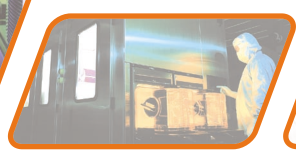
Skill Standards for Technicians in the Highly Automated Manufacturing Environment





MATEC
Maricopa Advanced Technology Education Center

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The development of *Skill Standards for Technicians in the Highly Automated Manufacturing Environment* was sponsored with major funding from the Intel Foundation and supported in part by a grant from the National Science Foundation, #DUE 9908419

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Companies whose personnel contributed significantly to the development, profiling and validation effort include:

Agilent Technologies
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Applied Materials, Inc.
ASML
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IBM
Intel Corporation
KLA-Tencor Corporation
LAM Research Corporation
National Semiconductor
PRI Automation, Inc.
Semitool, Inc.
TECH Semiconductor
Texas Instruments, Inc.

Acknowledgements

The development and publication of these skill standards has been a joint and collaborative effort between the industry and education communities. We are grateful to the industry personnel who participated in the development and validation process. Industry technicians, supervisors, managers and subject matter experts donated their time and effort to insure the relevancy and currency of the standards.

We gratefully acknowledge the financial support of the Intel Foundation and the leadership of Dr. Pat Foy from Intel who initiated and managed the initial stages of the project. Our thanks to the Technical Manufacturing Group Training Organization within Intel who loaned the services of Bob Simington, Training Specialist, to the project. Bob acted as co-manager and loaned his expertise, design and thoughtful effort to every aspect of the project. The continuing support of the National Science Foundation and the Maricopa Community Colleges in this project is gratefully acknowledged.

At MATEC, Vance Williams was in charge of the data management and set-up of the on-line surveys. Becky Shingler coordinated the project, kept us on track, handled the documentation and managed the development group meetings, budget and logistics. Bryan McIntyre designed the layout and created the printed version of the standards. In the early stages of the project the team had the opportunity to visit the control center of the Burlington Northern Railroad to explore the commonality of highly centralized control systems. Thanks to James Lacey and his colleagues for their courtesy during that visit.

The Performance Criteria Analysis List (PCAL) process was developed by Richland College,
http://www.rlc.dcccd.edu/annex/id/pcal.htm

One of the key project tasks was the conversion of the surveyed knowledge, skills and abilities into the actual skill standards. This occurred during an intensive two-day meeting in Tempe, Arizona, with a dedicated group of industry and education experts. We extend our appreciation to this group that included:

Jeff Baluch, *Intel*
Barbara Davenport, *Intel*
Matt Del Bianco, *Intel*
Buu Diep, *Texas Instruments*
Charlie Girard, *Intel*
Kevin Kilpatrick, *Texas Instruments*

Joe Mattoon, *MATEC*
Richard Newman, *Arizona State University*
TJ Putnam, *Intel*
Karen Shepard, *Intel*
Leonard Sledge, *MATEC*
Mary Jane Willis, *Albuquerque Technical Vocational Institute*

This material was presented in part at the Advanced Semiconductor Manufacturing Conference, April 2002, Boston.

Michael Lesiecki, Ph.D., *Executive Director*
Maricopa Advanced Technology Education Center — *Tempe, AZ*

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Skill Standards for Technicians in the Highly Automated Manufacturing Environment
First Edition, 2002
Published by the Maricopa Advanced Technology Education Center

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Visit the MATEC Website for updates and additions to the skill standards at www.matec.org/work/skills. Copies of the standards may be ordered from the MATEC product catalog on-line.

Cover photos courtesy of Intel Corporation, Varian Semiconductor Equipment Incorporated, PRI Automation, and SCP Global Technologies

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What Is a Skill Standard?

Skill standards are quality standards applied to people. They are specific statements of desired skill and knowledge presented in observable and measurable form.

The statement contains a condition that defines under what circumstances it will be observed and measured. The desired behavior is defined and the standard criteria are stated in terms of "how good is good enough?"

An example of a skill standard statement is:

Condition — Behavior — Standard

Given appropriate instructions and minimal assistance; maintain workflow software; **adhering to appropriate cleanroom and software specifications**

The ranking information in terms of importance, proficiency, frequency and difficulty are shown for each statement. (*see Appendix A)*.

Background and Process

Background

Skill standards specify the expected behavior, the condition and the standard for performance for technicians working in highly automated environments such as 300mm semiconductor fabs.

The manufacturing environment has evolved from one that was populated with self-contained tools utilizing robotics technology to one that is composed of large numbers of these tools interconnected by automated material handling systems (AMHS) and driven by a centralized manufacturing execution system (MES) in such a way as to maximize factory throughput and output.

The skills required to work in such an environment consist of most of the skills required by the previous environment (i.e., 200mm fabs) plus some emerging skills. These emerging skills are primarily skills and knowledge related to the new, enterprise automation systems, their maintenance, and the ability to utilize the vast amount of information they provide.

Importantly, these skills are transferable to a great extent to a variety of industries such as pharmaceuticals, biotechnology, food processing and automotive manufacturing. In the course of this project, research into transportation industries (railroads) and chemical processing (refineries) showed a high degree of commonality of the skills required.

Background and Process

The Process

The development process was designed to first determine the requisite knowledge, skills, and abilities (KSAs) for technicians working in highly automated environments such as 300mm fabs. Conventional methods of conducting task analysis for workers currently involved in this area were not viable since there are no operational fully automated, high-volume 300mm fabs at this time. The approach has been to work with manufacturers, tool suppliers and automation system vendors to develop a projected set of knowledge, skills, and abilities required. In addition, assays of tasks at companion industries in transportation and manufacturing using highly automated environments were conducted to determine the common skills for these areas.

After the initial set of 103 KSAs was determined, a cross-industry, on-line survey of subject matter experts was conducted using a Performance Criteria Analysis (PCAL) approach [1]. Each proposed knowledge, skill or ability was ranked for importance, proficiency, time spent (frequency) and difficulty. Sixty-five subject matter experts were identified and requested to respond to the survey. Of these, 48 responded for a rate of 74%. They represented 14 different companies and included fabs and suppliers. An overall emphasis rating was assigned to each KSA *(see Appendix A).*

The ranked KSAs were used as the basis for writing the skill standard statements. This was accomplished with a group of 12 subject matter experts, educators and instructional designers who developed 56 statements that represented the expected behavior, conditions and standards at the technician level for the first six months in the position. The example in the box below illustrates this process.

The ability defined by the KSA survey was "access parametric tool performance history." To transform this into a skill standard the working group considered similar KSAs and their rankings and developed a condition, a behavior and the standard that would represent this ability. The resulting skill standard statement is: Given a problem lot, correlate historic tool parametric data to resolve the problem, identifying at least one root cause of the anomaly.

