

The Microfluidic Reagent Storage Handbook for Diagnostic Developers

A Guide to
Reagent Storage
in Microfluidic
Cartridges

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Executive Summary



Select microfluidic reagent storage concepts early in development



Align storage strategy with final manufacturing requirements



Consider scalability beyond proof-of-concept testing



Use dry reagent solutions to maximize shelf life



Leverage carrier-based technologies to improve quality control and production efficiency



Design with both assay performance and commercialization in mind

Reader Benefits

THIS GUIDE WILL HELP YOU:

- Evaluate liquid and dry storage options
- Understand common development pitfalls
- Compare storage technologies
- Select a scalable manufacturing strategy



Why Reagent Storage Determines Product Success

- ➔ GROWTH OF POC DIAGNOSTICS
- ➔ IMPORTANCE OF USABILITY
- ➔ WHY REAGENT STORAGE IS OFTEN UNDERESTIMATED

Point-of-care (POC) diagnostics have transformed how testing is performed, bringing laboratory-quality results closer to patients, clinicians, and field operators. The key to this convenience is simplicity: users should be able to run complex assays with minimal training and very few manual steps.

To make that possible, the reagents required for an assay must be stored directly on the microfluidic cartridge design. While often overlooked during early development, reagent storage plays a critical role in:

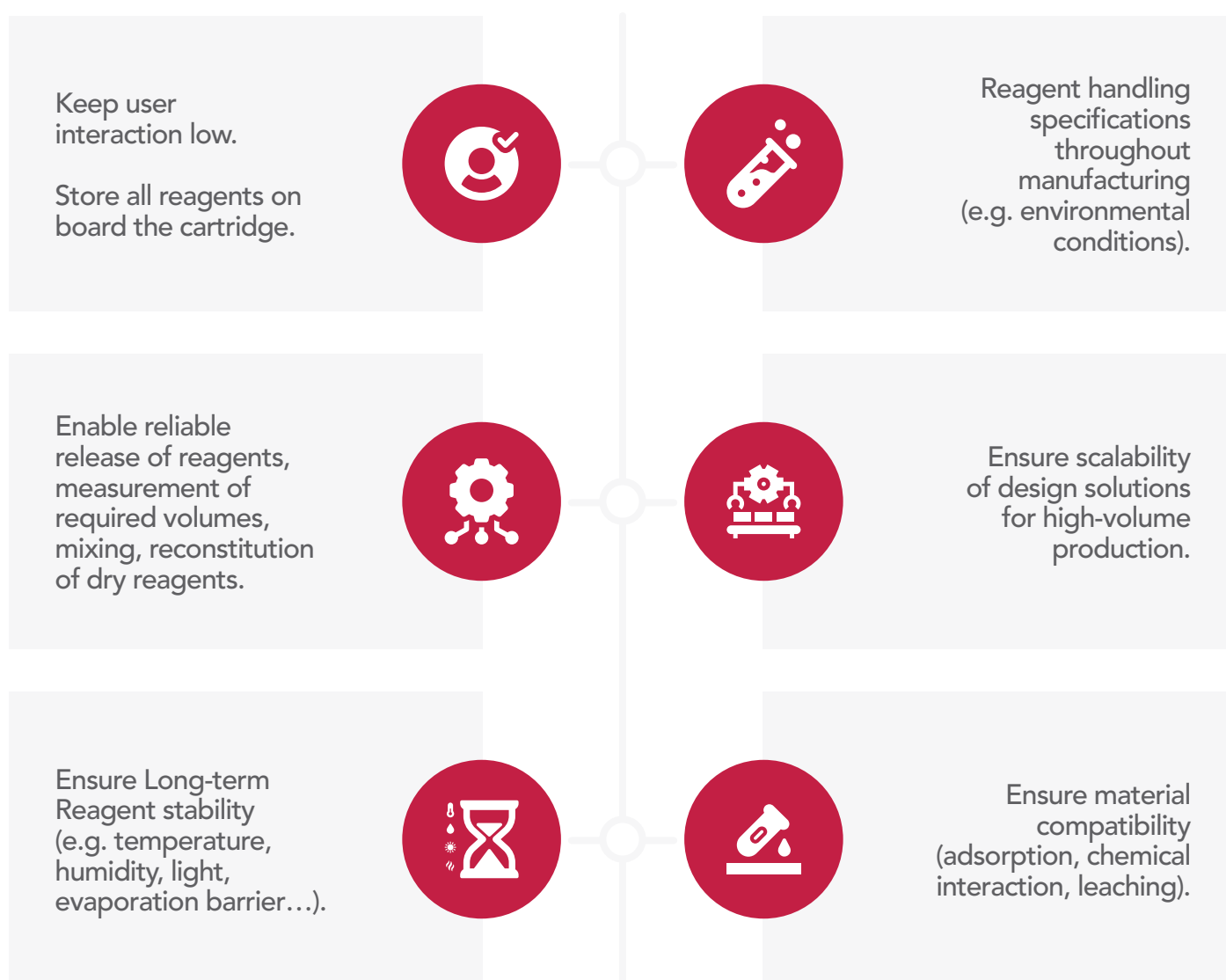
- ➔ Device reliability
- ➔ Assay performance
- ➔ User experience
- ➔ Shelf-life stability
- ➔ Manufacturing scalability



