Capacity Utilization Bottleneck Efficiency System (CUBES): Release 2.5

SEMATECH Confidential
Technology Transfer 94112634C-ENG

Capacity Utilization Bottleneck Efficiency System (CUBES): Release 2.5

Technology Transfer # **94112634C-ENG**
SEMATECH Confidential
February 26, 1996

Abstract: This technology transfer is the user manual and software for the Capacity Utilization Bottleneck Efficiency System (CUBES) Release 2.5. The CUBES model was developed to quickly analyze bottlenecks by calculating tool throughput and identifying where efficiency losses occur. CUBES is a generic package, built to accommodate and analyze a variety of tools. One CUBES option, E10, puts its results in terms of the SEMI E10 equipment states that are now standard for the semiconductor industry. It analyzes a tool's throughput and potential throughput in terms of the SEMI E10 equipment states. The other option, overall equipment effectiveness (OEE), focuses on the total productive maintenance ideology. Changes from the previous version are outlined in Section 3.1 of the user manual. The software is on a 3.5-inch DOS diskette and runs as a spreadsheet in Excel 5.0 or Lotus 1-2-3 5.0. Earlier versions of Excel and Lotus 1-2-3 are no longer supported.

Keywords: Overall Equipment Effectiveness, Computer Software, Throughput, Equipment States, Total Productive Maintenance

Authors: John Konopka, Sue Ellen Swink

Approvals: Sue Ellen Swink, Author
John Konopka, Author, Project Manager
Gary Gettel, Director
Eugene Woodall, Technical Information Transfer Team Leader

Table of Contents

List of Figures

List of Tables

Acknowledgements

We would like to thank Stuart Giegling, Roland Schelasin, and Bob Schlueter for their help with the final testing of CUBES version 2.5.

1 EXECUTIVE SUMMARY

SEMATECH's Capacity Utilization Bottleneck Efficiency System (CUBES) was developed to provide an easy method for analyzing the throughput and efficiency of a manufacturing line's bottleneck tools. The intent was to offer more than the traditional equipment utilization perspective which has taken only a one-dimensional approach. CUBES is unique in its analysis because it considers two dimensions: time and speed. This allows more efficiency loss factors to impact the tool utilization metric. CUBES is a decision support tool that identifies all throughput and efficiency loss factors. It calculates process improvements and potential throughput increases based on eliminating a particular loss factor.

CUBES is a generic package built to accommodate and analyze a variety of tools. It allows the user to evaluate throughput and efficiency in three ways:

1. Detailed analysis by speed factor and SEMI E10 equipment state;
2. The three OEE calculations of availability, performance, and quality; and
3. The six big losses of total productive maintenance (TPM).

2 INTRODUCTION / BACKGROUND

2.1 Purpose

One method to lower manufacturing costs in a manufacturing facility is to get more productivity and/or output from the same set of tools. If a manufacturing facility is already operating at its manufacturing line capacity, this task is not trivial. One cannot just add more production lots into the manufacturing line. This would lead to problems such as high levels of work in process (WIP) and increased cycle times, etc. Manufacturing line capacity is not the capacity of every tool involved in the production process. It is calculated by taking the one tool (the bottleneck) that has the lowest individual capacity and applying that capacity to the entire manufacturing line. Therefore, if the capacity of this bottleneck tool can be increased, the line capacity will increase along with it. The bottleneck tool controls the manufacturing line's capacity. CUBES was developed with this thought in mind. The model quickly analyzes bottlenecks by calculating tool throughput and identifying where efficiency losses occur. One unique feature of CUBES is that it identifies these losses in a two-dimensional grid. In the E10 option, the x-axis shows losses and/or impacts resulting from each SEMI E10 equipment state and the y-axis shows losses and/or impacts from tool speed degradation, rework, setup, and batching. In the OEE option, the x-axis shows losses and/or impacts resulting from each time-based loss (breakdowns, setups, adjustments, idling and minor stoppages) and the y-axis shows losses and/or impacts from speed and quality degradation (reduced speed, rework, yield, and scrap). This approach along with what-if scenario features allows manufacturing, production, equipment, and process personnel to work together and to understand what they must do as a team to increase tool throughput, thereby increasing manufacturing line production.

2.2 Target Users

CUBES can be used to support the efforts of equipment managers, manufacturing personnel, process engineers, and project managers at SEMATECH, member companies, and suppliers. CUBES can facilitate the analysis of bottlenecks, throughput, and equipment capacity. One

CUBES option, E10, puts its results in terms of the SEMI E10 equipment states. The other option, OEE, focuses on the total productive maintenance (TPM) ideology, calculating OEE and the effect of the six big losses (see Section 4.7.4.1 for definitions of the six big losses).

2.3 Prerequisites

The only prerequisite to using CUBES is the ability to manipulate computer spreadsheets in Excel or Lotus. If the user has no prior knowledge of computer spreadsheets, it may be useful to briefly work through one of the software's tutorials before beginning work with CUBES.

2.4 Software / Hardware Requirements

The CUBES spreadsheet was developed using Excel 5.0 software.

Minimum requirements to run the program:

- At least one of the following software packages: Excel 5.0 (or a later edition), Lotus 4.0 (or a later edition);
- Enough memory to run your version of Excel or Lotus;
- A disk drive; and
- Diskettes of SEMATECH's CUBES which are available in 3.5" MS-DOS format.

2.5 CUBES Release 2.5

CUBES Release 2.5, replaces the following earlier versions:

- CUBES-EX.XLS Release 1.0 February 1994 (Excel 4.0)
- CUBES-EX.XLS Release 1.0 March 1994 (Excel 4.0)
- CUBES-EX.WK4 Release 1.0 March 1994 (Lotus 4.0)
- CUBES-EX.WK3 Release 1.0 March 1994 (Lotus 3.0)
- CUBES Release 2.0 December 1994 (Excel 4.0 and Lotus 3.0)
- CUBES Release 2.1 April 1995 (Excel 4.0 and Lotus 4.0)

3 THE "NEED TO KNOWS" OF CUBES

Note: Prior to using CUBES, it is recommended that a back-up copy of the diskette be made.

3.1 Changes from CUBES Release 2.1 to CUBES Release 2.5

- **Acronym List**: The area on the spreadsheet beginning at cell AA134 has been designated for the user to keep a listing of frequently used abbreviations. Some abbreviations currently used in CUBES have been included. A button has been included at the top of the input section to transfer the user to the Acronym List.
- **ASCII Read/Write Capability**: CUBES data may be input via an ASCII text file. Also, at any time, the current input data may be written to an ASCII text file. Refer to Section 4.2 for more details.
- **Reset Capability**: CUBES data may be reset to default values by using the Reset Data button at the top of the input section. Refer to Section 4.2.4 for more details.

- **Buttons**: Print buttons have been included for all the input levels and the new Acronyms List. See Section 4.8 for an explanation of any unfamiliar buttons.
- **Data Entry**: Not all shaded cells in the *Input* section require data. A fourth level of time-related inputs has been included. This new level is located just to the right of Level 2 inputs on the CUBES spreadsheet. Refer to Section 4.1.6 for more details.
- **Order of Calculation in E10 Template**: The order of calculation in the *Summarized Outputs* section of the E10 template has been switched for Unscheduled Downtime and Engineering Time. These are graphed in their new order. This is a logical change which groups all the downtime states together on the CUBES Efficiency Analysis graph. The respective rows have also been switched in the *Summarized Inputs* section of the E10 template. There are no such changes in the OEE template.

3.2 Getting Started

- **Back-up copy**: prior to using CUBES, it is recommended that a back-up copy of the diskette be made.
- **Opening CUBES** (from Excel version 5.0):
  - With the CUBES disk in the disk drive, open the file “CUBES2_5.XLS” under the Excel application. This is an Excel 5.0 workbook that contains the CUBES spreadsheet and its accompanying macro sheet.
  - You are ready to begin entering your data. Any entries in the gray shaded cells are just sample data and may be changed.
- **Opening CUBES** (from Lotus 1-2-3 4.0):
  - With the CUBES disk in the disk drive, open the file “CUBES2_5.WK4” under the Lotus 1-2-3 application. This is the two-spreadsheet CUBES file. The accompanying macros are on the second spreadsheet page.
  - As in the Excel version, you are ready to begin entering your data. Any entries in the gray shaded cells are just sample data and may be changed.

3.3 Saving Your Work

The CUBES disk is write-protected so you may not save work to the disk. When you first use CUBES, use the *Save As* option under the *FILE* menu to save it to a different drive using the original workbook name. Please note that for the ASCII read/write functions to work correctly, you must have CUBES and the ASCII input file in the same directory and CUBES must be operating with its original name. A CUBES workbook may be saved under a different name; just remember, save the file under the original name, “CUBES2_5.XLS” for Excel or “CUBES2_5.WK4” for Lotus, before using the buttons *READ CUBES DATA FILE* or *WRITE CUBES DATA FILE*.

4 CUBES SPREADSHEET OVERVIEW

The CUBES spreadsheet will be discussed in the following order: the *Input* section, the *User Defined Variable Names* section, the *Acronyms List* section, the *Corrective Action Log* section, the *E10 Output* section, and the *OEE Output* section. Each section of the spreadsheet will be described in detail. Samples of the individual spreadsheet sections may be found in or just before the particular description.

Figure 1 is an overall picture of the physical structure of CUBES Release 2.5. Each section and its specific location on the CUBES spreadsheet is identified as well as the page where a description can be found in this manual.

INPUT SECTION

Figure 2 on p. 6-9
Description p. 5
Range A1:Q164
and S38:AG102

Level 1 -- Range A27:L37
Level 2 -- Range A38:L64
Level 3 -- Range A65:Q124
OEE Opt. -- Range A126:Q164

USER DEFINED VARIABLES

Figure 10 on p. 30
Description p. 29
Range Q1:AA36

Level 4 -- Range S38:AG102

ACRONYM LIST

Figure 11 on p. 31
Description p. 30
Range AA134:AH153

CORRECTIVE ACTION LOG

Figure 12 on p. 31
Description p. 31
Range AI1:AR110

E10 OUTPUT SECTION

Figure 13 on p. 33
Description p. 32
Range A194:AP270

Template -- Range A200:L245
Pareto Graph -- Range O212:W246
Pie Graph -- Range X212:AG246
Stack Bar Graph -- Range AJ212:AP246
Benchmark Data -- Range AI247:AP261

OEE OUTPUT SECTION

Figure 22 on p. 43
Description p. 42
Range A295:AQ350

Template -- Range A301:M342
Pareto Graph -- Range P303:X331
Pie Graph -- Range Y303:AH331
Stack Bar Graph -- Range AJ303:AQ331
Benchmark Data -- Range AI334:AP345

UNLOCKED CELLS

Open spreadsheet from Row 500 down.

Figure 1 Map of CUBES Spreadsheet

4.1 Input

Figure 2 is a complete picture of the *Input* section. The *Input* section is discussed according to *Global Inputs*, *Input Mapping Assumptions*, *Level 1 Inputs*, *Level 2 Inputs*, *Level 3 Inputs*, *Level 4 Inputs*, and *OEE Optional Inputs*. First, however, a few general points are mentioned.

General Knowledge:

- The user may enter information in the gray shaded cells of the input section.
- Possible data sources may include floor control system data, estimates, simulation results, target/goals, etc.
- The time-related data (Levels 1, 2, 3 and 4) are based on the SEMI E10 equipment states[1].
- Levels 1, 2, 3, and 4 need not all be completed. The choice of the levels entered in the *Input Mapping Assumptions* section determine what data must be entered. See Section 4.1.2 for further explanation.
- Rows 500 and below on the spreadsheet are unlocked for the user's own calculations.

---

[1] Please note that CUBES Levels 1 and 2 actually correspond to SEMI E10 92 levels L2 and L3, respectively. If you reference the SEMI E10 92 guidelines, keep this in mind. CUBES Levels 3 and 4 are examples of further partitioning of the SEMI E10 equipment states.

Input Section

Capacity Utilization Bottleneck Efficiency System (CUBES) | Version 2.5
Copyright SEMATECH 1993-1995 | Dec-18-95

E10 TEMPLATE | OEE TEMPLATE | OEE-TPM OPTIONAL INPUTS | ACRONYMS LIST | RESET DATA | READ CUBES DATA FILE | WRITE CUBES DATA FILE

GLOBAL INPUTS	
Total Time (Hours)	168
Theoretical Tool Speed (UPH)	45
Plan Tool Speed (UPH)	45
Actual Tool Speed (UPH)	40
Average Batch Size (% Full)	80
Quality Losses (% Loss)	10
Batch Size (# of Units)	1

Last input file read: example.csv

INPUT MAPPING ASSUMPTIONS	INPUT LEVEL	INPUT SUMMARY
Total Hours	GLOBAL	168.00
Non-Scheduled Hours	1	8.00
Scheduled Operation Hours	CALC	160.00
Scheduled Downtime	3	8.00
Engineering Time	1	8.00
Unscheduled Downtime	1	16.00
Standby / Idle Time	1	12.00
Other Production Time Losses	1	4.00

Level 1 thru 4 (See Below)

PRINT GLOBAL INPUTS

LEVEL 1 INPUTS

Other Production Time Losses	4
Unscheduled Downtime	16
Scheduled Downtime	8
Engineering Time	8
Standby / Idle Time	12
Non-Scheduled Hours	8

PRINT LEVEL 1 INPUTS

LEVEL 2 INPUTS

	INPUTS	HOURS		HOURS		LEVEL 2 TOTAL HOURS
Unscheduled Downtime	MTBF=	40	MTTR=	5		20.00
Requalification Time		0	(Hours per failure)			
Scheduled Downtime		1	EVERY	8	HOURS	20.00
Set-Up Time		0	EVERY	"	HOURS	
Requalification Time		0	EVERY	"	HOURS	
Engineering Time		8	EVERY	275	HOURS	4.65
Other Time Losses (in Hrs Loss)		8				8.00
Standby / Idle Time		0.1	EVERY	1	HOURS	12.80
Waiting Results / Qualification		0	EVERY	"	HOURS	
Non-Scheduled Hours		16				16.00

PRINT LEVEL 2 INPUTS

Figure 2 Sample Spreadsheet (Input Section)

LEVEL 3 INPUTS

UNSCHEDULED DOWNTIME:	HOURS
No Maint. Oper.	4
Equip. Failure	0
Data Failure	0
Factory Failure	0
Out-of-Spec	0
Requal	4
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
Total Unscheduled Downtime	8

SCHEDULED DOWNTIME:	HOURS
Requal	2
Prev. Maint.	6
Equip. Test	3
Process Test	3
Initialization	2
Changeover	2
Setup	2
Requal	1
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
Total Scheduled Downtime	21

OTHER LOSSES TO PRODUCTIVE TIME:	HOURS
New Product	0
Rework	0
Scrap	0
Production Test	4
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
Total Other Losses to Productive Time:	4

STANDBY:	HOURS
Waiting Results	1
Standby	1
Blocked	1
Starved - no WIP	1
Starved - not enough WIP	0
No Operator	1
No Tool	1
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
Total Standby/Idle Time	6

ENGINEERING:	HOURS
Engineering	33
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
Total Engineering Time	33

NON-SCHEDULED	HOURS
Non-Scheduled	5
To Be Delivered	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
User Defined	0
Total Non-Scheduled Time	5

Figure 2 Sample Spreadsheet (Input Section)

LEVEL 4 INPUTS

	UNSCHEDULED DOWNTIME:	HOURS
17	WILD CARD ONE	4
18	WILD CARD TWO	0
19	T.E.E. USER	0
20	T.A.E. USER	0
22	DOWN FOR FOREIGN MATERIAL	0
23	DOWN FOR FOREIGN MATERIAL	4
24	DOWN FOR FOREIGN MATERIAL	0
28	TOOL UNAVAILABLE TO MAINT.	0
30	DOWN FOR TOOL'S COMPUTER	0
31	DOWN FOR VERIFICATION	0
32	DOWN FOR HOST	0
33	DOWN FOR FACILITIES	0
34	DOWN FOR CUSTOMER ENGINE	0
35	WAITING FOR MAINTENANCE	0
36	WILD CARD THREE (MAINT)	0
37	MAINTENANCE REWORK / RE-D(	0
38	DOWN FOR FOREIGN MATERIAL	0
39	WAITING FOR VENDOR MAINTEI	0
40	UNPLANNED MAINTENANCE BY	0
43	STANDBY - WAIT FOR ENGINEEI	0
44	EQUIPMENT ENGINEERING	0
47	TOOL COOLDOWN	0
48	UNPLANNED MAINTENANCE / EN	0
50	DOWN FOR NO VENDOR SPARE	0
53	VENDOR UNPLANNED MAINTEN,	0
56	HANDLER UNPLANNED MAINTEN	0
57	QUALIFICATION RUN	0
74	STOP PRODUCTION NOTICE (SF	0
78	WILD CARD FOUR (PROCESS)	0
79	DOWN FOR I.S. (INFORMATION S	0
82	DOWN FOR PROCESS ENGINEE	0
83	DOWN FOR QUALITY ENGINEER	0
86	DOWN FOR NO SPARE PARTS	0
87	WAITING FOR MANUFACTURING	0
88	DOWN FOR UNPLANNED MAINTI	0
90	DOWN FOR PRODUCT ENGINEE	0
93	DOWN FOR CHEMICAL SUPPLY	0
99	OTHER / MISCELLANEOUS	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	Total Unscheduled Downtime	**8**

	SCHEDULED DOWNTIME:	HOURS
5	SET UP / START UP (ENGR.)	2
6	MACHINE CLEAN UP	6
7	QUALIFY / DUMMY RUN	3
27	MAINT SETUP / CHANGEOVER	3
45	PLANNED MAINTENANCE BY M.	2
49	SYSTEM IN USE BY MAINTENAI	2
51	RAMP UP SUPPORT	0
54	VENDOR PLANNED MAINTENAI	1
55	PLANNED TOOL CLEANING	0
60	CALIBRATION	0
61	SET UP / START UP (MFG.)	0
65	EXPOSURE MATRIX	0
66	CONTAMINATION CHECK	0
67	INTENSITY CHECK	0
68	OVERLAY CHECK	0
69	FOCUS CHECK	0
80	PROFILE	0
89	DOWN FOR PLANNED MAINTEI	0
98	WAITING FOR PLANNED MAINT	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	Total Scheduled Downtime	**19**

	OTHER LOSSES AND PRODUCTIVE TIME:	HOURS
10	OPERATOR TRAINEE PRODUC	0
11	REGULAR PRODUCTION	0
12	REWORK	0
13	MONITOR PRODUCTION	0
15	PARALLEL TESTING	0
16	EXPERIMENTAL WORK	0
62	STANDARDS	0
63	REDUCED THRUPUT	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	Total Other Losses:	**0**

Note: Total does not include productive time.

