SEMI E54.18-1106 (Reapproved 1211)
SPECIFICATION FOR SENSOR/ACTUATOR NETWORK SPECIFIC DEVICE MODEL FOR VACUUM PUMP DEVICE

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NOTICE: This Document is no longer published with the SEMI E54 suite of Standards. It is published and sold separately.

NOTICE: This Document was reapproved with minor editorial changes.

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1 Purpose

1.1 This Specification is part of a suite of Standards which specify the implementation of SEMI Standards for the Sensor/Actuator Network. The specific purpose of this Specification is to describe a network-independent application model comprised of device objects which are common to all vacuum pump devices (VPD) on a semiconductor equipment Sensor/Actuator communications network.

2 Scope

2.1 This Specification for a vacuum pump device specifically addresses the minimum attributes, services, and behavior a VPD must support to be interoperable on the Sensor/Actuator communication network. This specification describes the VPD as a class of devices that include mechanical roughing pumps, turbo molecular pumps, cryogenic pumps and roughing pumps each with a booster. The attributes, services and behaviors described for the VPD are either required or optional for each pump type. Additional manufacturer specific attributes, services and behaviors unique to each pump type are not detailed in this Specification.

2.2 This Specification is intended to ensure a high-degree of device interoperability on the sensor/actuator communication network, while still allowing flexibility for product differentiation and technology evolution.

2.3 The VPD model specified in this specification is used in conjunction with the sensor/actuator network common device model (CDM) to completely describe the vacuum pump as it appears from the network interface.

2.4 This Specification, together with the sensor/actuator network Standard, the sensor/actuator network CDM, and a sensor/actuator network communication Specification, form a complete interoperability specification for the VPD.

2.5 To comply with this Specification, a device must implement and support, at a minimum, the required attributes, services, and behavior identified in this Document. Support for optional attributes, services, and behavior are not required to be compliant to this Specification. Optional attributes, services, and behavior are specified in these Documents to promote further device interoperability as features evolve and are adopted by more manufacturers. If optional attributes, services, and behavior are implemented for this device, they must be implemented as identified in this Document.

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 Specification is a companion to a suite of specifications which together make up the sensor/actuator network communication Standard. Therefore, using portions of this Specification that relate to network communications necessarily requires an understanding of the associated network specification.

3.2 As this Document is a specification for the vacuum pump specific device model, it does not contain any definition of objects, attributes, services, or behavioral descriptions that are already defined in the sensor/actuator network CDM. Additional attributes, attribute assignments, services, and/or service parameters that are VPD-specific and/or implementation-specific are contained in this Specification.

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3.3 While this Specification is sufficient to completely describe the VPD as it appears from the communication network, it does not fully describe behavior of the VPD which is not visible from the specific network. This allows flexibility in implementation techniques and product differentiation between manufactures. Manufacture-specific value-add objects, attributes and services may be defined by the manufacturer, but are, by definition, outside the scope of this Standard Specification.

3.4 This Specification is compatible, but not compliant, with SEMI E39. This means that although this Specification does not require compliance with SEMI E39, it is extensible such that implementations may be developed that are fully compliant with both Standards. Note that the concepts and terminology of this Specification are compatible with those of SEMI E39. However, SEMI E39 has specific requirements that are intended for higher level applications and, thus, are not applied to the VPD model.

3.5 Operation over the entire range specified for an attribute within a specific object instance is not a requisite for compliance with this Specification.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E39 — Object Services Standard: Concepts, Behavior, and Services

SEMI E54 — Sensor/Actuator Network Standard

SEMI E54.1 — Standard for Sensor/Actuator Network Common Device Model

SEMI E52 — Practice for Referencing Gases and Gas Mixtures Used in Digital Mass Flow Controllers

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

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *CVP* — cryogenic vacuum pump

5.1.2 *RM* — routine maintenance

5.1.3 *RVP* — roughing vacuum pump

5.1.4 *RVPB* — roughing vacuum pump plus booster

5.1.5 *TVP* — turbo molecular vacuum pump

5.1.6 *VPD* — vacuum pump device

5.2 *Definitions*

5.2.1 *roughing vacuum pump (RVP)* — a vacuum pump device for reducing pressure from atmospheric to a specific value at which another pumping system can begin to operate.