Validating Skill Standard Statements

The final phase of the process involved the cross-industry validation of the skill standard statements. Survey participants were asked if these statements represented what technicians should know and be able to do. The survey results (see Appendix B) showed strong agreement with 54 of the 56 standards. For Standards 2.2 and 7.5 the agreement is tenuous and reflects the uncertainty of the requirements in these skill areas at this stage. As highly automated facilities come on-line, the validation data will be continually updated with information available at *www.matec.org/work/skills.*

References

[1] The Performance Criteria Analysis List (PCAL) process was developed by Richland College, http://www.rlc.dcccd.edu/annex/id/pcal.htm

How the Skill Standards Can Be Used

Business Applications for Skill Standards*

Skill standards are not only useful for educators and students. Many businesses are finding the standards helpful in employee hiring, evaluation and development processes. Listed below are applications provided by businesses of possible uses of skill standards.

— Review the functional job analysis. Specifically assess the functions and tasks for relevancy, frequency and importance for a particular job at your worksite. Develop hiring criteria, identifying which ones are most critical for a new job opening in your company or department.

— Use the scenarios to trigger relevant in-house situations in which an employee may be required to solve typically occurring problems or critical incidents. Customize the scenarios for the particular job; include scenarios during an interview or an in-house problem solving training session.

— Communicate performance expectations for specific tasks by adapting the performance criteria for the particular job in your firm. Define specifically what the employee is expected to know and do. Define what success looks like using the standards.

— Use the performance criteria for evaluating job and task performance.

— Create individual development plans based on the identified gaps in performance and skill level; chart an employee's progress toward achieving the skill standard.

— Ask for evidence of achievement for a particular function or task. This could be a demonstration, a portfolio or a description of accomplishments with appropriate documentation.

— Use the skill standards as the basis for a certificate or credential to assure employers of the level of proficiency of a new hire or transferred employee.

— Stimulate strategic thinking about workforce reorganization—evaluate how work gets done using the major functions identified in the skill standard.

* *Excerpted with permission from the Skills Standards Guidebook I and II, 1997, Washington State Board for Community and Technical Colleges*

Highly Automated Systems Technician Job Description

The job description for these technicians is emerging. There is no one cross-industry definition. The following description is a synthesis of the profile of a number of related positions. Each industry member may use variations of the profile described below.

Required Education and Experience: An Associates Degree in electronics, manufacturing, microelectronics, information technology or appropriate related field or equivalent recognized certifications.

Technician Profile

Technicians in this area are specialists with a broad background typically in electronics with special emphasis in semiconductor manufacturing technology and/or information technology. Their computer and related skills are critical to the successful operation of state-of-the-art highly automated manufacturing facilities. They must be familiar with a variety of software operating systems as well as automated materials handling systems. They may work in a centralized control center environment implementing manufacturing execution and scheduling systems or may work at the fab level insuring tool utilization, process optimization and work flow for maximum factory performance.

These technicians are skilled at multitasking and capable of leading a cross-functional team. Their knowledge must include a demonstrable understanding of the manufacturing process as well as the concepts that control the dynamics in a factory. They have excellent troubleshooting and problem solving skills and make informed decisions based on priorities. Their ability to access data on tool performance, work in progress and defect reduction, for example, is important to their support of the full factory automation system. Their abilities include working in multiple operating system environments as well as insuring data encryption and security. On a day-to-day basis the tech may insure the operation of interbay materials-handling systems, track the location of individual wafers through content maps, participate in troubleshooting of a problematic tool using e-diagnostics with the tool supplier and make recommendations based on statistical process control data.

Skill Standard Statement

1.1

Condition: Given graphical user interface based systems
Behavior: Interact with the interface
Standard: To produce desired results

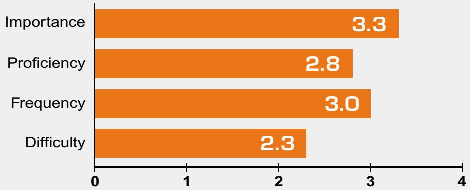
1.2

Condition: Given an anomaly in the manufacturing environment
Behavior: Interact with the material control system (MCS)
Standard: To resolve the anomaly

1.3

Condition: Given a functional reticle tracking system
Behavior: Interact with the reticle tracking system
Standard: To ensure data integrity

1.1



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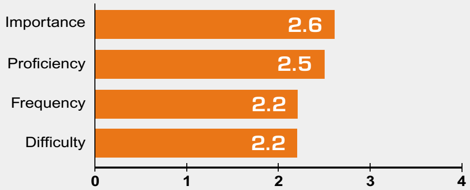

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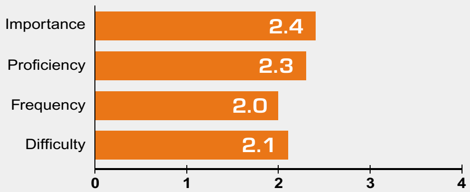


Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Photo courtesy of SCP Global Technologies

Skill Standard Statement

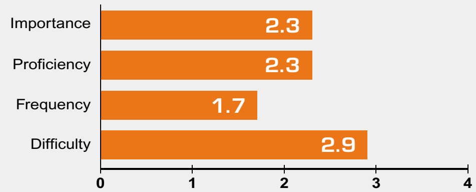
2.1

Condition: Given appropriate instructions and minimal assistance
Behavior: Maintain workflow software
Standard: Adhering to appropriate cleanroom and software specifications

2.2

Condition: Using application development software (commercial and internal)
Behavior: Write application programs
Standard: Adhering to standard programming methodologies

2.1



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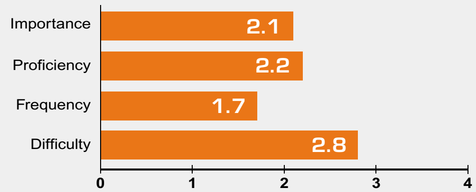

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Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

3.1

Condition: Given a networked automated manufacturing system

Behavior: Illustrate the connection (hardware) of production tools to the network

Standard: Using a block diagram that displays all major connections

3.2

Condition: Given a networked automated manufacturing system

Behavior: Verify network connectivity on tool side (by troubleshooting tool to terminal or controller)

Standard: To confirm communication is established to specification

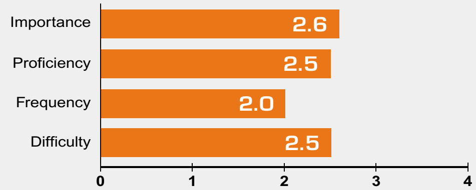
3.3

Condition: Given a networked automated manufacturing system

Behavior: Describe network communications security

Standard: To include firewalls, routers, IP security and other features as appropriate for a network protocol

3.1



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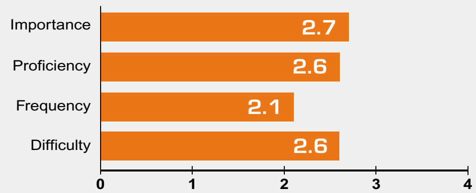

