

SEMI F116-0821

GUIDE FOR DRAIN SEGREGATION FOR SEMICONDUCTOR MANUFACTURING TOOLS TO SUPPORT SITE WATER REUSE

This Standard was technically approved by the Liquid Chemicals Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on May 27, 2021. Available at www.semiviews.org and www.semi.org in August 2021.

NOTICE: Paragraphs entitled ‘NOTE:’ are not an official part of this Standard or Safety Guideline and are not intended to modify or supersede the official Standard or Safety Guideline. These have been supplied by the global technical committee to enhance the usage of the Standard or Safety Guideline.

1 Purpose

1.1 This Guide provides definitions and recommendations for design of drain segregation to enable water reuse in a semiconductor manufacturing facility. It is intended to establish a common basis for developing design specifications and decisions concerning planning and design of water reuse systems. This Guide also includes implications for the water reclamation and reuse systems configurations.

1.2 This Guide is recommended to be used by semiconductor factory engineers and suppliers for developing tool-specific and site-specific design and construction documents used for the tool install activities and segregation decisions.

2 Scope

2.1 This Guide applies to drain and collection systems for the semiconductor manufacturing tools, supplying water to a variety of reuse applications. Such applications may include point of use (POU) recycling, directing secondary use water to the front end of an ultrapure water (UPW) system, cooling systems, scrubbers, POU abatement, thermal processes, as well as to irrigation. Choice of the reuse scheme depends on the quality of the water, application requirements, and applicable environmental regulations.

2.2 The scope of this Guide includes systems, assemblies, and components of the manufacturing tools and related infrastructure that are involved in segregation and treatment of the streams suitable for reuse. Given a broad range of reclaim water qualities and applications, the treatment portion of the scope is limited to the conceptual definitions only and does not include specific treatment processes.

2.3 The scope of this Guide is to provide recommendations in the context of possible water reuse segregation strategies.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This Guide does not define the actual specifications generally negotiated between the user and the manufacturing tool vendor.

3.2 This Guide does not recommend specific water reuse schemes, treatment methods or specific treatment systems for a semiconductor factory. Economics and environmental requirements as well as other location specific conditions may drive different solutions. If water reuse systems are added to existing facilities, installed equipment may add physical and other constraints.

3.3 This Guide focuses on the tool and the related installations and does not deal with facility systems outside of the tool boundaries (including support equipment and piping). Scope boundaries are indicated in Appendix 4, Figure A4-1.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM) and Utilization

SEMI F57 — Specification for Polymer Materials and Components Used in Ultrapure Water and Liquid Chemical Distribution Systems

SEMI F63 — Guide for Ultrapure Water Used in Semiconductor Processing

SEMI F98 — Guide for Water Reuse in Semiconductor Industry

SEMI F104 — Test Method for Evaluation of Particle Contribution of Components Used in Ultrapure Water and Liquid Chemical Distribution Systems

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

4.2 ASME Standards¹

ASME A13.1 — Scheme for the Identification of Piping Systems

4.3 ISA Standards²

ANSI/ISA-18.2-2016 — Management of Alarm Systems for the Process Industries

4.4 ISO Standards³

ISO/IEC 17025 — General Requirements for the Competence of Testing and Calibration Laboratories

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 This section focuses on definitions related to drain segregation and water reclamation (reuse/recycle/reclaim) systems in a semiconductor manufacturing industry.

5.2 Abbreviations and Acronyms

5.2.1 *CRT* — cleanroom technology

5.2.2 *POU* — point of use

5.2.3 *TOC* — total organic carbon

5.2.4 *UV* — ultraviolet

5.3 Definitions

5.3.1 *industrial waste drain (IWD)* — standard acidic or alkaline waste; unsuitable for water recovery due to presence of contaminants that make recovery economically infeasible.

5.3.2 *resist drain* — photo resist drain.

5.3.3 *rinse wastewater (RWW)* — segregated drain for recovering water suitable for reuse after treatment.

5.3.4 *ultrapure reclaim water (URW)* — segregated drain for rinse water of sufficient purity for recycle without treatment.

¹ American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA; Telephone: +1.973.882.1170, Fax: +1.973.882.1717, <https://www.asme.org>

² Instrument Society of America, 67 Alexander Drive, Research Triangle Park, NC 27709, USA; Telephone: +1.919.549.8411, <https://www.isa.org>

³ International Organization for Standardization, ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland; Telephone: +41.22.749.01.11, <http://www.iso.org>

6 General Recommendations

6.1 *Water Conservation Strategy Implications: Centralized vs. Decentralized* — Incorporating water recycle and reuse into an existing tool and factory infrastructure should be considered by determining if a centralized or decentralized system is needed to meet business needs, as seen in Appendix 1. Flexibility of the system to meet changing site needs along with treatment needs are examples of important considerations when choosing a centralized or decentralized system.