5.2.2 *roughing vacuum pump plus booster (RVPB)* — a vacuum pump device for reducing pressure from atmospheric to a value at which another pumping system can begin to operate. In this configuration a, booster pump is attached to the inlet of the main pump to further reduce the pressure at the inlet of the vacuum pump device.

5.2.3 *turbo molecular vacuum pump (TVP)* — an axial flow turbine vacuum pump device for operation in the molecular flow range designed to impart momentum change to gas molecules in a preferential direction from pump inlet to outlet.

5.2.4 *cryogenic vacuum pump (CVP)* — an entrapment vacuum pump device operating by the condensation, adsorption, and/or trapping of gas molecules on surfaces cooled to sufficiently low temperatures.

5.3 This Document inherits the following terminology defined by SEMI E54.1, Standard for Sensor/Actuator Network Common Device Model.

5.3.1 *attribute*

5.3.2 *behavior*

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5.3.3 *boolean (BOOL)*

5.3.4 *byte*

5.3.5 *character*

5.3.6 *common device model (CDM)*

5.3.7 *data type*

5.3.8 *data units*

5.3.9 *device*

5.3.10 *device manager (DM) object*

5.3.11 *device model*

5.3.12 *double integer (DINT)*

5.3.13 *enumerated byte (ENUM)*

5.3.14 *full scale range*

5.3.15 *instance*

5.3.16 *last valid value (LVV)*

5.3.17 *long integer (LINT)*

5.3.18 *long real (LREAL)*

5.3.19 *manufacturer*

5.3.20 *nibble*

5.3.21 *null character*

5.3.22 *object*

5.3.23 *real (REAL)*

5.3.24 *sensor actuator controller (SAC) object*

5.3.25 *service*

5.3.26 *signed integer (INT)*

5.3.27 *short integer (SINT)*

5.3.28 *state diagram*

5.3.29 *text string*

5.3.30 *unsigned double integer (UDINT)*

5.3.31 *unsigned double long integer (UDLINT)*

5.3.32 *unsigned integer (UINT)*

5.3.33 *unsigned long integer (ULINT)*

5.3.34 *unsigned short integer (USINT)*

6 Requirements

6.1 In order to implement this Standard in a VPD, it is necessary to also implement SEMI E54.1 and one of the sensor/actuator network communication Standards. See § 3 for more information on a complete interoperability Standard.

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7 Conventions

7.1 This Document utilizes the conventions specified in the CDM specification Document, SEMI E54.1.

8 Device High Level Structure

8.1 *General Description* — A high level object view of a VPD device is shown in Figure 1. The VPD objects are depicted in Figure 1 only for the purpose of illustrating a high level view of the device and its component objects. In the context of this Document, some of these objects are not addressable, do not have addressable attributes, do not have accessible services, nor have any defined behavior. All objects are included in Figure 1 to aid in the visualization of the VPD device. The VPD may also be configured as a 'roughing vacuum pump plus booster' (RVPB) which includes a main roughing pumping device and one booster pumping device. In this configuration, the main pumping device shall act as the control device for the booster pumping device. The main pumping device shall have the responsibility of providing visibility to the booster pumping device from the network. The specific mechanism employed to communicate to the booster pumping device from the main pumping device is manufacture specific and outside the scope of this Specification.

8.1.1 This Document defines in detail the component objects unique to the VPD device. References, rather than definitions, are included for the DM, the SAC, and other objects defined in SEMI E54.1.

8.1.2 Many of the objects defined in this Document inherit properties from other objects. The properties inherited include attribute, service, and behavior definitions. These other objects are specified here or in SEMI E54.1.

