Background Statement for SEMI Draft Document 6129
Revision to SEMI F61-0301 (Reapproved 0309):
GUIDE FOR ULTRAPURE WATER SYSTEM USED IN SEMICONDUCTOR PROCESSING
with Title Change to:
GUIDE TO DESIGN AND OPERATION OF A SEMICONDUCTOR ULTRAPURE WATER SYSTEM

NOTICE: This Background Statement is not part of the balloted item. It is provided solely to assist the recipient in reaching an informed decision based on the rationale of the activity that preceded the creation of this ballot.

NOTICE: For each Reject Vote, the Voter shall provide text or other supportive material indicating the reason(s) for disapproval (i.e., Negative[s]), referenced to the applicable section(s) and/or paragraph(s), to accompany the vote.

NOTICE: Recipients of this ballot are invited to submit, with their Comments, notification of any relevant patented technology or copyrighted items of which they are aware and to provide supporting documentation. In this context, 'patented technology' is defined as technology for which a patent has been issued or has been applied for. In the latter case, only publicly available information on the contents of the patent application is to be provided.

Background

This document is a complete rewrite of the existing SEMI F61 ultrapure water guide.

The objective is to provide minimum reference information and guidance to assist the end user with developing engineering design specifications as well as commissioning and operational criteria for cost effective and reliable UPW system. The guide supplies both recommended definitions as well as supplemental information about important ultrapure water system engineering parameters. This document is submitted for ballot together with the revision of SEMI F75, guide for UPW quality monitoring and is recommended to be used in conjunction with it.

Since this document is a guide it is not intended to tell the reader how exactly UPW system should be designed and operated, rather it suggests which parameters are important as well as providing reference information based on the current industry experience (contributed by the team of experts involved in the document development, who represented perspectives of the end users, equipment/material suppliers, analytical experts, and consultants).

This document is also intended to continue to be updated every two years, keeping it in alignment with the industry needs as defined by UPW IRDS. This document is based on current SEMI F63 UPW Quality Guide and references other relevant SEMI UPW related documents, such as SEMI F57, SEMI C93, SEMI C79, etc. This document is expected to be used as a root document, connecting all UPW relevant guides, test methods, and specifications.

The ballot results will be reviewed and adjudicated at the meetings indicated in the table below. Check www.semi.org/standards under Standards Calendar for the latest update.

Review and Adjudication Information

	Task Force Review	**Committee Adjudication**
Group:	Ultra Pure Water TF	NA Liquid Chemicals Committee
Date:	Monday, April 3, 2017	Tuesday, April 4, 2017
Time & Time zone:	8:00 AM to 11:00 AM, Pacific Time	3:00 PM to 6:00 PM, Pacific Time
Location:	SEMI Headquarters	SEMI Headquarters
City, State/Country:	Milpitas, California	Milpitas, California
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This meeting's details are subject to change, and additional review sessions may be scheduled if necessary. Contact the task force leaders or Standards staff for confirmation. Telephone and web information will be distributed to interested parties as the meeting date approaches. If you will not be able to attend these meetings in person but would like to participate by telephone/web, please contact Standards staff.

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LETTER BALLOT

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This Guide was technically approved by the Liquid Chemicals Global Technical Committee. This edition was approved for publication by the global Audits and Reviews Subcommittee on [TBD]. It was available at www.semi.org in XXXX. Originally published March 2001.

NOTICE: This Document was completely rewritten in 2017.

1 Purpose

1.1 This Guide should be used in conjunction with SEMI F63 and SEMI F75. Together these Guides provide recommendations for facility engineers and other manufacturing professionals who are responsible for establishing programs to monitor and control the quality of their ultrapure water (UPW) systems through to point-of-use (POU).

1.2 This Guide describes the engineering and component requirements for a UPW system used in semiconductor manufacturing. It is intended to establish a common basis for developing detailed specifications for design, operations, certification, and monitoring of UPW and HUPW systems.

2 Scope

2.1 This Guide applies to advanced UPW systems used in semiconductor manufacturing facilities for supplying high purity water for wafer processing, chemical dilutions and other facility applications. This Guide provides definitions used for identification of UPW system components and other commonly used terms associated with the semiconductor facility water systems.

2.2 This Guide provides reference to other relevant SEMI documents that ensure quality and reliability of UPW systems. This Guide logically follows the series of SEMI Guides developed for UPW, which includes SEMI F63, a Standard defining the quality of UPW, and SEMI F75, a Standard for monitoring UPW.

2.3 This Guide provides recommendations for design and operation of the UPW system including treatment plant, distribution system, and the semiconductor manufacturing tool hook up.

2.4 This Guide addresses the testing and prequalification of high purity polymer materials used in UPW system equipment and distribution.

2.5 This Guide provides minimum definitions for site utilities needed to support the UPW system.

2.6 This Document provides guidance for construction, qualification and commissioning of new or recently upgraded UPW systems.

2.7 This Document provides guidance on maintenance, operations, safety and redundancy of the UPW systems. This Guide provides further quality information on critical components such as ion exchange resin and filter media.

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 suppliers of the UPW system, against which water quality is tested and qualification is passed.

3.2 This Guide does not address the protocols and requirements defined by the suppliers concerning the installation of the UPW system.

3.3 The recommendations provided in this Guide are based upon information available at the time the document was prepared and on the experience of the group involved in the document development.

3.4 This Guide is limited to the scope of UPW treatment and distribution system; it does not address the considerations of the UPW materials and components within manufacturing tools.

3.5 This Guide focuses on the parameters and conditions which mitigate risks to manufacturing yield and UPW system performance; it does not deal with definitions that present opportunities for competitive intellectual properties of the technology providers.

3.6 In order to maintain the relevance of SEMI Documents, it is important that Documents be updated on a regular basis. In particular this Document, and Documents SEMI F63 and SEMI F75, will be updated at the same time to ensure continuity for the users of all three Documents. All three Documents will be reviewed and updated (if necessary) on a two-year cycle.

3.7 This Guide does not provide recommendations for the design or operation of POU specialty systems, such as Carbonated UPW water, Ozonated UPW water, low TOC UPW water, and low particle UPW Water.

4 Referenced Standards and Documents

4.1 SEMI Standards and Safety Guidelines

SEMI F19 — Specification for the Surface Condition of the Wetted Surfaces of Stainless Steel Components.

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

SEMI F63 — Guide for Ultrapure Water System Used in Semiconductor Processing.

SEMI F75 — Guide for Quality Monitoring of Ultra Pure Water Used in Semiconductor Manufacturing.

4.2 *ASTM Standard*[1]

ASTM D5127 — Ultra-Pure Water Used in the Electronics and Semiconductor Industries.

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

5 Terminology

NOTE 1: This section focuses on definitions related to UPW system used in microelectronic industry and does not include common water treatment process technology definitions used elsewhere. UPW quality related definitions are included in SEMI F63.

5.1 *Definitions*

5.1.1 *high volume manufacturing (HVM)* — refers to full size production facilities as opposed to a pilot or technology development production line.

5.1.2 *ultrapure water (UPW)* — purified water meeting microelectronic industry requirements documented in SEMI F63 and ASTM D5127 for the line width of one micrometer and smaller.

5.1.3 *UPW system* — a production and distribution facility comprising of unit operations including deionization, reverse osmosis, dissolved gas control, organics treatment, and particles removal to meet requirements of UPW quality. UPW system equipment boundaries start at the feed to the raw water tank (if exists) or otherwise at the feed to the raw water pump. The system boundaries end at the point of connection valves supplying UPW to the manufacturing tool or any other fab or facility user utilizing UPW to support production.

5.1.4 *deionized water (DI)* — any purified water that has level of ions reduced down to the resistivity of minimum 1 MΩ·cm. Although a commonly used term, this quality of water is not applicable for advanced semiconductor manufacturing.

[1] ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA; Telephone: +1.610.832.9585, Fax: +1.610.832.9555, http://www.astm.org

5.1.5 *DI system* — a system that comprises one or multiple deionization steps to produce DI water. DI system treatment is typically based on one or combination of the following technologies: ion exchange, reverse osmosis, and EDI technologies.

5.1.5.1 *Discussion* — UPW Plant is a complex automated system. In order to provide effective communication when dealing with specific treatment steps and components additional definitions are required. The following definitions of the UPW system sections are based on treatment steps located in between major tanks typically used: Raw Water Tank, Permeate Tank, and UPW Tank (see § 8.1, Figure 1).

5.1.5.2 Although typical design is based on the goal of producing and distributing single quality spec UPW, some fab or sub-fab users receive lower grade water, such as RO permeate or primary product. Such decisions are project specific.

5.1.6 *final filter* — usually it is the final treatment step in a UPW system; used to remove particulates.

5.1.7 *make-up plant* — portion of the UPW system upstream of the UPW tank that supplies water in the polishing loop to replace UPW consumed by the fab.

5.1.8 *raw water* — any water available to the site for the production of UPW (from river, lake, ground, or ocean). Such water may or may not be treated and can also include reclaim water.

5.1.9 *permeate water tank* — tank containing water treated by reverse osmosis in pre-treatment and other streams consistent with permeate quality.

5.1.10 *UPW tank*— tank that receives water from makeup plant and UPW return and then supplies water to the polish plant.

5.1.11 *UPW distribution loop* — The piping from the final filter of the polish system that distributes UPW to the end users and conveys the remainder to the inlet of the polish tank via UPW return.

5.1.12 *UPW supply* — UPW sent to end users.

5.1.12.1 *UPW return* — UPW sent to but not used by end users (returns to the UPW storage tank).

5.1.12.2 Points of measurement of the water quality in the polish loop:

5.1.12.2.1 *point of distribution (POD)* — sample port near the outlet of the final filter.

5.1.12.2.2 *point of connection (POC)* — sample port near a take-off valve on the lateral used to connect to the manufacturing tool.

5.1.12.2.3 *point of Entry (POE)* — sample port near the feed connection to the manufacturing tool.

5.1.12.2.4 *point of use (POU)* — sample port within the tool near the entry to the process chamber.

5.1.12.2.5 *point of Process (POP)* — water in production chamber.

6 General Recommendations

6.1 *Materials* — Components of the UPW system should be comprised of materials appropriate to the application and conform to electrical, mechanical, and purity requirements of the UPW. Materials should also comply with the purity as defined by applicable SEMI Standards. See Appendix 1 for details on the material quality requirements.

6.2 *System Installation* — A UPW system is installed according to a protocol that ensures mechanical integrity, leakproof operation, and none (or minimal) contamination during installation. See Appendix 1 for details on the piping supports, welding, and other requirements for system installation.

6.3 *Acceptance Tests* — Acceptance tests are conducted on each subsystem. Such tests may include performance demonstrations, demonstrations of reliability criteria, and achievement of purity standards and are the basis for acceptance or rejection by the purchaser against a pre-negotiated set of criteria for system performance. See Appendix 2 for details on the UPW system qualification methodology.

6.4 *Monitoring* — UPW systems are monitored for continuing performance against desired and achievable levels of quality. Action limits are set to determine when system performance suggests that corrective action is required.

6.5 *UPW Specifications* — UPW systems should deliver a specified water quality on an ongoing basis. The guaranteed performance is established in advance between the UPW equipment supplier and the system owner. Both qualification testing and monitoring testing use the guaranteed specifications to determine the parameters and levels of purity to be tested. SEMI F63 is the recommended reference guide for UPW quality in advanced semiconductor manufacturing.

6.6 *Recycle/Reclaim Opportunities* — Opportunities for recycling and reclaiming water within a UPW system should be recognized during the design phase. Examples: Use of 1st pass reject for cooling tower make-up water, returning UF reject to the Permeate Tank or Feed water Tank, and many others.

7 Source Water

7.1 *Raw Water* — Raw water quality and sources are what drive the design of the pretreatment plant. Raw water quality should be thoroughly characterized to ensure effective design of the pretreatment plant. See Appendix 3 for recommendations on analysis of the raw water and interpretation of the analytical data which facilitates design of the UPW Pretreatment.

7.2 *Municipal Drinking Water* — Municipal drinking water from different sources (such as desalinized seawater or brackish lakes and wells) is the most common source for UPW systems. However, the treatment plans to make such water potable and compliant with drinking water regulations may pose a challenge to the UPW systems. For example: disinfection by-products may damage RO membranes; fine silt particles may clog membranes, hardness and silica may form scaling on the RO membranes; trace level of organics may cause fouling or may enhance bio-growth, causing bio-fouling.

8 Major Treatment Processes

8.1 The following diagram provides UPW system definitions for the treatment blocks between the main system tanks:

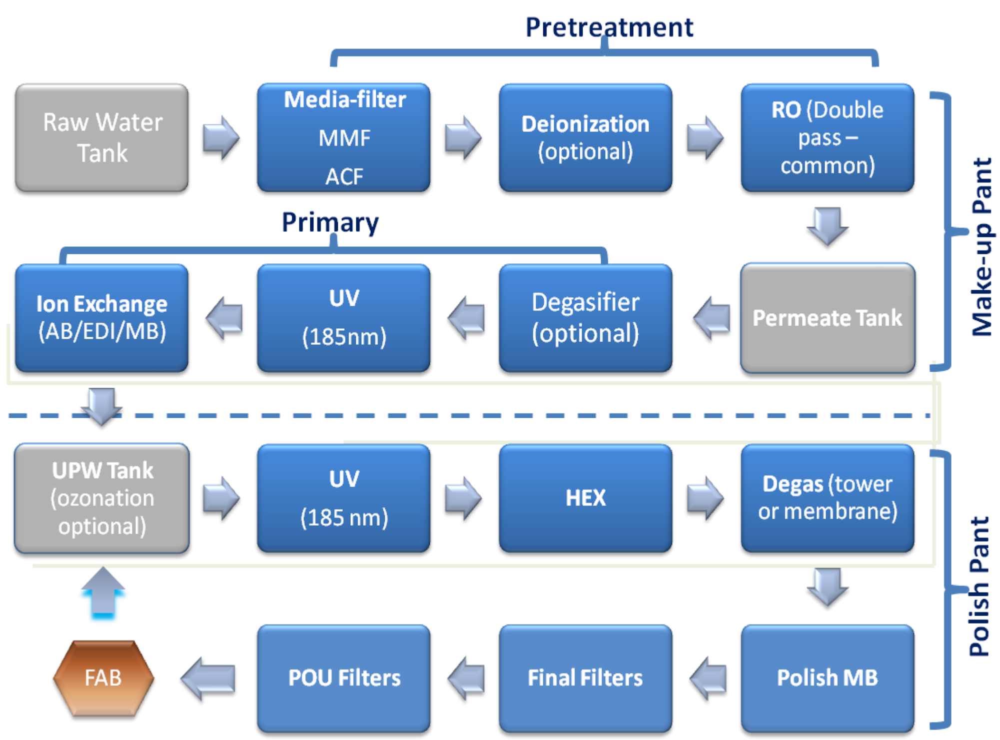

Figure 1
Typical UPW System Configuration

8.1.1 *Make-Up Plant* — The entire treatment system upstream of the UPW Tank. The Make-up Plant produces replacement water to supplement losses caused by fab consumption, polish system maintenance, and normal system operation.