The wrong storage approach may work during proof-of-concept testing but can quickly become a bottleneck when transitioning to high-volume production. That's why reagent storage should be considered from the earliest stages of microfluidic cartridge design.

Why Reagent Storage Determines Product Success (Cont.)

Development Challenges in POC





Designing Backward From the Assay

➔ **EVERY SUCCESSFUL MICROFLUIDIC DEVICE
BEGINS WITH A CLEAR UNDERSTANDING
OF THE ASSAY REQUIREMENTS**

Minimize User Interaction

- ➔ Pre-loaded reagents
- ➔ Reduced pipetting
- ➔ Simplified workflow

Enable Reliable Fluid Management

- Metering ➔
- Mixing ➔
- Controlled release ➔
- Reconstitution ➔

Ensure Long-Term Stability

- ➔ Manufacturing
- ➔ Shipping
- ➔ Storage
- ➔ End-use

Support Scalable Manufacturing

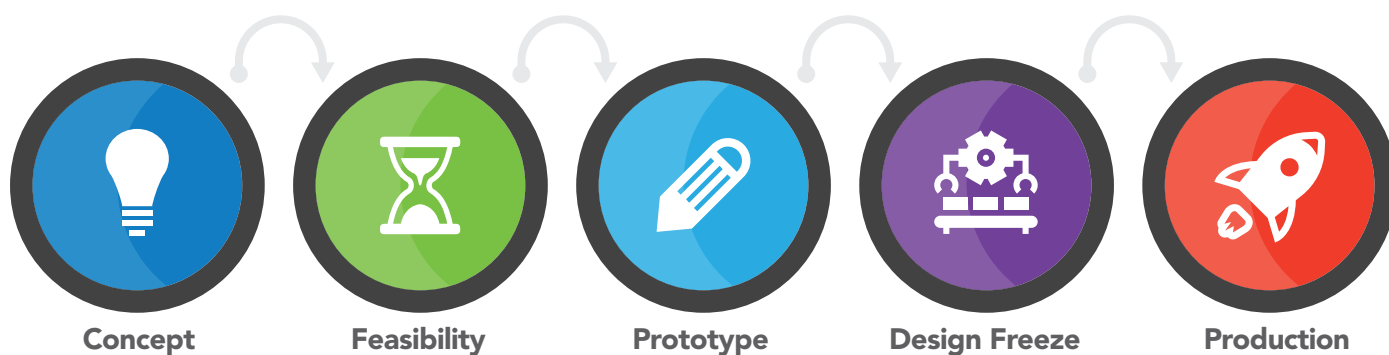
- Automation ➔
- Cost control ➔
- Robustness ➔
- High-volume production ➔



FOUR CRITICAL DESIGN REQUIREMENTS

The Hidden Cost of Late Storage Decisions

➔ MOST MICROFLUIDIC DEVELOPMENT PROJECTS FOLLOW A PHASE-GATE PROCESS:



COMMON DEVELOPMENT PATH

1. Concept
2. Feasibility
3. Prototype
4. Design Freeze
5. Production

A common mistake is selecting a storage solution that is easy to implement during feasibility testing but difficult to manufacture at scale.