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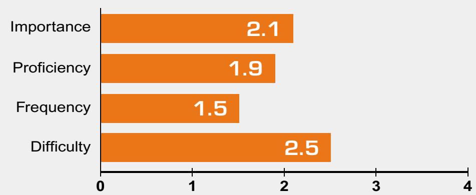

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Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Photo courtesy of Intel Corporation

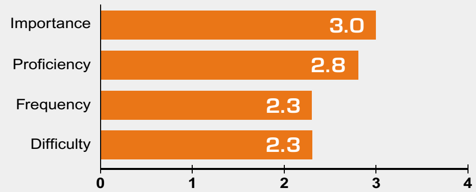
Skill Standard Statement

4.1

Condition: Given a handheld programmable logic controller (PLC) or similar device
Behavior: Teach a robotic device
Standard: Adhering to specified procedures

4.2

Condition: Using content (slot) maps
Behavior: Identify the location of a specified wafer
Standard: In a particular slot in a specific FOUP



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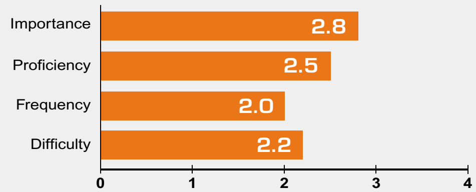


4.2

Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

5.1

Condition: Using SPC analysis techniques and established control limits and trends
Behavior: Assess when a process is approaching an out-of-control situation
Standard: Before the process is out of control

5.2

Condition: Given the results of SPC analysis
Behavior: Respond to an out-of-control situation
Standard: According to a defined escalation procedure

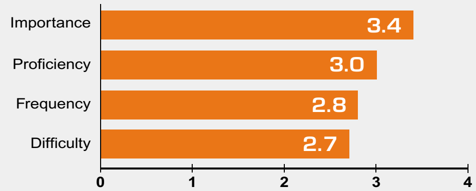
5.3

Condition: Given a specified equipment set
Behavior: Gather critical parameter data captured by the tool
Standard: Limiting the data to that which can be used to validate tool health

5.4

Condition: Given automated reporting and advanced SPC software
Behavior: Generate reports and statistical data
Standard: That are accurate and actionable

5.1



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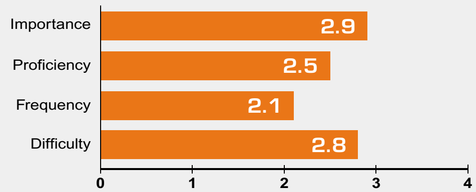

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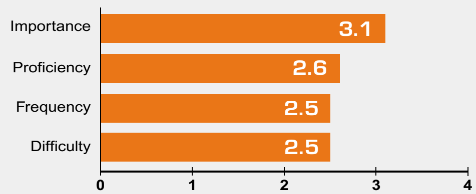

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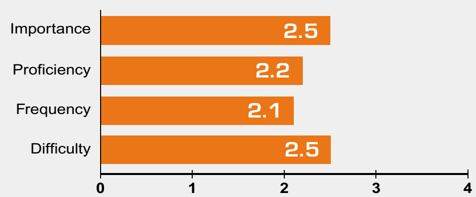

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Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

6.1

Condition: Within a manufacturing functional area

Behavior: Retrieve data from multiple data sources (such as tool logs, AMHS, log files and transaction histories)

Standard: Within specified range or parameters

6.2

Condition: Within a manufacturing functional area

Behavior: Insure validity of data retrieved from multiple sources (such as tool logs, AMHS, log files and transaction histories)

Standard: Achieving data that is complete, correct and inclusive (without gaps)

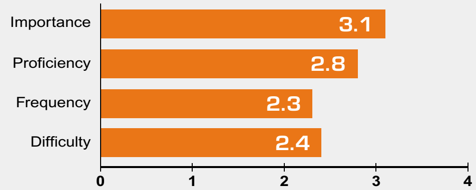
6.3

Condition: In a manufacturing environment

Behavior: Analyze data to distinguish the appropriate action to take for either equipment or process

Standard: Insuring tool or process is within specifications and maintained in control

6.1



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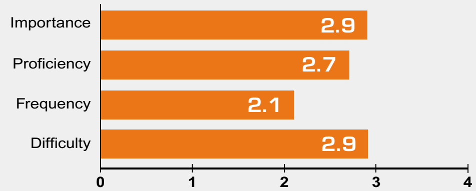

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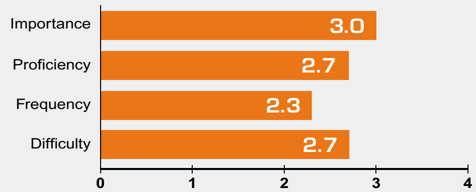

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Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

7.1
Condition: Using capacity, cycle time and understanding of process flow
Behavior: Control end product production
Standard: To consistently meet output goals

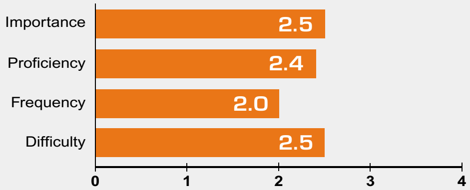
7.2
Condition: Given an equipment or process excursion
Behavior: Respond to process/equipment abnormalities
Standard: Adhering to appropriate factory escalation procedures

7.3
Condition: Given an established software-based factory scheduling system
Behavior: Operate the factory schedule systems for relevant tool sets
Standard: Adhering to established prioritization of WIP while assuring maximum tool utilization

7.4
Condition: Given expense and complexity of equipment/infrastructure in a highly automated environment
Behavior: Coordinate the preventative maintenance process
Standard: To efficiently meet the factory output goals (e.g., training, availability, utilization)

7.5
Condition: Given a set of factory protocols
Behavior: Write system error recovery protocols (AMHS, process equipment, metrology tools, etc.)
Standard: Adhering to established protocol specifications

7.1



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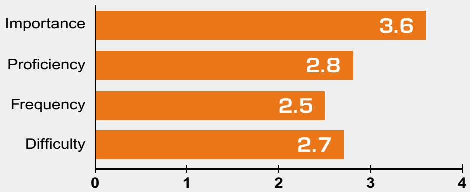

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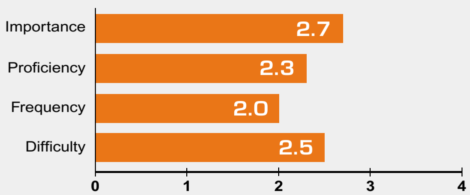

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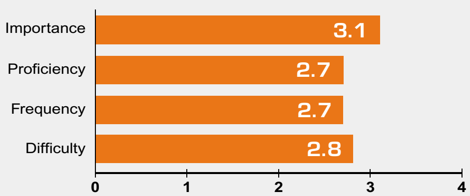

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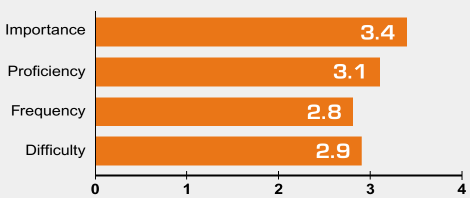

