



Overview of the United States cleanroom garment processing & laundering industry

United States cleanroom garment laundering service models have not changed in decades to the detriment of innovators in pharmaceuticals, biotechnology, and electronics. The cleanroom service model used in the U.S. has been used for almost 50 years with little change in technology or key service providers. As a result, cleanroom manufacturers remain tied to inflexible contracts and are increasingly exposed to regulatory and environmental risks. The industry would benefit from an innovative approach to processing cleanroom garments that offers cost, performance, and environmental advantages. TERSUS Cleanroom Solutions, offered by CO2Nexus, Inc., is proven technology that disrupts legacy protocols for cleanroom laundering using liquid carbon dioxide to replace water.

U.S. cleanroom laundry facilities and operations maintain a similar design with a large footprint and inefficient operations. AMD's Patent Number 61228931 outlines the basic cleaning methodology using a "pass-through" commercial washer to control garment exposure to contaminants. The washers use stainless steel baskets with ultra-pure water, which requires an energy-intensive process to produce. The dryers must open to the cleanroom and be constructed to eliminate potential contamination from the surrounding environment. Cleanroom service providers must verify the cleanliness of the garments by "measuring the number and sizes of particulates present within the laundered textiles using a Helmke Drum and aerosol particle counter."

Most laundering and processing is conducted off-site, which requires transport of customer garments over significant distances to regional hubs. Providers service cleanroom manufacturers through major regional market hubs where they process multiple clients' garments. Major regional market hubs are fairly easy to identify, as they are created by geographical grouping of customers that can be served from centralized, multi-customer consolidated operations. In many cases, legacy service providers have fully depreciated the infrastructure and equipment in service centers leaving little interest in investing in innovative technologies or revamping operations. Most consolidated facilities in the United States are located in or close to the following regional market hubs:

- Portland, Oregon
- The San Francisco Bay Area
- Los Angeles, California
- Phoenix, Arizona
- Austin/Dallas, Texas
- Northeastern U.S.
- Virginia triangle

Smaller regional hubs exist in Seattle, Denver, Minneapolis, and Boston. Similar service models are deployed from these locations.

Current cleanroom contracts diminish end user flexibility. Over the past 20 years, many end users have been pushed into de facto mandatory leasing of cleanroom garments through long-term contracts. In many situations a garment owner cannot have them cleaned by principal service providers unless they purchase or lease directly from that same provider. Service providers then group these contracts geographically, as described above, to consolidate multiple client orders to achieve economies of scale. This creates a challenge in the supply chain for end users; they must purchase or lease additional garments to offset long distance delivery schedules and delays. This move has locked end users into large, long-term contracts and further diminishing incentives to invest in new cleanroom garment processing technologies and services. Given how essential these garments are to manufacturing, end users are left with little to no leverage to negotiate.

Some cleanroom customers in the United States express frustration with existing and predominant cleanroom garment processing services. Major customers served by the current service providers note the following:

1. **Service pricing is not transparent:** laundering and rental/lease components of pricing are subject to seemingly arbitrary and periodic changes – without the requisite tracking and inventory management tools that would provide an appropriate basis for pricing changes over the life of a contract.
2. **Services are not located close enough to U.S. manufacturing operations.**
3. **Service often requires garment lease or sale contracts for extended time periods.** This could be further expressed as “if the service provider requires the lease or sale of the garments to be serviced then the profit incentive is focused on the replacement of the garments, versus reducing costs or improving services or technology.”

Under the status quo, cleanroom manufacturers in the United States remain exposed to regulatory and environmental risks from energy- and water-intensive processes. Existing cleanroom garment laundering technology relies heavily on clean water sources and is vulnerable to water price, quality, and scarcity; water regulations are pending across the United States. Inevitably these risks will drive up operating costs, which will be passed to end-users. Furthermore, supply chain transparency increasingly exposes end users to their service providers’ footprint. Acknowledging the drive towards more transparency, the International Organization of Standardization (ISO) published the principles and guidelines of tracking and managing an organization’s water footprint.

Existing U.S. cleanroom laundering services face the following environmental constraints:

- **Rising capital and operating costs due to energy and water consumption to:**
 - Treat, filter, store, and heat water
 - Condition air in facilities
 - Force dry garments
- **Deplete valuable water resources from local communities to:**
 - Use large volume of fresh water to wash garments
 - Must dispose of large volume of wastewater

New cleanroom operations in the United States will face substantial costs to secure fresh water and from siting, permitting, building, and managing the infrastructure needed to use and treat water. Meanwhile, the use of water-based washing processes degrades the garment integrity further increasing costs to service providers and ultimately to end-users.

The cleanroom laundry services industry needs to innovate. As cleanroom manufacturing evolves to produce more advanced products, including more sophisticated biotechnology and nanotechnology products, cleanroom laundry services will need to adapt as well. Cleanroom manufacturing is advancing rapidly while the services that support them lag behind. Likewise, the future of innovative manufacturing must take into account the environmental footprint of their operations; social and regulatory pressures are pushing industries toward this now. To date, innovative cleanroom garment laundering solutions have not been deployed despite their current availability in the market. Carbon dioxide-based cleanroom garment laundry is commercially available today and can deliver up to 60% energy savings, eliminate up to 96% of water usage, and improve garment life.

TERSUS Cleanroom Solutions, offered by CO2Nexus, Inc., is a proven technology that disrupts the existing legacy protocols for cleanroom laundering. TERSUS greatly reduces the use of energy and virtually eliminates the need for processing, heating, storing or disposing of water. Using the natural cleaning abilities of liquefied carbon dioxide, in a completely contained environment, TERSUS does not need dryers, boilers, or DI water systems. The footprint of cleanroom laundry shrinks and garments are never exposed to dry or wet heat resulting in extended garment life cycles.