TYPICAL MISTAKES

- ➔ Choosing convenience over scalability
- ➔ Redesigns during scale-up
- ➔ Manufacturing bottlenecks

A more effective strategy is to choose a scalable reagent storage concept from the start and maintain that approach throughout the entire product lifecycle.

By leveraging proven, standardized technologies early, development teams can significantly reduce risk and accelerate time-to-market.

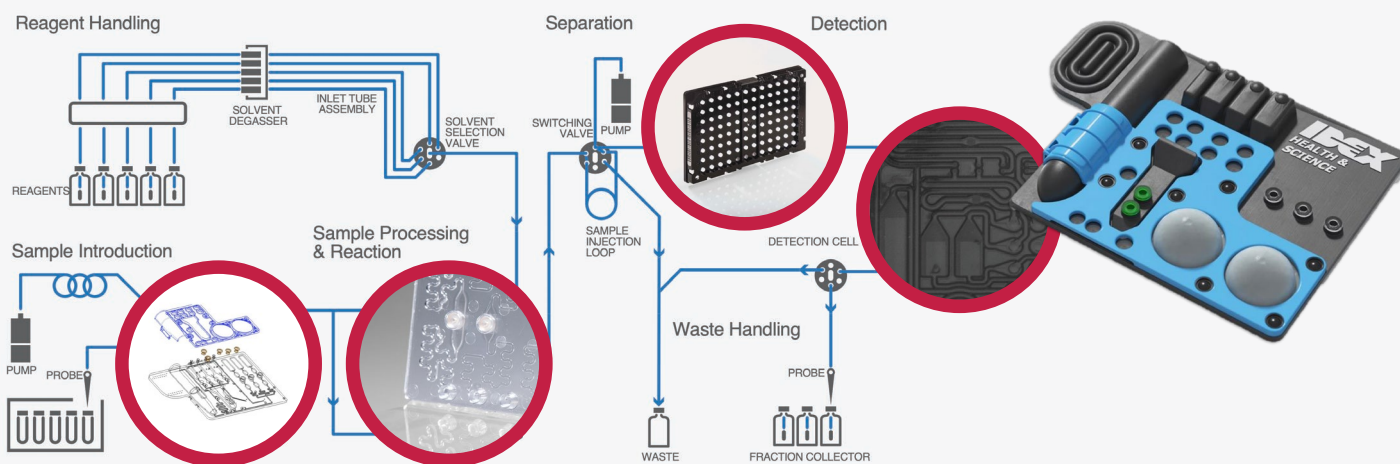


Development risk increases when reagent storage is added late.

The Hidden Cost of Late Storage Decisions (Cont.)

DEVELOPMENT PHASES

PHASE GATE APPROACH



thinXXS Development Process

The reagent plug can be adapted to the specific situation, but the concept does not change from concept through feasibility to production. Existing standards and test platforms can be used, and loops can be avoided, reducing the associated costs of developing a new card.

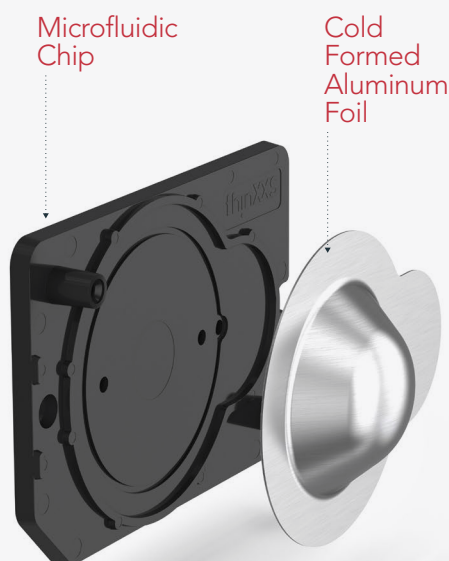
Liquid Reagent Storage Technologies

Liquid reagents remain essential in many diagnostic workflows, especially for buffers, wash solutions, and assay chemistries.