8.1.2 *Pretreatment* — The portion of the Make-up Plant upstream of the Permeate Tank which produces replacement water to supplement losses caused by fab consumption, fab permeate water consumption and downstream system maintenance.

8.1.3 *Primary System* — The portion of the Make-up Plant downstream of the Permeate Tank and upstream of UPW tank which treats the permeate water to the levels near target UPW quality.

8.1.4 *Polish Plant* — The treatment system downstream of the UPW tank that conducts final UPW purification. The most important function of the Polish Plant is particle removal and maintenance of recirculated-UPW purity. The Polish Plant is often located separately from the make-up plant adjacent to or within the fab building to reduce the length of expensive high purity piping.

8.2 *Pretreatment* — Includes all the water treatment steps ahead of the first pass of RO Membrane Treatment. The configuration of Pretreatment is more dependent on the incoming water quality and site specific requirements than other major steps in the UPW system. Pretreatment steps are required to protect the membrane units from scaling with sparingly soluble salts, from fouling with living or non-living suspended particles and from chemical attack by pH, oxidizing agents or other dissolved contaminants and to enhance performance of the RO. Examples of RO treatment include removal of hardness agents that allow increasing water efficiency and rejection of weakly acidic ions of boron, silicon, and organics under elevated pH conditions. Pretreatment equipment may include some, or a combination, of the following:

8.2.1 *Raw Water Tank* — The Raw water tank contains enough water to provide a sufficient retention time to conduct troubleshooting activities during short term water-supply interruption.

8.2.2 *HEX* — Heat exchanger for dealing with seasonal temperature fluctuation necessary for providing stable RO flux and rejection.

8.2.3 *Various Filters* —Filters to protect RO membranes from debris include media filtration, micro filtration, ultrafiltration (bulk suspended solids removal) and 1 to 5 micron cartridge filtration.

8.2.4 *Activated Carbon Filtration (ACF)* — ACF is primarily used for removal of oxidizing agents. Alternatively reducing agents can be employed to neutralize oxidants.

8.2.5 *RO Scale Control* — RO scale control can be done by cation exchange (softening, to remove scale-forming cations) or through the addition of scale inhibitor chemicals (acids and/or chelating agents).

8.2.6 *CO_2 Removal* — CO_2 removal by degasification uses either a decarbonator (forced draft) or vacuum membrane degasifier located before or after RO.

8.3 *RO Membrane Treatment* — RO membrane treatment provides effective rejection of dissolved ions, organic compounds, silica, and almost complete rejection of suspended contaminants. However RO will not effectively reject dissolved gases and some low molecular weight neutral and non-ionic volatile organic compounds. Effective removal of weakly dissociated acids (organic, boric, and silicic) requires pH adjustment. To enhance the removal of contaminants RO units may be configured in a double-pass arrangement where permeate (treated water) from the first RO unit is sent to the second RO unit to be treated again. It is not uncommon for the permeate from a double-pass RO unit to have a resistivity value in the range of 1 $\Omega\cdot$cm, approaching ppb levels of organic and silica contaminants.

8.3.1 *Permeate Water Tank* — The permeate water tank stores permeate water and provides sufficient retention time to conduct normal maintenance and allow troubleshooting activities during interruption in water supply.

8.4 *Dissolved Gas and Volatiles Removal* — The removal of dissolved oxygen, carbon dioxide, other gases, and volatile organic compounds is a necessary treatment step. The removal of these contaminants is accomplished to acceptable levels by vacuum degasifiers or by membrane degasification units. The degasification equipment can be located in either or both the Make-up and Polish plants (depending upon cost considerations and final UPW spec requirements for dissolved gases).

8.5 *Polish* — The Polish treatment section is designed for maintenance of UPW quality not for bulk removal. The primary water should be of UPW quality. TOC compounds that exit the primary ion exchange units are typically subjected to TOC-reducing UV irradiation to break them into ionized compounds to be removed by the Polishing

Ion Exchange Units. Design criteria for UV irradiation should accommodate the fact that 185 nm UV lamps produce hydrogen peroxide that is potentially detrimental to the downstream equipment and production. One critical role of polish is removal of particles. The final filter prior to Distribution has a pore size determined by the final UPW quality particle size specification, dependent on the manufacturing process quality needs.

8.5.1 *UPW Tank* — The UPW tank provides equalization during peak consumption and also sufficient retention time to perform system maintenance and conduct troubleshooting activities during interruption in the water supply.

9 Distribution

NOTE 2: See Appendix 4 for details on distribution system design considerations.

9.1 *Distribution* — Distribution system has one or more loops. The loops ensure consistent high-purity water quality by continuously re-circulating UPW through appropriate piping from the final filters to the manufacturing areas and back to a tank located within the Polish plant to be treated again.

9.1.1 Ozone can be injected into the distribution loop during start-up and commissioning to ensure deactivation of bacteria left post installation and construction. Such ozonation should not be necessary after start-up in a well-designed and maintained UPW system (see Appendix 7 for filtration details).

9.1.2 *Hot UPW System (HUPW)* — HUPW is a subset of the UPW Plant and distribution system. Refer to Appendix 5 for details and important design considerations.

9.1.3 *Dead-Leg* — A dead leg is a section of the UPW distribution piping that under normal operational conditions has no flow. A dead leg should not be longer than three times its inner diameter.

9.1.4 *Supply-to-Consumption Ratio* — The supply-to-consumption ratio is the ratio of the total flowrate of UPW supply divided by the projected average tool consumption (typically defined as one of the design criteria for sizing polish and distribution system).

9.1.5 *Maximum (or Peak) Consumption* — Maximum/peak consumption is the maximum flowrate that can be consumed by the maximum number of fab tools and facility users at any one point in time.

9.2 *Average Consumption* — Average consumption is the flowrate calculated for all factory tools consumption as well as consumption by facility users over an extended period of time. Average consumption is needed for sizing equipment of the Make-up plant, upstream to the UPW tank. The UPW tank provides sufficient storage to accommodate instances when short term peak demand exceeds the average design consumption.

9.3 *Specific Definitions for UPW Distribution System*

9.3.1 *Supply* — The piping and other distribution system components connecting UPW treatment system and the manufacturing tools/facility UPW users. Supply piping is located downstream (following direction of the flow) final filters and upstream to the UPW user equipment.

9.3.2 *Return* — The piping and other distribution system components connecting ends of Supply piping and UPW tanks. The return piping located upstream to the UPW tank downstream to the break points (or termination points) between Supply and Return. The break points are various types of valves, orifices, or tubing that provide the required excess flowrate at the ends of supply lines to ensure no stagnation. Those break points provide pressure transition from *Supply* pressure determined by the manufacturing tool pressure specification and *Return* pressure determined by the UPW tank hydrostatic pressure.

9.3.3 *Main Supply or Return Lines* — The largest diameter pipelines that deliver UPW to the subfab. The main lines start immediately downstream of the final filters and extend to their first split into two or more pipelines. Full-size HVM facility may have more than one distribution loop and therefore more than one supply and return mains.

9.3.4 *Lateral Piping* — Sections of the distribution lines commonly installed beneath tools in the cleanroom bay and supporting UPW demand of those tools. The lateral piping provides take-off valves (at POC) to connect the tool to the UPW distribution. This connection is commonly referred to as ‘tool hook-up piping’.

9.3.5 *Sub-Main Piping* — The large diameter piping that connects the main line with the lateral piping. Sub-main piping may not exist if the lateral piping is connected directly to the main line.

10 General Process Considerations

10.1 UPW Make-up Plant design has matured over recent decades of semiconductor fab technology development. The main differences in the current UPW system designs are in the Pretreatment process and are typically driven by the following factors:

10.1.1 Incoming water quality (see Appendix 3 for details of water quality concerns).

10.1.1.1 In most cases the water quality feeding UPW systems is within typical municipal water quality requirements. If it is not, additional pretreatment may be required (reclaim sources, etc.).

10.1.1.2 Water with a high number of suspended solids may require extensive filtration treatment such as MMF, UF, etc. Clear water may need minimum-to no-incoming filtration.

10.1.1.3 Underground water containing iron and manganese may require special oxidation filtration to remove the fouling contaminants.

10.1.2 Water conservation requirements may drive use of ion exchange in pretreatment to the RO. Use of ion exchange resins in Pretreatment (before the RO) can improve the overall performance of UPW, but it contributes high salinity regeneration wastewater to the environment. Environmental permits limiting effluent total dissolves solids (TDS) may be the reason of using double pass RO without pre-treatment.

10.1.2.1 *Double-Pass vs. Single-Pass Reverse Osmosis* — Advanced semiconductor manufacturing UPW systems frequently include double-pass RO—a configuration that allows for effective removal of weak ions such as boron and silica. Single-pass RO can be used when feed water contains a low content of weak ions or when ion exchange is used in Pretreatment.

10.1.3 Removing CO_2 may reduce operating costs for frequent ion exchange resin regenerations and for caustic injection when pH control is necessary for optimized RO operation.

10.1.4 The primary deionization process may consist of either anion resin followed by mixed beds, or electro-deionization (EDI) followed by mixed bed resins. Choice of specific configuration depends on overall process configuration, UPW quality specifications, performance reliability requirements, environmental considerations (water efficiency and use of regeneration chemicals), and cost.

10.1.4.1 *Boron Control* — Boron in form of borate is the weakest inorganic anion present in the raw water and is the most difficult to control. Under conditions of neutral or low pH, more than half of the boron is in the form of non-dissociated boric acid which is not rejected by RO. Therefore, high pH conditions are required to enhance boron removal by RO. However, when pH >9, an increased leakage of sodium should be expected and taken into account when deciding on the capacity of the downstream deionization equipment. Also, the ion exchange capability of the ion exchange resin is limited by the weak ionic properties of boron, resulting in a chromatography effect where boron is slowly released by the resin and passes through the column. The boron leakage is particularly important for design and operation of the polishing system when the ion exchange resin is used for long periods of time without resin replacement or regeneration. Boron should therefore be removed in the primary loop if possible.

10.1.5 *UV Considerations*

10.1.5.1 TOC removal occurs in close proximity to the UV sleeve therefore the UV reactors should provide a sufficient surface area to allow the UV radiation to break down the TOC molecules.

10.1.5.2 Different types of treated organics may require different energies for their decomposition.

10.1.5.3 Use of oxidizing chemistry (i.e., ozone) may enhance TOC removal.

10.1.5.4 H_2O_2 is a UV byproduct that may affect water quality and performance of the downstream equipment and manufacturing processes. H_2O_2 can be removed by platinum, palladium, or other catalyst beds.

10.2 *Polish Plant Design Considerations*

10.2.1 Most polish systems contain UPW tanks, pumps, degasification modules, UV, polish mixed beds, and the final filters. The unit sequence, specific design details, materials of construction, and equipment sizing may vary.

10.2.2 The material of construction may affect water quality. Use SEMI F57 (the standard for quality of high purity polymer materials) when making decisions on the choice of the materials. Stainless steel is recommended to be minimized. (See Appendix 1 for more details.)

10.2.3 Reliability of the polishing loop is particularly important as shutdown of the loop may have significant and extended impact on the fab operation. Reliability is facilitated by an uninterrupted power supply, equipment redundancy, effective maintenance, etc. (See Appendix 6 for more details.)

10.2.4 The polish system capacity should be optimized to ensure cost-effective and reliable operation. The capacity of the system should take into account when considering fab UPW consumption, pressure control, minimum by-pass flows (to maintain cleanliness), and the maintenance flows needed for rinsing the polish system components.

10.3 Distribution design considerations include the following:

10.3.1 Maintaining pressure at the tools.

10.3.2 Delivering unchanged UPW quality.

10.3.3 Maintaining UPW quality throughout the system (including UPW return).

10.3.4 System integrity and reliability.

10.3.5 Special consideration in the overall system design should be given to the choice of material of construction, thermal expansion of the piping, piping supports, pressure control scheme, and minimum flow sizing criteria and by-pass configurations.

10.4 *Specific Equipment Considerations*

10.4.1 The UPW system employs a number of different replaceable filters with the final filters being the most important. See Appendix 7 for detail recommendations for the choice and performance evaluation of the filters.

10.4.2 Choice of ion exchange resin is critical. See Appendix 8 for details of risks and recommendations.

11 UPW System Utilities

11.1 UPW system utilities provide electricity, cooling, heating, nitrogen gas, and other critical resources required for sustainable operation of UPW system. See Appendix 9 for more details.

12 Quality Assurance and Quality Control (QAQC)

12.1 QAQC definitions are especially important during start up and commissioning of the new or upgraded UPW plant. Effective definition of QAQC plan can reduce cost and time of the construction projects, while enabling UPW quality compliance. See Appendix 2 for more details.

13 System Documentation

13.1 A list of the System Documentation required from the UPW vendor upon the project completion should be included in the scope definition for the project. See Appendix 10 for more details.

14 UPW System Reliability and Redundancy

14.1 UPW System redundancy recommendations are described in Appendix 6.

15 Safety Considerations

15.1 Safety of UPW system construction and operation is critical in the semiconductor industry. See Appendix 11 for details of safety considerations.

16 UPW System Maintenance and Operation

16.1 Details of effective maintenance and operations plans for advanced critical UPW systems are described in Appendix 12.

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17 Related Documents

17.1 *SEMI Standards and Safety Guidelines*

SEMI C79 — Guide to Evaluate the Efficacy of sub-15 nm Gilters Used in Ultrapure water (UPW) Distribution Systems

SEMI C93 — Guide for Ultrapure Water System Used in Semiconductor Processing

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

SEMI F31 — Guide for Bulk Chemical Distribution Systems

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

17.2 *Other Documents*

ITRS — International Technology Roadmap for Semiconductors – Reports for Yield Section[2]

[2] http://www.itrs2.net

APPENDIX 1
RECOMMENDED MATERIALS OF CONSTRUCTION: CHOICE, PURITY, HANDLING, JOINING, AND INSPECTION

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A1-1 General — Polish Plant and Distribution

A1-1.1 Recommended piping materials in polish and post-polish portion of a UPW system include the following high purity options: High Purity (HP) PVDF, HP PFA, electro-polished (10Ra) 316L stainless steel, PTFE (expanded, gaskets), PFA (gasket and valves), gaskets and seals, FPM, final filters (ultrafilters and/or cartridge filters), HP valves for water service, HP lined butterfly valves, HP diaphragm valves, needle (sample ports, PFA), ¼ turn ball valves (PFA).

A1-1.2 The manufacturer should be able to certify that all materials are HP and traceable based on respective SEMI Standards. The manufacturer should be able to demonstrate that all materials (manufactured product and raw materials) are tested periodically (representing normal use of raw materials and equipment) using SEMI F57 and SEMI F49 testing methodologies using certified laboratories. All tested HP polymer materials should meet the SEMI F57 standard and all tested HP stainless steel components should meet SEMI F19 requirements.

A1-2 Piping and Conveyance

A1-2.1 Major piping materials for UPW should be PVDF for polish and distribution. Poly-propylene (PP) is commonly used in pre-polish and UPW return applications.