8.1.3 This Document is structured as to allow future extensions to the VPD class of devices to further specify the roughing vacuum pump, the turbo molecular vacuum pump (TMVP), the cryogenic vacuum pump (CVP), and the RVPB device types. This Document also provides the capability to allow manufacturer-specific enhancements, by reserving object attribute identifiers and object service identifiers. Specifically, all object definitions in this document specify or reserve the first 64 attribute identifiers (A1 to A64) and the first 64 service identifiers (S1 to S64), allowing manufacturers to specify identifiers beyond these ranges. Additionally, byte-enumerated attributes are specified or reserved from 0 to 63, allowing manufacturers to specify enumerations beyond this range (64 to 255).

8.2 *VPD Description* — The VPD profile is composed of the component objects and object relationships shown in Figure 1. The Actuator-VP object is a required object which is used to control and report the operational state of the VPD. The Sensor-AI objects are optional objects which are used to report environmental and operational characteristics of the VPD. A VPD may contain zero or more than one Sensor-AI object. The pump types, 'RVP,' 'TVP,' and 'CVP' may contain only one (1) object instance of a particular Sensor-AI object and Actuator-VP object. Specifically, these objects are addressed from the network as object instance one (1).

8.2.1 *Extension to the Model to Describe RVPB* — The vacuum pump device RVPB describes a pumping system consisting of a main roughing pump plus a booster pump. To support this device type, the model is extended by adding a second instance of the Actuator-VP object and by adding a second instance of those Sensor-AI objects which may be implemented by the manufacturer on the booster pump. Specifically, object instance 1 is used to address the main roughing pump Actuator-VP and Sensor-AI objects. Object instance 2 is used to address the booster pump Actuator-VP and Sensor-AI objects. The RVPB device must support two (2) object instances of the Actuator-VP but may support a mix of object instance 1 and object instance 2 Sensor-AI objects depending on the specific hardware configuration of the pump system. The booster pump is only visible from the network as an extension of the main roughing pump and can only be addressed through the main roughing pump specifically as object instance 2.

8.2.2 *General Requirements* — This section defines in detail the requirements and component objects unique to the VPD device. Additional requirements for future extensions to the VPD to describe and include a roughing vacuum pump, a TMVP, a CVP and a roughing pump plus booster may be provided as extensions and revisions to this section and Document.

8.2.2.1 *Device Objects* — All objects are defined in terms of their object name and instance identifier. Identifiers for all objects described in this document are summarized in Table 1.

8.2.2.2 *Object Services* — Not all object services listed in this document can necessarily be requested over the network. They are included in this document because their behavior may generate network activity.

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8.2.2.3 *Object Behavior* — When a service request is received over the network that is not supported by the object, or contains a parameter value which is beyond the supported range, or which is otherwise invalid, a network-specific service error response is generated as specified in SEMI E54.1, Appendix 2.

8.2.3 *Sensor Actuator Controller (SAC) Object* — The SAC object is the device component responsible for coordinating the interaction of the VPD device with the sensory/actuation/control environment as specified in SEMI E54.1. The following sections specify the components of the SAC object that are not specified in the CDM or require further definition than specified in the CDM.

8.2.3.1 *SAC Object Attributes* — The attributes provided by the SAC object are defined in SEMI E54.1. Additional required and optional SAC object instance attributes are listed in Table 2.

8.2.3.1.1 *Hours to Next Routine Maintenance (Optional)* — An attribute that specifies the time in hours until the next scheduled routine maintenance cycle. This attribute value is decremented by one each time an hour expires and may become a negative value. A negative value indicates that the maintenance cycle has expired and has been exceeded by the negative hours indicated. When the most negative number is reached it is held and is no longer decremented. The Exception Detail Warning[0, 2] Bit[6] (see Table 9) and/or Alarm[0, 2] Bit[6] (see Table 7) may optionally be set to alert that pump maintenance is required when this attribute decrements to a manufacturer specified value. This attribute is initialized and maintained by a manufacturer specific procedure which is outside the scope of this Specification.