	STANDBY:	HOURS
1	LUNCH	0
2	C.F.M. IDLE - MFG	1
3	C.F.M. IDLE - MAINT/EQUIP	1
4	C.F.M. IDLE - PROCESS	1
8	WAIT MONITORS / SEND AHEAI	1
9	INSUFFICIENT TIME TO COMPL	0
14	PROCESS QUALITY INSPECTIO	0
21	CHARACTERIZATION	0
25	TOOL UNAVAILABLE TO MAINT	0
26	TOOL WAITING FOR CAL.	0
29	SUPPORT EQUIPMENT DOWN	0
52	GLASS SHOP	0
59	AUTO TOOL IDLE	0
64	WAIT FOR OUTSIDE CONDITIO	0
70	NO MANUFACTURING OPERAT	0
72	NO PRODUCT AVAILABLE	0
73	PROD. PROB., NOT TOOL RELA	0
77	REPAIR WORK COMPLETE, WA	0
81	DOWN FOR MASK	0
84	NO VENDOR PRODUCT AVAILA	0
85	WAITING FOR M.O.S.	0
94	AREA CLEAN UP	0
96	TERMINAL / PAPERWORK	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	Total Standby/Idle Time	**4**

	NON-SCHEDULED	HOURS
46	ELECTRO/MECHANICAL E.C.	0
71	NON SCHEDULED TIME (WEEK	0
75	NO SCHEDULED ACTIVITY	0
76	POWERED DOWN	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	User Defined	0
	Total Non-Scheduled Time	**0**

Maintenance Delay	**11 hours**	**Process Engineering Delay**	**0 hours**
Equipment Engineering Delay	**16 hours**	**Manufacturing Delay**	**0 hours**

PRINT LEVEL 4 INPUTS

Figure 2 Sample Spreadsheet (Input Section)

OEE TEMPLATE | INPUTS

PLEASE NOTE: Adjustments to this section will alter the OEE value calculated using the OEE-TPM Template ONLY. No change will be incurred by the E10 Template. If no changes are made in Part 1 or Part 2, and Plan Tool Speed = Theoretical Tool Speed, values calculated by both templates will be identical.

OEE-TPM OPTIONAL INPUTS

OEE template is defaulted to use the same INPUTS as E10 Template.
Use [PART 1 - Availability Adjustment] to adjust OEE Availability Efficiency Calculation (DEFAULT is Total Time).
Use [PART 2 - Production Adjustment] if "ACTUAL" production information is available.
Use [PART 3 - Rate of Quality Adjustment] to adjust allocation of Rate of Quality percentages.

PART 1 - Availability Adjustment

INCLUDE IN OEE AVAILABILITY CALCULATION: (Default is YES in Both)	
Nonscheduled Hours: (Yes or No)	YES
Planned Downtime: (Yes or No)	YES

PART 2 - Production Adjustment

Override any assumption below by entering YES and enter required data below entry (DEFAULT is NO)

		OVERRIDE OEE INPUT SUMMARY
		FALSE (TRUE Override is on. FALSE Override is not used.) (IF FALSE all override values set to ZERO)
Do you wish to Override Inputs and Calculate OEE with "Gross Production" ?	NO	
Please enter "Gross Production" if answered YES above	4500	0 Gross Production
Do you wish to Override Inputs and Calculate OEE with "Net Production" ?	NO	
Please enter "Net Production" if answered YES above	4100	0 Net Production
Do you wish to Override Inputs and Calculate Rate of Quality with actual "Production Rejects"? (Instead of Percentage of other losses)	NO	
Please enter "Production Rejects" if answered YES above	125	0 Production Rejects

PART 3 - Rate of Quality Adjustment

Do you wish to specify allocation of Rate of Quality Loss percentages?		
Please enter Percentages below (Must Total to 100%)	TRUE	
Percent of Quality loss due to Defect,Scrap & Rework		50
Percent of Quality loss due to Yield		50

PART 4 - Performance Efficiency Adjustment

Do you want to use Plan Tool Speed (P) or Theoretical Tool Speed (T) in OEE calculation?	P

Figure 2 Sample Spreadsheet (Input Section)

4.1.1 Global Inputs

The inputs required in this section are speed related (except for the first entry—*Total Time*). As mentioned earlier, actual values should be entered in the gray shaded cells adjacent to the list of variable names (see Figure 3).

GLOBAL INPUTS

Total Time (Hours)	**168**
Theoretical Tool Speed (UPH)	**45**
Plan Tool Speed (UPH)	**45**
Actual Tool Speed (UPH)	**40**
Average Batch Size (% Full)	**80**
Quality Losses (% Loss)	**10**
Batch Size (# of Units)	**1**

Figure 3 Global Inputs Section

Each variable is defined below.

CELL E15 *Total Time*: in hours — the time period for which the data was gathered. In other words, the time period for which the analysis is relevant. For example, if the user wants to analyze a one week period and a work week is defined to be 24 hours/day for 7 days, then *Total Time* = 168 hours.

CELL E16 *Theoretical Tool Speed*: in units per hour (UPH) — the supplier's statement and/or R&D estimate for the tool's capabilities.

CELL E17 *Plan Tool Speed*: in units per hour (UPH) — the process/equipment engineering plan for the tool's capabilities.

CELL E18 *Actual Tool Speed*: in units per hour (UPH) — the speed at which the tool is operating. This may include the effects of excess setup time, the tool may be slower than expected, etc.

CELL E19 *Average Batch Size*: (% of full batch size) — the (total units processed by the tool * 100) / (total # of tool runs * tool batch size). If the analysis is for a single wafer processing tool, enter 100.

CELL E20 *Quality Losses*: (% Loss) — this input may include speed degradations that can be attributed to rate of quality, yield, and rework losses. If there are no such problems attributable to the tool, enter 0.

CELL E22 *Batch Size*: in number of units — this is the full batch size you want to consider in your calculations. It tells to what number the Average Batch Size (% of full batch size) is referring. This information is not used in the calculations; it is merely printed on the template heading for the user's information. If the analysis is for a single wafer processing tool, enter 1.

Here are a few issues to keep in mind when entering these quantities:

- All three tool speeds should be in terms of units per hour (UPH).
- *Theoretical Tool Speed* should be greater than or equal to *Plan Tool Speed*.
- *Plan Tool Speed* may be greater than or equal to *Actual Tool Speed*.
- Percentages must be between 0 and 100.

Note: These and other logical checks are made in the templates in the *Input Checks* column. See Sections 4.6.3 and 4.7.3 for more details.

4.1.2 Input Mapping Assumptions

This section handles only the time-related information. The actual data is not entered here; it is only summarized. What is entered is the user's preference for the level of detail that will be used to generate the summarized inputs. As discussed in later sections, data is entered in the *Level 1*, *Level 2*, *Level 3*, or *Level 4* input sections. The level the user chooses for input will be summarized in the *Input Mapping Assumptions*. Levels 1, 2, 3, and 4 are based on the SEMI E10 equipment states in various detail. Figure 4 depicts the six initial SEMI E10 equipment states. It should help to conceptualize how the states are used to divide total time.

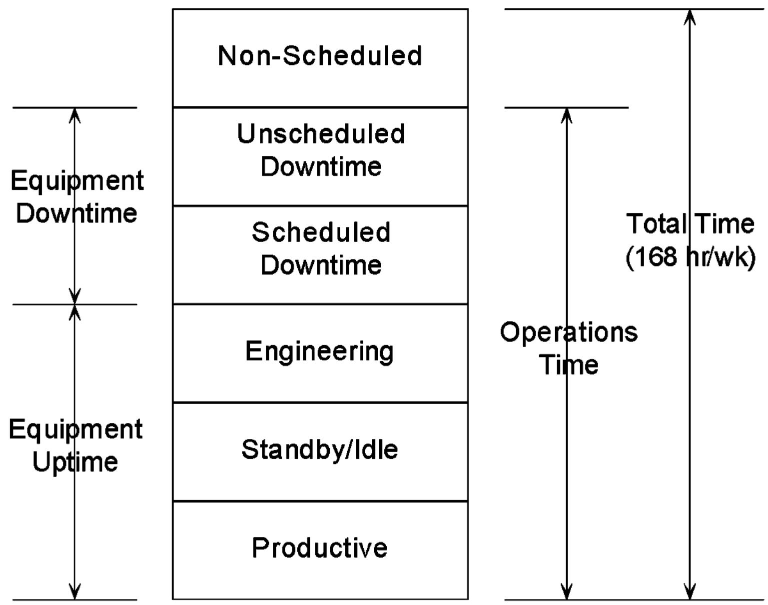


Figure 4 Equipment States Stack Chart[2]

INPUT MAPPING ASSUMPTIONS	INPUT LEVEL	INPUT SUMMARY
Total Hours	GLOBAL	168.00
Non-Scheduled Hours	1	8.00
Scheduled Operation Hours	CALC	160.00
Scheduled Downtime	3	8.00
Engineering Time	1	8.00
Unscheduled Downtime	1	16.00
Standby / Idle Time	1	12.00
Other Production Time Losses	1	4.00
	Level 1 thru 4	(See Below)

Figure 5 Input Mapping Assumptions Section

The *Input Mapping Assumptions* Section is shown in Figure 5. The *Input Level* column allows the user to indicate the level of data that should be aggregated for a particular summarized input. The value in the *Input Summary* column is the aggregated information. Possible entries for the *Input Level* column are 1, 2, 3, or 4. If a "1" is entered in a row, it means that *Level 1* data is used to generate the summarized input on that row. Similarly, if a "2" is entered in a row, it indicates

[2] SEMI E10-92 Guideline.

that *Level 2* data is used to generate that row's summarized input. The same would apply for an entry of "3" or "4". For example, consider the *Scheduled Downtime* row in Figure 5. The "3" in the *Input Level* column means the 21 hours in the *Input Summary* column is based on data from Level 3. All the values in the *Input Summary* column are calculated in the same manner with two exceptions. These are *Total Hours*, which is taken directly from the *Global Inputs* section, and *Scheduled Operation Hours*, which is the difference of the two cells above it (*Total Hours - Nonscheduled Hours*). For the rationale of why the user would prefer a particular level, refer to Sections 4.1.3, 4.1.4, 4.1.5, and 4.1.6.

4.1.3 Level 1 Inputs

The *Level 1* inputs correspond to SEMI E10 92 level L2. The *Level 1* input variables are defined below.

LEVEL 1 INPUTS	
Other Production Time Losses	4
Unscheduled Downtime	16
Scheduled Downtime	8
Engineering Time	8
Standby / Idle Time	12
Non-Scheduled Hours	8

Figure 6 Level 1 Input Section

CELL F29 *Other Production Time Losses*: time losses that are not accounted for in the other E10 equipment states (i.e., production tests).

CELL F30 *Unscheduled Downtime*: the time when the equipment is not in a condition to perform its intended function because of unplanned downtime events.

CELL F31 *Scheduled Downtime*: the time when the equipment is not available to perform its intended function because of planned downtime events.

CELL F32 *Engineering Time*: the time when the equipment is in a condition to perform its intended function (no equipment or process problems exist), but it is operated to conduct engineering experiments. This includes process engineering and equipment engineering.

CELL F33 *Standby / Idle Time*: the time other than nonscheduled time when the equipment is available and in a condition to perform its intended function. Chemicals and facilities are available, but the equipment is not operated. This includes no operator available, no product available, etc.

CELL F34 *Nonscheduled Hours*: the time when the equipment is not scheduled to be used in production, such as unworked shifts, weekends, and holidays.

4.1.4 Level 2 Inputs

Level 2 inputs are more detailed than *Level 1*; they correspond to SEMI E10 92 level L3. Figure 7 shows how *Level 1* expands into *Level 2*. Reading the same figure from right to left explains how *Level 2* inputs can be summarized. The *Level 2* input variables are defined below.

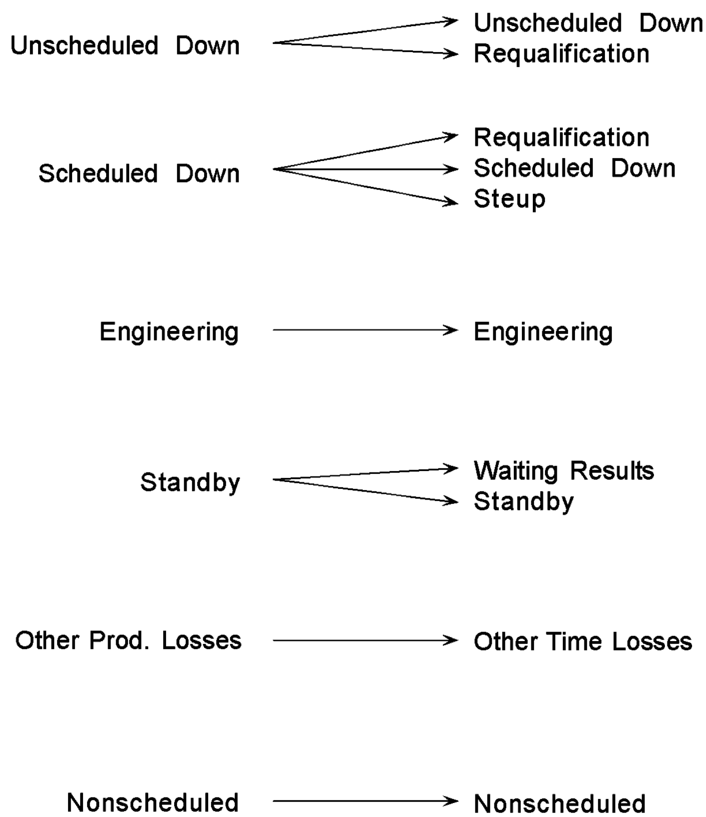


Figure 7 First Expansion of Equipment States[3]

CELL F44 *Unscheduled Downtime*: similar to the *Level 1* definition; however, requalification and repair time have been separated. Actually, *Unscheduled Downtime* is not really entered. Instead, some commonly kept statistics are used such as mean time between failures (MTBF) and mean time to repair (MTTR).

CELL F45 *Requalification Time*: the time typically needed to bring the equipment back on line after an *Unscheduled Downtime* event.

CELL F47 *Scheduled Downtime*: similar to the *Level 1* definition; however, *Set-up Time* and *Requalification Time* may be entered separately.

CELL F48 *Set-Up Time*: the means for measuring the impact of changes in lot size and the introduction of priority jobs into the facility.

---

[3] Tribula and Pratt

CELL F49 *Requalification Time*: the time typically needed to bring the equipment back into a productive state after a *Scheduled Downtime* event (same type of event as the *Requalification Time* for an *Unscheduled Downtime* event).

CELL F51 *Engineering Time*: exactly the same as *Level 1*.

CELL F53 *Other Time Losses*: time losses that are not accounted for in the E10 equipment states.

CELL F55 *Standby / Idle Time*: similar to the *Level 1* definition; however, time spent waiting for test results has been separated.

CELL F56 *Waiting Results / Qualification*: the time the equipment is idle because it must wait for the results of tests (i.e., when monitor wafers are run ahead of a lot).

CELL F58 *Nonscheduled Hours*: exactly the same as *Level 1*.