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Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Photo courtesy of VSEA Incorporated

Skill Standard Statement

8.1 **Condition:** Within a high-volume manufacturing environment

Behavior: Differentiate WIP prioritization schemes such as push/pull, steady stream, batch, polled or event driven, LIFO/FIFO (last in/first out; first in/first out)

Standard: Illustrating all critical aspects

8.2 **Condition:** Within an automated manufacturing environment

Behavior: Validate equipment performance metrics (measures)

Standard: In accordance with accepted standards (such as SEMI E10-0701, Specification for the Definition and Measurement of Equipment Reliability, Availability and Maintainability [RAM])

8.3 **Condition:** Given performance metrics collected in an automated manufacturing environment

Behavior: Maximize equipment utilization

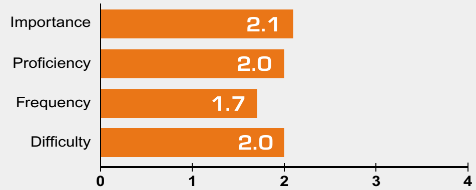
Standard: To meet or exceed area tool performance metrics

8.4 **Condition:** Within a high-volume automated manufacturing environment

Behavior: Apply the theory of constraints

Standard: Describing how elevating the constraints could improve factory performance and explaining how to subordinate to the constraint

8.1



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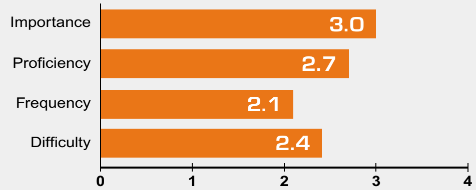

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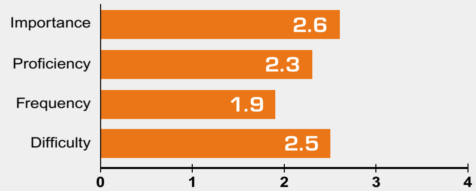

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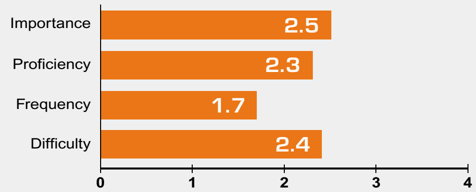

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Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Photo courtesy of PRI Automation

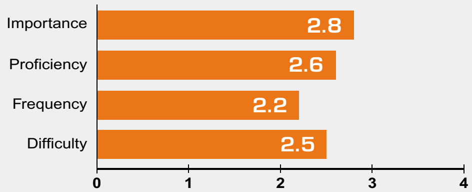
Skill Standard Statement

9.1
Condition: Given a tool with an in-line monitoring capability
Behavior: Verify machine operation or endpoint settings
Standard: Using monitor console commands

9.2
Condition: Given a problem lot
Behavior: Correlate historic tool parametric data to resolve the problem
Standard: Identifying at least one root cause of the anomaly

9.3
Condition: Given a problem lot and correlated historical tool parametric data
Behavior: Recommend process changes and or equipment settings
Standard: That resolve the problem

9.1



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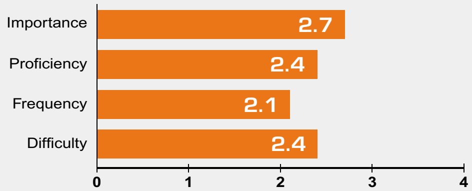

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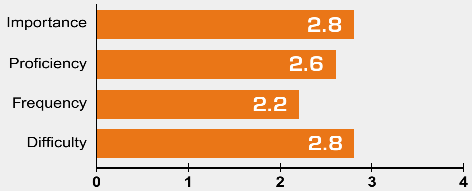

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Difficulty — how difficult is it to learn or do

Photo courtesy of Intel Corporation

Skill Standard Statement

10.1
Condition: Given all appropriate available information and a clear set of priorities
Behavior: Make an informed decision
Standard: To achieve a positive outcome

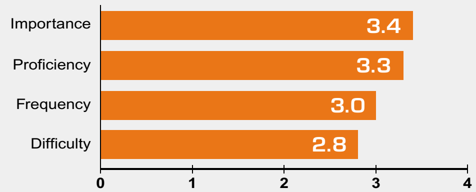
10.2
Condition: Given a clear set of project objectives, budget, timeframe and quality measures
Behavior: Manage a project
Standard: To meet or exceed expected deliverables and project criteria

10.3
Condition: Given simultaneous responsibilities and competing priorities
Behavior: Complete multiple tasks
Standard: To meet all task requirements

10.4
Condition: Given a scenario that requires a cross-functional team
Behavior: Participate as a productive team member
Standard: To achieve the team objectives

10.5
Condition: Given a problem scenario in the workplace
Behavior: Team with the customers (internal/external)
Standard: To resolve the problem

10.1



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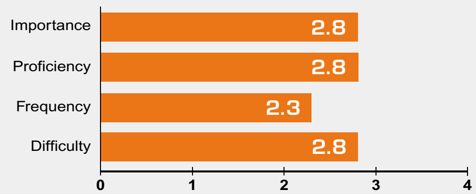

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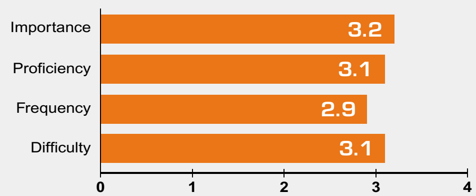

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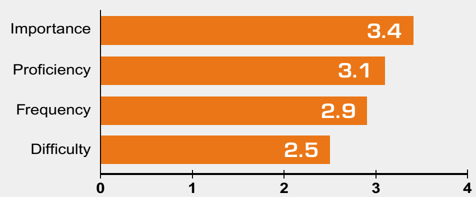

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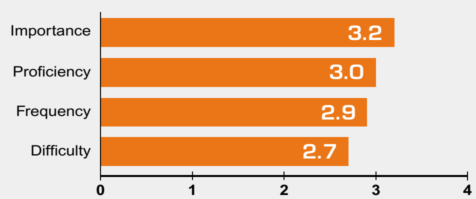


Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

10.6

Condition: Given stress in a workplace environment

Behavior: Recognize biological signs and behaviors that signal stress in oneself or co-workers

Standard: Listing five major signs of stress identified by an authority such as the National Institute of Occupational Safety

10.7

Condition: Given an individual, co-worker or team member under a high level of stress