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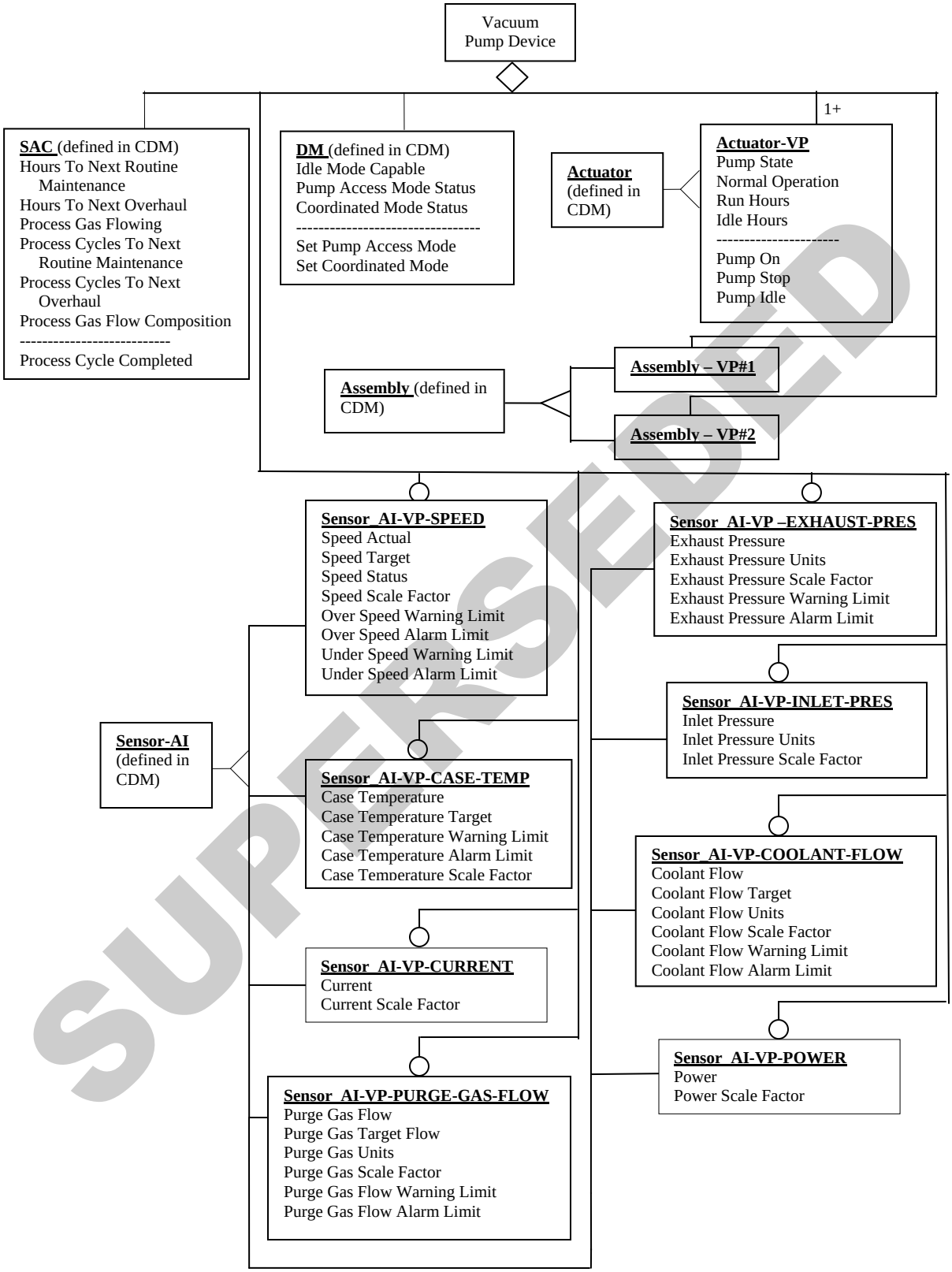