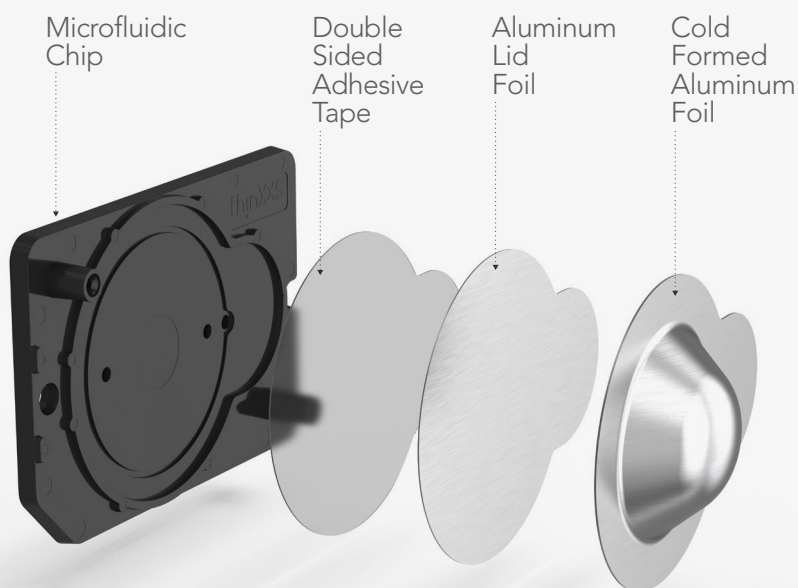
Two primary storage approaches commonly used are

Blister Packs and **Integrated Storage Tanks**.

thinXXS Integrated Blister Solution



Standard Industry Blister



Blister Pack Technology

➔ **BLISTER PACKS ARE AMONG THE MOST WIDELY ADOPTED SOLUTIONS FOR STORING LIQUID REAGENTS ON MICROFLUIDIC CARTRIDGES**

A Standard Blister Pack Consists of:

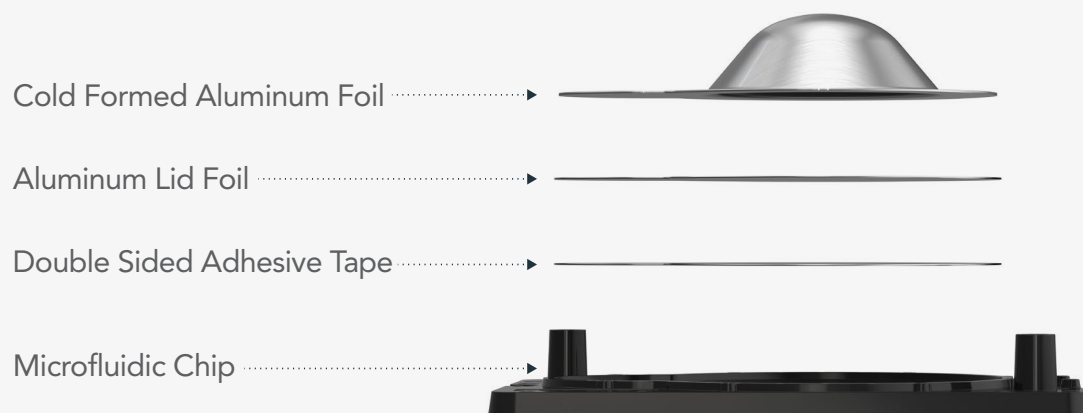
- ➔ A cold-formed aluminum blister dome
- ➔ An aluminum backing layer
- ➔ Adhesive attachment to the cartridge

HOW IT WORKS

Liquids are commonly stored either in separately prepared containers which are then assembled to the devices or in liquid tanks which are part of the cartridge backbone.

- 1.** The blister is compressed using a plunger.
- 2.** A piercing mechanism or frangible seal is activated.
- 3.** The liquid reagent is released into the fluidic network.

STANDARD INDUSTRY BLISTER



Blister Pack Technology (Cont.)

Blister Pack Technology Benefits & Challenges

BENEFITS

- Flexible storage volumes
- Reliable operation
- Established manufacturing methods

CHALLENGES

- Open-state filling processes
- Additional sealing steps
- Potential air entrapment
- Reduced liquid displacement consistency
- Increased processing complexity



Open blister is filled and then typically thermally sealed in a subsequent step. This may impact reagent stability, and furthermore, this will result in residual air inside the blister, which makes reagent displacement less reliable.