Behavior: Take appropriate action to reduce stress

Standard: To avoid debilitating effects on productivity and personal behavior

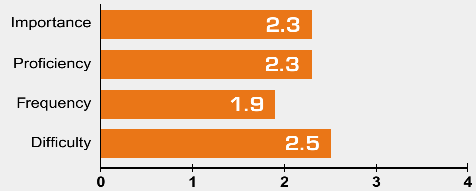
10.8

Condition: Given appropriate information, data, tools and format

Behavior: Generate formal and informal reports and specifications

Standard: To effectively communicate results or desired action

10.6



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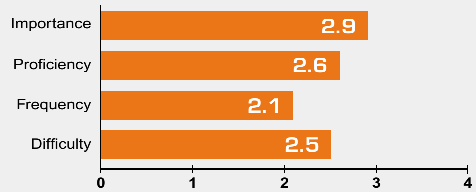

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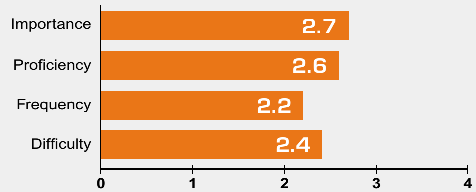


Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

11.1
Condition: Given a flowchart, process tool reports and/or automation databases and factory simulation software
Behavior: Troubleshoot problems that impact line and die yield and tool availability
Standard: Returning the line to factory goals

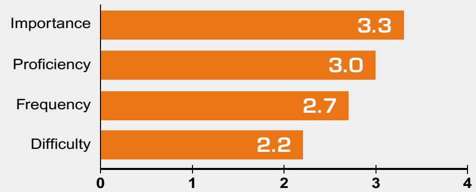
11.2
Condition: Given a problem in a production tool
Behavior: Utilize escalation procedure protocols for the equipment set
Standard: To notify the appropriate entity

11.3
Condition: Given a specific problem
Behavior: Describe a formal problem-solving process
Standard: That exemplifies an established systematic approach

11.4
Condition: Given factory tool problems that require WIP recovery (wafer)
Behavior: Describe the prioritization process
Standard: Adhering to documented procedures

11.5
Condition: Given equipment interface issues (e.g., automation systems, linked tools, etc.)
Behavior: Troubleshoot the software-controlled equipment interfaces
Standard: To return the interface to specifications

11.1



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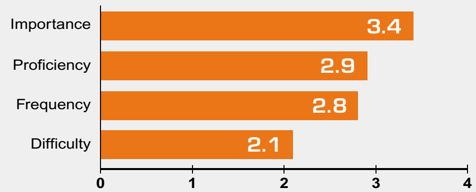

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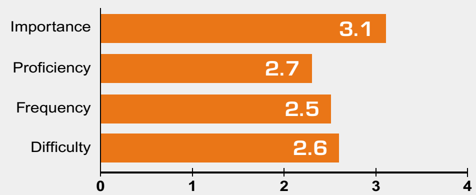

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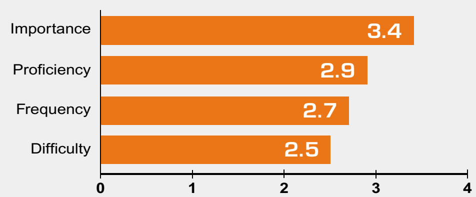

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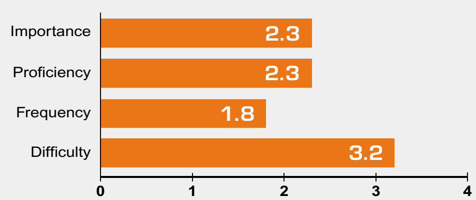


Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

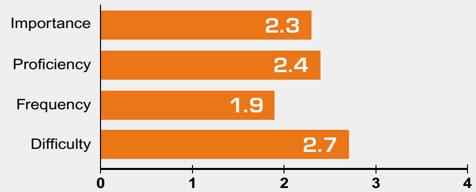
12.1
Condition: Given specific projects or tasks to accomplish
Behavior: Lead project teams
Standard: Using resources, skill sets and project management principles to meet goals and deadlines

12.2
Condition: Given a problem or project, tools to accomplish the objective and empowered people to make team decisions
Behavior: Achieve team-based decisions
Standard: To meet the stated objectives or to accomplish the work according to a schedule

12.3
Condition: Given team members with multiple skill sets
Behavior: Facilitate cross-training of team members
Standard: To maximize the efficiency of the team according to business objectives

12.4
Condition: Given a team working environment
Behavior: Evaluate performance of other members in the team
Standard: To defined performance standards

12.5
Condition: Given leadership responsibilities in a teamworking environment
Behavior: Provide constructive feedback to individuals regarding performance
Standard: Eliciting appropriate actions and skill development



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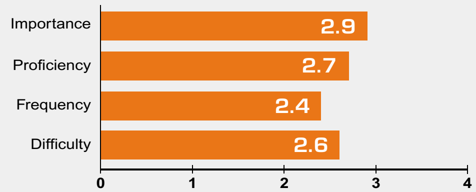

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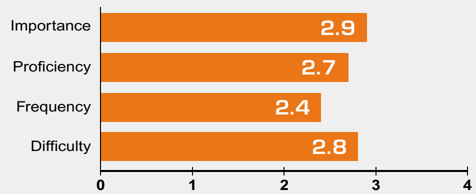

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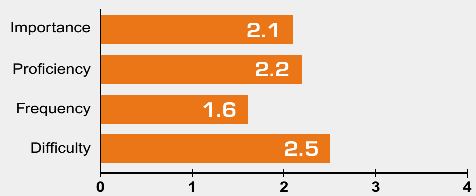

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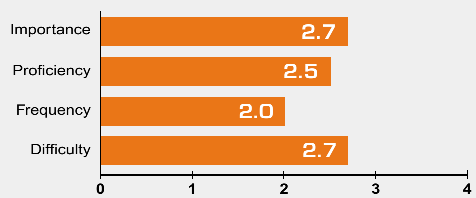


12.5

Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

13.1

Condition: Given appropriate reference material for a current process technology

Behavior: Explain the process flow from wafer start to completion including advanced process technologies such as copper interconnect

Standard: Identifying the process and tool involved in each step

13.2

Condition: For a manufacturing environment with an automated materials handling system

Behavior: Explain the purpose and functionality of the major equipment sets

Standard: Indicating each set's reliance on the AMHS for proper operation

13.3

Condition: Given an automated factory environment

Behavior: Illustrate how automated systems are integrated into the factory environment

Standard: Using a complete functional diagram showing system integration (including AMHS, stockers, station controllers and command center, if applicable)

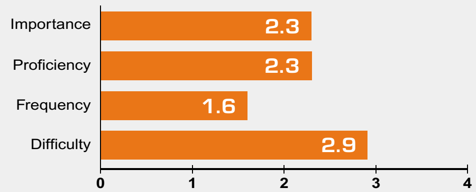
13.4

Condition: Given a process technology

Behavior: Describe the contamination potential inherent to the process design

Standard: Indicating the potential sources and potential implications of each type of contamination

13.1



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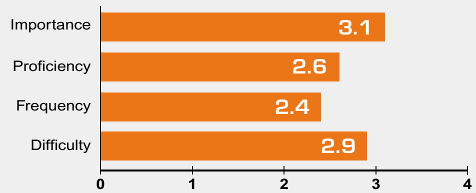