6.2 *Implication of Tool States on Water Conservation Strategy* — The quality and quantity of the water available for reuse or recycle from the tool or equipment depends on its state of operation. Appendix 3 details considerations for how the tool states of operation impact configuration and design of the tool water reuse system.

6.3 *Metrics and Measurement of the Useful Water Consumption and Reuse by the Tool* — Specification of quality parameters to measure should be included in a water recycle or reuse program. The determination of online or off-line sampling should factor operational needs and ISO/IEC 17025 accreditation, respectively. Appendix 3 outlines parameters along with recommendations for decision makers to consider water quality metrics and respective measurement techniques.

6.4 *Scope and the Basis of Design for Engineering of the Water Reuse Systems* — Appendix 4 refers to the necessary design basis that should include the system boundary and necessary factory tools that will receive a stream from water reuse.

6.5 *Capability (Performance Expectations) of the Reuse or Recycle System* — Minimum expectations for performance of POU reclaim and recycling systems are described in Appendix 5.

6.6 *Engineering Deliverables* — Documentation of a POU system should provide sufficient information including purpose, boundary conditions for design and operation, water quality, and system integration, as seen in Appendix 6.

6.7 *Safety Considerations (Mitigating Unsafe Conditions that Could Result from Water Reuse Activities)* — Substantial safety consideration, as seen in Related Information 1, should be part of a water reuse system. The safety considerations protect personnel, site operations, and additionally provide guidance on environmental means for proper disposal, which all ensure a successful water reuse application for a site.

6.8 *Labeling (Tool and Lines Within Facility)* — Effective labeling communicates piping contents, hazards, source and destination of contents, and other process information. Standardization of labeling ensures continuity throughout the reuse system. Best practices can be referenced in Appendix 7.

6.9 *Sample Ports and Sampling Recommendations* — Sampling methods are an important consideration for water quality monitoring of a waste reuse system. Appendix 8 provides recommendations for sampling material specification, design and configuration of a sampling station, and safety factors when sampling.

6.10 *Risk Management* — Implementation of a water reuse strategy should include a risk management plan that considers benefits to the site in addition to potential excursion or incident impacts. The plan is developed by starting at the feasibility or engineering concept and is reviewed against operating conditions after commissioning is complete or as long as the reuse system is in operation. Recommended risk topics are covered in Appendix 9.

6.11 *Commissioning Considerations* — Implementation of a water reuse system should include a commissioning plan that begins development during the engineering evaluation and is continuously developed through design and construction. Stakeholder involvement ensures management of change and engagement of personnel responsible for delivering and operating the water reuse system. Quality monitoring is also a key focus of a commissioning plan. More recommendations are found in Appendix 10.

6.12 *Training* — Site maturity will determine the level of training necessary from front-line operators and engineers, and up through functional managers. The focus should be to provide effective training that orients personnel with the sequence of operations, diversion, or escalation procedures, and long-term operating needs to reduce risk to tools and site production as seen in Appendix 11.

6.13 *Drains Matrix* — Recommended drain matrix definitions are provided in Appendix 12.

7 Related Documents

7.1 *SEMI Standards and Safety* Guidelines

SEMI C79 — Guide to Evaluate the Efficacy of Sub-15 nm Filters Used in Ultrapure Water (UPW) Distribution Systems

SEMI C93 — Guide for Determining the Quality of Ion Exchange Resin Used in Polish Application of Ultrapure Water System

SEMI E49 — Guide for High Purity and Ultrahigh Purity Piping Performance, Subassemblies, and Final Assemblies

SEMI F61 — Guide to Design and Operation of a Semiconductor Ultrapure Water System

SEMI F75 — Guide for Quality Monitoring of Ultrapure Water Used in Semiconductor Manufacturing

7.2 International Roadmap for Devices and Systems (IRDS)⁴

⁴ <https://irds.ieee.org/>

APPENDIX 1

WATER CONSERVATION STRATEGY IMPLICATIONS – CENTRALIZED VS. DECENTRALIZED

NOTICE: The material in this Appendix is an official part of SEMI F116 and was approved by full letter ballot procedures on May 27, 2021.

NOTE 1: This section focuses on the recommended strategy for incorporating water recycle and reuse into the existing tool and factory infrastructure. The water management strategy is addressed by SEMI F98.