Other Approaches

Other proposed, but by far less common, approaches include Stick Packs or Glass Ampoules.



STICK PACKS



GLASS AMPOULES



Integrated Blister Technology

→ thinXXS INNOVATION SPOTLIGHT: A MORE ADVANCED APPROACH INTEGRATES THE BLISTER DIRECTLY ONTO THE MICROFLUIDIC CHIP

In the Integrated Blister Technology Design:

- The aluminum blister is sealed directly to the cartridge.
- Reagents are filled through dedicated fill ports after assembly.
- Assay-specific filling can occur late in production.

Mechanical actuation opens a frangible seal, enabling controlled liquid release with stable flow characteristics. Because the technology can also be implemented as a stand-alone module, it is particularly useful during:

- Early feasibility testing
- Rapid prototyping
- 3D-printed cartridge development

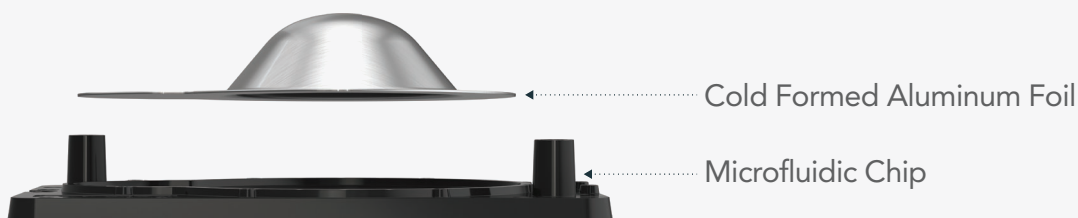
Benefits

- Lower material usage
- Simplified manufacturing
- Improved reagent protection
- Enhanced platform flexibility
- Consistent reagent delivery



The new thinXXS blister pack technology uses significantly less materials and requires fewer process steps.

thinXXS MICROTECHNOLOGY INTEGRATED BLISTER SOLUTION



The thinXXS blister pack utilizes a cold-formed aluminum foil that is directly sealed onto the microfluidic chip.



Integrated Liquid Tanks

For many biological assays, particularly those involving sensitive biomolecules, dry reagent storage is essential. These reservoirs are molded directly into the cartridge backbone during injection molding.

Ideal Applications

- Very small or large reagent volumes
- Or, in cases in which a high number of blisters would take too much of the cartridge footprint

Benefits

INTEGRATED TANKS:

- Reduce component count
- Simplify assembly
- Enable precise pre-metering during filling
- Support automated production workflows

LIQUID MOVEMENT CAN BE DRIVEN THROUGH:

- Pneumatic actuation
- On-chip pumping systems
- Elastomeric pump bellows

The result is a fully enclosed reagent storage architecture that improves reliability while reducing system complexity.



Integrating liquid reagent chambers directly into the cartridge reduces component count and enables reliable storage and precise reagent delivery.

Integrated Liquid Tanks (Cont.)

Liquid Reagent Storage: thinXXS Solution



These containers are formed during the injection molding process of the cartridge. No additional assembly step is required. Each container needs a fill port, which is permanently sealed after filling as well as valve on either end of the tank. We design these valves as frangible seal which can be mechanically opened by the instrument in a very simple manner.

- ✓ Containers on cartridge, sealed with a frangible seal for leak-tight storage
- ✓ Usable in a range of a few μ l up to several ml
- ✓ Favorable if several liquid reagents are stored to keep cartridge size compact and cost low
- ✓ When aluminum blisters are not compatible to the reagent to be stored

- ⚠ Seals are mechanically opened by an instrument
- ⚠ Reagent displacement and transport driven by instrument (pneumatically), ensures controlled liquid displacement
- ✓ Design supports complete reagent displacement, reagent pre-metered (when filled into tank)



Dry Reagent Storage

Why Dry Storage Matters

BENEFITS:

- Longer shelf life
- Better temperature stability
- Easier distribution

Traditional Methods

Common approaches include:

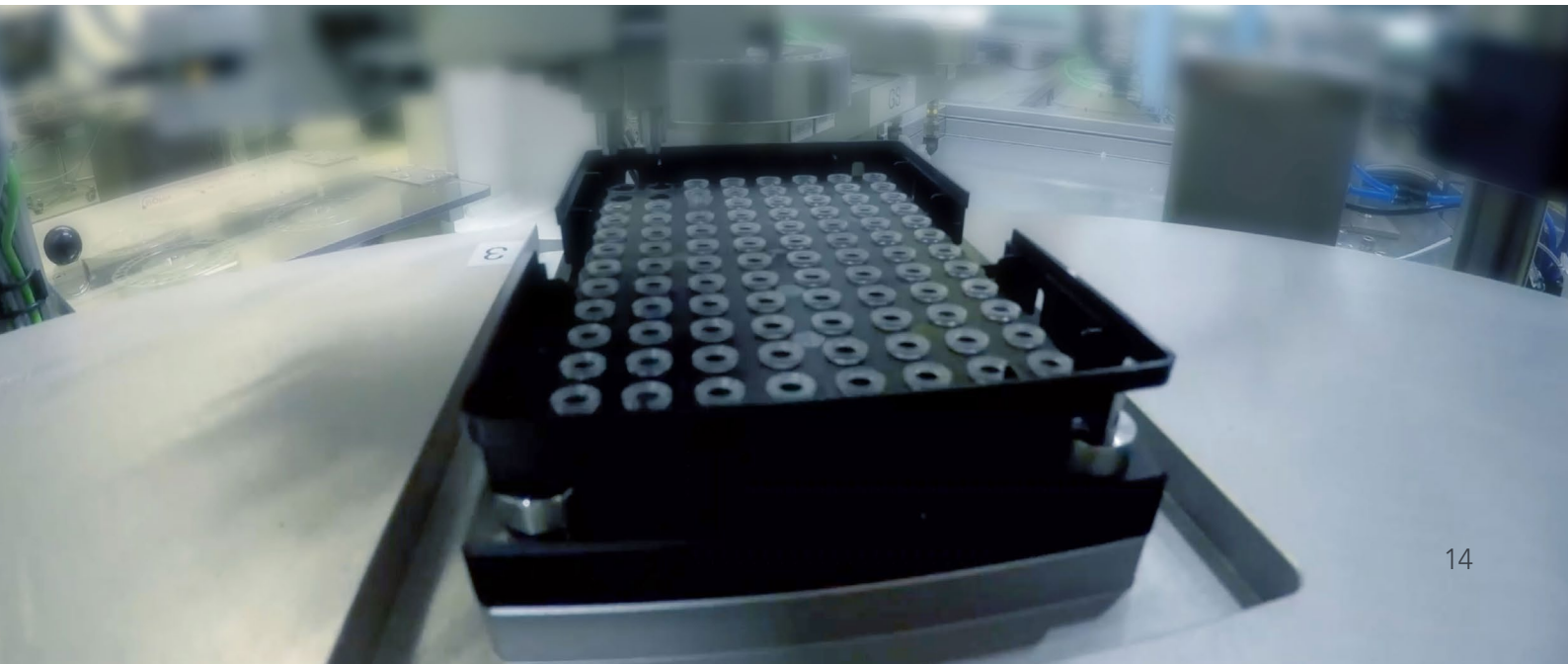
ON-CHIP DRYING

Reagents are dispensed directly into cartridge chambers and subsequently dried.

LYOPHILIZED PELLETS AND BEADS

Pre-formed pellets are inserted during cartridge assembly and reconstituted when needed.

While both solutions are widely used, scalability and reagent integration can become challenging during mass production.