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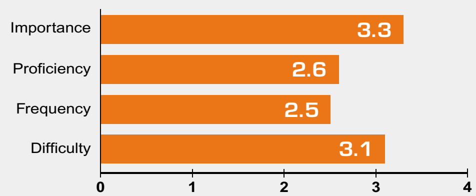

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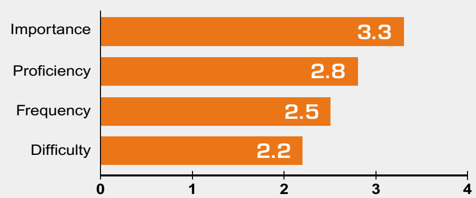


Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do

Skill Standard Statement

14.1 **Condition:** Given wafer handling and storage devices designed for automated materials handling of 300mm wafers
Behavior: Describe wafer transport and handling devices such as FOUPs and FOSBs
Standard: Illustrating the purpose of the devices and the impact on safety, ergonomics and contamination control

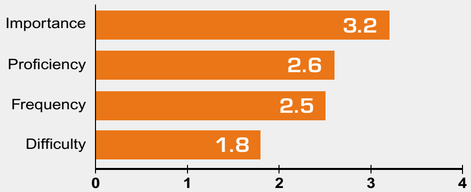
14.2 **Condition:** Given a microenvironment such as a FOUP, load lock, process chamber, etc.
Behavior: Maintain microenvironments
Standard: Adhering to referenced protocols

14.3 **Condition:** Given facility for the production of 300mm wafers
Behavior: Describe the importance of monitoring the backside of wafers for potential contamination
Standard: Illustrating the potential effects of backside contamination on wafer processing and handling

14.4 **Condition:** Given a diagram of the layout of a typical 300mm facility
Behavior: Describe the unique layout and design features of 300mm fabrication facilities
Standard: Illustrating the impact on manufacturing, materials handling, workflow, air handling and efficiency

14.5 **Condition:** Given an advanced process control (APC) system
Behavior: Describe the rationale and operation of an APC or excursion protection system
Standard: Illustrating how this system affects feed forward and feed backward process parameters

14.1



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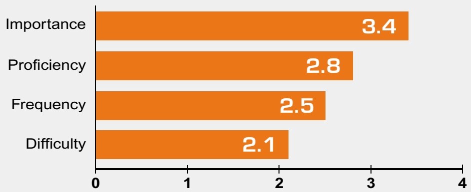

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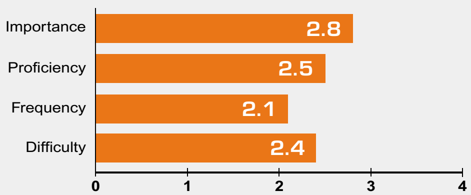

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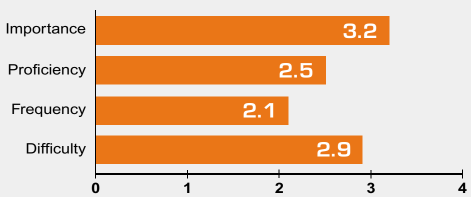

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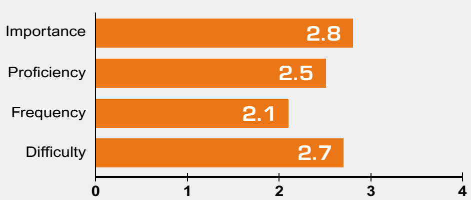
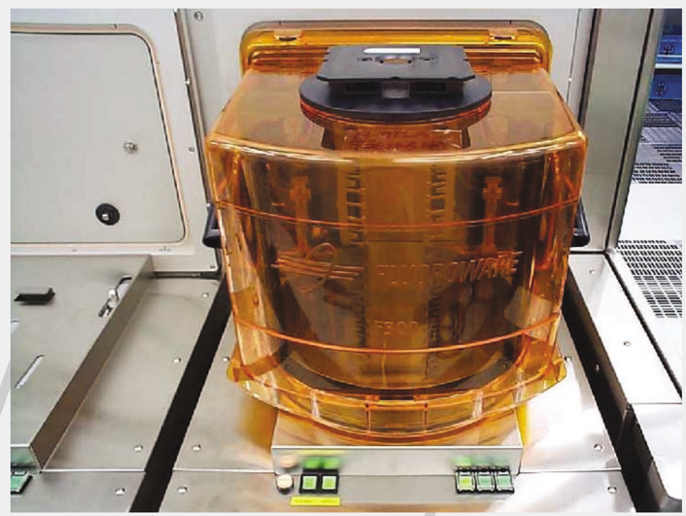


Ranking

For the first 6 months on the job:

Importance — how important is it to know or do
Proficiency — how well must it be done
Frequency — how frequently is the task done or the knowledge applied
Difficulty — how difficult is it to learn or do



Appendix A - Performance Criteria Ranking

Ranking

The PCAL (Performance Criteria Analysis List) process uses a ranking scale based upon four factors. For every performance criteria statement (PCS) in the list, a score was assigned as follows for each factor:

Importance ***(How important is it for entry-level employees to know or do the PCS?)***

4	=	Highest	Much higher priority than other PCSs on the list. Crucial and highest priority. Inadequate knowledge or performance of PCS would adversely impact quality or safety of products/services.
3	=	High	Somewhat higher priority than other PCSs on the list. Inadequate knowledge or performance of PCS might adversely impact quality or safety of products/services to some degree.
2	=	Low	Somewhat lower priority than other PCSs on the list. Inadequate performance of PCS may not directly impact quality or safety of products/services.
1	=	Lowest	Much lower priority than other PCSs on the list. Inadequate performance of PCS would not have a direct impact on quality or safety of products/services, but must be performed.

Proficiency ***(How good is good enough for entry-level employees to know or do the PCS?)***

4	=	Highest	Can recall and apply complex facts and principles and resolve problems. Can evaluate conditions and make proper decisions using complex facts and principles. Can do all elements of PCS quickly and accurately with no supervision.
3	=	High	Can recall and apply many facts and principles to different situations. Can analyze facts and principles and draw some appropriate conclusions. Can do all elements of PCS. Needs only spot checks of work.
2	=	Low	Can recall some facts and principles. Can state general principles about the subject. Can do many elements of the PCS but requires help on the hardest parts.
1	=	Lowest	Can recognize only simple facts and terms. Can do only simple parts of PCS and must be closely supervised.

Frequency ***(How frequently are entry-level employees expected to know or do the PCS?)***

4	=	Highest	Spends much more time doing this than most other PCSs on the list.
3	=	High	Spends a little more time doing this than other PCSs on the list.
2	=	Low	Spends somewhat less time doing this than other PCSs on the list.
1	=	Lowest	Spends much less time doing this than other PCSs on the list.

