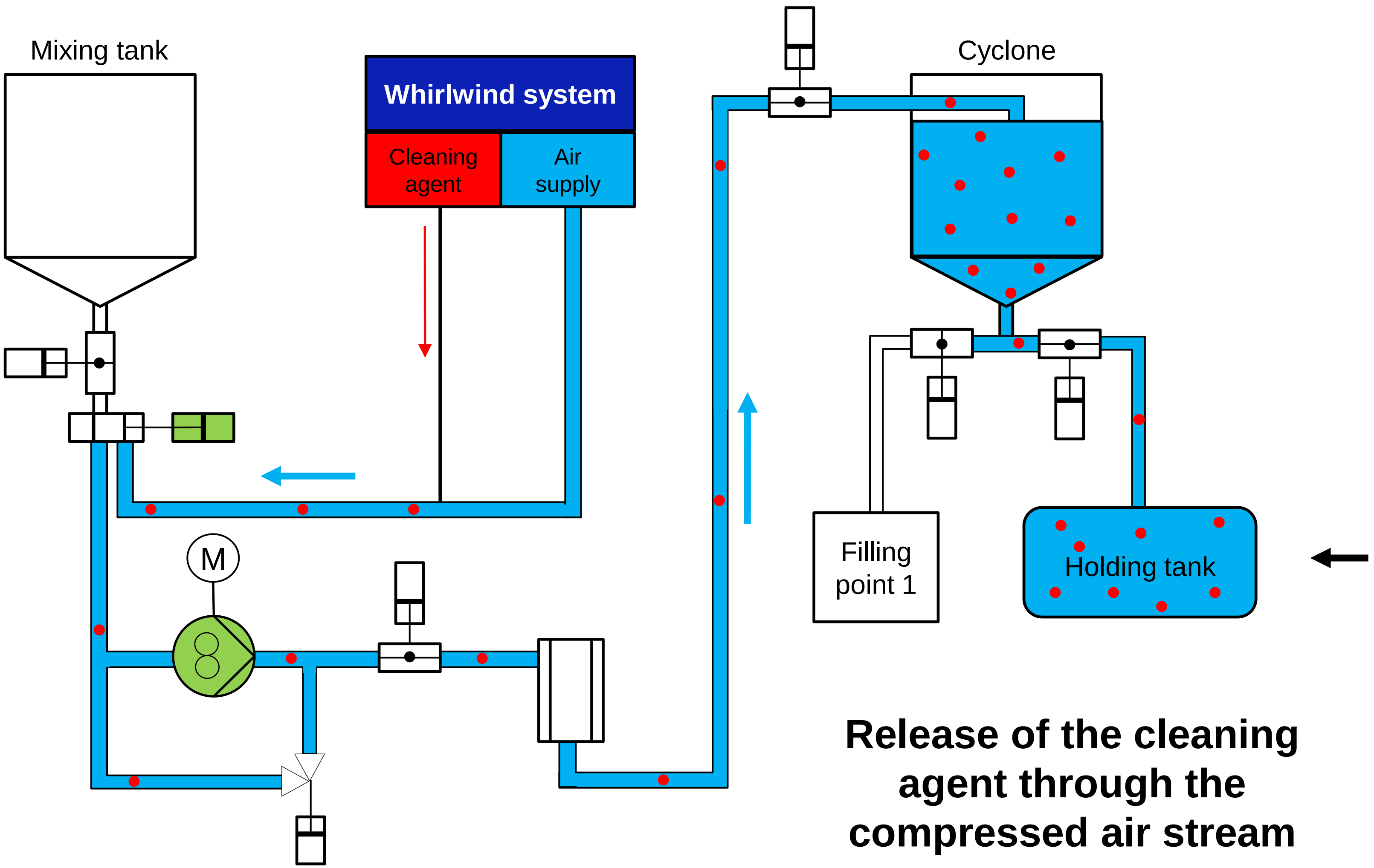
Product recovery using compressed air

Case Study 4: Pipeline Cleaning I



Product recovery using compressed air

Case Study 4: Pipeline Cleaning I



Release of the cleaning agent through the compressed air stream

Case Study 5: Pipeline Cleaning II

Procedure	A large national food manufacturer operates from multiple sites and produces tomato ketchup, sauces and various well known brands. The company's production facility works 24/7 and has many filling lines with frequent changes on each line involving CIP cleaning. Before installing a conventional CIP cleaning system, the company flushed the product left in the pipe down the drain at the end of each production run. This process used thousands of cubic metres of valuable water every year. Therefore, in late 2007, a clearing and cleaning system using whirlwind technology was installed.
Benefits	Within less than six months, the system generated significant savings for the client: • Product savings estimated at a minimum of 3,000 m^3 per year • Reduction in water consumption estimated at 65,000 m^3 and £65,000 per year • Reduction in effluent volume estimated at 68,000 m^3 and £200,000 per year • Reduced changeover time estimated at one hour per product changeover • Reduction in tank disposal of product waste estimated at £30,000 per year • Reduction in chemical costs estimated at £10,000 per year • Elimination of the risk of product cross contamination

Key Messages (I)

Manufacturers of chemical products often need to clean processing equipment between different batches of products. To do this, they need to remove the existing product from pipelines and vessels. Product loss and waste generation resulting from the cleaning of processing equipment increase production costs and have a negative impact on sustainability.

- Product recovery is typically done in combination with Clean-in-Place.
- The product (e.g. cosmetics, paints, polymers, etc.) remaining in the pipelines and process equipment has economic value and can be recovered using the following techniques:
  - Pigging systems
  - Whirlwind systems
  - Both technologies have options to combine product recovery and cleaning of process equipment and pipeline circuits.

Key Messages (II)

The choice of product recovery technology depends on certain criteria, e.g.:

- What is the substance to be removed and its volume?
- Where is the substance located, radially or longitudinally?
- Does the substance present any hazards?
- How is the pipe system designed (diameters of different parts, length, etc.)?
- What is the viscosity of the product to be removed?

Aspects must be considered when choosing pigging technologies, e.g.:

- Pipeline cannot be pigged if it contains butterfly valves
- Diameters of pipe and piggable valve must be the same
- Outward leakage through the valve possible if gasket material with the wrong specifications is used

Aspects to be considered when choosing whirlwind technology, e.g.:

- Shut-off elements within a pipeline have to be removed and cleaned separately.
- Whirlwind ineffective if change in diameters of a pipeline is too great (i.e. > twice the initial diameter).

Sources

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Images

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