A1-2.2 All HP materials should be cleaned at the manufacturer or manufactured in a certified ISO CLASS 5 at 0.5 µ (class 100) clean room. There should be a chain-of-material control from raw materials to finished product. If cleaned, the cleaning should be finished with UPW of at least 17.5 MΩ·cm water, with TOC <10 ppb, and total ion content of <100 ppb. Gaskets should not contribute particles during system operation. All cut edges should be die cut in a clean area with a controlled environment. All HP materials should come from the manufacturer double-bagged and marked as certified for HP service. Bagging should be a special clean material and not contribute any contamination to the product.

A1-2.3 *PVDF and PFA Pipe and Fittings* — HP PVDF pipe should come double-bagged. It should be marked on the outer bag as ‘HP PVDF’ and the pipe should be marked on the pipe with lot number and part number in a permanent manner. Pipe should also have protective caps. Both bags should be intact when the product is picked for use.

A1-2.4 *Isolation Valves* — This includes all lateral isolation valves off the main, all tool isolation valves off the lateral and any future isolation valve. All valves need to be HP grade. They should only have wetted parts that meet the acceptable materials listed in first section. They should be tested at the manufacturer for bubble tight and should not have any grease or lubricant used in assembly of the valve. It is strongly recommended that any terminating valve be a lug body type such that it can be installed with nothing on the downstream side. It is further recommended that a future valve have a blind flange installed on the downstream side to prevent opening. All future valves need to be properly supported. Valves should come double-bagged and marked for HP service.

A1-2.5 Materials need to be manufactured for intended purposes (not all grades are acceptable). They should be cut and capped as part of the extruder process to prevent dirt and debris from getting into pipe and fittings. They should be stored indoors in a controlled environment. Welding should be done with either IR butt fusion or non-contact heat fusion with feed forward and backward control. All welds should be traceable back to the worker and the machine. Fusion factors should be recorded for future reference and should include the material, size, date, and fusion parameters.

A1-2.6 For return piping materials of a lower standard may be used to reduce system cost. For the UPW return system this could be standard grade PVDF or high quality PP. The same rules apply to installation and material handling as for the polish loop except the materials will not be double-bagged BUT the materials should still be handled the same manner; that is, only unpack what you need immediately and the work environment should be clean and controlled.

A1-3 Pre-Fabrication

A1-3.1 Pre-fabrication should be done in a cleanroom or at least a clean environment. The complete pieces should be capped and bagged over the ends using a clean polyethylene sheet or bag and cleanroom-approved tape. Care should be taken in transport and handling as unintended stress may occur. The same guidelines for handling and work should be followed as above. The cleanroom should preferably be ISO CLASS 7 at 0.5 µ (class 10,000). There should be no metal working or painting going on in the clean area. Special clothing and footwear that are not exposed to general shop conditions should be worn.

A1-4 Installation of HP Materials

A1-4.1 *HP PVDF* — HP PVDF should be joined using non-contact infra-red (IR) high temperature fusion. The operator should be trained and certified by the manufacturer of the pipe, valves, and fittings. The welding device should have an input for the operator and the material to be joined (PP or PVDF with size and class [10 bars or 16 bars]). The welding machine should be able to measure and compensate the ambient temperature. Once material and size are entered, the machine should be able to automatically calculate overlap of the weld and weld time and cool down time. At the end of the fusion cycle the weld machine should be able to record that the weld met the specified conditions and print out the calibration info, operator info, weld machine info, material info, weld quality and the date and time for every weld. At the end of the fusion cycle a label should be printed providing traceability back to the printout and indicate that the weld was OK. The operator should be responsible to ensure for the weld is acceptable by visual inspection (e.g., the shape of the weld beads, the k-factor, etc.). The weld inspection criteria should be defined by the manufacturer such that an operator or QA/QC person can judge that the weld is acceptable via visual inspection.

A1-5 Mechanical Joints

A1-5.1 Flanged mechanical joints should use a gasket that is equal to the ID of the fitting ±1%. This ensures that there is neither impingement to flow nor any crevice at the joint. The flange backing ring should have a special shaped ID that directs the closing force toward the ID of the joint. This ensures that the applied forces are closing the gap in the joint and not opening the gap in the joint when tightened. Pipes need to be aligned within 1/8 in. in all directions. The joint is not intended to compensate for misalignment.

A1-6 Thermal Plastic Union Joints

A1-6.1 For PFA tubing mechanical connections flare type connectors should be used. For tubing ¼ in. and below standard wall thickness a mechanical flaring tool may be used. For all other tubing, leak free connections should be used; that is, a heated flaring system. All tubing should be cut with a tubing cutter and be square.

A1-6.2 Union joints on piping need to be made of HP materials. They should not exceed 2 inches. They should have an HP grade O-ring. They should be installed as a butt-fusion joint. Alignment is critical with this type of joint. The joint halves should be square face-to-face and should be <3 mm out of alignment. Flange joints are a better option for anything over 32 mm (1 in.). Do not over tighten union nuts as they are prone to failure.

A1-7 Receiving and Inspection

A1-7.1 For all PVDF and PFA tubing all materials should be inspected upon delivery, both the outer bag and the inner bag should be intact with no tears or holes. Proper marking for intended service should be confirmed as well. After inspection all materials need to be placed in clean bins or containers which should protect from dirt and contamination. Prior to use the outer bag should be removed and the inner bag wiped with a cleanroom wipe with at least 10% IPA to clean. The part can then be transferred into the clean assembly area.

A1-8 Moving Materials into the Clean Assembly/Fabrication Area

A1-8.1 After cleaning the outer bag remove it from the inner bag at the clean area pass-through. Immediately transfer it into the clean area. Once inside the clean area remove the inner bag only immediately prior to use. Only remove bags from the number of parts that may be needed that day. For pipe if the need is for a partial piece of pipe, remove the bag but retain the end cap. After cutting off the needed length re-cap and put the pipe back onto the rack.

A1-9 Filtration Materials

A1-9.1 As the primary job for filtration is to remove particles form the product, and as these materials are the last part of the treatment, they should NOT contribute any contamination to the system. Like the other materials in the polish system these require very closely controlled material control from the manufacture of the raw materials to the handling of the raw materials to the use of the raw materials, the manufacturing process and equipment, the manufacturing environment and the post manufacturing handling and packaging. SEMI F57 can be used to confirm cleanliness of the filtration material.

A1-9.2 The materials common to final filters are: nylon, PP, PVDF, and poly-sulfone. The filter should reside in a housing of some sort. For cartridge-type filtration it will be a stainless steel pressure vessel using 316L, EP to a 10 RA finish. Cross flow filter modules will come as a sub-assembly and should only be installed when the system is ready to start testing.

A1-10 Gaskets

A1-10.1 If PTFE gaskets are used, only expanded PTFE or PTFE encapsulated gaskets are recommended as the pure form of fluorinated polymer (an overcoat material). Gaskets should be pure, and meet or exceed SEMI F57 requirements. They should be manufactured in a clean environment. The gasket should be able to form a seal when compressed. Gaskets should be designed such that the force to seal does not exceed the strength of the pipe material or the bolts. This is specifically an issue for expanded per-fluoro compounds that are non-resilient. Use of any non-compressible material is not recommended. Per-fluoro (PFA, PTFE, ECTFE, and ETFE) compounds can be used as an over-coat of an elastomer or lining in other systems, such as tanks, vessels, pumps, valves, etc. For gaskets that are a two-part system with an inert material over-molded onto a resilient elastomer, there should be no exposure of the elastomer to the fluid.

A1-10.2 *FPM, EPDM, VITON, Silicon*

A1-10.2.1 It is important that these materials be clean and controlled. Refer to SEMI for elastomer material cleanliness testing. There are many forms of each of these and care should be taken to select high grade materials from reputable manufacturers that understand the intended application and need for low or non-contaminating product.

A1-10.2.2 FPM is the international abbreviation according to DIN/ISO.

A1-10.2.3 FKM is the short form for the fluoro-elastomer category according to the American standard ASTM.

A1-10.2.4 Viton® is the registered trademark of DuPont Performance Elastomers.

Table A1-1 Elastomer Material Compatibility

	Nitrile Rubber	Neoprene Rubber	EPDM Rubber	Fluoroelastomers FKM/FPM (such as Viton®)	Silicone	Clear Silicone (such as Silastic Clear medical grade)	Perfluoroelastomers FFKM (such as Kalrez®)	Perfluorocompounds PFA/PTFE/ECTFE/ECTFE (such as Teflon®, GORE®, Halar®, etc.)	XXXelastomers (such as Chemraz®)	Yyyvelastomers (such as zzzzz)
Pretreatment System	A	A	R	A	A	A	A	A	A	
Primary System	NA	NA	A	R	A	A	A	A	A	
Polish UPW	NA	NA	NA	A	A	R	A	R	A	
Ozonated UPW	NA	NA	NA	NA	A	NA	A	R	A	
Hot UPW	NA	NA	A	NA	NA	R	NA	R	NA	
Acid (HCl)	NA	NA	NA	R	NA	NA	NA	R	R	
Caustic	NA	NA	A	NA	NA	NA	NA	A	R	

Not Acceptable	NA
Acceptable	A
Recommended	R

#1 PTFE, ETFE, ECTFE, etc. should only be used in the modified version (expanded or encapsulated).

A1-10.2.5 EPDM rubber (ethylene propylene diene monomer [M-class] rubber) is the designation given for a saturated polymer chain of the polymethylene type, consisting of ethylene, propylene, and diene. The M refers to its classification in ASTM D1418.

A1-10.2.6 FKM (by ASTM D1418 standard) (equivalent to FPM by ISO/DIN 1629 standard) is the designation for about 80% of fluoroelastomers as defined in ASTM D1418. They provide additional heat and chemical resistance.

A1-10.2.7 Viton is a brand of synthetic rubber and fluoropolymer elastomer commonly used in O-rings, chemical-resistant gloves, and other molded or extruded goods. The name is a registered trademark of The Chemours Company. Viton fluoroelastomers are categorized under the ASTM D1418 and ISO 1629 designation of FKM.

A1-10.2.8 DuPont™ Kalrez® perfluoroelastomer parts (FFKM) resist over 1,800 different chemicals while offering the high temperature stability of PTFE (327°C). They are used in highly aggressive chemical processing, semiconductor wafer fabrication, pharmaceutical, oil and gas recovery, and aerospace applications.

A1-11 High Purity Stainless Steel Applications

A1-11.1 Certified 316L, passivated and electropolished to a 10 ra finish is recommended for HP wet applications. This is typically found around UV, large pump headers, pumps housing and impeller, pressure control valves, check valves, sample valves, the vacuum degasifier, and filter housings (see SEMI F19, Stainless Steel Surface Finishes). Use of stainless steel piping and components should be minimized, especially downstream polish Mixed Beds.

A1-12 Material Handling (i.e., high purity welding environment) and Joining Requirements

A1-12.1 *Environment*

A1-12.1.1 Welding should be performed in a cleanroom, preferably ISO 7 at 0.5 µ (class 10,000) or better. There should be no metal work occurring in the area of PVDF or PFA joining. All materials that come into the cleanroom should have the outer bag removed prior to passing into the cleanroom. The second bag should be removed only prior to immediate use. All materials in the cleanroom should be stored in clean containers with lids. All equipment should be wiped down with dilute IPA prior to entering the cleanroom to remove any surface dirt and oils. After all the work is done in the cleanroom the sub-assemblies should be covered on any open end with clean polyethylene bag or sheet and the cover taped on using cleanroom certified tape. Only then should it be removed from the cleanroom to a place for safe storage. If a cleanroom is not available, joining should be done in a clean area with hard walls and a sealed floor. There should not be any metal work occurring in that room (grinding, welding or painting).

A1-12.2 *Material Handling*

A1-12.2.1 All materials should come from the supplier marked as 'HP' or equal. All materials should be double-bagged with the part number clearly shown on both the inner and outer bag. Each part should be inspected to make sure that neither the part nor the packaging has been damaged.

A1-12.2.2 Prior to passing the part into the production area the outer bag should wiped with a cleanroom wipe wetted with DI water. Then the outer bag can be cut with a scissor and removed. Immediately pass the part into the cleanroom.

A1-12.2.3 This applies for PVDF, PFA and HP SS.

A1-12.3 *IR Butt Fusion Joining for PVDF or PFA*

A1-12.3.1 Use only machines approved/recommended by the material manufacturer. Machines should only be non-contact IR butt fusion machines. Plate heater machines which contact the part should not be allowed. Only vendor recommended clean wipes should be used for cleaning ends prior to welding. The welding machine should be able to specify the material type, size, wall thickness, and part type (fitting or pipe) in the set up. It should require inputs for room conditions (temperature and humidity) and the name and certification number of the person doing the weld. It should be capable of printing out the weld data on a tag whish should contain as a minimum the date, the material welded, the time of day, the welder machine number, and the name of the person doing the weld. This should also be stored in an internal memory that can be accessed later. The weld label should then be placed at the just completed joint if it is a successful weld. The machine should reject any weld that does not conform to the weld requirements as defined by the manufacturer during each weld; for example, end surface trimming and squaring, if the heat time is not correct, or the cool down time is not correct, wall offset, or the closing force is not correct, etc.

A1-12.3.2 The welding machine manufacturer or the material manufacturer should give clear direction on how to visually inspect every weld upon completion to determine if it is acceptable. The criteria should include weld bead shape, foreign material imbedded in weld, weld bead consistency around whole weld, pipe offset, pipe flatness at weld, etc. Every weld should be inspected by the person welding and the contractor QA/QC person. At the end of the project every weld should have a tag.

APPENDIX 2
ULTRAPURE WATER SYSTEM QUALIFICATION GUIDELINES

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A2-1 Defining the Scope for Analytical Work

A2-1.1 When designing a UPW system, it is important that the project-specified water quality requirements are aligned between the UPW system provider and the end user. SEMI F63 provides recommended water quality specification for the advanced semiconductor facility. Other generations of technologies may consider ASTM D5127 specification for reference. SEMI F63 also provides additional information about the risks associated with situations when the specified levels are exceeded.

A2-1.2 The scope of the analytical work is determined by water quality requirements and the project specific requirements for the system commissioning. Typical questions addressed, when defining commissioning requirements include:

- Using online vs. grab sample analyses (depends on the water quality spec and available analytical equipment).
- Duration of the final system commissioning (i.e., 30 days of in-compliance operation).
- Location of the samples and the number of samples to be taken during final commissioning.
- Use of duplicates to eliminate wrong readings due to sampling errors.
- Typical analytical instruments to be used for commissioning.
- Certified labs for off line analytical results.

A2-2 Qualification Testing Recommendations

A2-2.1 When qualifying new or recently modified UPW system, the following qualification areas should be considered:

- Make-up plant qualification. Qualifying the make-up plan helps to mitigate risks for start-up of the polish plant. Generally the make-up plant is started first.
- Polish plant qualification represents the ability of the UPW system to produce UPW at certain quality.
- Distribution system qualification may be important by itself. Although the UPW system may be able to meet the specified quality requirements, new distribution system components are known to add contamination (be it dissolved ions or particles) during first months of operation.

NOTE 3: To minimize commissioning schedule it may be required to rinse the polish distribution with a small external UPW source while qualifying the makeup plant.