LEVEL 2 INPUTS

	INPUTS					LEVEL 2 TOTAL
		HOURS		HOURS		HOURS
Unscheduled Downtime	MTBF=	40	MTTR=	5		20.00
Requalification Time		0	(Hours per failure)			
Scheduled Downtime		1	EVERY	8	HOURS	20.00
Set-Up Time		0	EVERY	"	HOURS	
Requalification Time		0	EVERY	"	HOURS	
Engineering Time		8	EVERY	275	HOURS	4.65
Other Time Losses (in Hrs Loss)		8				8.00
Standby / Idle Time		0.1	EVERY	1	HOURS	12.80
Waiting Results / Qualification		0	EVERY	"	HOURS	
Non-Scheduled Hours		16				16.00

PRINT LEVEL 2 INPUTS

Figure 8 Level 2 Input Section

Most of the inputs in *Level 2* do not need to be in terms of hours per *Total Time* as in *Level 1*. Instead, different reference periods may be used (i.e., cells H47, H51, and H55). This makes it convenient for averaging over shifts or using information from the floor control system. CUBES then computes the time for that equipment state in accordance with the user's specified *Total Time*. The right-hand column of Figure 8 contains the results. Below are the calculations used:

$$\textbf{Unscheduled Downtime} = \left(\frac{\textbf{SchOp}}{\text{MTBF}}\right) \times (\text{MTR} + \text{Requal})$$

$$\textbf{Scheduled} = \left(\frac{\textbf{SchOp}}{\text{RefPeriod}}\right) \times (\text{SchDT} + \text{Setup} + \text{Requal})$$

$$\textbf{Engineering} = \left(\frac{\textbf{SchOp}}{\text{RefPeriod}}\right) \times \text{Engineering}$$

$$\textbf{Other Time Losses} = \text{Other Time Losses}$$

$$\textbf{Standby} = \left[\frac{\textbf{SchOp} - (\textbf{Unsch} + \textbf{Sch} + \textbf{Eng})}{\text{RefPeriod}}\right] \times \text{Waiting Results}$$

$$\textbf{Non-Scheduled Hours} = \text{Non-Scheduled Hours}$$

Note: The non-bolded words refer to *Level 2* inputs; SchOp is taken from the *Input Mappings Assumptions* section.

The values in the far right-hand column of Figure 8 are then used to compute the summarized inputs according to the *Input Mapping Assumptions*.

4.1.5 Level 3 Inputs

See the second page of Figure 2 for the sample spreadsheet of this section.

Level 3 is an example of further division of the various E10 equipment states, taken from Trybula and Pratt. *Level 3* may be used as is or the user can redefine the terms in this section to include the user's own level of detail. If the inputs are user-defined, keep in mind that the columns are added. Therefore, whatever breakdown of the E10 equipment states the user prefers should add up to the total time of each equipment state. The original *Level 3* is depicted in Figure 9 as it relates to *Level 1* and *Level 2*. Definitions are not included at this level since the terms are now very specific and self-explanatory.

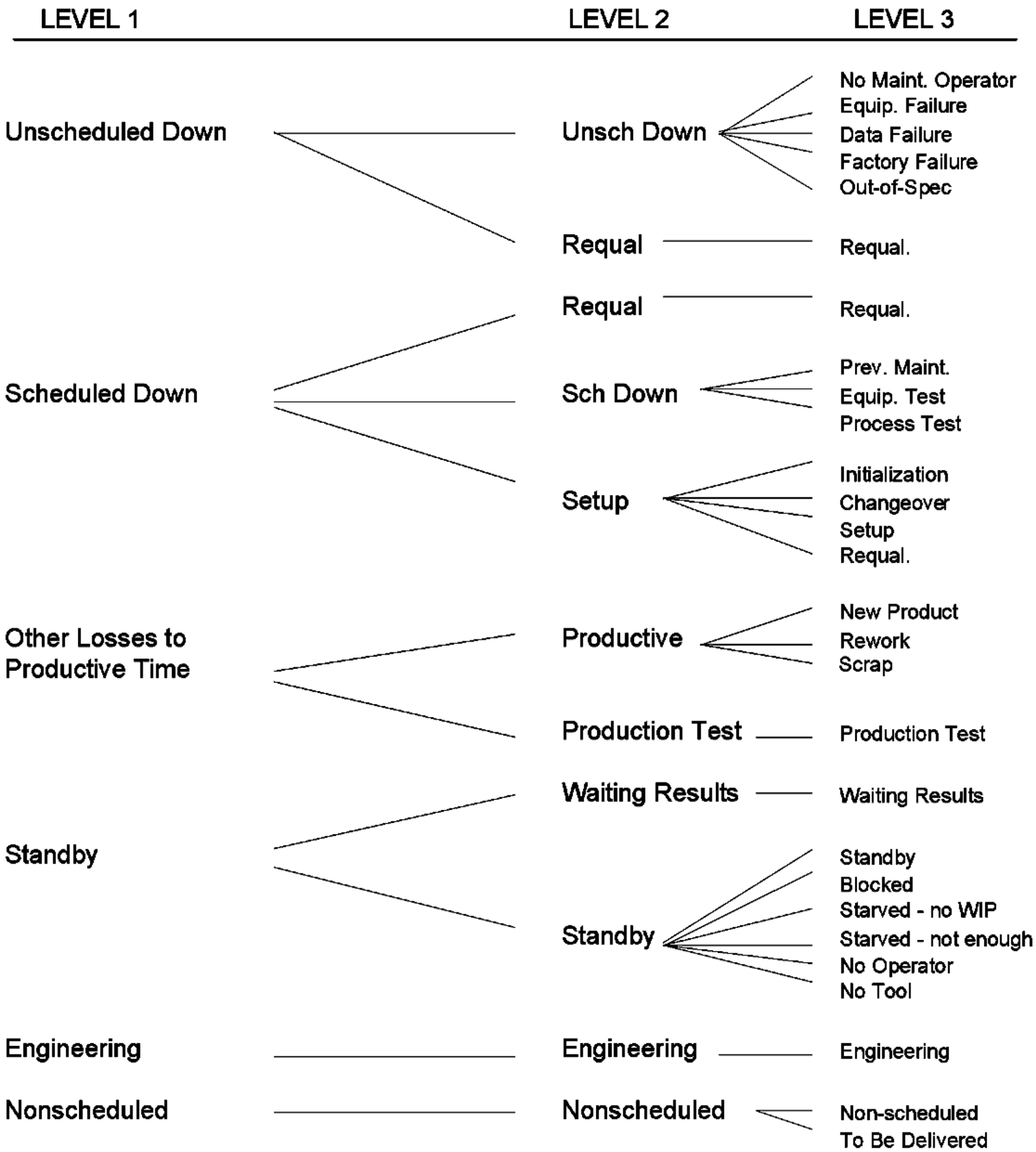


Figure 9 Second Expansion of Equipment States[4]

4.1.6 Level 4 Inputs

See the third page of Figure 2 for the sample spreadsheet of this section.

Level 4 is another example of a detailed partitioning of the various E10 equipment states. *Level 4* may be used as is or the user can redefine the terms in this section to include the user's own level of detail. If the inputs are user-defined, keep in mind that the columns are added. Therefore,

[4] Tribula and Pratt. Also, recall that CUBES levels 1 and 2 equate with SEMI E10 92 levels L2 and L3 respectively.

whatever breakdown of the E10 equipment states the user prefers should add up respectively to the total time of each equipment state.

4.1.7 OEE Optional Inputs

See the fourth page of Figure 2 for the sample spreadsheet of this section.

Brief instructions can be found on the spreadsheet. A more detailed understanding is offered here. When the *OEE Optional Input* default settings are used, the *OEE Template* uses the same inputs as the *E10 Template*.

Part 1 - Availability Adjustment:

The responses to the two questions will determine the total amount of time on which the OEE calculation will be based (that is, *Gross Time* in the *OEE Template*). The two responses allow the user to follow a preferred OEE formulation. Default settings are “YES” and “YES”; in this case, the analysis is based on Gross Time = Total Time.

- *NONSCHEDULED HRS*: (YES or NO) A “YES” answer means that *the Nonscheduled Hours* are included in the *Gross Time* and, therefore, contribute to the inefficiency of the tool. A “NO” answer will remove any *Nonscheduled Hours* from the *Gross Time*. That is, OEE is calculated without any availability efficiency loss being attributed to *Nonscheduled Hours*.
- *PLANNED DOWNTIME*: (YES or NO) A “YES” answer means *Planned Downtime* is included in the *Gross Time* and, therefore, contributes to the inefficiency of the tool. A “NO” answer will remove any *Planned Downtime* from the *Gross Time*. That is, OEE is calculated without any availability efficiency loss being attributed to *Planned Downtime*.

Part 2 - Production Adjustment:

If the user has less information (in particular, regarding tool speed), then it is appropriate to use this optional section. Three questions are asked, but not all need to be answered. The default answers are “NO”.

- Question 1: Do you wish to override inputs and calculate OEE with *Gross Production*?

  A “YES” means that efficiency calculations are based on the total number of units produced and *Plan Tool Speed* rather than the tool speed analysis in the E10 version.

- Question 2: Do you wish to override inputs and calculate OEE with *Net Production*?

  Similar to question 1, a “YES” means that efficiency calculations are based on the total number of units produced and *Plan Tool Speed* rather than the tool speed analysis in the E10 version.

  Note that there is no advantage to answering question 2 over question 1; it is merely a matter of what information is available.

- Question 3: Do you wish to override inputs and calculate *Rate of Quality* with actual *Production Rejects* ”?

  A “YES” means that the calculations are based on the actual number of rejected units rather than a percentage that might have been estimated or averaged. Note that for a “YES” to be implemented here, either question 1 or question 2 also must be answered “YES”.

If all three of these questions are answered "YES", then it should be true that

Gross Production = Net Production + Production Rejects.

If that is not true, then CUBES assumes that the first two answers are valid and computes

Production Rejects = Gross Production - Net Production.

Part 3 - Rate Of Quality Adjustment:

- Question: Do you wish to specify allocation of *Rate of Quality Loss* percentages?

  A yes/no answer is not required. Simply change the percentages if you would like them to be different than 50% because of scrap, defects and rework and 50% because of yield losses. Note that the two percentages must total 100%.

Part 4 - Performance Efficiency Adjustment:

- Question: Do you want to use *Plan Tool Speed* (P) or *Theoretical Tool Speed* (T) in the OEE calculation?

  A "P" means that *Plan Tool Speed* will be used as the Ideal Tool Speed in the *Performance Efficiency* calculations. A "T" means that *Theoretical Tool Speed* will be used as the Ideal Tool Speed. The default is "P".

4.2 ASCII Read / Write Capability

CUBES data can be read in from or written out to an ASCII text file. For both the Excel version and the Lotus version, Comma Separated Variable (CSV) files can be read and written.

4.2.1 Format of Input Data File

Table 1 describes each of the input fields in CUBES 2.5, along with its default value, its cell location, and its mapping number. Each line in the input file should be written in the following format: mapping number, input value, comments. The input file should be an ASCII file which can be created with either word processors or text editors. Here is an example input file:

```
5,80,Average Batch Size
6,3,Other Speed Losses
4,40,Actual Tool Speed
20,5,Unscheduled Downtime MTTR
7,1,Non-Scheduled Hours
8,1,Scheduled Downtime
0,Tool 1,Tool Name
```

All of the fields **do not** have to be present in the input file and the mapping numbers in the input file do not have to be sorted in any type of order. This allows the user to perform a quick analysis by just entering the global and level 1 inputs. Note that when data is input into only some of the fields, data from the previous analysis will remain in the other fields. This data will be included calculations. If you wish to prevent this, reset CUBES as described in Section 4.2.4 before importing the data. Also, the comments at the end of each line are not required but will be helpful in insuring data integrity. The only **required** feature of the input file is that the mapping number and input value must be present. Otherwise, the input file read-in procedure will cause error messages to appear in the CUBES spreadsheet.

Fields that require text (mapping numbers 0 and 275-281) should be entered without special delimiters such as quote marks or apostrophe's; these delimiters may cause errors. In case of errors, type the text directly into the CUBES input cells. This should remove the error messages.

A file containing an example set of input data has been included on the CUBES diskette along with the spreadsheet. The file is "example.csv"; it contains the example data which is in CUBES when you receive it.

Table 1 ACSII File Mappings

Level	Field	Qualifier	Units	Default Value	Cell	Map #
	Tool Name			Tool 1	B201	0
Global	Total Time		hours	1	E15	1
Global	Theoretical Tool Speed		uph	1	E16	2
Global	Plan Tool Speed		uph	1	E17	3
Global	Actual Tool Speed		uph	1	E18	4
Global	Average Batch Size		% full	100	E19	5
Global	Quality Losses		% loss	0	E20	6
Mapping	Non-Scheduled Hours			1	K16	7
Mapping	Scheduled Downtime			1	K18	8
Mapping	Engineering Time			1	K19	9
Mapping	Unscheduled Downtime			1	K20	10
Mapping	Standby / Idle Time			1	K21	11
Mapping	Other Production Time Losses			1	K22	12
1	Other Production Time Losses		hours	0	F29	13
1	Unscheduled Downtime		hours	0	F30	14
1	Scheduled Downtime		hours	0	F31	15
1	Engineering Time		hours	0	F32	16
1	Standby / Idle Time		hours	0	F33	17
1	Non-Scheduled Hours		hours	0	F34	18
2	Unscheduled Downtime	MTBF	hours	100	F44	19
2	Unscheduled Downtime	MTTR	hours	0	H44	20
2	Requalification Time		hours	0	F45	21

Level	Field	Qualifier	Units	Default Value	Cell	Map #
2	Scheduled Downtime	# of Hours	hours	0	F47	22
2	Scheduled Downtime	Every	hours	24	H47	23
2	Set-Up Time		hours	0	F48	24
2	Requalification Time		hours	0	F49	25
2	Engineering Time	# of Hours	hours	0	F51	26
2	Engineering Time	Every	hours	24	H51	27
2	Other Time Losses		hours	0	F53	28
2	Standby / Idle Time	# of Hours	hours	0	F55	29
2	Standby / Idle Time	Every	hours	24	H55	30
2	Waiting Results / Qualification		hours	0	F56	31
2	Non-Scheduled Hours		hours	0	F58	32
3	Unscheduled Downtime	No Maint. Oper.	hours	0	E70	33
3	Unscheduled Downtime	Equip. Failure	hours	0	E71	34
3	Unscheduled Downtime	Data Failure	hours	0	E72	35
3	Unscheduled Downtime	Factory Failure	hours	0	E73	36
3	Unscheduled Downtime	Out-of-Spec	hours	0	E74	37
3	Unscheduled Downtime	Requal	hours	0	E75	38
3	Unsched DT User Defined		hours	0	E76	39
3	Unsched DT User Defined		hours	0	E77	40
3	Unsched DT User Defined		hours	0	E78	41
3	Unsched DT User Defined		hours	0	E79	42
3	Unsched DT User Defined		hours	0	E80	43
3	Unsched DT User Defined		hours	0	E81	44
3	Unsched DT User Defined		hours	0	E82	45
3	Unsched DT User Defined		hours	0	E83	46
3	Unsched DT User Defined		hours	0	E84	47
3	Unsched DT User Defined		hours	0	E85	48
3	Unsched DT User Defined		hours	0	E86	49
3	Unsched DT User Defined		hours	0	E87	50
3	Unsched DT User Defined		hours	0	E88	51
3	Unsched DT User Defined		hours	0	E89	52
3	Scheduled Downtime	Requal.	hours	0	K70	53
3	Scheduled Downtime	Prev. Maint.	hours	0	K71	54

Level	Field	Qualifier	Units	Default Value	Cell	Map #
3	Scheduled Downtime	Equip. Test	hours	0	K72	55
3	Scheduled Downtime	Process Test	hours	0	K73	56
3	Scheduled Downtime	Initialization	hours	0	K74	57
3	Scheduled Downtime	Changeover	hours	0	K75	58
3	Scheduled Downtime	Setup	hours	0	K76	59
3	Scheduled Downtime	Requal	hours	0	K77	60
3	Sched DT User Defined	User Defined	hours	0	K78	61
3	Sched DT User Defined		hours	0	K79	62
3	Sched DT User Defined		hours	0	K80	63
3	Sched DT User Defined		hours	0	K81	64
3	Sched DT User Defined		hours	0	K82	65
3	Sched DT User Defined		hours	0	K83	66
3	Sched DT User Defined		hours	0	K84	67
3	Sched DT User Defined		hours	0	K85	68
3	Sched DT User Defined		hours	0	K86	69
3	Sched DT User Defined		hours	0	K87	70
3	Sched DT User Defined		hours	0	K88	71
3	Sched DT User Defined		hours	0	K89	72
3	Other Losses To Productive Time	New Product	hours	0	Q70	73
3	Other Losses To Productive Time	Rework	hours	0	Q71	74
3	Other Losses To Productive Time	Scrap	hours	0	Q72	75
3	Other Losses To Productive Time	Production Test	hours	0	Q73	76
3	Other Loss User Defined		hours	0	Q74	77
3	Other Loss User Defined		hours	0	Q75	78
3	Other Loss User Defined		hours	0	Q76	79
3	Other Loss User Defined		hours	0	Q77	80
3	Other Loss User Defined		hours	0	Q78	81
3	Other Loss User Defined		hours	0	Q79	82
3	Other Loss User Defined		hours	0	Q80	83
3	Other Loss User Defined		hours	0	Q81	84
3	Other Loss User Defined		hours	0	Q82	85