Dry Reagent Storage: Standard Solutions

Industrial Standard

- Dispense reagent in solution onto cartridge and dry in place
- Pick and place lyophilized spheres directly into cartridge

Drying on Cartridge

- Drying is an integral part of the manufacturing process; Environmental conditions required for the reagents must be respected.
- Different reagents may need different drying conditions
- Complete cartridge experiences drying process; materials and components need to comply with drying conditions.
- Drying may be slow, which may be difficult in a high-volume manufacturing setting

Lyophilized Spheres, Beads, and Cakes

- Drying/Lyophilization process is done off-line, which simplifies the cartridge production line and offers more flexibility.
- Benefits from industrial standard processes
- Reconstitution properties of pellets often better than properties of reagents dried in place
- Pellets can be challenging to handle (texture, shape, stability)
- Environmental conditions required for the pellets must be respected

Both solutions are established but come with some disadvantages especially with regards to high-volume production. While LyoBeads or reagent pellets offer clear advantages over on-chip reagent drying, these benefits can only be fully achieved if the cartridge is designed with the appropriate interface for reagent integration. This design must allow for the integration of reagents at a stage in the manufacturing process where subsequent procedures do not affect the LyoBeads. It must be ensured that functionality — both biologically and fluidically — is maintained during reconstitution.





Dry Reagent Management

thinXXS Dry Reagent Plug Technology Explained

One of the most promising advancements in reagent handling is the use of carrier-based reagent integration. Rather than drying reagents directly inside the microfluidic cartridge, reagents are first immobilized onto a separate carrier component. This decouples:

- Reagent preparation
- Cartridge manufacturing

The result is greater flexibility and improved production efficiency.

BENEFITS:

- Batch-based reagent preparation
- Improved quality control
- Higher manufacturing yields
- Simplified assembly workflows
- Greater platform versatility



thinXXS developed the Reagent Plug as a carrier for dry reagents to address challenges in the efficient, high-throughput drying of reagents and the handling of dried reagent pellets during manufacturing.

thinXXS Reagent Plug Workflow



Reagent Plug



Apply Reagent on Reagent Plug



Dry / Lyophilize Reagent

Reagent Plug Platform:



The Reagent Plug acts as a carrier for the reagents



Reagents are dried/immobilized on the plug surface



Reagent immobilization is realized offline, simplifying and improving processes and cycle times, particularly in high-volume production



Thermoplastic polymer material, different material options, sizes, and immobilization surface textures are possible



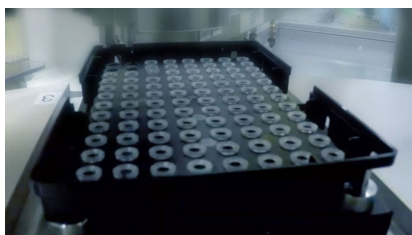
Scalable process

thinXXS Reagent Plug Workflow

→ THE REAGENT PLUG PLATFORM FOLLOWS A HIGHLY SCALABLE 5-STEP WORKFLOW

STEP 1: INDEPENDENT MANUFACTURING

Reagent plugs are injection molded separately from the microfluidic cartridge.



STEP 4: AUTOMATED ASSEMBLY

Robotic systems place the finished reagent plugs into designated cartridge locations.



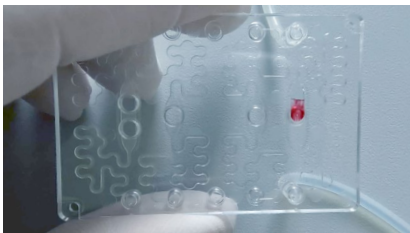
STEP 2: REAGENT LOADING

Reagent solutions are dispensed onto each plug's immobilization surface.



STEP 5: FINAL INTEGRATION

The plugs can be permanently sealed into the cartridge when required.



STEP 3: DRYING OR LYOPHILIZATION

The loaded plugs undergo drying or freeze-drying.



BENEFITS

- Better process control
- Higher throughput
- Improved quality assurance
- Easier scale-up to commercial production

Advanced Applications

Combining Reagent Plugs with Lyophilized Beads

Reagent plug technology can also support lyophilized bead integration. When fabricated from thermoplastic elastomers, the plug becomes an active functional element within the cartridge.

BENEFITS:

- Pellet containment
- Mechanical pellet crushing
- Improved mixing performance
- Reduced dead volume after reconstitution

The result is stronger assay performance while maintaining a highly scalable manufacturing process.

LyoPellet in
Microfluidic Card



The thinXXS plug can be deflected mechanically. This can be used to facilitate reconstitution of the reagent.

Advanced Applications (Cont.)