Appendix A - Performance Criteria Ranking

Difficulty ***(How difficult is it for entry-level employees to know or do the PCS?)***

4	=	Highest	Much more difficult to learn and perform than other PCSs on the list.
3	=	High	Somewhat more difficult to learn and perform than other PCSs on the list.
2	=	Low	Somewhat easier to learn and perform than other PCSs on the list.
1	=	Lowest	Much easier to learn and perform than other PCSs on the list.

A sample shown below illustrates the rating scale.

Skill	Imp	Pro	Fre	Dif
Identify and communicate trends of machine performance	3.5	2.5	2.7	3.2

The values are based on a scale of 0–4, with 4 being the highest rank. The numbers shown are an average of all respondents (43 possible). Similar data exist for the entire list of skills.

Emphasis Rating (ER)

The emphasis rating shown below combines the importance, proficiency, frequency and difficulty rankings to give a weighted, overall rating. This was used to prioritize and determine which skills were eventually considered most important to be included in the final list.

$$ER = \frac{1}{8}\left[\frac{\left(\frac{\text{\# of responses}}{43}\right)}{.25} + (\text{Imp} \times 3) + \text{Pro} + \text{Fre} + (\text{Dif} \times 2)\right]$$

The first term in brackets weights the number of responses compared to the 43 total respondents. Not all respondents replied to every skill in the list if their expertise was outside of the area, for example. Thus a skill that is performed by all gives a higher ER.

Both importance and difficulty are weighted given multiplying factors of three and two respectively to reflect their emphasis. The term 1/8 normalizes the maximum ER value to 4.0. In the skill example above, there were 43 responses to give an ER as shown below:

$$ER = \frac{1}{8}\left[\frac{\left(\frac{43}{43}\right)}{.25} + (3.5 \times 3) + 2.5 + 2.7 + (3.2 \times 2)\right]$$

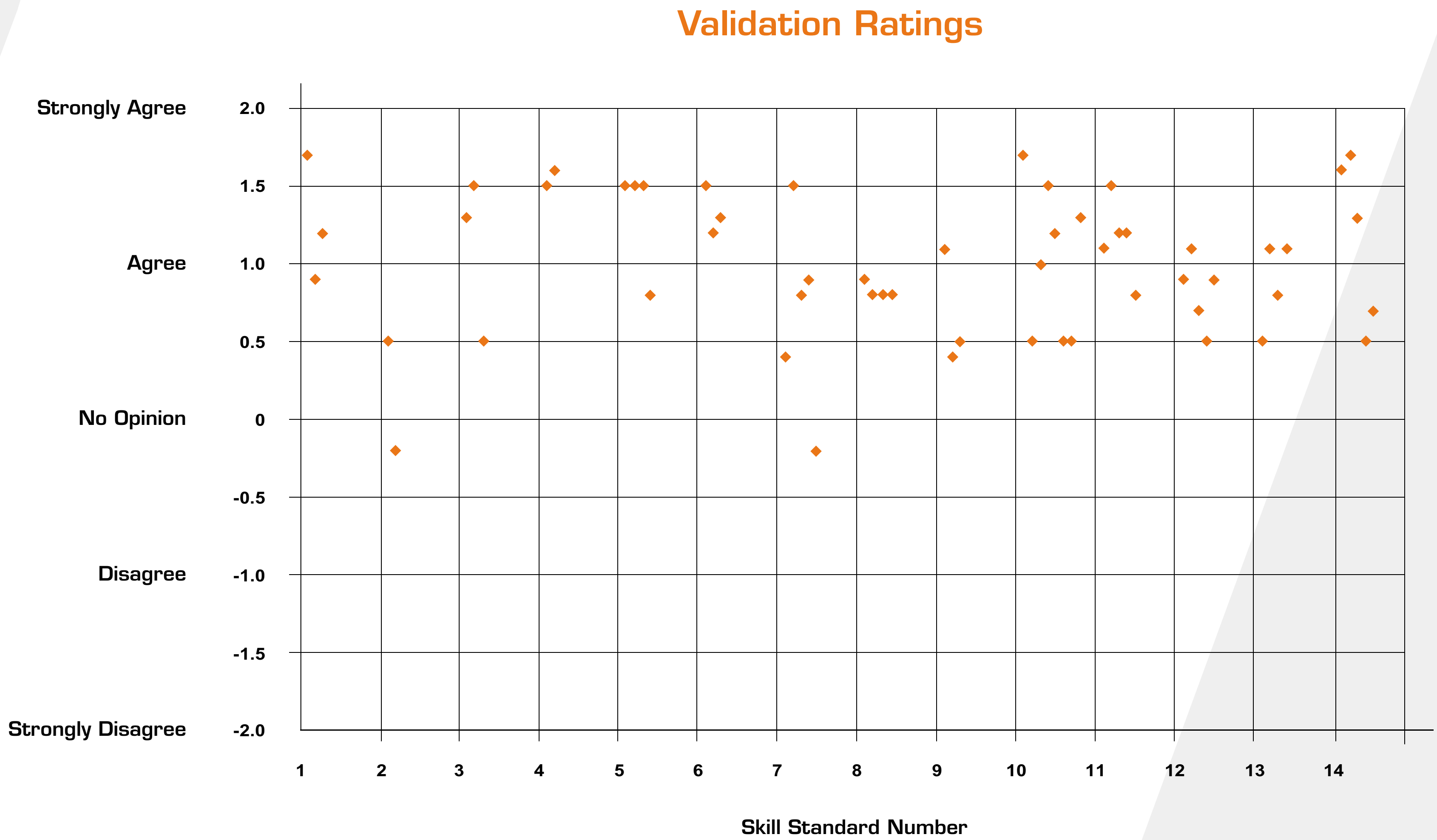
$$= 3.3$$

In the process of creating the skill standards, those skills with ERs of less than 2.0 were not considered.

Appendix B - Validation Data

The skill standards as stated were reviewed for agreement by industry subject matter experts using a Likert Scale (-2 = strongly disagree, -1 = disagree, 0 = no opinion, +1 = agree, +2 = strongly agree). The average rating for all the statements is shown on the graph at right. For Standards 2.2 and 7.5 the agreement is tenuous and reflects the uncertainty of the requirements in these skill areas at this stage. As highly automated facilities come on-line, the validation data will be continually updated with information available at *www.matec.org/work/skills.*

Appendix B - Validation Data



Appendix C - The 300mm Semiconductor Manufacturing Environment

There are a variety of sets of assumptions about the 300mm manufacturing environment. As the facilities come on-line, it will be easier to describe this environment based on direct experience.

Bob Simington, Training Specialist at Intel Corporation, offers this view:

The semiconductor manufacturing environment has evolved from one that was populated with self-contained tools utilizing robotics technology to one that is composed of large numbers of these tools interconnected by automated material handling systems (AMHS) and driven by a centralized manufacturing execution system (MES) in such a way as to maximize factory throughput and output.