Level	Field	Qualifier	Units	Default Value	Cell	Map #
3	Other Loss User Defined		hours	0	Q83	86
3	Other Loss User Defined		hours	0	Q84	87
3	Other Loss User Defined		hours	0	Q85	88
3	Other Loss User Defined		hours	0	Q86	89
3	Other Loss User Defined		hours	0	Q87	90
3	Other Loss User Defined		hours	0	Q88	91
3	Other Loss User Defined		hours	0	Q89	92
3	Standby	Waiting Results	hours	0	E99	93
3	Standby	Standby	hours	0	E100	94
3	Standby	Blocked	hours	0	E101	95
3	Standby	Starved - no WIP	hours	0	E102	96
3	Standby	Starved - not enough WIP	hours	0	E103	97
3	Standby	No Operator	hours	0	E104	98
3	Standby	No Tool	hours	0	E105	99
3	Standby User Defined		hours	0	E106	100
3	Standby User Defined		hours	0	E107	101
3	Standby User Defined		hours	0	E108	102
3	Standby User Defined		hours	0	E109	103
3	Standby User Defined		hours	0	E110	104
3	Standby User Defined		hours	0	E111	105
3	Standby User Defined		hours	0	E112	106
3	Standby User Defined		hours	0	E113	107
3	Standby User Defined		hours	0	E114	108
3	Standby User Defined		hours	0	E115	109
3	Standby User Defined		hours	0	E116	110
3	Standby User Defined		hours	0	E117	111
3	Standby User Defined		hours	0	E118	112
3	Engineering	Engineering	hours	0	K99	113
3	Eng User Defined		hours	0	K100	114
3	Eng User Defined		hours	0	K101	115
3	Eng User Defined		hours	0	K102	116
3	Eng User Defined		hours	0	K103	117
3	Eng User Defined		hours	0	K104	118
3	Eng User Defined		hours	0	K105	119

Level	Field	Qualifier	Units	Default Value	Cell	Map #
3	Eng User Defined		hours	0	K106	120
3	Eng User Defined		hours	0	K107	121
3	Eng User Defined		hours	0	K108	122
3	Eng User Defined		hours	0	K109	123
3	Eng User Defined		hours	0	K110	124
3	Eng User Defined		hours	0	K111	125
3	Eng User Defined		hours	0	K112	126
3	Eng User Defined		hours	0	K113	127
3	Eng User Defined		hours	0	K114	128
3	Eng User Defined		hours	0	K115	129
3	Eng User Defined		hours	0	K116	130
3	Eng User Defined		hours	0	K117	131
3	Eng User Defined		hours	0	K118	132
3	Non-Scheduled	Non-Scheduled	hours	0	Q99	133
3	Non-Scheduled	To Be Delivered	hours	0	Q100	134
3	Non-Sched User Defined		hours	0	Q101	135
3	Non-Sched User Defined		hours	0	Q102	136
3	Non-Sched User Defined		hours	0	Q103	137
3	Non-Sched User Defined		hours	0	Q104	138
3	Non-Sched User Defined		hours	0	Q105	139
3	Non-Sched User Defined		hours	0	Q106	140
3	Non-Sched User Defined		hours	0	Q107	141
3	Non-Sched User Defined		hours	0	Q108	142
3	Non-Sched User Defined		hours	0	Q109	143
3	Non-Sched User Defined		hours	0	Q110	144
3	Non-Sched User Defined		hours	0	Q111	145
3	Non-Sched User Defined		hours	0	Q112	146
3	Non-Sched User Defined		hours	0	Q113	147
3	Non-Sched User Defined		hours	0	Q114	148
3	Non-Sched User Defined		hours	0	Q115	149
3	Non-Sched User Defined		hours	0	Q116	150
3	Non-Sched User Defined		hours	0	Q117	151
3	Non-Sched User Defined		hours	0	Q118	152
4	Unscheduled Downtime	Wild Card One	hours	0	W43	153

Level	Field	Qualifier	Units	Default Value	Cell	Map #
4	Unscheduled Downtime	Wild Card Two	hours	0	W44	154
4	Unscheduled Downtime	T.E.E. User	hours	0	W45	155
4	Unscheduled Downtime	T.A.E. User	hours	0	W46	156
4	Unscheduled Downtime	Down For Foreign Material (Manufacturing)	hours	0	W47	157
4	Unscheduled Downtime	Down For Foreign Material (Equipment)	hours	0	W48	158
4	Unscheduled Downtime	Down For Foreign Material (Process)	hours	0	W49	159
4	Unscheduled Downtime	Tool Unavailable To Maint.	hours	0	W50	160
4	Unscheduled Downtime	Down For Tool's Computer	hours	0	W51	161
4	Unscheduled Downtime	Down For Verification	hours	0	W52	162
4	Unscheduled Downtime	Down For Host	hours	0	W53	163
4	Unscheduled Downtime	Down For Facilities	hours	0	W54	164
4	Unscheduled Downtime	Down For Customer Engineer (C.E.)	hours	0	W55	165
4	Unscheduled Downtime	Waiting For Maintenance	hours	0	W56	166
4	Unscheduled Downtime	Wild Card Three (Maint)	hours	0	W57	167
4	Unscheduled Downtime	Maintenance Rework / Re-Do	hours	0	W58	168
4	Unscheduled Downtime	Down For Foreign Material (Maintenance)	hours	0	W59	169
4	Unscheduled Downtime	Waiting For Vendor Maintenance	hours	0	W60	170
4	Unscheduled Downtime	Unplanned Maintenance By Maintenance	hours	0	W61	171
4	Unscheduled Downtime	Standby - Wait For Engineering	hours	0	W62	172
4	Unscheduled Downtime	Equipment Engineering	hours	0	W63	173
4	Unscheduled Downtime	Tool Cooldown	hours	0	W64	174
4	Unscheduled Downtime	Unplanned Maintenance / Engineering Assist	hours	0	W65	175
4	Unscheduled Downtime	Down For No Vendor Spare Parts	hours	0	W66	176
4	Unscheduled Downtime	Vendor Unplanned Maint.	hours	0	W67	177
4	Unscheduled Downtime	Handler Unplanned Maint.	hours	0	W68	178
4	Unscheduled Downtime	Qualification Run	hours	0	W69	179
4	Unscheduled Downtime	Stop Production Notice (SPN)	hours	0	W70	180
4	Unscheduled Downtime	Wild Card Four (Process)	hours	0	W71	181

Level	Field	Qualifier	Units	Default Value	Cell	Map #
4	Unscheduled Downtime	Down For I.S. (Information Services)	hours	0	W72	182
4	Unscheduled Downtime	Down For Process Engineering	hours	0	W73	183
4	Unscheduled Downtime	Down For Quality Engineering	hours	0	W74	184
4	Unscheduled Downtime	Down For No Spare Parts	hours	0	W75	185
4	Unscheduled Downtime	Waiting For Manufacturing Maint.	hours	0	W76	186
4	Unscheduled Downtime	Down For Unplanned Maint. By Manufacturing	hours	0	W77	187
4	Unscheduled Downtime	Down For Product Engineering	hours	0	W78	188
4	Unscheduled Downtime	Down For Chemical Supply	hours	0	W79	189
4	Unscheduled Downtime	Other / Miscellaneous	hours	0	W80	190
4	Unsched. DT User Defined		hours	0	W81	191
4	Unsched. DT User Defined		hours	0	W82	192
4	Unsched. DT User Defined		hours	0	W83	193
4	Unsched. DT User Defined		hours	0	W84	194
4	Unsched. DT User Defined		hours	0	W85	195
4	Scheduled Downtime	Set Up / Start Up (Engr.)	hours	0	AB43	196
4	Scheduled Downtime	Machine Clean Up	hours	0	AB44	197
4	Scheduled Downtime	Qualify / Dummy Run	hours	0	AB45	198
4	Scheduled Downtime	Maint Setup / Changeover	hours	0	AB46	199
4	Scheduled Downtime	Planned Maintenance By Maintenance	hours	0	AB47	200
4	Scheduled Downtime	System In Use By Maintenance	hours	0	AB48	201
4	Scheduled Downtime	Ramp Up Support	hours	0	AB49	202
4	Scheduled Downtime	Vendor Planned Maintenance	hours	0	AB50	203
4	Scheduled Downtime	Planned Tool Cleaning	hours	0	AB51	204
4	Scheduled Downtime	Calibration	hours	0	AB52	205
4	Scheduled Downtime	Set Up / Start Up (Mfg.)	hours	0	AB53	206
4	Scheduled Downtime	Exposure Matrix	hours	0	AB54	207
4	Scheduled Downtime	Contamination Check	hours	0	AB55	208
4	Scheduled Downtime	Intensity Check	hours	0	AB56	209
4	Scheduled Downtime	Overlay Check	hours	0	AB57	210
4	Scheduled Downtime	Focus Check	hours	0	AB58	211
4	Scheduled Downtime	Profile	hours	0	AB59	212

Level	Field	Qualifier	Units	Default Value	Cell	Map #
4	Scheduled Downtime	Down For Planned Maint. By Manufacturing	hours	0	AB60	213
4	Scheduled Downtime	Waiting For Planned Maintenance	hours	0	AB61	214
4	Scheduled DT User Defined		hours	0	AB62	215
4	Scheduled DT User Defined		hours	0	AB63	216
4	Scheduled DT User Defined		hours	0	AB64	217
4	Scheduled DT User Defined		hours	0	AB65	218
4	Scheduled DT User Defined		hours	0	AB66	219
4	Quality	Operator Trainee Production	hours	0	AB72	220
4	Quality	Regular Production	hours	0	AB73	221
4	Quality	Rework	hours	0	AB74	222
4	Quality	Monitor Production	hours	0	AB75	223
4	Quality	Parallel Testing	hours	0	AB76	224
4	Quality	Experimental Work	hours	0	AB77	225
4	Quality	Standards	hours	0	AB78	226
4	Quality	Reduced Thruput	hours	0	AB79	227
4	Quality User Defined		hours	0	AB80	228
4	Quality User Defined		hours	0	AB81	229
4	Quality User Defined		hours	0	AB82	230
4	Quality User Defined		hours	0	AB83	231
4	Quality User Defined		hours	0	AB84	232
4	Standby	Lunch	hours	0	AG43	233
4	Standby	C.F.M. Idle - Mfg	hours	0	AG44	234
4	Standby	C.F.M. Idle - Maint/Equip	hours	0	AG45	235
4	Standby	C.F.M. Idle - Process	hours	0	AG46	236
4	Standby	Wait Monitors / Send Aheads	hours	0	AG47	237
4	Standby	Insufficient Time To Complete Run	hours	0	AG48	238
4	Standby	Process Quality Inspect.	hours	0	AG49	239
4	Standby	Characterization	hours	0	AG50	240

Level	Field	Qualifier	Units	Default Value	Cell	Map #
4	Standby	Tool Unavailable To Maint.	hours	0	AG51	241
4	Standby	Tool Waiting For Cal.	hours	0	AG52	242
4	Standby	Support Equipment Down	hours	0	AG53	243
4	Standby	Glass Shop	hours	0	AG54	244
4	Standby	Auto Tool Idle	hours	0	AG55	245
4	Standby	Wait For Outside Conditions	hours	0	AG56	246
4	Standby	No Manufacturing Operator	hours	0	AG57	247
4	Standby	No Product Available	hours	0	AG58	248
4	Standby	Prod. Prob., Not Tool Related	hours	0	AG59	249
4	Standby	Repair Work Complete, Wait For Manufacturing	hours	0	AG60	250
4	Standby	Down For Mask	hours	0	AG61	251
4	Standby	No Vendor Product Available	hours	0	AG62	252
4	Standby	Waiting For M.O.S.	hours	0	AG63	253
4	Standby	Area Clean Up	hours	0	AG64	254
4	Standby	Terminal / Paperwork	hours	0	AG65	255
4	Standby User Defined		hours	0	AG66	256
4	Standby User Defined		hours	0	AG67	257
4	Standby User Defined		hours	0	AG68	258
4	Standby User Defined		hours	0	AG69	259
4	Standby User Defined		hours	0	AG70	260
4	Non-Scheduled	Electro/Mechanical E.C.	hours	0	AG76	261
4	Non-Scheduled	Non Scheduled Time (Weekends)	hours	0	AG77	262
4	Non-Scheduled	No Scheduled Activity	hours	0	AG78	263
4	Non-Scheduled	Powered Down	hours	0	AG79	264
4	NonSched User Defined		hours	0	AG80	265
4	NonSched User Defined		hours	0	AG81	266
4	NonSched User Defined		hours	0	AG82	267
4	NonSched User Defined		hours	0	AG83	268
4	NonSched User Defined		hours	0	AG84	269
OEE Optional	Actual Production Parameters	Gross Production	units	0	J146	270
OEE Optional	Actual Production Parameters	Net Production	units	0	J149	271

Level	Field	Qualifier	Units	Default Value	Cell	Map #
OEE Optional	Actual Production Parameters	Production Rejects	units	0	J153	272
OEE Optional	Actual Production Parameters	Defects and Rework Percent	%	0	J159	273
OEE Optional	Actual Production Parameters	Yield Percent	%	0	J160	274
OEE Optional	Override Gross Product		Yes / No	NO	J145	275
OEE Optional	Override Net Production		Yes / No	NO	J148	276
OEE Optional	Override Production Rejects		Yes / No	NO	J152	277
OEE Optional	Performance Efficiency Adjustment		P / T	P	J163	278
OEE Optional	Include Nonscheduled Hours in Gross Time		Yes / No	YES	D139	279
OEE Optional	Include Planned Downtime in Gross Time		Yes / No	YES	D140	280
Global	Batch Size		# of Units	1	E22	281

4.2.2 How to Read in an Input Data File

In order to input data via an ASCII text file the user must click on the “READ CUBES DATA FILE” button found at the top of the Input Section. Clicking this button brings up a prompt for a file name.

For Excel:

- Before clicking the “READ CUBES DATA FILE” button, make sure the data file is in the same directory as CUBES.
- At the prompt, type in the file name with the “.csv”. Do not type in the path.

For Lotus 1-2-3:

- Be sure to specify the path to the file and to include the “.csv” or “.txt” with your file name.

Once the appropriate path and name are entered, click on “OK”. The data is then automatically read in from the file to the CUBES input section. When this is done, a message box with “CUBES Data File read successfully” will appear. Note that when CUBES reads in data from an ASCII text file, it only overwrites the specific fields listed in that file. All other input data in CUBES will remain unchanged.

4.2.3 How to Write Input Data to a File

In order to write the current input data to an ASCII text file the user must click on the "WRITE CUBES DATA FILE" button found at the top of the Input Section. Clicking this button brings up a prompt for a file name.

In Excel, enter the filename and include the ".csv". Excel will save the CUBES data in the current directory and a message box with "CUBES Data File written successfully" will appear. In Lotus, the "SAVE AS" dialog box appears. The user will need to select the file type "text", type in a filename with a ".csv" extension, then select the drive and directory where the file is to be saved. This will save the data as a CSV file. Then, a message box with "CUBES Data File written successfully" will appear.

4.2.4 How to Reset Inputs to Default Values

All CUBES input fields may be reset to default values by clicking on the "RESET DATA" button at the top of the global inputs section. The default values are listed in Table 1 in Section 4.2.1. Clicking this button will clear all data from previous analyses. If this is done before a data file is read, it ensures that data from a previous analysis does not get included in the current calculations. Note that the *Corrective Action Log* is not reset.

4.3 User Defined Variable Names

The *USER DEFINED VARIABLE NAMES* section (see Figure 10) offers the user three options for terms that are used throughout the CUBES spreadsheet. The first is to use standard names. These are the default variable names. If the user has changed the variable names but wishes to return to the standard names, the user clicks on the *USE STANDARD NAMES* button to change the term back. If the user is analyzing testers in the backend, the second option is appropriate. Clicking on the *USE TESTER SPECIFIC NAMES* button will change the current unique variable names to those that are specific for testers. The final option allows the user to select unique variable names. Simply enter the desired variable names in the shaded cells and click on the *USE USER DEFINED NAMES* button to have these new terms used in the spreadsheet. The button at the bottom of the section will return the user to the *Input* section of the spreadsheet.

CAUTION: The disclaimer at the bottom of this section is to draw the user's attention to the fact that simply changing the variable names does not change any of the formulations used in CUBES. All of the variables, regardless of name, are still related in the same way.