A1-1 Centralized vs Decentralized Systems

A1-1.1 While using a decentralized water recovery strategy gives more flexibility to adapt treatment to the water quality and requirements of specific functional areas or toolsets, adopting this strategy creates significant cost and space challenges due to the need to procure and incorporate new treatment, collection, and distribution systems into the existing factory infrastructure. Numerous decentralized systems also place significant demands on headcount to operate and maintain them.

A1-1.2 Using a centralized recovery and treatment system leverages existing wastewater collection and water distribution infrastructure, as well as minimizing take-up of valuable cleanroom and sub fab space, thus using a centralized system will minimize costs. A central treatment facility can also reduce required headcount to maintain and operate the system.

A1-1.2.1 Both strategies are relevant and possible depending on the site specific and technology specific conditions.

A1-1.2.2 Understanding the quantity of water usage by the tools in each tool state (as defined in SEMI E10) will assist in driving a decision on which strategy is adopted for water recovery. Refer to Appendix 2 for more details.

A1-1.2.3 In the context of each strategy, the following should be considered when deciding on the POU recycling:

A1-1.2.3.1 *Priority* — Non-wafer process reuse is covered by reclaim.

A1-1.2.3.2 POU recycling reduces reclaim availability.

A1-1.2.3.3 POU recycling can help to reduce capital cost on UPW system, while potentially providing consistent quality of water.

A1-1.2.3.4 The space availability may limit POU recycling application.

A1-1.2.3.5 Ability to segregate the drains for the dedicated recycling (high purity drains infrastructure).

A1-1.2.3.6 POU recycling may add operational complexity, including performance quality control.

A1-1.2.3.7 Manufacturing tool pure water recycling vs. that including integrated chemistry recycling (e.g., ozone, CO₂, etc.).

A1-1.2.3.8 Cost of the chemistries in the streams that can be recycled along with the water.

A1-1.2.3.9 Overall cost of ownership implications.

APPENDIX 2

IMPLICATION OF TOOL STATES ON WATER CONSERVATION STRATEGY

NOTICE: The material in this Appendix is an official part of SEMI F116 and was approved by full letter ballot procedures on May 27, 2021.

NOTE 2: This section focuses on the impact of the various tool states on water consumption by the site tool(s), and how this impacts the strategy for water recovery from the tool(s).

A2-1 Tool State

A2-1.1 The quality of the water available for reuse or recycle from the tool or equipment depends on its state of operation. When a tool is processing wafers, the quality of water passing to the tool drains may be significantly different to when it is in standby mode or under maintenance. In SEMI E10-0814, Figure 1 describes the tool states as follows. The tool idle or standby states provide considerable opportunity for water conservation.

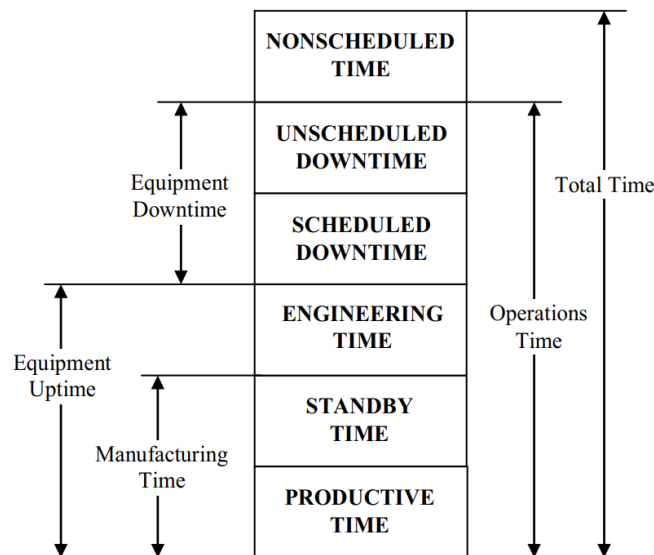


Figure A2-1
Tool States as Defined by SEMI E10

A2-1.1.2 Where possible, consideration should first be given to minimize these idle flows; a reuse or recycle strategy can then be developed for the remaining idle flow from the tools in the standby state. Minimizing the idle flows reduces the overall capacity requirements of the UPW system feeding the tools, as well as reducing the required size of the recovery or recycle system.

A2-1.2 The quality and amount of water available for reuse in each tool state will have an impact on the strategy chosen. For example, if there is a considerable amount of water flowing to the tool while the tool is in standby mode, adding a dedicated drain to collect and recover this water (e.g., using a POU recycle system or a dedicated central recovery or reuse system) may be preferred as the water sent to drain will be relatively pure and would require little or no treatment to make it suitable for reuse or recycle.