Figure 1
VPD High Level Structure

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Table 1 VPD Objects

Referenced Document Section	*Object Name*	*Object Identifier*	*VPD Minimum Instances*	*VPD Maximum Instances*
8.2.3	Sensor Actuator Controller (SAC)	VPD1	1	1
8.2.4	Device Manager (DM)	VPD2	1	1
8.2.5	Actuator-VP	VPD3	1	2
8.2.6	Sensor-AI-VP-SPEED	VPD4	0	Manufacturer-Specified
8.2.7	Sensor-AI-VP-EXHAUST-PRES	VPD5	0	Manufacturer-Specified
8.2.8	Sensor-AI-VP-INLET-PRES	VPD12	0	Manufacturer-Specified
8.2.9	Sensor-AI-VP-CASE-TEMP	VPD6	0	Manufacturer-Specified
8.2.10	Sensor-AI-VP-CURRENT	VPD7	0	Manufacturer-Specified
8.2.11	Sensor-AI-VP-POWER	VPD8	0	Manufacturer-Specified
8.2.12	Sensor-AI-VP-COOLANT-FLOW	VPD9	0	Manufacturer-Specified
8.2.13	Sensor-AI-VP-PURGE-GAS-FLOW	VPD10	0	Manufacturer-Specified
8.2.14	Assembly-VP#1	VPD11	1	1
8.2.14	Assembly-VP#2	VPD13	0	1
-	Reserved	VPD14–VPD64	-	-
-	Manufacturer-Specified	>VPD64	-	-

Table 2 SAC Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Hours To Next Routine Maintenance	SacA65	R	No	INT
Hours To Next Overhaul	SacA66	R	No	INT
Process Gas Flowing	SacA67	RW	No	Enumerated Byte
Process Cycles To Next Routine Maintenance	SacA68	R	No	INT
Process Cycles To Next Overhaul	SacA69	R	No	INT
Process Gas Flow Composition	SacA70	RW	No	Structure of: (see Table 5) INT Size of List Struct of: INT Standard Gas Number INT Flow Rate BYTE Flow Unit INT Flow Scale Factor

8.2.3.1.2 *Hours to Next Overhaul (Optional)* — An attribute that specifies the time in hours until the next scheduled device overhaul cycle. An overhaul is an event that requires the physical removal of the pump for servicing. This attribute value is decremented by one each time an hour expires and may become a negative value. A negative value indicates that the overhaul cycle has expired and has been exceeded by the negative hours indicated. When the most negative number is reached it is held and is no longer decremented. The Exception Detail Warning[0, 2] Bit[6] (see Table 9) and/or Alarm[0, 2] Bit[6] (see Table 7) may optionally be set to alert that pump maintenance is required when this attribute decrements to a manufacturer specified value. This attribute is initialized and maintained by a manufacturer specific procedure which is outside the scope of this Specification.

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8.2.3.1.3 *Process Gas Flowing (Optional)* — An attribute which uniquely identifies to the VPD that process gas is flowing. This attribute is typically set to indicate to the VPD that it is pumping a process gas. The flow rate and composition of the process gas can be specified using the optional attribute 'process gas flow composition.' The interpretation of this information is manufacturer specific. It may be used for example, to help determine the manufacturer's suggested routine maintenance cycle for the pump device. This attribute is an enumerated byte that can take on one of the following values:

- 0 = No process gas is flowing
- 1 = Process gas is flowing
- 2 to 63 = Reserved
- 64 to 255 = Manufacturer Specific

8.2.3.1.4 *Process Cycles to Next Routine Maintenance (Optional)* — An attribute that records the number of process cycles that can be completed before the device requires scheduled routine maintenance. This attribute is maintained by the pump device based on the number of times the 'process cycle completed' service is invoked by the tool together with any other manufacturer specific operating conditions monitored by the pump device. The management of this attribute and the value assigned to this attribute is manufacturer specific. For example, the pump device may monitor its current consumption, temperature, process gas flowing attribute and the process cycle count to determine how many process cycles can be completed before scheduled maintenance is required. The Exception Detail Warning[0, 2] Bit[4,5 and/or 6] (see Table 11), and/or Exception Detail Alarm[0, 2] Bit[6] (see Table 7) may optionally be set to alert that pump maintenance is required when this attribute reaches the manufacturer specified value. This attribute is initialized by a manufacturer specific procedure which is outside the scope of this Specification. The definition of a 'process cycle' is manufacturer specific and is outside the scope of this Specification.