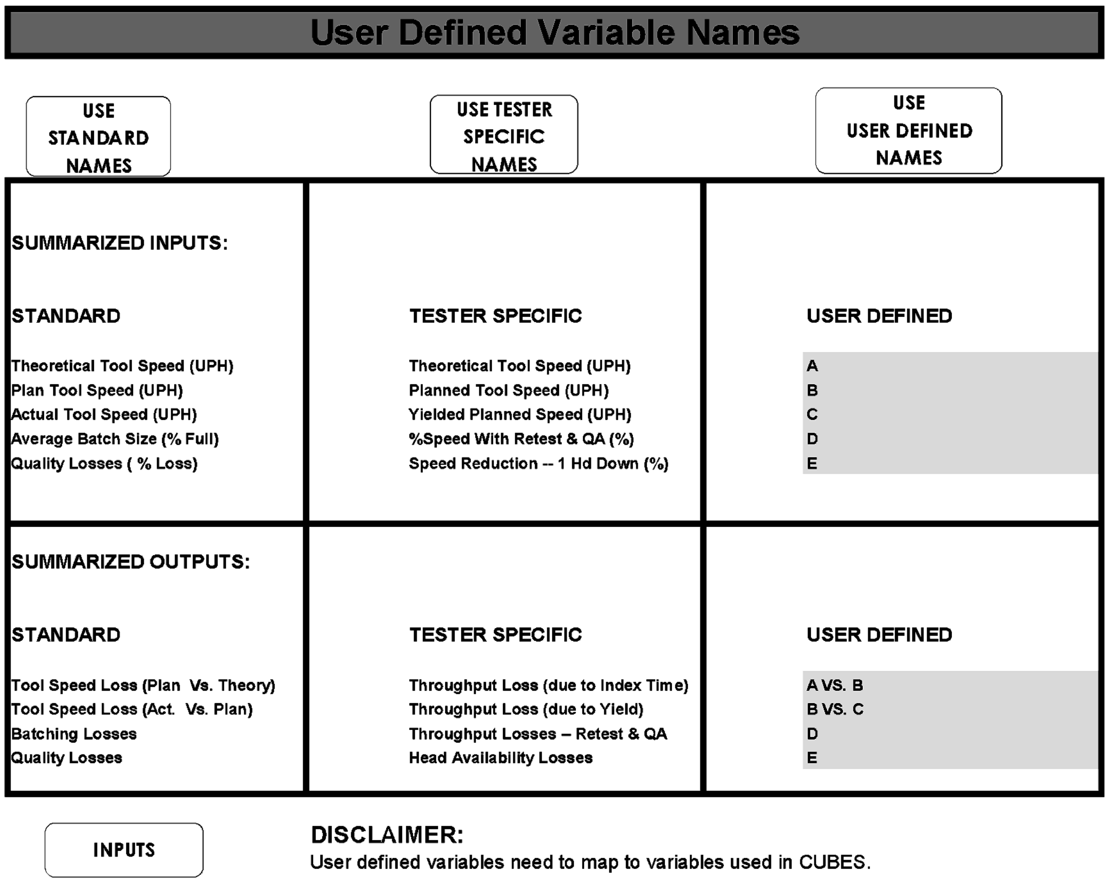


Figure 10 User Defined Variable Names Section

4.4 Acronyms List

The *ACRONYMS LIST* section (see Figure 11) provides a place for the user to record frequently used abbreviations in CUBES. Some abbreviations currently used in CUBES have been included. A button has been included at the top of the input section to transfer the user to the Acronym List.

PRINT ACRONYMS | INPUTS

Acronyms List

ACRONYM	DEFINITION
CUBES	Capacity Utilization Bottleneck Enhancement System
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
QA	Quality Assurance
TPM	Total Productive Maintenance
UPH	Units Per Hour

Figure 11 Acronyms List Section

4.5 Corrective Action Log

The *CORRECTIVE ACTION LOG* section (see Figure 12) is a place for the user(s) to record any actions that are to be taken to improve the efficiency of the tool. The column entries are self-explanatory. No input is actually required for CUBES to run properly; the log is here for the user's convenience. The log is 100 lines long.

Corrective Action Log

PRINT CORRECTIVE ACTION LOG | INPUTS | E10 TEMPLATE | OEE TEMPLATE

E10 BENCHMARK DATA | OEE BENCHMARK DATA

Date	Corrective Action Taken	Target Date	Responsible Person	Completion Date
15-May-95	Recalibrated Tool	21-May	Konopka	16-May

Figure 12 Corrective Action Log Section

4.6 E10 Version

The E10 version of CUBES analyzes a tool's throughput and potential throughput in terms of SEMI E10 equipment states that are now standard for the semiconductor industry. Figure 13 is the *E10 Template*. The discussion of this version will be broken out into the following five distinct areas:

- Template header information,
- Summarized inputs,
- Input checks,
- Numerical output, and
- Graphical output.

OUTPUT - CUBES (E10 TEMPLATE) EFFICIENCY ANALYSIS TOOL

INPUTS | OEE TEMPLATE | E10 BENCHMARK DATA | PRINT E10 TEMPLATE

CUBES v. 2.5 (E10 TEMPLATE) EFFICIENCY ANALYSIS TOOL 11/13/95

TOOL: TOOL 1 SUPPLIER: MODEL:
TOOL ID: SOURCE DATA DATE:
BATCH SIZE 1 SOURCE DATA FROM:

SUMMARIZED INPUTS		INPUT CHECKS	SUMMARIZED OUTPUTS	CUBES EFFICIENCY (%)		THRUPUT
			Actual Production	42.67		3226
Theoretical Tool Speed (UPH)	45		Speed Efficiency (%)	64.00		
Total Time	168		Time Efficiency(%)	66.67		
				OVERALL EFFECT (%)	INDIVIDUAL EFFECT (%)	THRUPUT INCREASE ANALYSIS IN UNITS
Plan Tool Speed (UPH)	45	TRUE	Tool Speed Loss (Plan Vs. Theory)	0.00	0.00	
Actual Tool Speed (UPH)	40	TRUE	Tool Speed Loss (Act. Vs. Plan)	7.41	11.11	403
Average Batch Size (% Full)	80	TRUE	Batching Losses	11.85	20.00	806
Quality Losses (% Loss)	10	TRUE	Quality Losses	4.74	10.00	358
Other Time Losses (ie. Prod. Test etc.)	4.00	TRUE	Other Time Losses (ie. Prod. Test etc.)	2.38	3.45	115
Standby /Idle Time	12.00	TRUE	Standby/Idle Time	7.14	9.38	346
Engineering Time	8.00	TRUE	Engineering Time	4.76	5.88	230
Unscheduled Downtime	16.00	TRUE	Unscheduled Downtime	9.52	10.53	461
Scheduled Downtime	8.00	TRUE	Scheduled Downtime	4.76	5.00	230
Non-Scheduled Time	8.00	TRUE	Non-Scheduled Time	4.76	4.76	230

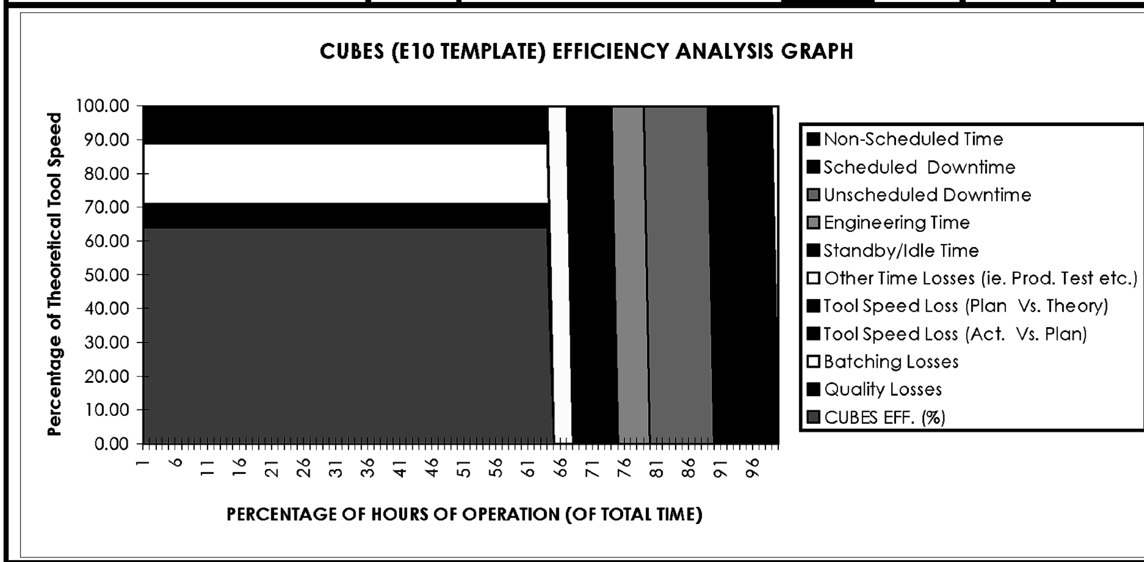


Figure 13 Sample Spreadsheet — E10 Output

The other graphs that are considered part of the E10 output are not shown here. See Section 4.6.5 for their descriptions.

4.6.1 Template Header Information

The template header is shown in Figure 14. None of this information is necessary to run a CUBES analysis. However, this type of information is useful in identifying the particular tool being analyzed. The top right-hand corner always displays the current date.

CUBES v. 2.5 (E10 TEMPLATE) EFFICIENCY ANALYSIS TOOL					11/13/95
TOOL:	TOOL 1	SUPPLIER:		MODEL:	
TOOL ID:		SOURCE DATA DATE:			
BATCH SIZE:	1	SOURCE DATA FROM:			

Figure 14 Header Information

Table 2 contains examples of the type of information the user might want to record in this section. Note that the tool name or type entered in the shaded "TOOL 1" cell will appear on the graphical output discussed in Section 4.6.5.

Table 2 Identification Information

Solicited Information and Description	Example
TOOL: the name or type of tool being analyzed.	Ion Implanter
TOOL ID: the code or id that uniquely identifies the tool	IMP02
SUPPLIER: the maker of the tool.	Company A
MODEL: the tool model number.	MDL 2.1
SOURCE DATA FROM: who gathered the input.	Joe Average, Floor Control System
SOURCE DATA DATE: what time period the input is from.	10/13/94 - 10/19/94

4.6.2 Summarized Inputs

The *Summarized Inputs* (see Figure 15) on the *E10 Template* are the actual numbers that are used in the efficiency calculations. These values are mapped in from the *Input Summary* column in the *Input* section. In previous CUBES releases, the user could overwrite these values in the template by clicking on the appropriate cell and entering the new number. This is no longer possible. The user may not change anything on the actual template.

SUMMARIZED INPUTS		INPUT CHECKS
Theoretical Tool Speed (UPH)	45	
Total Time	168	
Plan Tool Speed (UPH)	45	TRUE
Actual Tool Speed (UPH)	40	TRUE
Average Batch Size (% Full)	80	TRUE
Quality Losses (% Loss)	10	TRUE
Other Time Losses (ie. Prod. Test etc.)	4.00	TRUE
Standby /Idle Time	12.00	TRUE
Engineering Time	8.00	TRUE
Unscheduled Downtime	16.00	TRUE
Scheduled Downtime	8.00	TRUE
Non-Scheduled Time	8.00	TRUE

Figure 15 Summarized Inputs Column

The following definitions are the same as those given in the *Inputs* subsections.

CELL D208 *Theoretical Tool Speed*: in units per hour (UPH) — the supplier's statement and/or R&D estimate for the tool's capabilities.

CELL D209 *Total Time*: in hours — the time period for which the data was gathered. In other words, the time period for which the analysis is relevant. For example, if the user wants to analyze a one week period and a work week is defined to be 24 hours/day for 7 days, then *Total Time* = 168 hours.

CELL D211 *Plan Tool Speed*: in units per hour (UPH) — the process/equipment engineering plan for tool capabilities.

CELL D212 *Actual Tool Speed*: in units per hour (UPH) — the speed at which the tool is operating. This may include the effects of excess setup time, the tool may be slower than expected, etc.

CELL D213 *Average Batch Size*: (% of full batch size) — the (total units processed by the tool * 100) / (total # of tool runs * tool batch size). If the analysis is for a single wafer processing tool, enter 100.

CELL D214 *Quality Losses*: (% Loss) — this input may include speed degradations that can be attributed to rate of quality, yield, and rework losses. If there are no such problems attributable to the tool, enter 0.

CELL D215 *Other Time Losses*: (hours) — this input allows for other events that detract from the total production time of the tool, i.e., production tests.

CELL D216 *Standby/Idle Time*: (hours) — the time other than nonscheduled time when the equipment is available and in a condition to perform its intended function. Chemicals and facilities are available, but the equipment is not operated. This includes no operator available, no product available, etc.

CELL D217 *Engineering Time*: (hours) — the time when the equipment is in a condition to perform its intended function (no equipment or process problems exist), but it is operated to conduct engineering experiments. This includes process engineering and equipment engineering.

CELL D218 *Unscheduled Downtime*: (hours) — the time when the equipment is not in a condition to perform its intended function because of unplanned downtime events.

CELL D219 *Scheduled Downtime*: (hours) — the time when the equipment is not available to perform its intended function because of planned downtime events.

CELL D220 *Nonscheduled Time*: (hours) — the time when the equipment is not scheduled to be used in production, such as unworked shifts, weekends, and holidays.

4.6.3 Input Checks

The *Input Checks* column found on the right side of Figure 15 allows for a quick check of the validity of the CUBES analysis. The column consists of logical checks that ensure the summarized inputs are appropriate. The two possible column entries are "TRUE" and "FALSE". As long as all entries are "TRUE", the results of CUBES are valid. If one or more are "FALSE", then it is inappropriate to draw any conclusions from the analytical or graphical outputs. The following is an example of the checks being made. Consider the row with the summarized input *Plan Tool Speed*. A “TRUE” will appear in this row if *Plan Tool Speed* is less than or equal to *Theoretical Tool Speed*. Otherwise, a “FALSE” will appear in this row to indicate an illogical input. Table 3 lists all of the checks.

Table 3 E10 Input Checks

Row	Check (“TRUE” entered if the following holds)
211	(Plan Tool Speed) ≤ (Theoretical Tool Speed)
212	(Actual Tool Speed) ≤ (Plan Tool Speed)
213	0 ≤ (Avg. Batch Size Percentage) ≤ 100
214	0 ≤ (Quality Losses Percentage) ≤ 100
215	Other Time Losses ≤ (Total Time - Non-Sched.-Sched.- Eng.- Unsched.- Standby/Idle)
216	Standby/Idle Time ≤ (Total Time - Non-Sched.-Sched.- Eng.- Unsched.)
217	Engineering Time ≤ (Total Time - Non-Sched.- Sched.)
218	Unscheduled Time ≤ (Total Time - Non-Sched.- Sched.- Eng.)
219	Scheduled Downtime ≤ (Total Time - Non-Sched.)
220	Nonscheduled Time ≤ Total Time

4.6.4 Summarized Outputs

CUBES focuses on two key metrics: 1) Tool efficiency (*CUBES Efficiency*) and 2) tool throughput. Both are located on the *Actual Production* row of the *Summarized Outputs* section (see Figure 16). The *CUBES Efficiency* is the product of the tool’s speed efficiency and the tool’s time efficiency. It is the tool’s capability remaining after all the efficiency loss factors (i.e.,*Tool Speed Loss*, *Unscheduled Downtime*, etc.) have been taken into account. *Tool Throughput* is the number of good units that were produced during the total time over which the analysis is based.

SUMMARIZED OUTPUTS		CUBES EFFICIENCY (%)		THRUPUT
Actual Production		42.67		3226
Speed Efficiency (%)	64.00			
Time Efficiency(%)	66.67			
		OVERALL EFFECT (%)	INDIVIDUAL EFFECT (%)	THRUPUT INCREASE ANALYSIS IN UNITS
Tool Speed Loss (Plan Vs. Theory)		0.00	0.00	
Tool Speed Loss (Act. Vs. Plan)		7.41	11.11	403
Batching Losses		11.85	20.00	806
Quality Losses		4.74	10.00	358
Other Time Losses (ie. Prod. Test etc.)		2.38	3.45	115
Standby/Idle Time		7.14	9.38	346
Engineering Time		4.76	5.88	230
Unscheduled Downtime		9.52	10.53	461
Scheduled Downtime		4.76	5.00	230
Non-Scheduled Time		4.76	4.76	230

Figure 16 Summarized Output Columns

The remaining 10 items listed in the *Summarized Outputs* section are the efficiency loss factors. Each contributes to the inefficiency of the tool, as a speed degradation or as a detractor to total productive time. Each loss factor is characterized in three ways: *Individual Effect*, *Overall Effect*, and *Throughput* (or *Thruput*) loss. The *Individual Effect* is the loss factor's impact on tool efficiency if the factor is isolated, that is, if only this factor is considered. This information is useful in indicating how large this particular problem is. The *Overall Effect* is the loss factor's impact on tool efficiency with respect to all other factors. This information indicates how much of the total efficiency loss is attributable to this particular factor. Finally, the *Throughput* loss is the amount of potential throughput that is not achieved because of the particular loss factor. This quantity represents how much throughput could increase if this particular problem was fixed.

Note that the *Individual Effect* and *Overall Effect* are percentages and the throughput loss is an integer number of units (i.e., wafers).

4.6.5 Graphs (E10)

CUBES offers four graphical outputs. The first is the *CUBES Efficiency Analysis Graph* located on the bottom half of the *E10 Template* (see Figure 17). This graph is a visual analysis of how the efficiency loss factors are impacting the tool's efficiency.