A2-2.2 It is recommended to initiate the qualification testing when the system has rinsed to resistivity specification. It is recommended to conduct preliminary tests for the following parameters, before initiating the final compliance testing program:

- Bacteria (typical after construction contamination—may require sanitization)
- Boron and silica (may indicate ion exchange issues due to quality of resin or start-up issues)
- Online Particles and TOC (may indicate leaching from polisher resins, potting glue from UF)

A2-2.3 Samples are typically collected weekly for a period of four weeks to measure UPW quality stability. For critical parameters, it is recommended to sample in duplicates. If the water quality is stable, a routine monitoring program may be initiated. Monthly sampling is typical frequency of the grab sample analysis for routine monitoring.

A2-2.4 It is also common that some of the parameters, such as bacteria, fail during the initial compliance testing.

A2-2.5 The following table provides reference for planning analytical qualifications. SEMI F63 provides reference analytical methods and recommendation of using different sampling volumes to verify start-up and commissioning contamination results.

A2-2.6 Sampling bottles should be pre-qualified for the analyses and sampling should follow the instructions provided by the analytical laboratory. The laboratory used for analysis should be ISO17025 compliant. The following factors should be taken into consideration: cleanliness of the sample port, environmental contamination, material of construction of the sample port, etc. The sample port should consider its physical location with respect to the application considered. Standardized sampling instructions may be available from the qualified laboratories. It is important that the sampler is trained for the sampling protocol.

A2-2.7 In case of incompliance with the target UPW quality levels, extensive list of troubleshooting tests, such as organic speciation, material characterization, material cleanliness tests, air/gas/chemicals quality analyses.

Table A2-1 Typical Location for Different Methods of Water Quality Monitoring in UPW Systems

UPW Low Level Analyses	*Typical Sample Locations*				*Comments*
	Pre-treatment	*Make-up (UPW tank feed)*	*UPW Supply at POD*	*Distribution at POC*	
SDI	In situ	N/A	N/A	N/A	City Water and RO Feed
ORP	Online	N/A	N/A	N/A	RO feed
THM	GRAB	GRAB	GRAB		
Conductivity/Resistivity	GRAB or online	online	online	online	RO probing and profiling may be needed RO rejection: actuals against projections
Dissolved Oxygen	N/A	online (if controlled in Make-up)	online	online	
Dissolved Nitrogen	N/A	NA	online (if controlled)	online (if controlled)	
Online particles		NA	online	online	Also, polish IX particle shedding profiles
Nonvolatile residue	N/A		online		Recommended particularly for IX resin rinse qual
TOC (Option 1)	online	online	online	online	
TOC (Option 2)	GRAB	GRAB			If on-line unavailable: applicable for TOC > 5ppb Recommended to test RO rejection performance
Metals by ICPMS	GRAB	GRAB	GRAB	GRAB	Particularly important to track initial piping leach-outs at POD vs. POC
Anions by IC	GRAB	GRAB	GRAB	GRAB	
Ammonia by IC			GRAB	GRAB	
Bacteria	N/A	N/A	GRAB	GRAB	
SEM 0.05 µ			GRAB	GRAB	Particle characterization also recommended
Silica (dissolved)	GRAB	GRAB	GRAB	GRAB	Need to confirm the DLs meet the water quality spec
Silica (total)	GRAB	GRAB	GRAB	GRAB	
Urea (1-3 samples)	GRAB		GRAB		Optional test
Organic Speciation	GRAB	GRAB	GRAB	GRAB	Recommended for initial fingerprint—reference for future troubleshooting

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APPENDIX 3
INCOMING WATER QUALITY

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A3-1 Source Water Definition

A3-1.1 Water for semiconductor manufacturing can come from a variety of sources. Most commonly the source is surface water or well-water, and in some cases seawater desalination. In some cases the reclaim water sources are used to feed the UPW system. A semiconductor facility draws water from the local municipality, where the feed water quality may be affected by environmental contamination and how it is treated.

A3-1.2 The municipal water supply is tested to meet regulatory requirements for drinking water standards. In cases if the source is not controlled by the city, special attention should be paid to the water quality monitoring and control. Understanding the water source and seasonal variability is key to maintaining an ultrapure water quality for critical microelectronic manufacturing.

A3-1.3 Historical data of total dissolved solids (TDS) is a primary indication for consistency of the water quality. Temperature range should be defined taking into account extreme conditions to ensure effective temperature control. Urea and some other organic compounds listed below are subject to seasonal variations.

A3-2 Key Parameters

A3-2.1 *Total Organic Carbon (TOC)* — Water quality is affected by organic compounds. High Molecular weight (HMW) compounds such as humic acids and polysaccharides are readily removed, but may cause membrane (i.e., RO or UF) fouling. Some organics decomposing may cause biofouling. However, low molecular weight (LMW) neutral compounds, such as fertilizer (urea) and pesticides (atrazine) commonly used in agriculture can have an adverse effect on final quality. Chlorination by a municipal supply will also increase trihalomethanes (THMs), which is also LMW neutral. Organic speciation can help determine treatment requirements.

A3-3 Particulates

A3-3.1 These are typically measured as turbidity (NTU), silt density index (SDI), or as total suspended solids (TSS). Once understood these are readily removed in the treatment system. When particulate loading is high, effective design of the pretreatment is required to ensure low operating cost.

A3-4 Ions

A3-4.1 Ionic loading needs to be fully understood for treatment loading. Specifically, it is important to measure weakly dissociated ions such as boron, silica, and organic acids.

A3-5 Silica

A3-5.1 Some underground waters may contain high concentration of silica that may limit RO recovery and foul membranes.

Table A3-1 Typical Inlet Water Quality Table

CERTIFICATE OF ANALYSIS[#1]					
CATIONS	*TYPICAL RESULT*	*UNITS*	*ANIONS*	*TYPICAL RESULT*	*UNITS*
Calcium (Ca)	24.2	mg/L $CaCO_3$[#2]	Bicarbonate (HCO3)	33.6	mg/L $CaCO_3$
Magnesium (MG)	13.0	mg/L $CaCO_3$	Fluoride (F)	<0.020	mg/L $CaCO_3$
Sodium (Na)	25.9	mg/L $CaCO_3$	Bromide (Br)	10.0	mg/L $CaCO_3$
Potassium (K)	1.1	mg/L CaCo3	Nitrate (NO_3^-)	3.68	mg/L $CaCO_3$
Iron (Fe)	0.003	mg/L $CaCO_3$	Phosphate (PO_4^{3-})	<0.080	mg/L $CaCO_3$
Manganese (Mn)	<0.001	mg/L $CaCO_3$	Sulfate (SO_4^{2-})	13.4	mg/L $CaCO_3$
Aluminum (Al)	0.005	mg/L $CaCO_3$	Silica (SiO_3^{2-})	15.2	mg/L $CaCO_3$
Barium (Ba)	0.007	mg/L $CaCO_3$	Boron (B)	0.002	mg/L
Strontium (Sr)	0.043	mg/L $CaCO_3$	Nitrite, (NO_2^-)	<0.020	mg/L $CaCO_3$
Copper (Cu)	0.122	mg/L $CaCO_3$[#3]			
Zinc (Zn)	0.007	mg/L $CaCO_3$			
OTHERS	*RESULT*	*UNITS*	*OTHERS*	*RESULT*	*UNITS*
pH	7.36	Stand. Units	Total Harness	37.2	mg/L CaCO3
Turbidity	0.05	NTU	TOC (C)	0.78	mg/L
Conductivity	127	uS/cm			
TDS	70	mg/L			

#1 Analysis should be performed by an accredited laboratory.

#2 Results may be expressed as ion or an equivalent. Anions and Cations should balance.

#3 Where reclaim water is the source additional background metals should be tested such as Gold (Ag) or metals in the process.

A3-5.2 THMs and Organic speciation are recommended for the projects with low UPW TOC specification (<5 ppb) or in cases when organic/bio-fouling is of concern.

A3-5.3 In case where there are more than one source feeding the site, each source should be characterized separately.

A3-5.4 The seasonal data (monthly samples) are important to allow effective design. If available, the data should be presented in the form of minimum, maximum, and average for each parameter. The city may have the data from its own analysis. The minimum recommended number of samples (in case of lacking data) are two within a week's time between the samples. City/Public owner water source data is generally very average in results. Peak variations will not be available. It gives a good general idea of what the water make up is and is the first basis for pretreatment design.

APPENDIX 4
UPW DISTRIBUTION SYSTEM

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A4-1 Sizing Criteria

A4-1.1 UPW Distribution should be sized to provide flowrates in the piping within defined minimum and maximum recommended flow criteria. These criteria are chosen to ensure long term mechanical stability of the piping system and maintenance of high purity of conveyed UPW. Tightly controlled flow and pressure will provide best results for both delivery to the tool and final filtration performance. Highly variable flow will have a negative impact on polish system unit operation and particularly on final filtration.

A4-1.2 The definition of the criteria assumes the use of piping material of construction made of high purity PVDF or similar, possessing similar mechanical strengths and meeting quality definitions as specified by SEMI F57 standard. The criteria are based on years of prior experience of successful operation of PVDF piping.

A4-1.3 Main and sub-main supply piping should not exceed maximum flow criteria of three meters per second. Although laterals and tool hook-up lines may support higher flow velocity their maximum flow criteria should be limited to 2 to 2.5 meters per second to provide additional capacity flexibility in the distribution system.

A4-1.4 Minimum flow criteria should be set at any point of the supply portion of the distribution system to ensure minimum UPW exchange and minimize accumulation of the contamination in the deadlegs and bacterial growth as a result. Minimum flow criterion is recommended to be based on the Reynolds number of 4000. Lower flow criteria may be considered in the areas without deadlegs. Deadlegs should be eliminated as much as possible.

A4-1.5 Use of minimum flow criteria results in the UPW supply flowrate higher than what is needed for the tool consumption. It is recommended not to use 'supply-to-consumption ratio' for sizing UPW polish and distribution system.

A4-2 System Configuration

A4-2.1 There are two common distribution systems design strategies: 'direct' return and 'reverse' return. There are benefits of one approach versus the other. This is a fundamental decision that should be made early in the planning phase.

A4-2.1.1 Direct return is more common configuration used in UPW. In this configuration supply and return sub-mains and laterals are installed parallel and next to each other with diameters decreasing as accumulative UPW consumption decreases (often called 'telescoping' due to stepwise diameter reduction). The diameters are 'directly' equivalent along the pipe length. In this configuration the pressure in each point of the distribution system varies with the pressure losses. From the tool point of view the feed pressure differences are relatively insignificant that justifies use of direct return configuration. However, hundreds of 'minimum flow' by-passes at the end of each supply line require additional investment into flow control elements (flow meters, valves, pressure sensors, etc.). Such systems also require operating cost for periodical rebalancing and fine tuning of the flows.

A4-2.1.2 Reverse return configuration provides pressure equalization throughout the distribution. In this configuration the diameters of the supply and return sub-mains and laterals are 'reversed' with respect to each other (largest diameter of supply will be next to the smallest diameter of the respective return section of the distribution pipe). In contrast with the direct return, reverse return laterals may require an additional third pipe if they are connected to the supply and return lines located next to each other (see Figure A4-1). This concept is normal for air systems applications (i.e., compressible fluids), where pressure equalization is important. The benefits for UPW distribution systems are not as obvious. On one hand it adds cost for third pipe, but it reduces capital and operating cost for the end of loop flow control. It may also be beneficial in cases where spec pressure across the systems is equal.

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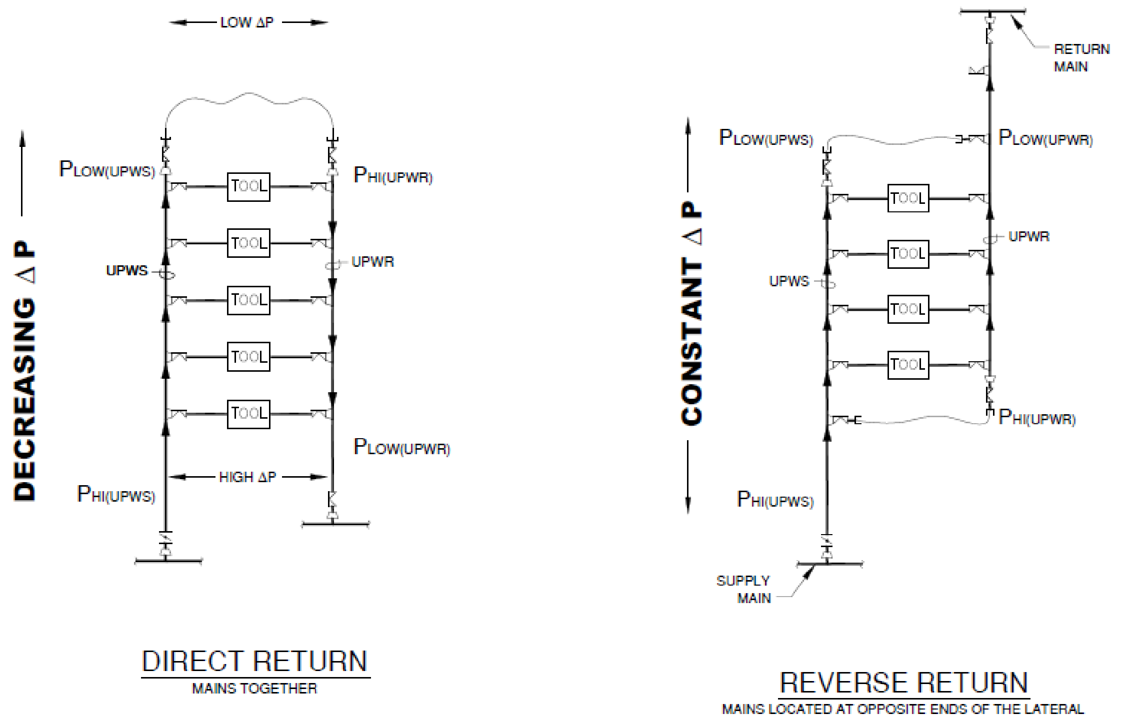

Typical ‘Direct’ and ‘Reverse’ Return Lateral Configuration (Libman et al. 2012)

A4-3 Pressure Control

A4-3.1 *End of Supply (EOS) Pressure Control*

A4-3.1.1 The PCV is located near end or at the end of the UPW supply main and is connected to the UPW return. Supply pressure control provides low transient response time when controlling pressure at the tools. It also maintains relatively high differential pressure between UPW supply and return, which stabilizes a stand-by flow. One of the risks of the supply pressure control is that PCV may close to maintain pressure at high tool consumption resulting in losing pressure control. Although that risk can be mitigated by increased return flow, that requires higher overall capacity of the polish system, which is costly and not always feasible.

A4-3.2 *End of Return (EOR) Pressure Control*

A4-3.2.1 In this option, PCV is installed between the last lateral return and the UPW tank. The EOR valve modulates based on the signal from the UPW supply main pressure. As the tools consumption increases, the supply pressure decreases and the PCV begins to close. As the result, UPW return flow is variable and decreases with increased tools consumption. An important advantage of the return pressure control is the fact that pressure control can be maintained at any tools consumption rate. However, at early phases of tool install, return pressure control is challenging as there is no modulating main bypass capable of bypassing the excess flow. As a result, the entire flow should pass through the tool bypasses when it is not consumed. The supply to return jumpers or shunts need to be installed in order to provide a bypass path to the UPW when few tools are consuming water. Using EOR valve for the entire system pressure control is particularly challenging for large UPW distribution system with multiple distribution loops and very long main lines.