8.2.3.1.5 *Process Cycles to Next Overhaul (Optional)* — An attribute that records the number of process cycles that can be completed before the pump device requires a scheduled overhaul. An overhaul is an event that requires the physical removal of the pump for servicing. This attribute is maintained by the pump device based on the number of times that the 'process cycle completed' service is invoked by the tool together with any other manufacturer specific conditions monitored by the pump device. The management of this attribute and the value assigned to this attribute is manufacturer specific. For example, the pump device may monitor its current consumption, temperature, process gas flowing attribute and the process cycle count to determine how many process cycles can be completed before an overhaul is required. The Exception Detail Warning[0, 2] Bit[4,5 and/or 6] (see Table 11), and/or Exception Detail Alarm[0, 2] Bit[6] (see Table 7) may optionally be set to alert that pump maintenance is required when this attribute reaches the manufacturer specified value. This attribute is initialized by a manufacturer specific procedure which is outside the scope of this Specification. The definition of a 'process cycle' is manufacturer specific and is outside the scope of this Specification.

8.2.3.1.6 *Process Gas Flow Composition (Optional)* — An attribute that specifies the elements of the process gas flow composition. This attribute is configured as a structure of gas flow elements used to describe the gas or gas mixture that will be pumped by the VPD. Setting this attribute defines the gas flow composition, but does not indicate that gas is currently flowing. The attribute 'process gas flowing' is used to indicate when process gas to be pumped is actually flowing to the VPD. The formatted data structure used to describe this attribute is detailed in Table 3. The elements of this table may be used in a manufacturer specific method for e-diagnostics, determining the number of hours to the next scheduled maintenance cycle or to ensure the safe operation of the VPD. The use of this attribute is manufacturer specific and is outside the scope of this Specification.

Table 3 Process Gas Flow Composition Definition

Table Element	*Data Type*	*Description*
Size Of List	INT	Number of gas types in the table
Standard Gas Number	INT	Standard gas number as specified in SEMI E52-00-0703
Flow Rate	INT	The rate of flow for the specified gas
Flow Unit	Enumerated Byte	The unit of flow (see SEMI E54.1, Appendix 1)

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Table Element	Data Type	Description
Flow Scale Factor	INT	A divisor used to scale the integer Flow Rate

8.2.3.1.6.1 *Size Of List* — This entry is used to specify the number of elements to follow that is used to configure the Process Gas Flow Composition attribute. An element is defined as the structure of standard gas number, flow rate, flow unit, and flow scale factor. The number of elements is defined by the size of list entry. A size of list value of zero (0) indicates that the table is empty.

8.2.3.1.6.2 *Standard Gas Number* — This entry identifies the process gas or process gas mixture for the current process as defined in SEMI E52-0703, Practice for Referencing Gases and Gas Mixtures Used in Digital Mass Flow Controllers.

8.2.3.1.6.3 *Flow Rate* — This entry identifies the process gas or gas mixture flow rate for the current process.

8.2.3.1.6.4 *Flow Unit* — This entry identifies the unit for the flow rate parameter. This entry is enumerated and can be assigned one of the values specified in Appendix 1 of SEMI E54.1.

8.2.3.1.6.5 *Flow Scale Factor* — This entry identifies the scale factor divisor to be applied to the flow rate entry. As an example, a value of 10 indicates that flow rate entry is to be divided by 10.

8.2.3.1.7 *Initial and Default Values*

Table 4 SAC Object Attribute Initial and Default Values

Attribute	Initial Value	Default Value	Comment
Hours To Next Routine Maintenance	LVV	0	
Hours To Next Overhaul	LVV	0	
Process Gas Flowing	0	0	Values based on device 'process gas flow' conditions
Process Cycles To Next Routine Maintenance	LVV	0	
Process Cycles To Next Overhaul	LVV	0	
Process Gas Flow Composition	LVV	Manufacturer Specific	Values based on device 'process gas flow' conditions

8.2.3.2 *SAC Object Services* — The services provided by the SAC object are defined in SEMI E54.1. Table 5 contains additional services required for the SAC object.