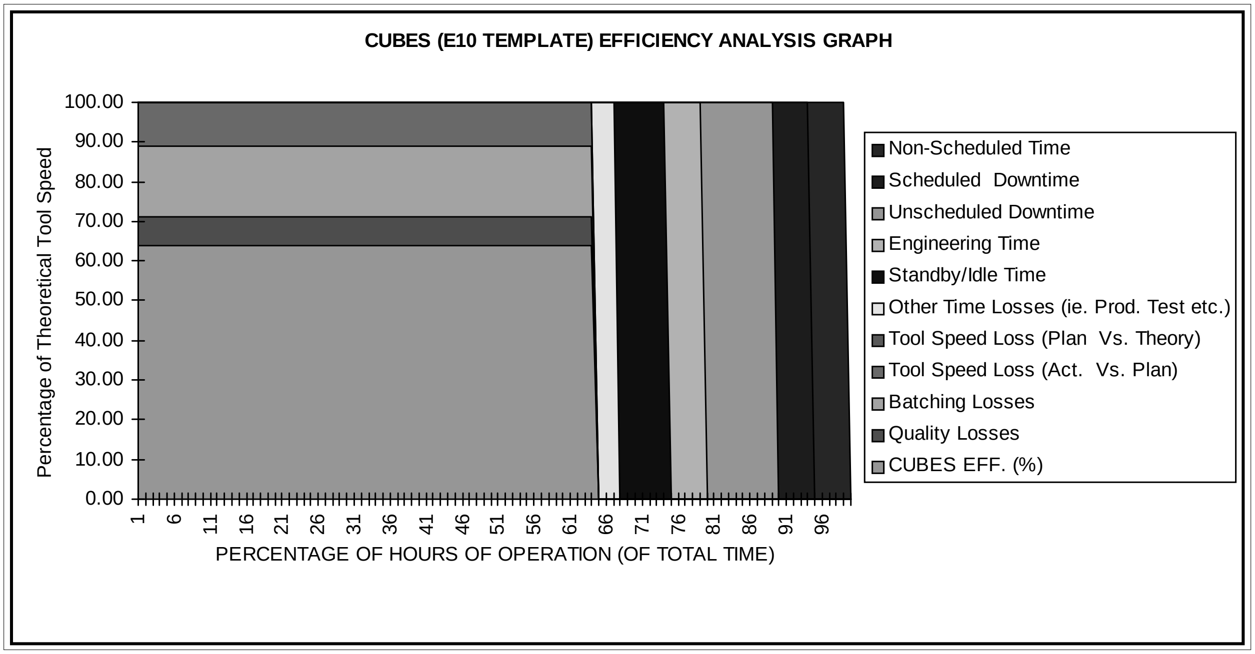


Figure 17 CUBES Efficiency Analysis Graph

The graph's x-axis is time and the y-axis is speed. Notice that vertical bars represent the time loss factors and horizontal bars are the speed degradations. The graph is generated using the values from the *Summarized Outputs Overall Effect* column. The overall effect values are the areas of the associated bars in the graph. The green bar, always found in the lower left-hand corner of the graph, shows the area of the *CUBES Efficiency*. It can be thought of as representing the actual throughput:

Speed (in units per hour) x Time (in hours) = Throughput (in units)

The second graph offered in CUBES is the *Throughput Leverage Analysis Graph* (see Figure 18). It is found several columns to the right of the *E10 Template*. This graphical analysis allows comparisons between the throughput losses due to each factor. The bars in the graph are generated using the *Summarized Outputs Throughput* column.

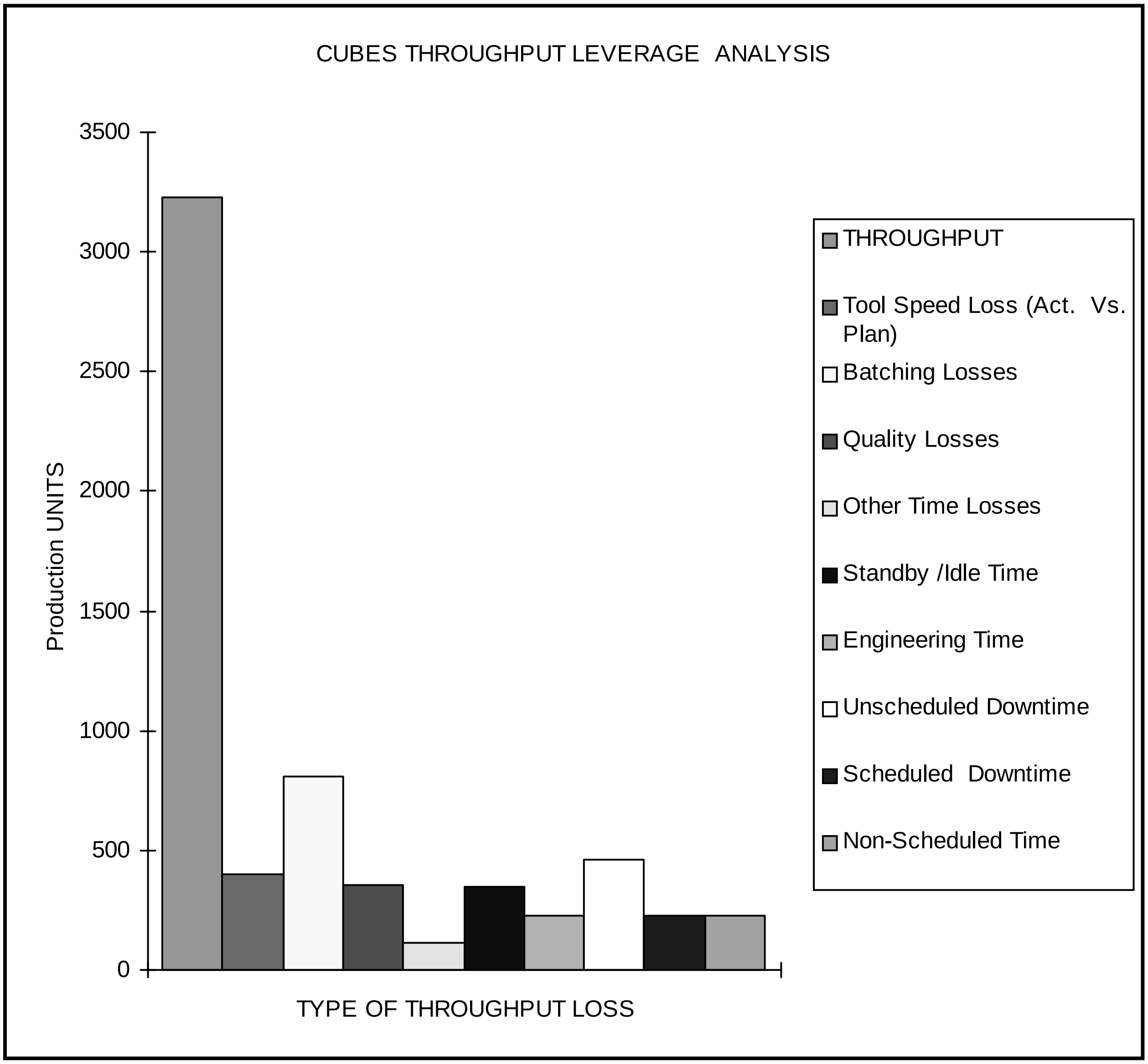


Figure 18 Throughput Leverage Analysis Graph

CUBES' third graph is the *Tool Efficiency Analysis Pie Chart* (see Figure 19). It is found several columns to the right of the *Throughput Leverage Analysis Graph*. This graphical analysis offers an alternative way to view the *Overall Effect* values. The graph represents the potential 100% CUBES efficiency. Each piece of the "pie" is associated with a loss factor's *Overall Effect* percentage.

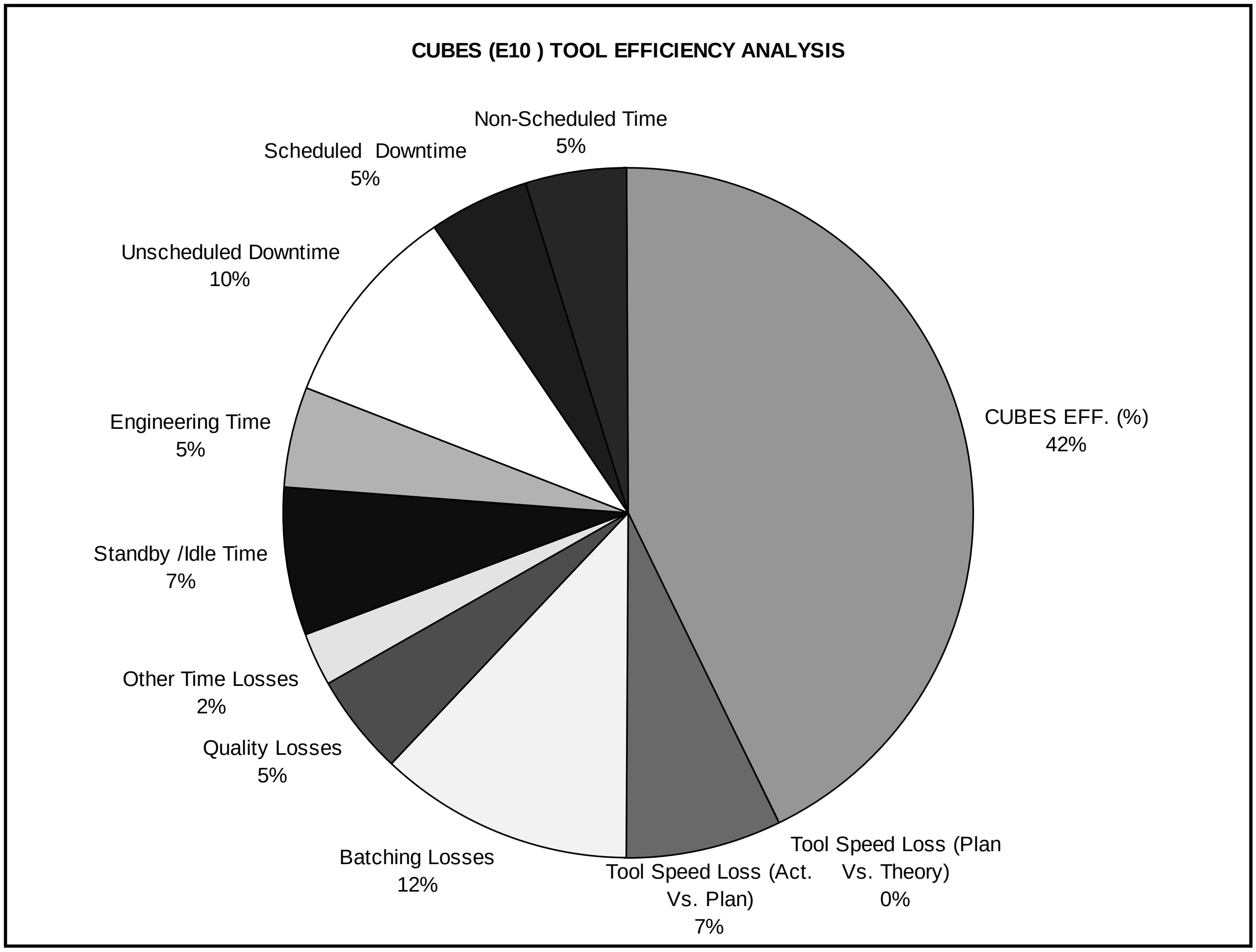


Figure 19 Tool Efficiency Analysis Pie Chart

CUBES' fourth graph is the *Benchmark Analysis Stacked Bar Graph* (see Figure 20). It is found several columns to the right of the *Tool Efficiency Analysis Pie Chart*. This graphical analysis offers another alternative way to view the *Overall Effect* values. The height of the stacked bar represents 100% CUBES efficiency. Each layer of the stacked bar is a loss factor's *Overall Effect* percentage.

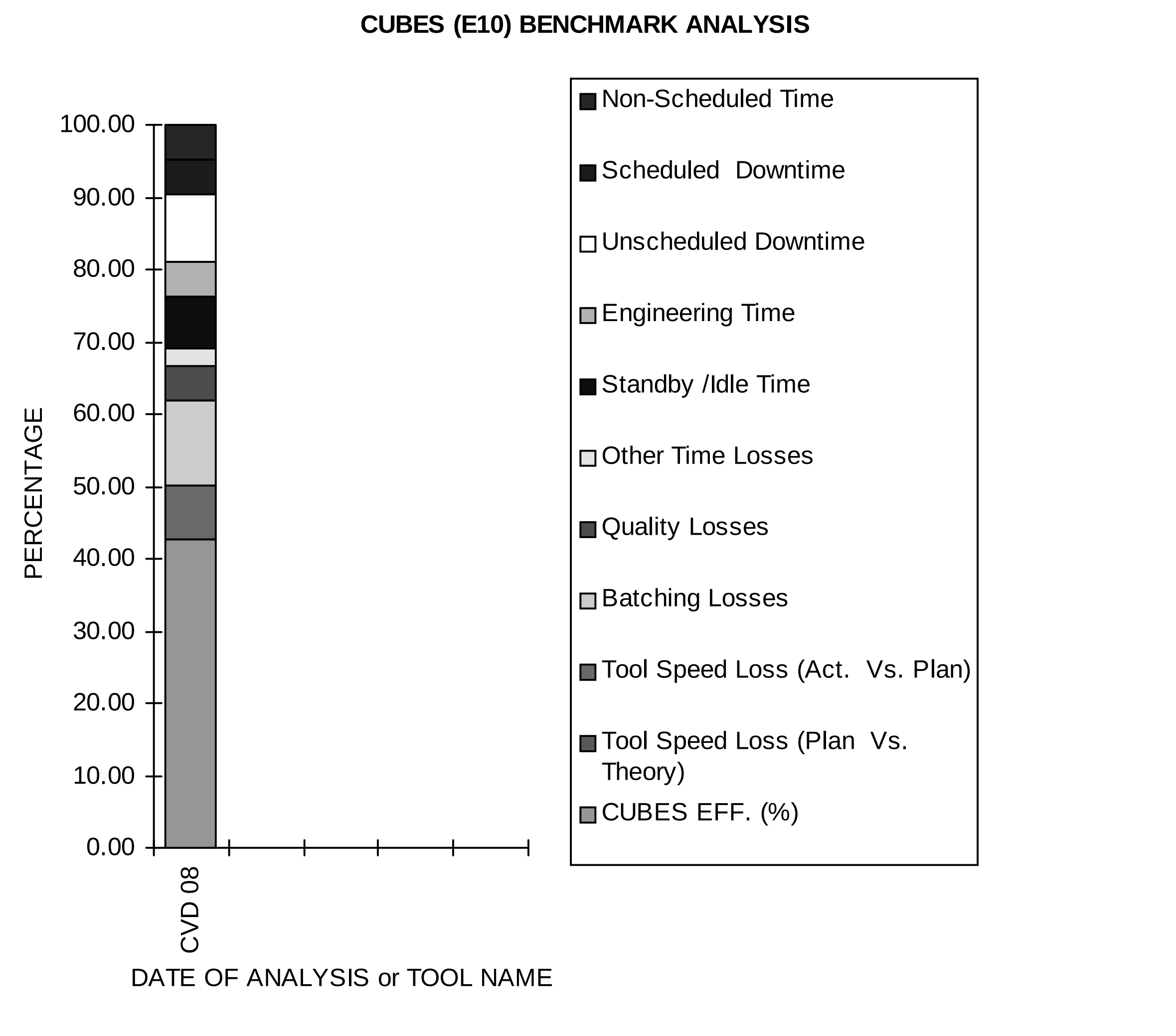


Figure 20 Benchmark Analysis Stacked Bar Graph

In the *Stacked Bar Graph*, there is room to display as many as five different bars. This allows the user to compare various what-if scenarios, look at trends, juxtapose the analysis of several tools, etc.

To include the current scenario in the *Stacked Bar Graph*, click on the *UPDATE WITH TODAY'S DATA* button (see Figure 21). The current data will be inserted in the leftmost blank column on the graph. In earlier versions this process was not automated. If all of the columns are filled, clear the shaded cells in one column for the current data. CUBES will place tool names or dates on the x-axis of the graph. To specify which type is preferred, answer the question above the Benchmark Data with a "T" for tool names or a "D" for dates. Next, in the column where the current data has just been placed, enter a tool name and a date in the gray-shaded *Tool* and *Date* rows. This information will now appear below the appropriate bar on the graph.

Use Tool name (T) or Date (D) in plot? T

TODAY'S CALCULATIONS						
	Tool	CVD 08				
	Date	4/21/95				
	INPUTS for Stacked BAR	CVD 08				
42.67	CUBES EFF. (%)	42.67				
0.00	Tool Speed Loss (Plan Vs. Theory)	0.00				
7.41	Tool Speed Loss (Act. Vs. Plan)	7.41				
11.85	Batching Losses	11.85				
4.74	Quality Losses	4.74				
2.38	Other Time Losses	2.38				
7.14	Standby /Idle Time	7.14				
4.76	Engineering Time	4.76				
9.52	Unscheduled Downtime	9.52				
4.76	Scheduled Downtime	4.76				
4.76	Non-Scheduled Time	4.76				

UPDATE WITH TODAY'S DATA | VIEW E10 BENCHMARK CHART | CORRECTIVE ACTION LOG

Figure 21 Benchmark Data

4.7 Overall Equipment Effectiveness Version

The OEE version of CUBES was developed to address equipment efficiency in terms of the TPM philosophy. Most of the TPM concepts discussed in this section are taken from Nakajima [3]. TPM is one methodology for improving tool efficiencies and thus improving the throughput level of the tool. The philosophy is not limited to dealing solely with breakdowns. The goal is to raise the level of overall equipment effectiveness by improving all related factors: availability, performance, and quality. As in the discussion of the E10 version, the discussion of this version will be broken out into the following five areas:

- Template header information,
- Summarized inputs,
- Input check,
- Numerical output, and
- Graphical output.