A4-3.3 *Combined Pressure Control*

A4-3.3.1 Combined pressure control utilizes both supply and return PCVs. At low tools consumption, only supply PCV is active and it controls pressure when tools consumption is in the range of no demand up to the design high demand. During peak consumption, return PCV is activated reducing the return flow. That allows using part of the return flow for tools consumption during peak demand, which in effect, provides additional UPW capacity.

A4-4 Future Expansion

A4-4.1 Future expansion capabilities should be decided during design phase. Unless provisions for future expansions are made, it may be impossible to expand system capacity in future without major cost impact and interruption to production. The project scope should include the number and pipe diameters of 'future' connection points needed for laterals that could potentially be added in the future.

A4-5 Start-Up and Commissioning: Preparations to Qualification and Qualification Testing

A4-5.1 The following considerations are recommended to be considered at the stage of the system design:

A4-5.1.1 *Enabling Timely Rinse to Qualification* — Time allotted and schedule for commissioning and acceptance activities. New polymer material requires numerous weeks for rinse-up to meet tight UPW quality specifications (i.e., SEMI F63 or similar). When a project schedule is tight, it is recommended to install the distribution system as early as possible and consider using a mobile small UPW system to provide piping rinse.

A4-5.1.2 *Start-Up Strategy* — Entire system at once vs. ramping-up system in phases. The choice may depend on schedule of the project and other factors. The resolution may affect system configuration and design.

A4-5.1.3 Sanitization provisions are recommended to ensure effective bacteria control and fast qualification. Ozonation is the commonly used method for distribution loop sanitization, while laterals and tool hook-up can be sanitized using hydrogen peroxide. The design considerations should include the required hardware and material compatibility, as well as injection points, feed/bleed ports and sample ports. The incompatible materials or unit operation may require by-passes.

A4-5.2 *Start-Up Risks*

A4-5.2.1 Ion Exchange resin may shed contamination unless resin quality is confirmed using the SEMI C93 guide.

A4-5.2.2 Piping material contamination can be reduced when high purity material is verified using SEMI F57 compliant materials.

A4-5.2.2.1 Even for high purity materials increased fluoride, TOC, and metals contamination should be expected during initial weeks of rinse.

A4-5.2.3 Final filtration protection should be considered when developing start-up and commissioning sequence. Initial after-start-up contamination may overload the filters, while hydraulic stresses or fluctuation may cause risks to filter integrity. Sacrificial cartridge filters are often used, where the system includes cartridge filters in the final filter position or in front of the ultra-filters to address initial post construction contamination.

A4-5.2.3.1 Final filter rinse-up time needs to be considered. For example, ultra-filters may be acquired without preservatives to expedite the rinse time, however this means they should be put into use immediately after installation.

A4-6 Location, Number, and Type of Sampling Ports for Testing for Spec Parameters

A4-6.1 Qualification testing should be considered early in the processes, including the following:

A4-6.1.1 Availability of the qualified lab and metrology.

A4-6.1.2 Qualification criteria regarding the specifications.

- Special qualification criteria for early users, such as chemical delivery systems qualification, humidification, and others that require less tight UPW quality specs than SEMI F63.
- Typical qualification includes a sequence of the multiple samples taken with predefined frequency (i.e., 10 samples, every 3 days). Failure of one or more samples may trigger re-qualification.
- Criteria for the system re-qualification may need to be defined—determining when new qualification should start if performance issues are identified.
- Qualification sampling plan (timing, frequency, number of replicates, etc.).
- Availability of the qualified bottles, trained samplers, sampling instructions, etc.

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A4-7 References

A4-7.1 Libman V., Buesser D., and Ekberg B. "Next Generation of UPW Distribution System for the Next Generation of Semiconductor Factories." *Ultrapure Water Journal*, 29(1), (2012): pp. 23-30.

APPENDIX 5
HUPW

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A5-1 General Guide

A5-1.1 HUPW is a subset of UPW polish and distribution system. It is fed from the final UPW quality source. The water is heated to the target temperature level (typically 60°C to 70°C), filtered and then distributed to the manufacturing tools. Typical application of HUPW is to wafer rinse processes requiring an elevated temperature to enhance the cleaning process. Other applications of HUWP are possible. Depending on the physical location of the UPW polish treatment system, the HUPW equipment may be fed from the location either upstream or downstream of the UPW polish final filters. When polish system is located in the fab building, feeding HUPW upstream to the final filters reduces the load and the cost of the final filters.

A5-1.2 Typical configuration of the HUPW equipment includes a booster pump that compensates the pressure losses in HUWP equipment, a heat recovery heat exchanger that preheats water using HUPW return stream (thus recovering energy), a final heating heat exchanger (bringing the temperature up to the target level and controlling the temperature), and the final filters responsible for low particulate final quality water. HUPW is expected to be in compliance with SEMI F63 quality parameters as well.

A5-1.3 Minimum flow piping design criteria in HUPW is typically not as strict as that of ambient UPW. In an adequately sized HUPW system bacteria is not a concern. However, if the system is undersized (insufficient capacity), the tools can be pulling water from the HUPW return, thus creating potential for contamination.

A5-1.4 Sizing HUPW is often more challenging than sizing of ambient UPW. Higher peaking factors should be taken into consideration. Due to the relatively small size of the system, even one high consumption tool may pose challenge to the pressure control of the entire system.

A5-1.5 One of the biggest engineering difficulties of designing HUPW distribution piping is due to thermal expansion that significantly increases the length of the pipe when it is heated from ambient to target level of temperature. The piping is built from expansion loops, thus preventing from too extensive elongation of straight sections of PVDF pipe causing physical conflicts with the building structure or other systems. Actual support choice and design should also be based on the piping vendor recommendation. The engineer should follow recommendations of the PVDF piping vendor when designing piping supports. The support should have well-defined location of the fixed points, as well as, the support guides allowing for piping expansion, this preventing pipe breakage.

A5-1.6 HUPW piping is typically insulated to prevent loss of heat, overheating environment, and providing safety protection for the operators. Insulation material type should be chosen based on the building and fire code requirements. Possible generation of particles from the insulation material into the air should be taken into consideration. This may be particularly important when the system is located in the clean sub-fab area, sensitive to particulates in the air.

A5-1.7 Typical water quality monitoring in HUPW is for resistivity, TOC, and particles. It is also recommended that HUPW is periodically tested for metals and anions. Defects in HUPW heat exchangers may cause cross-contamination from the boiler or chilled water. Grab sample analysis may help to identify the issue. That may be more difficult to do through the resistivity sensor due to its insufficient sensitivity. One of the analytical challenges associated with HUPW is sample cooling without contamination. This is particularly important for the on-line particle counters that need cooling. Small cooling HEX should be considered for this purpose.

A5-1.8 Plate and frame HEXs, commonly used in HUPW, are typically made from titanium, and require special manufacturing for UPW service. They require a significant number of gaskets. Choice of elastomers may drive cost, quality, or schedule issues. Use of SEMI F51 and SEMI F57 for this purpose is advised.

A5-2 Specific Recommendations for Design Guide

A5-2.1 PVDF has high co-efficient of thermal expansion (8 in./100 ft. at 75oC) so expansion should be built into the design. This includes anchored points and expansion loops.

A5-2.1.1 Piping Supports Design Considerations.

A5-2.1.2 Any system that runs hot or temperature cycles should consider continuous support from a tray or channel.

A5-2.1.3 Support system should allow for free movement of the pipe.

A5-2.1.4 All changes of direction should allow pipe to flex as designed.

A5-2.1.5 Guides that don’t restrain movement should be used for safety and seismic concerns.

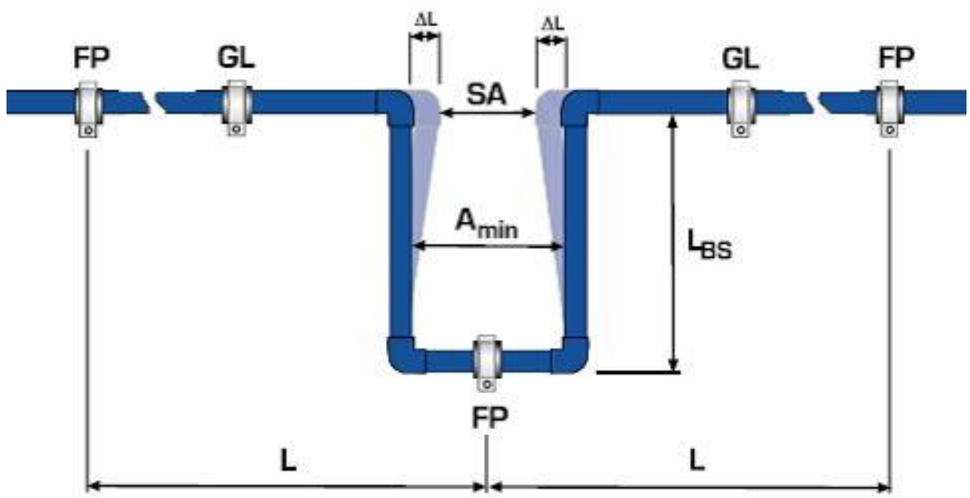
A5-2.1.6 All future connections need to be supported at the connection point.

A5-2.1.7 All high point vents or drains need to be protected.

A5-2.1.8 All instrumentation or other equipment inserted in to a plastic piping system needs independent support.

A5-2.1.9 Care needs to be taken to ensure supports don’t create unintended anchors.

A5-2.1.10 Vibration Isolation and expansion joint need to be a designed solution that accounts for physical properties of the materials involved.



Typical Configuration of the Design for Thermal Expansion Loop for Plastic Piping

A5-3 Insulation

A5-3.1 ASTM E84 25/50 is the specification for closed-cell insulation. It is then jacketed with a hard PVC sheet material with Low VOC, fiber-free, not shedding particulates, formaldehyde-free insulation. It should have antimicrobial product protection that inhibits the growth of mold and mildew in the insulation prevents moisture wicking and eliminates need for additional vapor retarder.

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APPENDIX 6
UPW SYSTEM RELIABILITY AND REDUNDANCY

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A6-1 UPW System

A6-1.1 The UPW System is a critical semiconductor fab utility. Interruption in UPW system operation may lead to a major factory shutdown for an extended period of time. UPW systems operate 24-7 without shutdowns for maintenance for years.

A6-1.2 To prevent interruptions or mitigate their effects, the following redundancy scheme is recommended (see Table A6-1). N factor in the table indicates the minimum total number of the same type unites of equipment required to support design capacity. N+1 implies that in addition to N, there is a need for one additional unit to be installed and ready to operate in the case of the maintenance of one of the N unites.

NOTE 4: This section does not consider redundancy requirements during construction project interruptions. If such additional redundancy is needed, special provisions may be made to minimize process interruptions. This may include piping by-passes, storage volumes, etc.

NOTE 5: The equipment list below is generic and will vary between the facilities. It is provided for redundancy definition only. The system owner should make the specific definitions.

Table A6-1 UPW System Reliability Scheme

System/Unit Operations/ Equipment	*Frequent Maintenance Needed*[2]	*Minimum Recommended Redundancy*	*Rational*	*Emergency Power*	*Comments*
Make-up Plant					
Feed water Tank	No	N	Operator response time	N/A	Full sized bypass recommended; minimum recommended retention time is 1 hr.
Feed water pumps	No	N+1	Maintenance	No	
Back-wash pumps	No	N	Less critical	No	Shelf spare parts
MMF	Yes	N+1	Maintenance	N/A	
ACF	Yes	N+1	Maintenance	N/A	
Chemical dosage pumps	No	N+1	Maintenance	No	
Heat Exchangers	No	N + 1	N+1 may not be needed in pretreatment when feed water temperature is stable 21 ± 3°C	N/A	Critical in cold climates (winter water T<18°C)
Pretreatment Ion Exchangers	Yes	N+1	Maintenance	N/A	
RO pre-filters	No	N+1	Maintenance	N/A	
1st Pass RO	No	N+1	Maintenance	N/A	
2nd pass RO	No	N+1	Maintenance	N/A	
Decarbonator	No	N	Lower risk/impact	No	
RO Tank	No	N+1	Operator response time	N/A	minimum recommended retention time is 1 hr.
Primary pumps	No	N+1	Maintenance	No	

System/Unit Operations/ Equipment	*Frequent Maintenance Needed*[2]	*Minimum Recommended Redundancy*	*Rational*	*Emergency Power*	*Comments*
Primary 185nm UV	No	N+1	Maintenance	No	
EDI	No	N+1	Maintenance	No	
Anion Beds	Yes	N+1	Maintenance	N/A	
Primary Mixed Beds	Yes	N+1	Maintenance	N/A	
Cartridge Filters	No	N+1	Maintenance	N/A	
Polish System					
UPW Tank	No	N+1	Operator response time	N/A	Nitrogen ON; minimum recommended retention time is 1 hr.
Polish Pumps	No	N+1	Maintenance	Yes	
Membrane Vacuum Degasifier	No	N+1	Maintenance	N/A	
Vacuum Degasifier Tower	No	N	No maintenance is needed for extended period	N/A	
Polish 185 nm UV	No	N+1	Maintenance	No	
Polish MB	No	N+1	Maintenance	N/A	
Degasifier Vacuum Pump	No	N+1	Maintenance	Yes	
Polish Booster Pumps	No	N+1	Maintenance	Yes	
Final Filters	No	N+1	Maintenance	N/A	
Others					
Piping[3]	No	N	Reliable	N/A	
Distribution PCV	No	N + bypass	Critical	Yes	Shelf spare
PLC	No	2N	Critical, 2nd for changes	Yes	
Analytical Equipment and Instrumentation					
Active control instrumentation	No	N+1	Maintenance and drift control	Yes	pH, Level, pressure, temperature
Conductivity/ Resistivity	No	N	Polish MB has resistivity meters, not sensitive	Yes	Portable
Dissolved Oxygen[1]	No	N	cost	Yes	Portable
Dissolved Nitrogen[1]	No	N	cost	Yes	Portable
Sodium[1]	No	N	cost	Yes	Grab sample
Dissolved Silica[1]	No	N	cost	Yes	Grab sample
Particles[1]	No	N	cost	Yes	Portable back-up
NRM[1]	No	N	cost	Yes	
TOC[1]	No	N	cost	Yes	Portable back-up

NOTE 6: Spec instruments listed are those typically used for monitoring. This list should not be viewed as a recommended list of instruments. The decisions on the choice specific types, models, and brands of instruments and how to use the data produced by them is expected to be made by the end users.

NOTE 7: High frequency of maintenance increases downtime risks, potentially requiring higher redundancy. N+2 may be needed if major maintenance/repair activity is expected on the top of the regular maintenance activities. By-pass provisions can be considered as alternative to N+1.