A2-1.3 The overall water usage by the tool should be quantified for each state. This will allow the wafer-level usage (i.e., during tool productive time) to be compared to non-wafer or idle usage (e.g., purges to keep water flowing at all points of the tool, flows during the tool standby time, engineering time and downtime) so that potential opportunities to reduce or recover these idle flows can be quantified.

A2-2 Measurement to Quantify Water Usage and Verify Water Quality in Each Tool State

A2-2.1 Measurement of the flow and quality of the water sent to drain during each tool state is recommended. Ideally flow measurements would be made online, so that real-time data can be collected to profile the tool water usage in each state. If inline measurement is not practical, consideration should be given to accommodating removable flow meters on the tool water lines to allow measurements to be done for a finite period of time.

A2-2.1.1 Use of ultrasonic clamp-on flow meters has been proven to be a simple and effective method to measure these tool flows provided that the tool has sufficient space to accommodate the flow meter hardware and there is a sufficient length of straight pipe or tubing to allow accurate measurement of the water flow. Multiple vendors have developed highly effective clamp-on measurement devices which are compact, require only minimal distance of straight piping between the measurement element and elbows or fittings upstream or downstream, and can function effectively with a variety of piping or tubing materials.

A2-2.2 Water quality should be measured to determine if the water is suitable for reuse or recycle during each tool state. Initial analysis to determine feasibility can be performed using grab samples; if reuse or recycle is adopted for a water stream from a particular tool, refer to the recommendations in Appendix 3 for measuring ongoing water quality in water reuse and recycle applications.

APPENDIX 3

METRICS AND MEASUREMENT OF THE USEFUL WATER CONSUMPTION AND REUSE BY THE TOOL

NOTICE: The material in this Appendix is an official part of SEMI F116 and was approved by full letter ballot procedures on May 27, 2021.

NOTE 3: This section focuses on the recommended metrics and measurement techniques for water consumption and reuse by site tool(s).

A3-1 Metrics and Measurement

A3-1.1 A semiconductor fab has many different tools manufactured by a variety of vendors. Different tool vendors design different water segregation systems, depending on the purpose of the tool. For the purpose of this Guide, it is assumed that the tool vendor has designed a waste stream segregation within the tool. Each stream can be defined as intended for reuse, reclamation, or recycling. In some cases, a waste stream might be so contaminated with solvents or with a high percentage of solid waste, this waste stream is essentially unusable and must be removed from the site. Specific regulation(s) may define certain streams unusable for reuse independently of their composition.

A3-1.2 Quality parameters to measure in addition to flow rate would depend on the application and would include some, but not all, of the following in Table A3-1.

Table A3-1 Quality Parameters for Measurement

Parameters	Online vs. Grab Sample	Application	
		Recycle ^{#1}	Reclaim
Flow rate	Online	Recommended	Recommended
Pressure	Online	Optional	Optional
Oxidizers (ORP)	Online	Recommended	Recommended
Temperature	Online	Recommended	Recommended
pH	Online	Recommended	Recommended
Conductivity	Online	Recommended	Recommended
Organics	Grab LC-OCD	Optional	Optional
	Grab or Online TOC	Recommended	Recommended
Particles	Grab – SEM	Recommended	Optional
	Online – LPC 50 nm	Recommended	Optional
Metals	Grab	Recommended	Optional
Dissolved oxygen	Online	Recommended	Optional
Bacteria	Grab	Recommended	Optional
Silica	Grab	Recommended	Recommended

#1 If UPW is to be recycled directly back into the tool then it is Optional that all of the parameters be monitored as described in Table 1 of SEMI F63, Guide for Ultrapure Water Used in Semiconductor Processing.

A3-2 Measurement to Qualify the Decision on the Reuse vs. Ongoing Monitoring to Control Quality

A3-2.1 Ideally these measurements would be made online, so that any problems can be reported in near real-time, and appropriate action can be taken to divert a waste stream to a discharge for downstream treatment. Adequate sample ports must be installed either at the tool or in the waste stream going to a central processing location (see Appendix 8).

A3-2.2 If a measurement requires off-line analysis, for example bacteria cultivation or trace metal analysis or organic speciation, adequate care must be taken to ensure the integrity of the sample. This would involve using the correct

sample bottle, following a strict sample collection procedure and sample handling (i.e., packaging, documentation, refrigeration, shipping urgency, etc.). The method of sampling and handling should follow qualified lab instructions, including timely delivery to the lab (i.e., bacteria, organics, etc.).