OUTPUT - CUBES (OEE) EFFICIENCY ANALYSIS TOOL

INPUTS	E10 TEMPLATE	OEE-TPM OPTIONAL INPUTS	OEE BENCHMARK DATA	PRINT OEE TEMPLATE

CUBES v. 2.5 (OEE) EFFICIENCY ANALYSIS TOOL
OEE & TPM'S 6 BIG LOSSES — 11/13/95

TOOL:	TOOL 1	SUPPLIER:	MODEL:	
TOOL ID:		SOURCE DATA DATE:		
BATCH SIZE:	1	SOURCE DATA FROM:		

SUMMARIZED INPUTS		INPUT CHECKS	SUMMARIZED OUTPUTS			THRUPUT
			OVERALL EQUIPMENT EFFECTIVENESS			
			OEE (%)	42.67		3226
Total Time	168.00					
Gross Time	168.00			OVERALL EFFECT (%)	INDIVIDUAL EFFECT (%)	THRUPUT INCREASE ANALYSIS IN UNITS
Non-Scheduled Time	8.00	TRUE				
Scheduled Downtime	8.00	TRUE	EFFICIENCY RATINGS			
Engineering Time	8.00	TRUE	Availability Efficiency (due to losses 1&2 below)		80.95	922
Unscheduled Downtime	16.00	TRUE	Performance Efficiency (due to losses 3&4)		58.56	2282
Standby/Idle Time	12.00	TRUE	Quality Efficiency (due to losses 5&6)(Rate of Quality)		90.00	358
Other Time Losses (ie. Prod. Test etc.)	4.00	TRUE	LOSSES DUE TO:			
			1) Setups/Adjustments	9.52	9.52	461
Ideal Tool Speed (UPH)	45.00	TRUE	2) Breakdowns	9.52	10.53	461
			3) Idling/Minor Stoppages	14.29	17.65	691
			4) Reduced Speed	19.26	28.89	1310
			5) Defects/Rework	2.43	5.13	174
			6) Yield	2.31	5.13	174

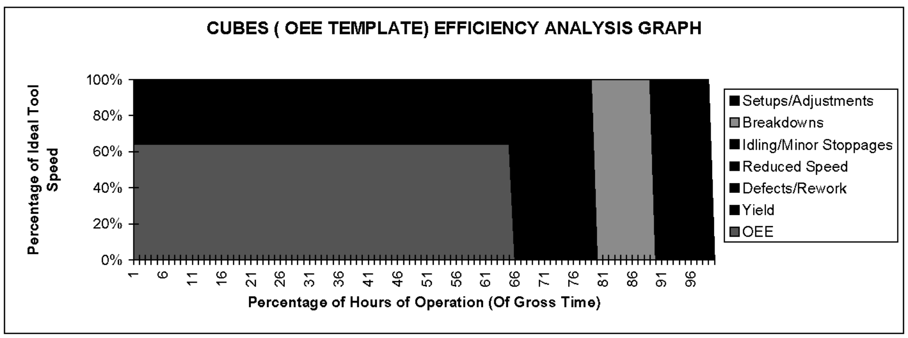


Figure 22 Sample Spreadsheet - OEE Output

The other graphs that are considered part of the OEE output are not shown here. See Section 4.7.5 for their descriptions.

4.7.1 Template Header Information

This section is the same as that on the *E10 Template*. See Section 4.6.1 for more information.

4.7.2 Summarized Inputs

The values in the *Summarized Inputs* (see Figure 23) are mapped from the *Input Summary* column in the *Input* section. In previous CUBES releases, the user could overwrite these values in the template by clicking on the appropriate cell and entering the new number. This is no longer possible. The user may not change anything on the actual template.

.

SUMMARIZED INPUTS		INPUT CHECKS
Total Time	168.00	
Gross Time	168.00	
Non-Scheduled Time	8.00	TRUE
Scheduled Downtime	8.00	TRUE
Engineering Time	8.00	TRUE
Unscheduled Downtime	16.00	TRUE
Standby/Idle Time	12.00	TRUE
Other Time Losses (ie. Prod. Test etc.)	4.00	TRUE
Ideal Tool Speed (UPH)	45.00	TRUE

Figure 23 Summarized Inputs Column

The following definitions are the same as those given in the *Inputs* subsections.

CELL D309 *Total Time*: in hours — the time period for which the data was gathered. In other words, the time period for which the analysis is relevant. For example, if the user wants to analyze a one week period and a work week is defined to be 24 hours/day for 7 days, then *Total Time* = 168 hours. (See *Gross Time* for the time period that is actually used in the analysis.)

CELL D310 *Gross Time*: in hours — the amount of time on which the analysis is based. *Gross Time* is determined according to the responses in the *OEE Optional Inputs*: Part 1. The default is *Gross Time = Total Time*.

CELL D312 *Nonscheduled Time*: (hours) — the time when the equipment is not scheduled to be used in production, such as unworked shifts, weekends, and holidays.

CELL D313 *Scheduled Downtime*: (hours) — the time when the equipment is not available to perform its intended function because of planned downtime events.

CELL D314 *Engineering Time*: (hours) — the time when the equipment is in a condition to perform its intended function (no equipment or process problems exist), but it is operated to conduct engineering experiments. This includes process engineering and equipment engineering.

CELL D315 *Unscheduled Downtime*: (hours) — the time when the equipment is not in a condition to perform its intended function because of unplanned downtime events.

CELL D316 *Standby/Idle Time*: (hours) — the time other than nonscheduled time when the equipment is available and in a condition to perform its intended function. Chemicals and facilities are available, but the equipment is not operated. This includes no operator, no product available, etc.

CELL D317 *Other Time Losses*: (hours) — this input allows for other events that detract from the total production time of the tool, i.e., production tests.

CELL D319 *Ideal Tool Speed*: in units per hour (UPH) — the process/equipment engineering plan for tool capabilities. This is equivalent to *Plan Tool Speed* from the Inputs Section.

4.7.3 Input Checks

The *Input Checks* column found on the right side of Figure 23 allows for a quick check of the validity of the CUBES analysis. The column consists of logical checks that ensure the summarized inputs are appropriate. The two possible column entries are “TRUE” and “FALSE”. As long as all entries are “TRUE”, the results of CUBES are valid. If one or more are “FALSE”, then it is inappropriate to draw any conclusions from the analytical or graphical outputs.

Table 4 lists all of the checks that are made.

Table 4 OEE Input Checks

Row	Check (“TRUE” entered if the following holds)
312	Scheduled Downtime ≤ (Total Time - Nonsched.)
313	Scheduled Downtime ≤ (Total Time - Nonsched.)
314	Engineering Time ≤ (Total Time - Nonsched.- Sched.)
315	Unscheduled Time ≤ (Total Time - Nonsched.- Sched.- Eng.)
316	Standby/Idle Time ≤ (Total Time - Nonsched.- Sched.- Eng.- Unsched.)
317	Other Time Losses ≤ (Total Time - Nonsched.-Sched.- Eng.- Unsched.- Standby/Idle)
319	Actual Production ≤ (Total Time - All time losses) x Plan Tool Speed

4.7.4 Summarized Outputs

CUBES focuses on two key metrics: 1) OEE and 2) tool throughput. Both of these are located in the *OEE (%)* row of the *Summarized Outputs* section. The OEE is the product of the tool’s three efficiency ratings. The tool throughput is the number of “good” units that were produced during the gross time over which the analysis is based. To see the actual formulations used to calculate these metrics, go to Appendix A. The *Summarized Outputs* section will be broken down and described in terms of three important subsections: *Losses Due To, Efficiency Ratings,* and *Overall Equipment Effectiveness.*

4.7.4.1 Losses Due To

The six items listed in this section are the summarized inputs converted into the “six big losses” of TPM. (For formulations, see Appendix A.) As explained by Nakajima (1988), TPM classifies losses of equipment effectiveness into the following six big losses:

1. Setups/ Adjustments,
2. Breakdowns,
3. Idling/Minor Stoppages,
4. Reduced Speed,
5. Defects/Rework, and
6. Yield.

Each contributes to the inefficiency of the tool as a speed degradation or as a detractor from total productive time. Each of the six big losses is characterized in three ways: individual effect, overall effect, and throughput (or thruput) loss. The individual effect is the impact of the loss on tool efficiency if it were considered in isolation, that is, if only this factor is considered. This information is useful in indicating how large this particular problem is. The overall effect is the impact of the loss on tool efficiency with respect to all other losses. This information indicates how much of the total efficiency loss is attributable to this particular factor. Finally, the throughput loss is the amount of potential throughput that is not achieved because of the particular loss. This quantity represents how many units throughput could increase if this problem were fixed. Note that the individual and overall effects are percentages and the throughput loss is an integer number of units, i.e., wafers (see Figure 24).

The definitions of the six big losses are as follows:

1. *Setup and Adjustment Losses*: the losses resulting when production of one product type ends and the tool needs to be adjusted to meet the requirements of another product type. The goal is to minimize setup times.
2. *Breakdown Losses*: the losses caused by unexpected equipment failures or chronic minor breakdowns. The goal is to have zero breakdowns on the equipment (or tool).
3. *Idling and Minor Stoppage Losses*: the losses that occur when production is interrupted by temporary malfunctions or when the machine is idle because no operator is available, no product is available, etc. Again, the goal is to reduce these occurrences to zero.
4. *Reduced Speed Losses*: the losses due to the difference between the tool’s ideal speed and actual operating speed. The goal is to eliminate this gap.
5. *Quality Defects and Rework Losses*: the losses in product quality that are caused by this particular tool when it malfunctions. The goal is zero defects.
6. *Yield Losses* (also called Startup Losses): scrapped units and the losses in yield that occur during early stages of production. The latter is the potential production that is lost between when production starts and when the process stabilizes. The goal is to minimize these losses.

SUMMARIZED OUTPUTS				THRUPUT
OVERALL EQUIPMENT EFFECTIVENESS				
OEE (%)		42.67		3226
		OVERALL EFFECT (%)	INDIVIDUAL EFFECT (%)	THRUPUT INCREASE ANALYSIS IN UNITS
EFFICIENCY RATINGS				
Availability Efficiency (due to losses 1&2 below)			80.95	922
Performance Efficiency (due to losses 3&4)			58.56	2282
Quality Efficiency (due to losses 5&6)(Rate of Quality)			90.00	358
LOSSES DUE TO:				
1) Setups/Adjustments		9.52	9.52	461
2) Breakdowns		9.52	10.53	461
3) Idling/Minor Stoppages		14.29	17.65	691
4) Reduced Speed		19.26	28.89	1310
5) Defects/Rework		2.43	5.13	174
6) Yield		2.31	5.13	174

Figure 24 Summarized Output Columns

4.7.4.2 Efficiency Ratings

The next subsection, *Efficiency Ratings*, expresses the six big losses as tool efficiency ratings. The actual formulations may be found in Appendix A. The three efficiency ratings are *availability*, *performance*, and *quality*. Equipment availability is directly related to downtime. For this reason, the availability efficiency rating is based on breakdown losses and setup/adjustment losses. *Availability Efficiency* is the ratio of the net productive time (Gross Time - all downtime) to *Gross Time* (from the *Summarized Inputs*). Equipment performance is based on speed losses and net productive time (i.e., reduced speed losses and idling/minor stoppage losses). So, *Performance Efficiency* is the ratio of *Plan Tool Speed* to *Actual Tool Speed*. The quality rating of the tool is lowered by yield losses and defects in the process that will require rework. The *Quality Efficiency* is the ratio of good throughput to total throughput.

4.7.4.3 Overall Equipment Effectiveness

The third subsection, *Overall Equipment Effectiveness,* measures the rate of equipment effectiveness. It combines the factors of operating time, tool speed, and quality of equipment operation.

$$\textbf{OEE} = \text{availability efficiency} \times \text{performance efficiency} \times \text{quality efficiency}$$

Note: *Quality Efficiency* is also commonly referred to as rate of quality.

All three efficiency ratings are used in computing OEE. Therefore, high OEE can be achieved only when all three rates are high. OEE is a consistent measure of how productive a tool is or can be. It is the linkage that allows the TPM philosophy to be applied over a broad range of tools in a consistent manor.

TPM has a double goal: zero breakdowns and zero defects. When breakdowns and defects are eliminated, equipment operation rates improve, costs are reduced, and inventory can be minimized. OEE is the quantitative measure that puts this TPM philosophy into tangible numbers. Firms can use CUBES and TPM to address their efficiency losses and begin to realize their goals.

4.7.5 Graphs (OEE)

CUBES offers four graphical outputs. The first is the CUBES *Efficiency Analysis Graph* located on the bottom half of the *OEE Template*. This graph is a visual analysis of how the six big losses of TPM are impacting the tool's overall efficiency or OEE. The x-axis of the graph is time and the y-axis is speed. The vertical bars represent time losses while the horizontal bars are speed losses. The chart is generated using the values in the *Overall Effect* column in the *Summarized Output* section. The green bar found in the lower left corner of the graph is the *Overall Equipment Effectiveness*. This is the section of the graph that the user wishes to maximize. What-if scenarios can be played out using CUBES, and the resulting changes in efficiency will be evident in the graph. The graph allows comparisons among each of the six big losses. This can assist users in ranking what improvements are most beneficial and where efforts should be concentrated to improve tool efficiencies.

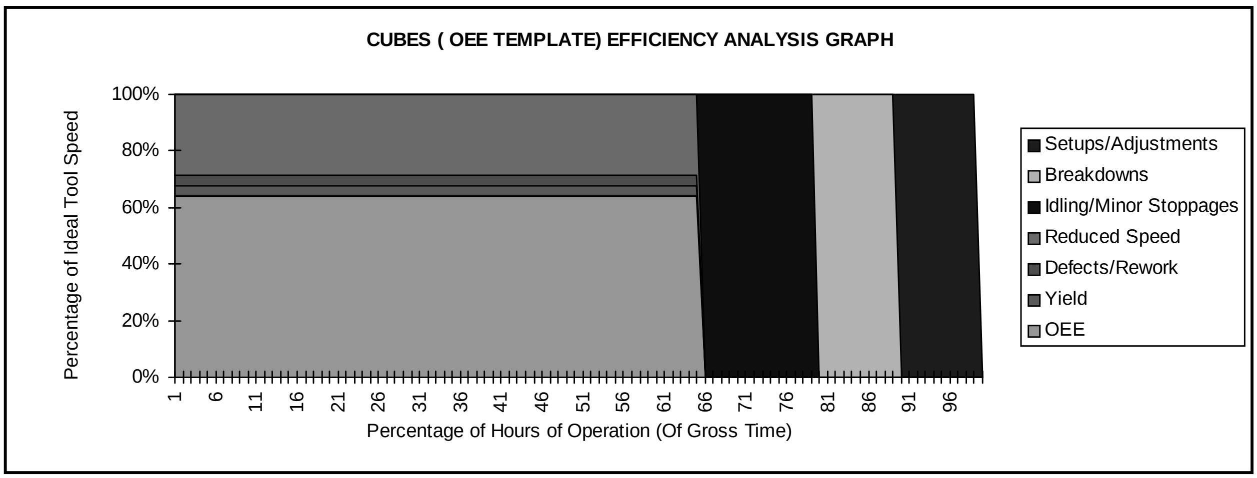


Figure 25 CUBES Efficiency Analysis Graph

The second graph offered in CUBES is the *Throughput Leverage Analysis Graph*. It is found several columns to the right of the *OEE Template*. This graphical analysis allows visual comparisons among the throughput losses resulting from each of the six big losses. The bars in the graph are generated using the *Summarized Outputs Throughput* column.