NOTE 8: For critical piping, partial redundancies may be considered. For example, if the main supply is 12 in., it can be designed in a way providing 2 8 in. main pipes with capacity combined meeting the required flows of 1.

A6-1.3 In case of failure, troubleshooting, or construction interruption, each of these pipes will serve 50% of each modules/sections (Diffusion, Etch etc.) that requires UPW.

A6-1.4 All UPW tanks should have N2 blanket conservation vents that will prevent tank from collapse in event of too high a discharge flow.

NOTE 9: The UPW system typically has several instruments throughout the process (i.e., TOC, resistivity, etc.) that may also be used or their data be considered for redundancy purposes.

NOTE 10: Each actuated valve used in the system requires definition of the failed OPEN or CLOSED position in the way that reset to that default position would not cause any problem. In some cases, valve may stay in their last position (if required for the process reliability).

A6-2 Power

A6-2.1 Semiconductor UPW Systems are expected to operate for several years with no allowed downtime. In order to achieve that level of uptime, there are typically multiple sources of power supplied to the UPW System. These sources are typically designated as: Normal Power, Emergency Power Supply (EPS) and Uninterruptable Power Supply (UPS).

A6-2.2 Normal Power supply to the electrical distribution system provided by UPW vendor should be sufficient to support maximum power consumption at full factory production, considering operation of all heavy power consuming equipment, including all installed redundancy. If possible normal power should come from two separate sources (dual feed into site).

A6-3 Minimum Capacity for Sizing EPS and UPS

A6-3.1 Minimum capacity for sizing EPS and UPS should at the very least provide for uninterrupted operation of the polish loop and the control systems as shown in Table A6-1 above. During a normal power outage it is assumed that the fab will not have significant power consumption, but recirculation of the UPW polish system and distribution piping will be critical to preserve high purity of UPW and UPW polish/distribution system. As minimum, several of the polish distribution pumps, all the system PLC network, (UPS ONLY) and the analytical cabinets should be fed from the EPS and/or UPS sources. It is important to note that there needs to be at least two separate EPS and UPS systems and that any multiple units (i.e., two distribution pumps) need to be on different EPS/UPS circuits. This includes redundant PLC’s. Redundant PLC’s should be configured as master - slave to assure proper operation and hierarchy. This assures the highest reliability for critical components and operations. Distribution pumps can be on EPS because they can tolerate a ~5 second interruption. The controls should be on UPS due to the long re-start period after a hard re-boot.

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APPENDIX 7
FILTERS

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date].

Table A7-1 Guide for Design and Operation of Critical UPW Filters

Filters	*Purpose*	*Performance Criteria*	*Risk*	*Comments*
Final Filters (POD) Cartridge Type UF Modules Type	Final Filtration at point of distribution into Fab To reduce particle levels (cts/l @ given size) and assure UPW Water quality consistent with wafer processing needs. To provide efficient particle capture and not allow particle shedding, nor leaching of harmful contaminants from the final filter into the UPW stream.	Particle size depends on device geometry (node) and process sensitivity. It is recommended to refer to the ITRS 2015 or the current IDRS document and SEMI F63 for guidance. The most critical application and the smallest “killer” size particle should be considered for the POD filter performance criteria To evaluate filter performance, it is recommended using SEMI C79. Filtration system flow rates should match UPW system design criteria and be aligned with filter manufacturer’s recommendations for flow and flux. Cleanliness of Final Filter should be consistent with UPW loop baseline requirements (See SEMI F63 for reference). Using SEMI F57 for filter cleanliness analysis	Operating filtration systems above manufacturer’s recommended flux rates may cause fiber damage (UF) and may adversely impact particle capture efficiency (Cartridge). Filtration devices have certain retention capability. Higher incident particle concentrations may result in higher levels of particles in the UPW product. Upon installation, Final Filters should be rinsed with UPW to baseline requirements. Rinse water should be monitored for particles, resistivity, TOC, NVR, dissolved gases, etc. Length of filter service life and dynamic flow and/or pressure conditions may impact performance and cause fiber breakage UF).	Filtration system design and type selection should balance risk of system component failure with high particle excursions vs. cost of over design and redundancy. Overall Fab UPW purity needs versus individual process UPW purity requirements should be assessed when deciding on system design and filter selection. Online particle monitoring should be employed to monitor filter performance and ensure UPW quality. Note: for the most advanced manufacturing nodes it is important to monitor and possibly control particles in the feed to the final filters. Use of power law coefficient is estimating particles level at the sizes smaller than what existing metrology allows is recommended
POU Filters Cartridge Type UF Modules Type	POU Filtration at UPW supply lines to Wafer Processing Equipment or UPW Filters installed within Process tools. To reduce particle levels (cts/l @ given size) and assure UPW Water quality consistent with wafer processing needs.	Particle size depends on device geometry (node) and process sensitivity. It is recommended to refer to the ITRS 2015 or the current IRDS document and SEMI F63 for guidance.	Operating POU Filters above manufacturer’s recommended flux rates and may adversely impact particle capture efficiency. Filtration devices have certain retention	POU Filter installations may not have on-line monitoring for filter performance nor monitoring for POU UPW quality.

Filters	*Purpose*	*Performance Criteria*	*Risk*	*Comments*
	To provide efficient particle capture and not allow particle shedding, nor leaching of harmful contaminants from the POU filter.	POU filter performance criteria should be driven by the definition of the critical particle size at given process step where POU filter is installed To evaluate filter performance, it is recommended using SEMI C79. POU Filter flow rates should match process flow needs and be aligned with filter manufacturer's recommendations for flow and flux. Cleanliness of POU Filter (metals, TOC, NVR, etc.) should be consistent with wafer processing UPW requirements.	capability. Higher incident particle concentrations may result in higher levels of particles in the UPW product. Upon installation, POU Filters should be rinsed with UPW to wafer processing requirements. If online monitoring is not available, POU filters should be rinsed to filter manufacturer's recommendations or for a time consistent with wafer processing needs. POU Filters are subject to on demand flow requirements. Such dynamic flow and/or pressure conditions may impact filter performance.	Unless effective new particle monitoring is available in future, it is recommended that after installation of POU Filters, process metrology techniques and monitor wafers be employed to ensure POU UPW quality meets wafer processing requirements. There is not a 'one for one' relationship between particles in UPW vs. particles deposited on wafers.

APPENDIX 8
ION EXCHANGE

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

Table A8-1 Guide for Design and Operation of Ion Exchange Resin Used in UPW System

Type of Resin Bed	*Purpose*	*Performance*	*Risks*	*Comments*
Pretreatment Different types of resin beds depending on the application	Remove some species like organics (WBA) or excessive CO2 that could impact RO performance. Pre-RO softening may be required when there is excessive hardness. It allows for more efficient RO operation (HERO) with less chemical treatment. Complete deionization using both anion and cation exchange resin in combination with degasifier/decarbonator are also common as pretreatment to RO	Depending on configuration, those beds remove difficult anions and cations, providing extremely high recovery ratio of RO and very high rejection of organics	Easy to overrun capacity to exhaustion, resulting in large than incoming organic sloughage which will impact RO's. If not operated properly high alkalinity will shorten ion exchange bed life and hardness will significantly affect RO.	Ion exchange is used in pretreatment where high water efficiency and low waste stream generation are required. Depending on incoming water quality, this may provide cost effective solution for meeting tightest UPW quality requirements.
Primary Anion Exchange Primary Beds	Silica, CO2, and boron removal or carbonate/bicarbonate. Provide means to remove ions that will negatively impact the Primary mixed beds performance resulting in either excessive regeneration or poor removal in case of silica.	This should reduce incoming carb/bicarb up to 99% or boron and silica >90% (SBA).	If not operated properly the SBA will release silica (and/or Boron) to the primary beds which the measurement of is difficult. Increased differential pressure was another risk reported in the industry.	
Primary Mixed Beds The part of the UPW treatment train that immediately precedes the polish equipment. This treatment typically occurs upstream to UPW tank	Reducing the level of ionic contamination to the level of or near final quality spec.	Main focus is efficiency of the regeneration measured by how quickly the product water reaches 18.1 Ω·cm after regeneration. Typically performance success is measured by boron or silica breakthrough and largely depends on the feed water quality and performance of upstream equipment.	High particle contribution as a result of bead fracture is a potential problem. Too much regeneration will cause the bead to fail. Care should be taken to avoid end of life for resin. Poor internal design can result in chemical hideout which will show up as leakage of ions. Rinsing to quality will take huge quantities of water.	The resin should be selected to have high capacity and low leakage. Recommended minimum bed depth of 3.5 ft. and a flux of 8 – 10 gpm/sq. ft. are required.

Type of Resin Bed	*Purpose*	*Performance*	*Risks*	*Comments*
Polish This is the final treatment for ion and particle removal and control. It treats very high quality water form primary system. In some places lead/lag configuration of the polishers is used to ensure better performance capacity and reliability of the beds.	Final polishing ions and protection from contamination coming from UPW return; very effective for removing particles.	Low leach outs per SEMI C93 best-in-class resins performance	Resin leach-outs of organics, metals, and particles.	Resin suppliers process to minimize organic release and particle sheading.

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APPENDIX 9
UTILITY REQUIREMENTS FOR UPW SYSTEMS

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A9-1 Definition

A9-1.1 UPW System utilities refer to all he power, fluid, gas, chemical and communications connections feeding into and out of the facilities UPW Systems.

A9-2 Objectives

A9-2.1 UPW system utility requirements vary by system supplier. The facilities infrastructure systems installed. The utilities should be designed to adequately support the connected and peak loads for the UPW System that is being chosen. All required utilities should be defined and quantified as part of the system design. It is equally important to consider and document the potential for short- and long-term variability within each of those utility sources.

Table A9-1 Utility Capacity Sizing Reference Guide

Utility	*Capacity Sizing Guide*	*Basis for Sizing*	*Comments*
Power	Total N based peak connected	Allow for all connected equipment to operate simultaneously	It is highly recommended to have dual independent power feeds to the site.
Feed water	Maximum average consumption at full build-out plus largest media filter backwash	Peak consumption is covered by the system tanks	Assuming no other maintenance activities in pretreatment requiring feed water. It is recommended that there is emergency storage of >24 hrs. somewhere in feed water system.
N2 used for degasification, resin mixing and N2 blanket	Polish pump flowrate + degas system flowrate	Full build-out polish consumption flowrate + Mixed Bed resin mixing (maintenance, high instantaneous flow)	Assuming that peak N2 draw will be when there is no feed to UPW tank (failure mode).
CDA (Instrument Air)	Nominal (as it is not consumed)	Pressure is defined by the specification of the related instrumentation	Need to consider leakage (failure mode).
Heating water/steam	Coldest possible feed water + HUPW loads	Full build-out and historical lowest temperature	Seasonal min and max for normal UPW both hot and cold.
Chilled water	Degasifier vacuum pump cooling load + expected system heating due to frictions	Full build-out Polish recirculation flowrate	In hot climate, feed water cooling may be required (should take into account peak feed water temperature).
Regeneration chemicals	Target: one week storage capacity	All ion exchange beds requiring regeneration at full fab build out UPW consumption	
Other chemicals	To be sized depending on the system specific needs		By UPW vendor.

#1 The above is based on the minimum required capacity assumption.

A9-3 Key Utilities and Parameters

A9-3.1 Feedwater for a Semiconductor UPW System is typically supplied to the UPW System from the facilities Industrial Water (IW) distribution system or the City Water (CW) distribution system. It is essential that that IW or CW distribution system be designed to supply enough water to the UPW System. Refer to the Incoming Water

Parameters Section for additional information about properly assessing and documenting the feedwater conditions and variability.

A9-3.1.1 It is recommended that the feedwater system have storage tanks with sufficient capacity to provide water during potential city water outages. It is common that the site water is supplied from two independent sources to further mitigate the risk of feedwater supply interruption.

A9-3.1.1.1 Unless dual supply with reliable city water system exists, the minimum recommended Site water storage is 1 days' worth of capacity.

A9-3.1.2 The volume of UPW system raw water tank capacity (when installed) is recommended to have minimum of 1 hr of hydraulic retention time.

A9-3.2 *Power*

A9-3.2.1 Semiconductor UPW Systems are expected to operate for several years with no allowed downtime. To achieve that level of uptime, there are typically multiple sources of power supplied to the UPW System. These sources are typically designated as: Normal Power, Emergency Power Supply (EPS) and Uninterruptable Power Supply (UPS). Normal Power supply to the electrical distribution system provided by UPW vendor should be sufficient to support maximum power consumption at full factory production, considering operation of all heavy power consuming equipment, including all installed redundancy.

A9-3.2.2 Minimum capacity for sizing EPS and UPS should at the very least provide for uninterrupted operation of the polish loop and the critical control systems. During a normal power outage, it is assumed the fab will not have significant power consumption, but recirculation of the UPW polish system and distribution piping will be critical to preserve high purity of UPW and UPW polish/distribution system. At minimum, several of the polish distribution pumps, the system PLC network, and the analytical cabinets should be fed from the EPS and/or UPS sources.

NOTE 11: In case if UPW tanks have ozonated water, ozone destruct UVs should also be added to the UPS minimum required list of users

A9-3.3 *Heating and Cooling Sources*

A9-3.3.1 Semiconductor fabrication facilities typically require both Cold UPW Systems and Hot UPW (HUPW) Systems. These systems may also have strict temperature control limitations. To achieve and control temperature within those limitations, these systems will normally require heating and cooling heat exchangers in several locations within the Cold UPW and Hot UPW Systems. The definitions for cooling and heating media (hot water, steam, chilled water, etc.) should consider extreme temperature conditions of the incoming city water, as well as peak and minimum fab UPW/HUPW consumption levels. It is common to use heat recovery water for preheat of the incoming city water. Cost/risk/benefit analysis should be done when making decision regarding use of heat recovery water.

A9-3.4 *Liquid Chemicals*

A9-3.4.1 Several liquid chemicals are required for the operation of the UPW System. These may be supplied in several ways; for example, by bulk tanker deliveries, or in totes or drums. Typical chemicals in UPW may include:

A9-3.4.1.1 *Pretreatment* — Flocculants, antiscalant, sodium hypochlorite, biocides, sodium bi-sulfite, (when activated carbon is not used for dechlorination), RO feed pH adjustment, and ion exchange regeneration chemicals (acid/base).

A9-3.4.1.2 *Primary* — Regeneration chemicals for Primary Ion Exchange Beds (NaOH and HCl); and strong oxidizers used for TOC treatment and disinfection (ozone, ammonium persulfate, and H_2O_2).

A9-3.4.1.3 *Polish* — It is recommended to eliminate use of chemicals in polish system. However, when used, special attention should be paid to their quality. When the ion exchange resin is regenerated (as opposed to using virgin resin), the minimum quality criteria should be within Table A9-2.

A9-3.4.2 The choice and quality of the Pretreatment chemicals should depend on their process efficiency (to be determined by the UPW vendor). It is also important to consider environmental requirements when deciding on the type of the chemical treatment.

A9-3.4.3 Growing UPW quality requirements drive application of high purity regeneration chemicals for the Primary and polishing applications.