A3-2.3 Wherever possible an ISO/IEC 17025 accredited laboratory should be used for all analyses. All hazardous material shipping requirements must be followed in accordance with the applicable law and regulation if a sample is shipped to a laboratory. It may also be necessary to dilute a sample in order to comply with hazmat requirements. It is incumbent on the sample taker and sample shipper to become familiar with the regulations applicable to shipping a specific chemical or compound.

NOTE 4: Hazardous materials in acceptable quantities may allow small amounts of samples to be shipped for analysis.

A3-2.4 The detection of organic molecules for proper segregation poses a particular problem. Real time, online instruments are not always available to easily quantify and identify the complete composition of the organic compounds. In addition, treatment of wastewater containing organics is more difficult in some cases, depending on the organic composition being treated. There has been progress with developing organic speciation techniques. It is recommended to consider possible options for organic speciation, including ion chromatography, liquid chromatography mass spectrometry, and gas chromatography. However, liquid chromatography with organic carbon detector and organic nitrogen detector is recommended as the method covering a broad range of organic compounds and considered cost and time effective for this application. (Huber's 2011 paper was referenced in SEMI F98.)

APPENDIX 4

SCOPE AND THE BASIS OF DESIGN FOR ENGINEERING OF THE WATER REUSE SYSTEMS

NOTICE: The material in this Appendix is an official part of SEMI F116 and was approved by full letter ballot procedures on May 27, 2021.

NOTE 5: This section focuses on the recommended engineering scope and basis for design of a water reuse system.

A4-1 Scope Considerations

A4-1.1 One tool or group of tools

A4-1.2 Boundaries

A4-1.3 Type of the tool

A4-1.4 Location of the system including space constraints

A4-1.5 Description of the system (piping, POU treatment, instrumentation, and controls, etc.)

A4-1.6 Type of water source for reuse (UPW, reclaim, other)

A4-1.7 Destination of reuse or recycling

A4-1.8 Available utilities

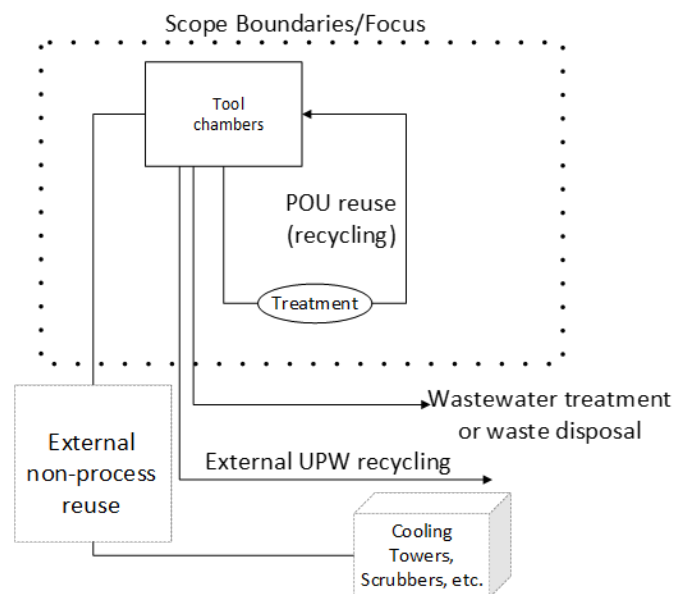


Figure A4-1
Water Reuse Scope Boundary and Focus

A4-2 Stream Parameters

A4-2.1 Quality of source water from the tool drain (see Appendices 1 and 3)

A4-2.2 Flowrates including average, minimum, maximum, and flow pattern

A4-2.3 Temperature

A4-2.4 Pressure

A4-3 Performance Parameters

- A4-3.1 Quality of water at the destination (in case of POU treatment, effluent quality)
- A4-3.2 Flowrates including average, minimum, maximum, and flow pattern
- A4-3.3 Temperature
- A4-3.4 Pressure
- A4-3.5 Uptime/redundancy
- A4-3.6 Process specific sensitivities (relative priority to certain parameters)
- A4-3.7 Level of automation and operator involvement
- A4-3.8 Environmental impacts (including safety)
- A4-3.9 Effluent compatibility with downstream processes
- A4-3.10 Wafer yield data (for recycle water used in wafer processing)

A4-4 General Expectations

- A4-4.1 Preferred technologies
- A4-4.2 Materials of construction
- A4-4.3 Methods of delivery (off-site manufacturing, prefabricated, etc.)
- A4-4.4 Constructability and accessibility