Elasto Plug: Combining the Reagent Plug Interface with LyoPellets

- Designed specifically for securing and handling lyophilized reagent pellets in microfluidic cartridges
- Thermoplastic material, providing flexibility while ensuring stability for handling during production processes
- Allows the plug to be deflected mechanically or pneumatically to adjust the chamber volume, enabling a wide range of applications
- Scalable size (10 μ l – 50 μ l)
- Different surface designs (flat or “pockets”)

With the thinXXS design, the LyoPellet is first loaded in the designated chamber on the card, which is then closed with the reagent plug. The advantage is that the plug can be deflected mechanically. This can be used to facilitate reconstitution of the reagent, e.g., by crushing the pellet and by imposing a mixing action. After reconstitution, the plug can remain deflected, which reduces the chamber dead volume.



A lyophilized pellet fixed in the chamber, with the Elasto Plug conforming to its shape.



The Elasto Plug flattens the pellet as fluid flows and rehydration begins.



Pellet fully rehydrated within the chamber.



Decision-Making Toolkit

→ REAGENT STORAGE TECHNOLOGY COMPARISON AND FAQs

Decision Matrix

Technology	Best For	Scalability	Manufacturing Complexity	Shelf Life
Traditional Blister	Liquid Reagents	Medium	Medium-High	Medium
Integrated Blister	Liquid Reagents	High	Low-Medium	High
Integrated Tank	Small/Large Volumes	High	Low	High
Reagent Plug	Dry Reagents	Very High	Low	Very High

Buyer Questions Checklist:

- ☐ What reagent format am I using?
- ☐ What is my target production volume?
- ☐ Is long shelf life required?
- ☐ How automated is my manufacturing process?
- ☐ What commercialization timeline am I targeting?



Decision-Making Toolkit (Cont.)

FAQs: Reagent Storage in Microfluidic Cartridges

WHAT IS REAGENT STORAGE IN A MICROFLUIDIC CARTRIDGE?

Reagent storage is the method used to store liquid or dry assay reagents directly on a microfluidic cartridge so they can be released during testing without additional user handling.

WHY IS REAGENT STORAGE IMPORTANT FOR POINT-OF-CARE DIAGNOSTICS?

Reagent storage impacts assay performance, shelf life, user experience, manufacturing scalability, and overall device reliability.

WHAT ARE THE MOST COMMON LIQUID REAGENT STORAGE METHODS?

The most common approaches are blister packs and integrated liquid storage tanks built into the cartridge.

WHAT ARE REAGENT PLUGS?

Reagent plugs are carrier-based components that allow reagents to be dried, stored, and integrated into cartridges separately from cartridge manufacturing, improving scalability and quality control.

WHICH REAGENT STORAGE METHOD IS BEST FOR COMMERCIAL MANUFACTURING?

The optimal solution depends on assay requirements, volume needs, stability requirements, and production scale, but storage concepts that support automated assembly and scalable manufacturing are generally preferred.

Conclusion and Case Studies

Conclusion

The optimal reagent storage strategy is not simply the one that works in the lab. It is the one that supports:

- Assay performance
- User experience
- Manufacturing efficiency
- Regulatory readiness
- Commercial scale

Reagent storage is a foundational design decision that influences every stage of microfluidic diagnostic development, from assay performance and user experience to manufacturing efficiency and commercial scalability. Selecting the right storage concept early helps avoid costly redesigns, reduces development risk, and accelerates the path to market.

As diagnostic products move from prototype to commercialization, storage technologies that support automation, robust quality control, and high-volume manufacturing become critical. Carrier-based solutions such as the thinXXS Reagent Plug platform provide a scalable framework for integrating dry reagents while simplifying production workflows and improving process consistency.

Case Studies



Accellix automated benchtop flow cytometry for GMP manufacturing focused on cell therapy.



Ador Diagnostics delivered faster, more accurate answers driven by multiplexed amplification and sensing.



VIEW ALL CASE STUDIES:
<https://www.thinxxs.com/en/downloads>

About the Author



Stefan Leidheiser is a Senior Customer Project Manager at thinXXS. Stefan studied microsystems engineering. He joined thinXXS in 2010, initially focusing on different microfluidic liquid reagent storage concepts. He has spent the last 14 years as an R&D Project Manager / Customer Project Manager.