Table A9-2 Typical UPW System Liquid Chemical Supply Reference Quality Table

UPW SYSTEM UTILITY REQUIREMENTS – Sodium Bisulfite Solution 25%				
Component	*Typical*	*Min*	*Max*	*Comments*
$NaHSO_3$	25.0%	23.0%	27.0%	
SO_2	15.4%	14.1%	16.6%	
Na_2SO_3	0.5%		2.0%	
Na_2SO_4	1.0%		2.0%	
Fe	1 ppm		5 ppm	
pH	4.5	3.5	5.0	

A9-3.5 *Gasses*

A9-3.5.1 Several pressurized gasses are usually required for UPW Systems. Most often these include: Compressed Dry Air, Instrument Air, Utility Nitrogen, High-Purity Nitrogen and High Purity Oxygen.

A9-3.5.2 Of all the gases listed, high purity nitrogen represents the highest potential risk of UPW contamination due to its high volume and its critical applications within the UPW System operations. Its quality should meet the requirements listed in Table A9-3:

Table A9-3 Typical UPW System N2 Gas Supply Reference Quality Table

Component	*Typical*	*Min*	*Max*	*Comments*
Nitrogen	99.999%	99.995%	100%	
O_2	0.1 ppm		1 ppm	
CO_2	0.1 ppm		1 ppm	
CO	0.5 ppm		2 ppm	
THC	0.5 ppm		1 ppm	
H_2	0.5 ppm		2 ppm	

A9-3.6 *Drains*

A9-3.6.1 At a minimum, a UPW System should have one waste water connection point and that would typically flow to the facilities Acid Waste Neutralization (AWN) System. UPW System owners will often segregate their waste streams into several additional drain headers such as Pretreatment Backwashes, RO Reject, Regeneration Waste, Rinse Reclaim, UF Reject, etc. The purpose of having several different collection headers would be to enable those segregated waste streams to be more readily treated or recovered within the facility. Special consideration should be given to planning gravity collection systems. It is common to use well-developed trench system covering all major waste generation streams. The trench may have gravity drain lines of sufficient capacities to collect and convey the normal and peak maintenance stream flows to the lift station(s) which transfer that wastewater to the fabs waste neutralization systems. The trench capacity should also be sufficient to contain sufficient volume of water in case of failure (specific failure conditions should be determined together with UPW vendor).

A9-3.7 *Exhaust Considerations*

A9-3.7.1 UPW System designs utilizing nitrogen, ozone or generating any chemical fumes (such as those which might be liberated during transfers and usage of HCl) may also require exhaust connections to evacuate, capture and/or manage those gases and fumes. Special attention should be given to the possible asphyxiation conditions and corrosion potential, including both construction activities and system maintenance.

A9-3.8 *Communications*

A9-3.8.1 UPW Systems will usually be connected to and integrated within the facility monitoring systems and life safety systems via Ethernet or fiber optic connections.

A9-3.9 In case if there is more than one source for any of the aforementioned utilities, the conditions of each source should be characterized separately. An example of this would be where there are several different regional liquid chemical vendors which might be supplying the same chemical, but in different forms or concentrations and with varying delivery methodologies.

Table A9-4

Utility	*Value*	*Units*	*Allowable Deviation*	*Average Usage*	*Peak Load*	*Comments*
Feedwater Flow#1		m3/hr		m3/hr	m3/hr	
Feedwater Pressure#1		kPa	Min.			
Normal Power#2	380-460	VAC	±x.x%	KVA	KVA	
Emergency Power#2	380-460	VAC	±x.x%	KVA	KVA	Xx second delay
Uninterruptable Power Supply	120	VAC	±x.x%	KVA	KVA	Xx minute reserve
Hot Water Supply	80	º C	Min.	X,xx0,000 MBTU	Xx,xx0,000 MBTU	
Hot Water Return	60	º C	Min.			xx°C Max Δ
Steam Supply	140	º C	Min.	X,xx0,000 MBTU	Xx,xx0,000 MBTU	
Condensed steam Return	100	º C	Min.			xx°C Max Δ
Chilled Water Supply	10	º C	Max.	Xx0,000 MBTU	X,xx0,000 MBTU	
Chilled Water Return	20	º C	Max.			xx°C Max Δ
$NaHSO_3$		Kg		Kg/Day	Kg/Day	Tech. Grade
NaOCl		Kg		Kg/Day	Kg/Day	Tech. Grade
NaOH		Kg		Kg/Day	Kg/Day	Rayon Grade
H_2SO_4		Kg		Kg/Day	Kg/Day	Xxx Grade
HCl		Kg		Kg/Day	Kg/Day	Xxx Grade
H_2O_2		Kg		Kg/Day	Kg/Day	Tech. Grade
Other Chem		Kg		Kg/Day	Kg/Day	Xxx Grade
Nitrogen (Utility)		kPa	Min.	N m^3/hr	N m^3/hr	99.99% purity
Nitrogen (High Purity)		kPa	Min.	N m^3/hr	N m^3/hr	99.995% purity
Compressed Dry Air		kPa	Min.	N m^3/hr	N m^3/hr	−40°C Dew Point
Instrument Air		kPa	Min.	N m^3/hr	N m^3/hr	−40°C Dew Point
Oxygen		kPa	Min.	N m^3/hr	N m^3/hr	99.9x% purity
Other Gas		kPa	Min.	N m^3/hr	N m^3/hr	
Vacuum#3		Tor	Max.	N m^3/hr	N m^3/hr	
Exhaust#4		Tor		N m^3/hr	N m^3/hr	Ozone compatibility
Waste Drain		m^3/hr		m^3/hr	m^3/hr	To AWN
Other Drain		m^3/hr		m^3/hr	m^3/hr	
Other Drain		m^3/hr		m^3/hr	m^3/hr	
Other Drain		m^3/hr		m^3/hr	m^3/hr	
Controls Network						Ethernet
LSS Network						Ethernet

#1 The feedwater capacity and pressure requirements are included here to document those requirements as a physical utility connection to the UPW System. The quality parameters for the feedwater itself are more thoroughly addressed within the Incoming Water Quality section.

#2 Some semiconductor facilities will have more than one incoming normal power feed to the UPW System. In those cases, the UPW System loads will be split across those different sources. For example, a triplex pump skid might have pumps 1, 2 and 3being fed by Normal Power A, Normal Power B and Emergency Power respectively.

#3 UPW Systems requiring a vacuum connection will typically be discharging a saturated vapor containing water and carbonic acid. If the UPW System vacuum loads are connected to the facilities either a house or process vacuum connection, it is imperative that the projected vapor load and composition has been conveyed to the vacuum system provider for those systems.

#4 Several of the unit processes within the UPW System utilize Nitrogen and/or Ozone gas. Since these systems are typically installed indoors, they will also require exhaust connection(s) to prevent the dangerous accumulation of those gasses in habitable spaces. An ambient O2/O3 monitor is strongly recommended for indoor O3 gas system. If the UPW System exhaust loads are connected to any facilities exhaust connection(s), it is imperative that the projected load and composition of those exhaust loads be conveyed to the exhaust system provider.

APPENDIX 10
RECOMMENDED LIST OF DOCUMENTATION PER RESPECTIVE PROJECT MILESTONE

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

Table A10-1 Typical Project Documentation Checklist

List of Engineering Deliverables	*Bid*	*DRM1*	*DRM2*	*IFC*	*Close Out*
Raw Water Analysis	X				
UPW Specification	X				
UPW Consumption Matrix	X				
Project Timelines, incl. major milestones	X	X	X		
Mass Balance	X	X			X
Process Flow Diagram	X	X			X
Equipment List (with main technical data)	X	X			
List On Line Analyzer	X	X			X
Operation Cost Calculation	X				
Energy Calculation (Heat Exchanger)		X			
Pressure Drop Calculation			X		
Process Data Sheets (Data sheets for long lead items)		X			X
P&ID's		X	X	X	X
Process Description (process narrative)			X		X
Logic Documents/Functional Description (SOO)			X	X	X
Layout (Arrangement Drawing)	X	X		X	X
Layout with Floor Load			X	X	X
Supplier List (Components)	X		X		
Specification of Media (AC, Ion Exch., etc.)			X		X
Utility List	X	X			
Interface Matrix		X			
General Arrangement Drawing of Skids			X	X	X
Drawing of Vessels			X	X	X
Drawing of Tanks		X	X	X	X
Seismic Calculation (PE)			X	X	
Pump Performance Curve			X		X
Critical Components Datasheets/Cutsheets			X		X
Operation and Maintenance Manual (OMM)					X
Instrumentation List		X			X
Motor List		X			X
PLC Architecture			X		X
Electrical Component List (VFD, Soft Starters, etc.)		X			X
I/O List			X		X
Cable Routing Diagram			X	X	X
SCADA System Graphics			X		X
List of Consumables			X		

List of Engineering Deliverables	*Bid*	*DRM1*	*DRM2*	*IFC*	*Close Out*
Interconnecting Design (BIM)			X	X	
Inspection and Test Plans			X	X	
Commissioning Plan		X	X	X	
Training Plan				X	
Spare Part List				X	X

A10-2 Abbreviations Used in Table A10-1

A10-2.1.1 *DRM* — design review meeting

A10-2.1.2 *DRM1* — conceptual review + long lead items

A10-2.1.3 *DRM2* — detailed design review

A10-2.1.4 *IFC* — issued for construction

A10-2.1.5 *PE* — professional engineer

A10-2.1.6 *BIM* — building information modeling

APPENDIX 11
GENERAL SAFETY RECOMMENDATIONS

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

NOTE 12: This section highlights some of the safety considerations in operating an UPW system. It assumes that the safety requirements in operating a facilities system have been understood and well covered in the main section of Safety specifications.

A11-1 Vessels and Tanks

A11-1.1 Regular inspection of tanks and vessels, as well as replacement of consumables such as resins and carbon media is common in UPW system. In such a situation, one should be careful to handle this work as under 'Confined Space' protocols. Extra care should be taken when entering the tanks and vessels. Where entry is necessary, system should be depressurized, proper ventilation and exhaust done and confined space 'checked' for safety before entry. A manhole greater than 600 mm should be considered minimal recommended.

A11-1.2 Where height is concerned, a proper safety harness should be worn while proper scaffolding and access to the top of the tank should be administered.

A11-1.3 Material of construction used for the tanks and vessel including lining, should be considered to ensure chemical compatibility and mechanical strengths required for proper operation.

A11-1.4 UPW Tank and Permeate Tank which potentially operate under sub-atmospheric pressure should be designed properly to ensure it can handle the pressure swing and will not collapse under abnormal operation. A bleeder valve should be installed under such circumstances.

A11-2 Chemical and Dosing System

A11-2.1 Chemicals are added in the UPW processing to provide coagulation, pH adjustment, redox processes, and chemical cleaning purpose.

A11-2.2 Proper labeling of chemical containers and respective supply lines is important. The labeling should follow appropriate safety standards and government regulations. Safety Data Sheets (SDS) should be available and easily accessible to provide appropriate handling information.

A11-2.3 The chemical formula and name of the chemicals should be clearly displayed on the tank or drums to avoid mixing of incompatible chemicals.

A11-2.4 Proper classifications, storage and segregations, of oxidizers, reducers, caustics and acid should be provided. Engineering protections should be incorporated in the design to avoid cross contamination of different (and even more important) incompatible chemicals.

A11-2.5 Double-containment pipe should be used for distribution of hazardous chemicals from source to point of use. When appropriate, the leak detection systems are recommended in the secondary containment.

A11-2.6 Dosing pump system should be designed with splash protection and chemical tanks should have a double containment.

A11-2.7 Clean-in-place (CIP) cleaning requires extensive handling of corrosive and hazardous chemicals at elevated temperatures. This poses potential danger involved in handling the chemicals. Proper engineering protections should be made and protocol should be developed (barricading, communication, etc.) to ensure safe operation when chemical cleaning is in progress.

A11-2.8 *Regeneration Chemicals* — Use of flange wraps/guards and splash protection should be considered around regeneration pump skids. There should be adequate berms around chemical areas for containment. Where applicable, hot caustic (up to 55°C) may be used for regeneration of anion resins in the mixed bed system—this requires extra caution in design and operation. It is not uncommon to experience severe corrosion of HCl dosing systems resulting in safety incident. Special attention should be paid to proper material selection for HCl dosing system components.

A11-2.9 Proper personal protection equipment (PPE) should be worn when handing UPW chemicals during maintenance.

A11-2.10 Proper housekeeping should be done after every maintenance and top up to avoid any stains, drips and spill-over of the chemical during the service.

A11-2.11 Proper chemical spill kit items such as absorber, pillows, and neutralizer should be available in the vicinity of the chemical systems.

A11-3 Pressurized Systems

A11-3.1 UPW is a pressurized system with the pressures ranging from vacuum and to 10 Bars except for RO systems which could operate at even higher pressures.

A11-3.2 Where appropriate, a pressure dampener should be installed at the discharged of the pressurized pump. Routine maintenance to ensure alignment of the *x*, *y*, *z* axis of the pump should be carried out on an annual basis to avoid excessive vibration which could result in mechanical damages.

A11-3.3 Proper SOP for pressurization and de-pressurization of the system, addressing air pockets in the system should be developed. Before start-up of any pressurized portion of the system, detailed checklist should be prepared including inspection of isolation valves (fail open or closed by design), avoidance of dead head and proper bleeding of air pockets in the system should be filled out. Valve operation, where applicable, should be done in a controlled manner during start up and shut down of the system to avoid a surge of pressure in the system during those operations. Operators should be trained to perform such tasks.

A11-3.4 Proper joining of the plastic pipes should be provided and inspected during installation to avoid pre-mature failure of the pipe due to poor workmanship.

A11-3.5 Appropriate type of piping and proper pressure rating of those pipes should be selected during design depending on expected maximum operating pressure.

A11-3.6 Where N2 is introduced into the system for drying, resin mixing, and other purposes proper operational procedure should be instituted to prevent gas pocket in the system. Proper venting should be performed before the system is put back into operation after the introduction of N2.

A11-3.7 To avoid accidental opening or closing of manual valves that could result in surge of pressures, a tag-out and lock-out should be implemented.

A11-3.8 Proper positioning of the valve, especially check valves, should be checked during start-up and commissioning of the UPW system to avoid any reverse direction and resulting in dead-heading the system. Position of the direction of the valves should be clearly marked.

A11-4 Blower

A11-4.1 Where a blower is used, appropriate caging should be installed to ensure that the blade will not spin off resulting in potential damage to property and people. This is especially true when the blower is installed at elevated height and where maintenance of such equipment tends to be neglected. Depending on design details, noise protection may be needed.

A11-5 Hot Systems

A11-5.1 In some cases, steam may be used for sterilization of carbon beds or cleaning of UFs. Under such circumstances, care should be taken to avoid direct contact with the heat source which would result in burns.

A11-5.2 Wherever feasible, hot surfaces should be insulated. Proper labeling of hot surface should be provided if insulation is impossible. Extra caution should be given to prevent such hot liquids from spilling into the environment causing.

A11-5.3 Where a heat exchanger is used, routing maintenance is required to ensure that the gasket does not leak over time and potentially hurt a person when it squirts due to the leak.