This level of automation is referred to in Intel as the "7th Level" of automation or simply "Level 7." A "Level 7" automated factory is intended to run "lights out," with no human intervention in the normal operation of the factory. At "Level 7" all work in progress is automatically dispatched to the appropriate tool at the appropriate time according to predefined rules. All tests are performed automatically and failed tests initiate recovery systems (including the dispatching of maintenance techs). Process monitors are embedded in the tools and statistical process control is monitored and maintained continuously. Appropriate actions are automatically initiated when control limits are violated. Human intervention is only required in this environment to change the operating rules, to change the “tags” associated with particular lots so they are handled specially, to monitor for system failures and safety violations and to perform maintenance.

The skills required to work in such an environment consist of most of the skills required by the previous environment (i.e., 200mm fabs) plus some emerging skills. These emerging skills are primarily skills and knowledge related to the new, enterprise automation systems, their maintenance, and the ability to utilize the vast amount of information they provide.

Implications for Training, Education and Workforce Development: The technician's abilities to troubleshoot, problem solve and escalate a problem or situation will be critical to maintaining workflow and production expectations in a modern fab. The ability to make an informed decision on the basis of set priorities is a clear expectation. The skill standards set forth expected and measurable behavior for these abilities. These standards can form the fundamental basis for training and education programs that focus on competencies—what technicians know and what they are able to do.

The value of skill standards documents lies in their ability to reflect the real nature of the workplace. The standards as published today reflect the vision of the 300mm environment. However, semiconductor manufacturing technology is characterized by its rapid pace of change. Therefore, the skill standards themselves must reflect that change through a constant process of update and revision. As 300mm facilities come on-line, the key functional areas of the standards will be revisited, updated and disseminated.

Appendix D - Manufacturing Execution Systems

Introduction

Modern fab technicians have become system monitors instead of "machine operators." Technicians who monitor an automated process must develop the ability to solve factory flow problems and effectively contribute to manufacturing problem-solving teams. Manufacturing execution systems (MES) are not foolproof and often "crash" and require teams to troubleshoot the problem and process engineers to make adjustments. The technician's ability to solve problems or contribute to problem-solving activities concerning factory flow require basic knowledge of the MES, factory dynamics principles, business rules used by the MES to control WIP, process plans and relationships among variables that interact—all of which affect the flow of work in progress. In a highly complex manufacturing environment, very large quantities of multivariate data are collected, stored and processed in order to provide enough decision-making information to automate factory equipment. At its simplest level, a manufacturing execution system represents the software component of factory automation. The MES can be considered the "brains" of a highly automated factory environment. Of course, engineers and technicians still play a major role in making decisions, but a modern MES manages most of the process flow, WIP, and messaging that take place between tool groups and the automated material handling system.

An MES is a complex computer software program that manages factory entities and makes computer integrated manufacturing possible. An MES manages process flow, tracks WIP, stores and analyzes process data and supports various types of report generation such as statistical process control charts. In order to fully understand factory automation, it is necessary to understand MES, because virtually all processes are either under its control or provide the information that technicians and engineers use to make control decisions. Fab technicians interact with the MES on a daily basis to process wafer lots and input information needed by other personnel. MES systems that run highly automated fabs are built on client-server architecture. This type of architecture can support the networking and system integration capabilities needed for fully automated fabs. Data are passed by the MES to and from processing equipment via an "MBX" or message bus. The MBX is a vehicle that enables the MES to: (1) control routing of each lot to the correct operation in the correct order, (2) generate recipes for wafer lots at each tool station, and (3) store lot data and share tool operation and status data among technicians on different work shifts and at different stations across the fab [1].

Appendix D - Manufacturing Execution Systems

Examples of some of the common software packages that have been used as an MES in the semiconductor industry include WorkStream [2] and FACTORYworks [3].

Unlike most technical manufacturing topics that focus on a specific process, type of equipment or practice, MES includes many subtopics that are crucial to a generic understanding of its purpose, basic functions and makeup. This is partially due to the fact that MES affects and is affected by every entity in an automated factory. In a fab MES operations and maintenance involve interconnected computer hardware and software, interfaces on wafer processing equipment, and automated material handling systems.

References:

[1] This material is excerpted from: Palace, L., & Mattoon, J. (in press). Manufacturing Execution Systems (Module 126). Tempe, AZ: Maricopa Advanced Technology Education Center.

[2] http://www.appliedmaterials.com/products/workstream.html

[3] www.brooks-pri.com

Appendix E - Acronyms & Definitions

APC: Advanced process control, a software application that uses real time data to insure that process tools are running to specification, automatically making process adjustments as necessary.

AMHS: Automated material handling system

Batch: Manufacturing process flow variable

Cycle Time: The ratio of the total time that a lot is in process to the time the lot is undergoing a manufacturing step. Example: Total lot in process for 60 hours; lot undergoing manufacturing processes for 20 hours; cycle time = 3X.

Event Driven: Manufacturing process flow variable

FIFO: First in first out, manufacturing process flow variable

FOSB: Front opening shipping box

FOUP: Front opening unified pod

IP: Internet protocol

LIFO: Last in first out, manufacturing process flow variable

Appendix E - Acronyms & Definitions

MCS: Material control system, provides real-time intra-bay and inter-bay dispatch of material, batching and queuing of lots according to priorities/equipment status. The MCS must interface with the AMHS.*

MES: Manufacturing execution system *(see Appendix D)*

Microenvironment: A concept that is part of the 300mm tool specification that requires each tool to maintain a Class 1 environment within the tool, allowing the microcontamination standards in the bays and chases to be relaxed.

Polled: Manufacturing process flow variable

Push/Pull: Manufacturing process flow variable

SEMI: Semiconductor Equipment and Materials International

Theory of Constraints: Portrays the capacity of a factory (or any productive system) as equal to the most constraining factor in the system.

WIP: Work in Progress

*Clint Harris, Putting Automation to Work in Advanced 200 and 300mm Wafer Fabrication, Brooks Automation

Appendix F - About the Maricopa Advanced Technology Education Center

MATEC—Since 1996, the National Science Foundation's U. S. Center of Excellence for Education in Semiconductor Manufacturing

About the Center

MATEC is a nonprofit center for education and workforce development in the semiconductor industry. From the "Silicon Desert" of Phoenix, Arizona, MATEC helps educate technicians in the science and competencies of the exacting semiconductor workplace. MATEC collaborates with SIA (Semiconductor Industry Association), SEMI (Semiconductor Equipment and Materials International) and companies such as Intel, Motorola, Texas Instruments, ST Microelectronics, IBM, Microchip and others, and with colleges and technical schools in the United States, Europe and Asia.

MATEC Services

Curriculum modules for industry-recommended instruction in semiconductor tools, processes & protocols
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Faculty development
Industry-validated skills standards
Curriculum assessment
Clearinghouse for semiconductor resources
Career awareness
K-12 science resources
Annual educator/industry conference
Industry-sponsored summer institutes
Employee upskilling
Contracted services for companies