Table 5 SAC Object Services

Service	Service Identifier	Type	Description
Process Cycle Completed	SacS33	R	Used to maintain device scheduled maintenance counters.

8.2.3.2.1 *Process Cycle Completed (Optional)* — This service is used to indicate that a process cycle has been completed. The device uses this service to maintain the 'process cycles to next routine maintenance' (refer to ¶ 8.2.2.1.4) and 'process cycles to next overhaul' (refer to ¶ 8.2.2.1.5) attributes. There are no parameters specified for this service.

8.2.3.3 *SAC Object Behavior* — The behavior exhibited by the SAC object is defined in SEMI E54.1. Additional behavior required for the SAC object is detailed below.

8.2.3.3.1 The 'process cycles to next routine maintenance' and 'process cycles to next overhaul' attributes is updated each time the service 'process cycle completed' is invoked by the tool. These attributes are managed and set

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based upon manufacturer specific operating conditions. These attributes may assume a negative value to indicate that the specific maintenance cycle has been exceeded.

8.2.4 *Device Manager (DM) Object* — The DM object instance is the device component responsible for managing and consolidating the device operation as specified in SEMI E54.1. The following sections specify the components of the DM object that are not specified in the CDM.

8.2.4.1 *DM Object Attributes* — Additional required and optional DM object instance attributes as well as additional requirements placed on attributes defined in SEMI E54.1 are listed in Table 6.

Table 6 DM Object Attributes

Attribute Name	*Attribute Identifier*	*Access Network*	*Required*	*Form*
Device Type	DmA1	R	Yes	Refer to CDM (SEMI E54.1).
Exception Detail Alarm	DmA13	R	Yes	Refer to CDM (SEMI E54.1).
Exception Detail Warning	DmA14	R	Yes	Refer to CDM (SEMI E54.1).
Idle Mode Capable	DmA33	R	Yes	BOOL
Pump Access Mode Status	DmA34	R	Yes	Enumerated Byte
Coordinated Mode Status	DmA35	R	No	Enumerated Byte

8.2.4.1.1 *Device Type* — An attribute which uniquely identifies the type of the device on the network. The device type attribute is assigned as follows:

- Roughing Vacuum Pump Device = ‘RVP’
- Turbo Molecular Vacuum Pump = ‘TVP’
- Cryogenic Vacuum Pump = ‘CVP’
- Roughing Vacuum Pump plus Booster = ‘RVPB’

8.2.4.1.2 *Exception Detail Alarm* — A 2-byte attribute which identifies the detailed alarm status of the device. All pumps must support the ‘general’ alarm bit defined below, and optionally other alarm bits. Tables 7 and 8 define the bit assignments associated with the alarm exception detail for the VPD. An alarm condition is cleared by a manufacturer specified action. Alarm bits are set and cleared according to manufacturer specified actions. For example, filtering, hysteresis, or timing algorithms may be applied before an alarm condition is set. Definition of these techniques is outside the scope of this Specification. An ‘RVPB’ device type will report 2 additional alarm bytes through the Exception Detail Alarm [2] and Exception Detail Alarm [3] bit assignments which detail the alarms associated with the booster pump.

Table 7 VPD Exception Detail Alarm [0] Bit Assignments

Bit	*Device-Specific Alarm [0]*	*Description*
0	General	The pump is in an alarm condition. At least one alarm condition exists (either one of the other alarm bits is set, or a manufacturer-specific alarm condition exists).
1	Mains Failure	Insufficient Power
2	Device Failure	Physical Fault
3	Startup Timeout	Unable to start up within the manufacturer specified time
4	Reserved	Reserved
5	Reserved	Reserved
6	RM	Pump device is in need of routine maintenance
7	Emergency Stop	Emergency stop button has been pressed

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