A11-5.4 Proper service and maintenance of a temperature gauge and its control system should be done to ensure that the system does not operate outside the desired temperature range due to instrument failure.

A11-6 Electrical and Control System

A11-6.1 It is unavoidable to have electrical systems components in an operational facilities system. Proper engineering should be conducted to minimize the impact of burst, spillage, or leakage of water from pipes into the electrical and control system resulting in damages to property and personnel. Care should be taken to ensure control and electrical panels are sufficiently protected especially where the high-pressure pump is located.

A11-6.2 Where such electrical or control panels are located near to chemical system, proper assessment should be performed to avoid corrosion of such systems resulting in premature failure. When appropriate, lock-out and tag-out should be used.

A11-6.3 A password may be mandated for key operational procedures in relation to safety to ensure that operators are fully aware of their intended actions.

A11-7 Ozone

A11-7.1 Ozone is occasionally generated in situ for UPW system for the purpose for sterilization. Where its use is required, an ambient monitor is recommended to ensure that there is no leakage of ozone into the environment which could potentially result in fatality.

A11-7.2 Proper engineering to ensure compatibility of the components used in the ozonated system is required as poor compatibility can result in leakage of ozone into the environment.

A11-7.3 Welding of the pipe should be used instead of flanged connection or compression fitting as often as possible.

A11-7.4 Where in situ measurement of ozone is designed, the instrument and detector should be calibrated and maintained to ensure that the desired amount of ozone is generated.

A11-8 UV System

A11-8.1 UV is commonly used in the UPW system for TOC reduction as well as sterilization. Proper design of the system is needed to ensure that the UV radiation is not leaked to the environment.

A11-8.2 Proper material selection is required to ensure that the material does not degrade over time due to long-term exposure to UV light.

A11-8.3 During replacement of the UV lamp and quartz sleeve, care should be taken to ensure the system is properly depressurized. There should be a proper procedure addressing the start-up and shutdown of the UV system for the purpose of replacement of UV lamps or quartz sleeves.

A11-8.4 Inappropriate start-up or shutdown sequences can result in breakage of the quartz sleeves or lamps due to surge of pressure as well as due to gas pockets formation.

A11-8.5 UV lamps should be disposed of properly due to environmental concerns.

A11-9 Access

A11-9.1 In systems where the valves or any other components are located at elevated height, there should be proper and safe access to those valves and components. Appropriate chained system, scaffold or ladder should be designed to ensure safety.

A11-10 Disposal

A11-10.1 Proper labels should be provided for disposal of used consumables, such as resins, carbon, media, UV lamps, chemical reagents etc. Proper documentation should be done to ensure safe disposal of such products.

A11-11 Overflows

A11-11.1 Overflow of water can occur from tanks, as well as damaged vessels or piping systems. A large volume of water could result in flooding, contact with electrical and control system, movements of equipment that are not anchored, shifting of pipes, damages to equipment and/or drowning of personnel. Proper controls and alarm systems should be in place to ensure that in the event of such catastrophic overflow, the UPW system could be systematically and safely shutdown.

A11-11.2 Trenches and sump pit should be designed in to handle overflows. It is important to consider where the trench water will be pumped to avoid creating a closed loop where the overflow is not discharged safely but remains within the same zone.

APPENDIX 12
ULTRA PURE WATER PRODUCTION — PHILOSOPHY OF MAINTENANCE AND OPERATIONS

NOTICE: The material in this Appendix is an official part of SEMI F61 and was approved by full letter ballot procedures on [A&R approval date TBD].

A12-1 Purpose

A12-1.1 The purpose of this section is to enable plant owners to setup their operations and maintenance to a standard that ensures a safe, reliable and predictable output from the UPW production plant. This Document can also be used by turn-key vendors and third party operations and maintenance organizations to set up the plant operations and maintenance to the satisfaction of the owners.

A12-2 Maintenance

A12-2.1 The maintenance philosophy of a UPW plant is predominantly determined by the amount of work activities that have been defined and identified. A baseline well-run maintenance program allows the owner to systematically optimize the maintenance requirements using Lifetime and Failure Analysis tools. It is important to take into consideration all of the maintenance requirements set forth by the equipment vendor while starting a maintenance program. Sometimes it is also helpful to perform a Failure Mode and Effect Analysis (FMEA) on the system with the equipment designers to ensure that all failure modes are understood and the importance of maintenance is established through documented risk management techniques.

A12-3 Elements of a Maintenance Program

A12-3.1 A well-run maintenance program should have the following elements at a minimum.

A12-3.2 A three-tiered approach is used to ensure safe, reliable, predictable output of the work.

A12-3.2.1 *Tier 1* — Typically plant maintenance requirements are documented in a centralized maintenance management system like Maximo/SAP. The elements include:

- Equipment Make, Model, OEM supplier.
- Right maintenance (corrective or predictive).
- Right frequency (monthly, quarterly, annually, etc.).
- Right materials (parts and kitting for the job. O-ring, gasket, filters, etc.).
- Right tools (allen wrenches, screwdrivers, LOTO devices, etc.).
- Adequate time to finish the job in a safe manner.
- Targets and limits

A12-3.2.2 *Tier II* — Typical plant maintenance work instruction are also documented in a centralized document management system and each instruction should cover the following:

- Energy control procedure/Control of Hazardous Energy requirements for the job.
- Personal Protective Equipment requirements for the job.
- Tools and Material required for the job.
- Training and qualification requirements for the job.
- Shutdown instructions to isolate the equipment.
- Maintenance step by step instructions for standardized execution.
- Startup and qualification instruction to ensure zero impact integration.
- Cleanup and disposal of any waste generated.

A12-3.2.3 *Tier III* — Training and Qualification is typically also managed through a centralized training platform and documented:

- Read and understand vendor provided O&M Documentation.
- Skills training through seminars and hands-on workshops.
- On the job training of documented work activities with trainers (engineers/technicians/vendors).
- Skills training to understand engineering design documentation.

A12-4 Workload Balancing

A12-4.1 Work can be split into two discrete workloads. An example workload document has been created below.

A12-4.1.1 *Equipment Maintenance*

- Pump Maintenance

A12-4.1.1.1.1 Coupling change outs

A12-4.1.1.1.2 Impeller changeout

A12-4.1.1.1.3 Volute changeout

- Motor Maintenance

A12-4.1.1.1.4 Oil change

A12-4.1.1.1.5 Bearing replacement

A12-4.1.1.1.6 Motor changeout

- Media changeouts for carbon or multimedia filters
- Filter changeouts
- RO membrane changeouts
- UV lamp/sleeve changeouts
- Resin Changeouts

A12-4.1.2 *Instrumentation and Controls*

- Instrumentation

A12-4.1.2.1.1 pH/ORP probes

A12-4.1.2.1.2 Conductivity probes

A12-4.1.2.1.3 Turbidity meters

A12-4.1.2.1.4 TOC meters

A12-4.1.2.1.5 Boron, Silica, Na Analyzers

A12-4.1.2.1.6 Particle analyzers

A12-4.1.2.1.7 Bacteria monitors

- Controls

A12-4.1.2.1.8 PLC programming to improve sequence of operations

A12-4.1.2.1.9 Conditioning of Alarms

A12-4.1.2.1.10 Fuse pulls, IO cards and PLC replacements

A12-5 Maintenance (Predictive and Corrective)

A12-5.1 Plant maintenance in a UPW production facility is broken down into two basic work categories:

- Preventative Maintenance
- Corrective Maintenance or condition-based maintenance

A12-5.2 The preventative maintenance program is based on the anticipated failure of components if the adequate amount of maintenance is not performed. This is usually always time-based. Typically, there is a lack of motivation to measure the condition of the equipment prior to the maintenance as the measurement of the component quality itself may be more costly than the maintenance, or the detection of the failure might be too difficult and the risk of a gross failure is to impactful to the plant.

A12-5.3 Examples are the following:

A12-5.3.1 Oil change

A12-5.3.2 Lubrication / greasing

A12-5.3.3 Pump alignment

A12-5.3.4 Filter replacements

A12-5.3.5 Quartz sleeves on UV's

A12-5.4 The corrective maintenance program is based on the measured deterioration of performance of components within the factory. Typically, one or more of the plant performance variables degrade to a sufficient limit which triggers this maintenance.

A12-5.4.1 Vibration monitoring.

A12-5.4.2 RO membrane change outs based on permeate quality or other performance indicators.

A12-5.4.3 Resin change out based on core sampling to measure the integrity of the resin or permeate ion leakage.

A12-5.4.4 UV lamp change-outs are typically based on the loss of intensity or the product water quality (TOC, ozone, residual chlorine, etc.).

A12-5.4.5 Filter change outs based on pressure drop across filters.

A12-6 Critical Spares Strategy

A12-6.1 A UPW production facility should have a critical spares strategy and parts stocked and maintained to certain min-max levels. The spares should be identified using the following criteria at a minimum. If any of the criteria fail, a critical spare should be stocked at the UPW production facility.

A12-6.1.1 System has redundancy to operate with failed component for 12 weeks or greater.

A12-6.1.2 Lead-time of components is greater than 16 weeks.

A12-6.2 *Examples*:

A12-6.2.1 *RO Membranes*

- System has 6 RO units—5 required for production and 1 in standby;
- Failed RO membrane results in downtime;
- RO cleans required at a frequency of every 3 months.
  - 5 ROs/15 weeks ~ 1 RO clean every 3 weeks.
  - Lead-time of RO membranes is 12 weeks from placement of purchase order.

A12-6.2.1.1 *Conclusion* — System does not have adequate redundancy to operate without a critical spare of RO membranes and it is recommended to stock at least one set of RO membranes.

A12-6.2.2 *UV Lamps*

- System has 100 lamps in parallel and 75% are required to maintain equipment performance
- Failed UV lamp
  - UV lamp maintenance is once every 12 ~ 15 months.
  - Lead-time of UV lamps is < 2 weeks from placement of purchase order.

NOTE 13: System has adequate redundancy to operate with a few failed UV lamps and it is not recommended to stock any critical spares for operations.

A12-6.3 *Operations*

A12-6.3.1 *Daily Operations*

A12-6.3.2 Daily operations means work that is not maintenance-related and are required activities that are required to keep the plant operating to produce UPW in a reliable manner with a predictable output. They can be broadly be split into two categories

A12-6.3.2.1.1 *Routine Work* — Repeats at a regular frequency

- Structured shift - shift pass-downs
- Control room operations of human-machine interface screens
- Engineering data reviews
  - SPC (Statistical Process Control charts of quality parameters
  - Equipment alarm
  - Equipment performance trends
    1. Pump performance (current draw, pressure, flow, etc.)
    2. HX performance (valve positions, temperature, etc.)
    3. Filter performance (pressure drop, turbidity, etc.)
    4. RO performance (pressure drop, permeate quality, etc.)
    5. Ion Exchange performance (throughput, breakthrough, etc.)
  - Rounds and Readings
  - Regular sampling to determine equipment health
  - MMF backwashes
  - RO cleans
  - Ion exchange regenerations

A12-6.3.2.1.2 *Non-Routine Work* — Ad-hoc work assignment:

- Alarm Response and troubleshooting
- OOC/OOS response

A12-6.4 *Change Management*

A12-6.4.1 To ensure that there is a comprehensive risk management and consistency of documentation representing the on-field activities, equipment configuration and setpoints, the plant should have a robust change management policy. Any permanent change proposed that results in the alteration of the means and methods to do a job, an equipment configuration or a programmed setpoint on the system should require a thorough change control review. The elements of a well-defined documented change control process at a minimum are the following:

- A clear purpose for the change

- Ergonomics/Safety
- LEAN driven to optimize time, inventory, motion, waste, over-processing, over production or defects
- Cost Savings
- Quality
  - Current State
  - Proposed State
  - Concerns and Considerations on managing the risk of the change
  - Clear Measurable Success Criteria to measure the efficiency and effectiveness of the change
  - A clear trackable step-by-step action-item driven plan to move from current state to proposed state
    1. Who
    2. What
    3. When
  - A clear documentation update plan that is triggered by the change

A12-6.5 *Cost Management*

A12-6.5.1 Cost Management is integral to optimizing the quality and output of the UPW production plant at the lowest lifecycle cost. To attain this optimization, a clear understanding should be developed of the following costs of running a UPW production plan.

A12-6.5.2 *Sustaining Costs (forecasted)* — These are costs for a production plant based on the water production efficiency and the equipment configuration.

A12-6.5.2.1.1 Consumables: filters, O-rings, UV lamps, etc.

A12-6.5.2.1.2 Chemical: bisulfite, pH adjustment, regenerations, etc.

A12-6.5.2.1.3 Incoming water, plant generated waste water, electricity, etc.

A12-6.5.2.1.4 Services for instrumentation calibration, alignment, etc.

A12-6.5.3 *Capital Improvement Projects* — Projects that are driven by the following should have a clear prioritization and budget to execute.

A12-6.5.3.1.1 Ergonomics/Safety

A12-6.5.3.1.2 LEAN driven to optimize time, inventory, motion, waste, over-processing, over production or defects

A12-6.5.3.1.3 Cost Savings

A12-6.5.3.1.4 Quality

A12-6.5.4 *Life Cycle Asset Management* — Major maintenance whose costs are relatively the same magnitude as the capital cost of the equipment itself should be cataloged in a life cycle asset management system. This should encompass the long term (10 yr. +) costs of maintaining the plant to its performance expectations at system acceptance finalization.

A12-6.5.4.1.1 Major maintenance like liner replacements, media replacements for degasifier towers or multimedia filters.

A12-6.5.4.1.2 Major equipment refurbishments replacement of corrosive chemical service piping/pumping cabinets.

A12-6.6 *Head-Count Management*

A12-6.6.1 *Company Specific* — Not covered in this section.

A12-6.7 *Excursion Management*

A12-6.7.1 Excursion management is critical to the recovery of any plant from an unplanned event.

A12-6.7.2 Although, all failures can never be eliminated completely, there are methods to minimize the impact and recover in an expeditious manner.

A12-6.7.3 These events can be of the following nature with the following guidance:

A12-6.7.3.1.1 Out of Spec or Out of Control on a quality parameter.

A12-6.7.3.1.2 Have clear alignment with fab functional areas: Wafer Cleans, Planarization, LithoLithography, etc.

- Thresholds/bounds to define an event
- Action plan/response flow checklist
  - Problem identification
  - Containment
  - Resolution/recovery
- Module action plans on wafer processing conditions during the event

A12-6.7.3.1.3 Hold lots ahead of the tools.

A12-6.7.3.1.4 *Processing Wafers* — Continue processing at risk.

A12-6.7.3.1.5 *Processing Wafers* — Abort processing and rework.

A12-6.7.3.1.6 *Processing Wafers* — Abort processing and scrap.

A12-6.7.4 Piping breaks

A12-6.7.5 Compromised Equipment

A12-6.7.5.1.1 Damaged internals within ion exchange beds

A12-6.7.5.1.2 Leaking HX

A12-6.7.5.1.3 Broken fibers in GTM’s, UF’s, etc.

A12-6.7.6 Excursion management drills should be conducted at a routine frequency to test and measure the efficacy of action plans set in place to recover the plan from these abnormal events.

<end of ballot>