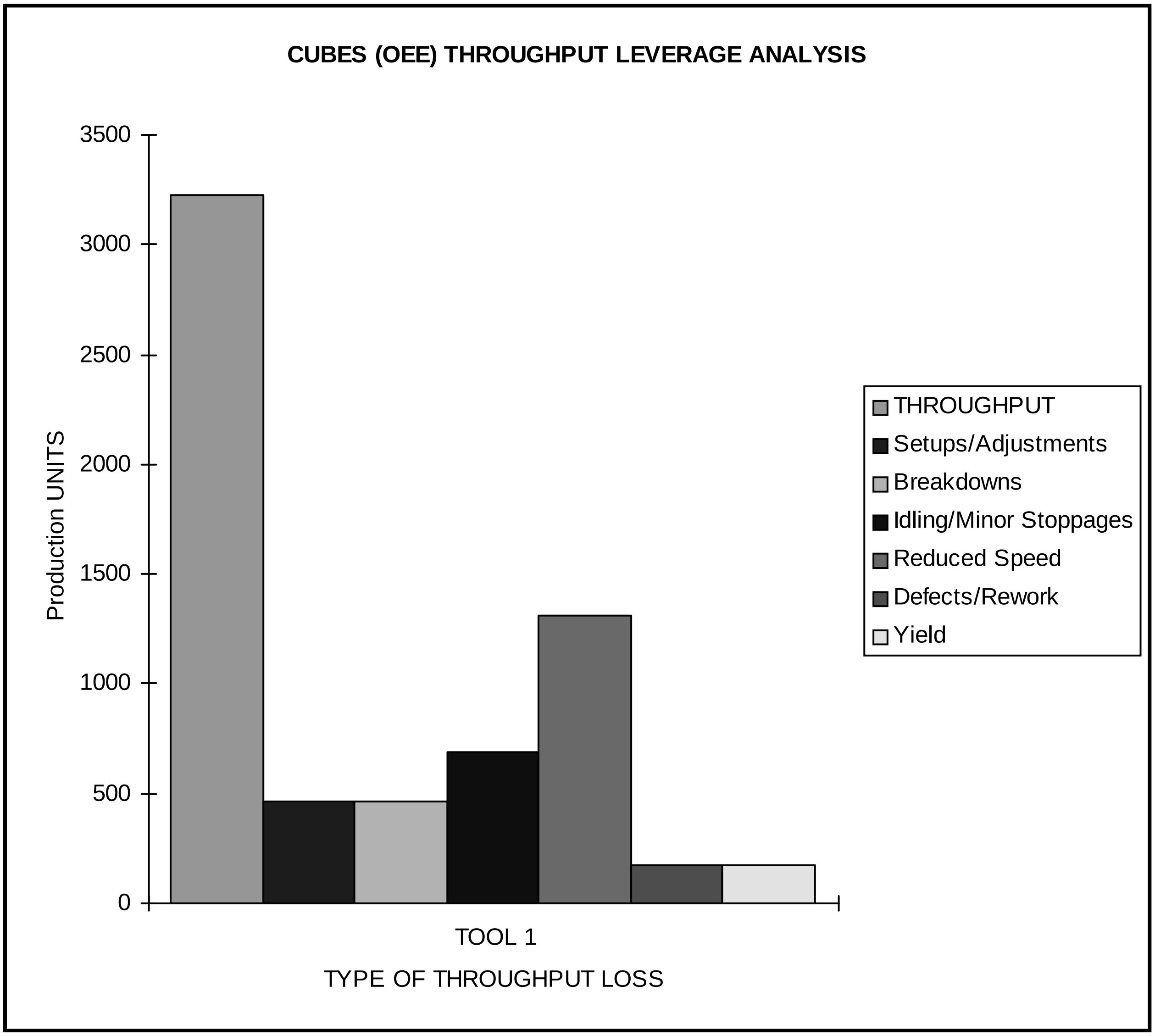


Figure 26 Throughput Leverage Analysis Graph

CUBES' third graph is the *Tool Efficiency Analysis Pie Chart.* It is found several columns to the right of the *Throughput Leverage Analysis Graph*. This graphical analysis offers an alternative way to view the *Overall Effect* values. The "pie" represents the potential 100% CUBES efficiency. Each piece of the pie is associated with a loss factor's *Overall Effect* percentage.

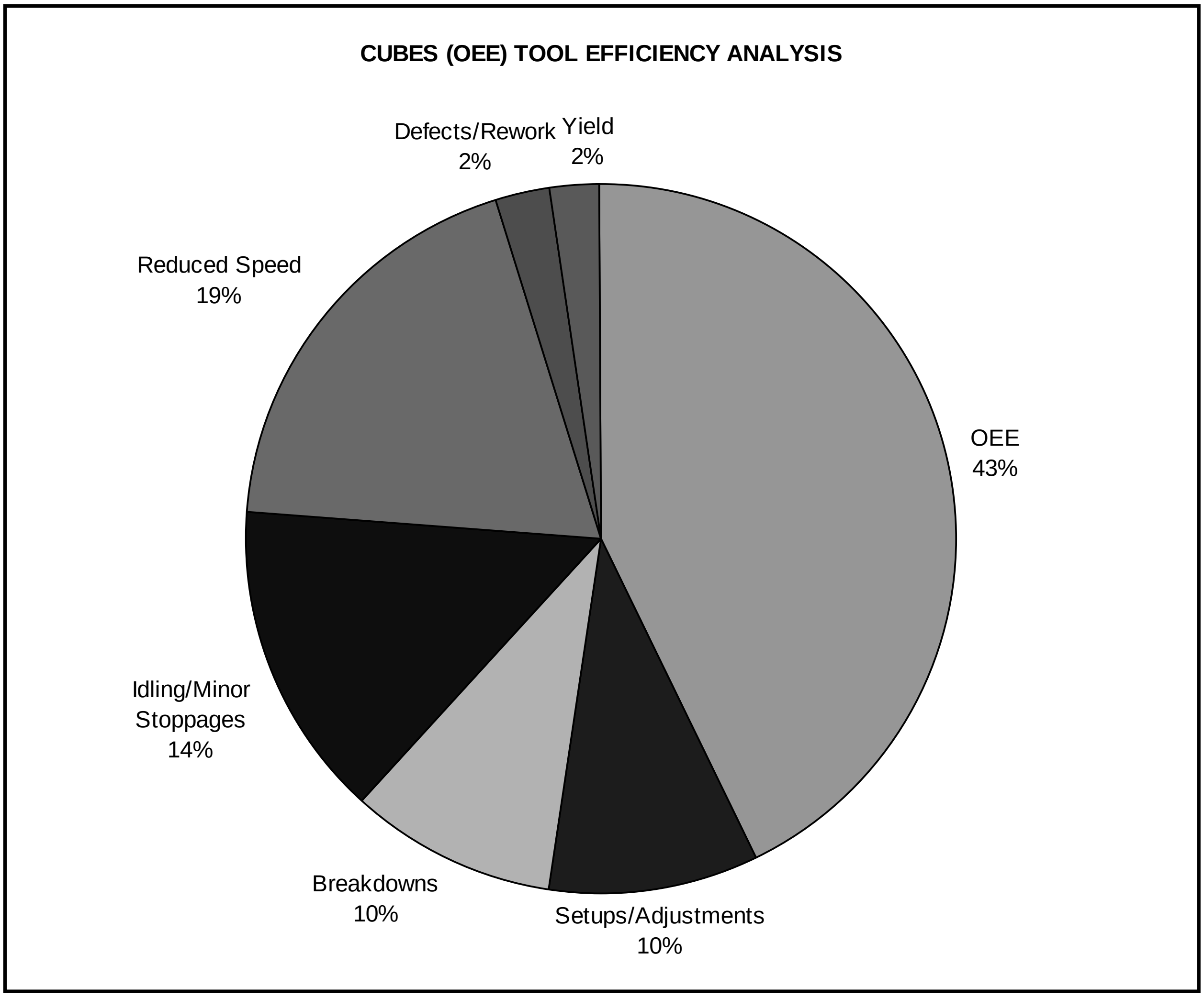


Figure 27 Tool Efficiency Analysis Pie Chart

CUBES' fourth graph is the *Benchmark Analysis Stacked Bar Graph.* It is found several columns to the right of the *Tool Efficiency Analysis Pie Chart*. This graphical analysis offers another alternative way to view the *Overall Effect* values. The height of the stacked bar represents 100% CUBES efficiency. Each layer of the stacked bar is a loss factor's *Overall Effect* percentage.

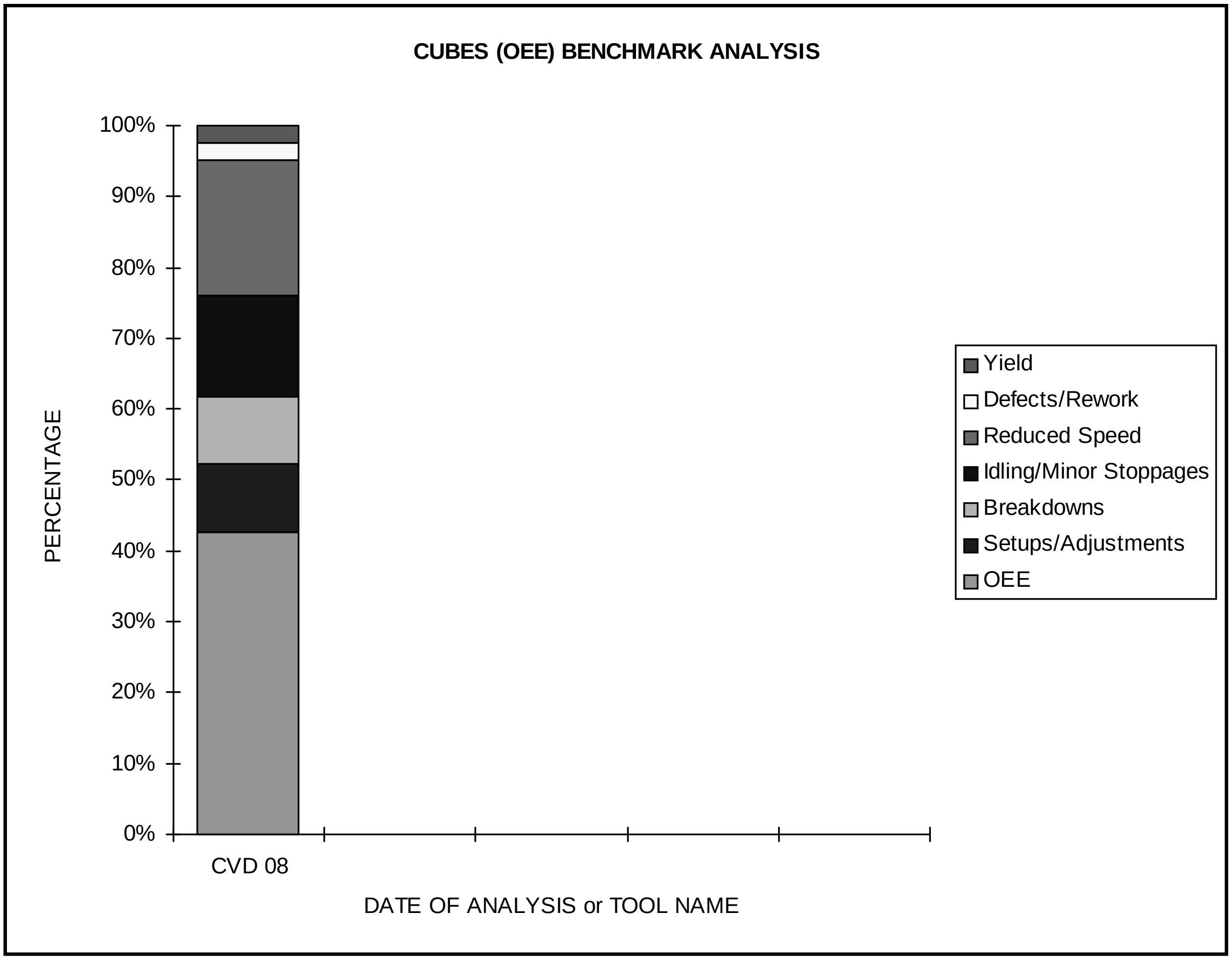


Figure 28 Benchmark Analysis Stacked Bar Graph

In the *Stacked Bar Graph,* there is room to display as many as five different graphs. This allows the user to compare various what-if scenarios, look at trends, juxtapose the analysis of several tools, etc.

To include the current scenario in the *Stacked Bar Graph,* click on *the UPDATE WITH TODAY'S DATA* button (see Figure 29). The current data will be inserted in the leftmost blank column on the graph. In earlier versions this process was not automated. If no columns are blank, clear the shaded cells in one column for the current data. CUBES will place tool names or dates on the x-axis of the graph. To specify which type is preferred, answer the question above the Benchmark Data with a "T" for tool names or a "D" for dates. Next, in the column where the current data has just been placed, enter a tool name and a date in the gray-shaded *Tool* and *Date* rows. This information will now appear below the appropriate bar on the graph.

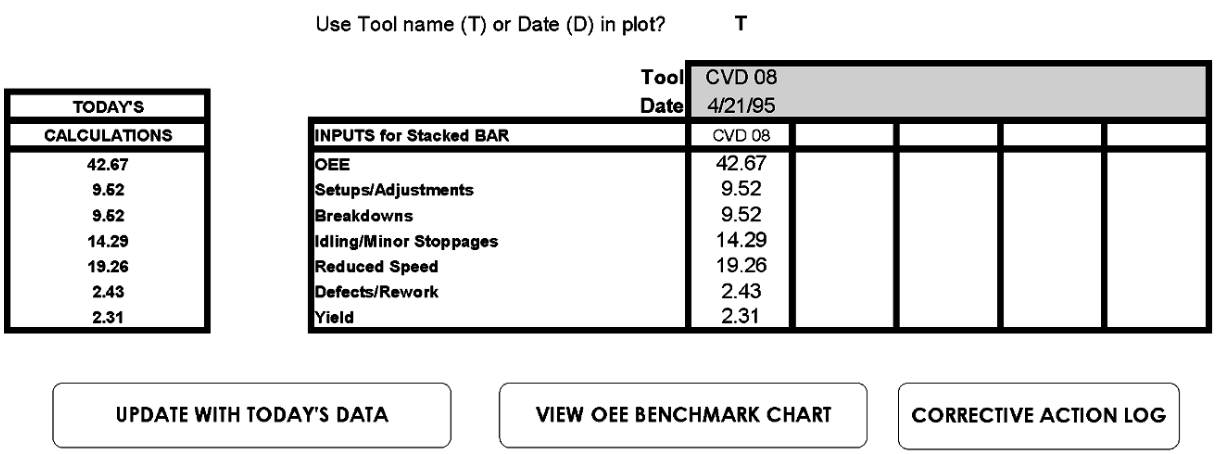


Figure 29 Benchmark Data

4.8 Buttons

Throughout the CUBES spreadsheet, many buttons are available to the user. They offer such functionality as printing various screens, moving the user from section to section, and updating graphs.

Table 5 is an alphabetical listing of all the buttons and their particular functions.

Table 5 Buttons

BUTTON	FUNCTION
ACRONYMS LIST	Transfers user to the Acronyms List.
CORRECTIVE ACTION LOG	Transfers user to the Corrective Action Log.
E10 BENCHMARK DATA	Transfers user to Benchmark Data associated with the E10 template.
E10 TEMPLATE	Transfers user to E10 Output section.
INPUTS	Transfers user to top of Input section.
OEE BENCHMARK DATA	Transfers user to Benchmark Data associated with the OEE template.

BUTTON	FUNCTION
OEE-TPM OPTIONAL INPUTS	Transfers user to OEE Optional Inputs section.
OEE TEMPLATE	Transfers user to OEE Output section.
PRINT ACRONYMS	Prints the entries in the Acronyms List.
PRINT CORRECTIVE ACTION LOG	Prints the entries in the Corrective Action Log.
PRINT E10 BENCHMARK CHART	Prints the Benchmark Analysis stacked bar graph associated with the E10 template.
PRINT E10 BENCHMARK CHART WITH DATA	Prints the E10 Benchmark Analysis stacked bar graph and the Benchmark Data together on one page.
PRINT E10 LEVERAGE ANALYSIS CHART	Prints the Throughput Leverage Analysis graph associated with the E10 template.
PRINT E10 TEMPLATE	Prints E10 Template.
PRINT E10 TOOL EFFICIENCY CHART	Prints the Tool Efficiency Analysis pie chart associated with the E10 template.
PRINT GLOBAL INPUTS	Prints the Global inputs section.
PRINT LEVEL 1 INPUTS	Prints the Level 1 Inputs section.
PRINT LEVEL 2 INPUTS	Prints the Level 2 Inputs section.
PRINT LEVEL 3 INPUTS	Prints the Level 3 Inputs section.
PRINT LEVEL 4 INPUTS	Prints the Level 4 Inputs section.
PRINT OEE BENCHMARK CHART	Prints the Benchmark Analysis Stacked Bar graph associated with the OEE template.
PRINT OEE BENCHMARK CHART WITH DATA	Prints the OEE Benchmark Analysis stacked bar graph and the Benchmark Data together.
PRINT OEE LEVERAGE ANALYSIS CHART	Prints the Throughput Leverage Analysis graph associated with the OEE template.
PRINT OEE TEMPLATE	Prints OEE Template.
PRINT OEE TOOL EFFICIENCY CHART	Prints the Tool Efficiency Analysis pie chart associated with the OEE template.
READ CUBES DATA FILE	Reads in an ASCII text file which contains CUBES input data.
RESET DATA	Resets all input fields to the default values.
UPDATE WITH TODAY'S DATA	Places the latest data from the CUBES template into a Benchmark Data column and places a new bar on the Efficiency Analysis Stacked Bar graph.
USE STANDARD NAMES	Changes all labels back to the original CUBES terminology.
USE TESTER SPECIFIC NAMES	Changes all labels to the tester specific terminology.
USE USER-DEFINED NAMES	Changes all labels to the user-specified terminology.
VIEW E10 BENCHMARK CHART	Transfers the user to the Efficiency Analysis stacked bar graph associated with data from the E10 template.
VIEW OEE BENCHMARK CHART	Transfers the user to the Efficiency Analysis Stacked Bar graph associated with data from the OEE template.
WRITE CUBES DATA FILE	Writes the current CUBES input data to an ASCII file.

4.9 E10 / OEE Comparison

CUBES is a generic package, built to accommodate and analyze a variety of tools. It allows the user to evaluate throughput and efficiency in three ways:

1. Detailed analysis by speed factor and SEMI E10 equipment state;
2. The three OEE calculations of availability, performance, and quality; and
3. The six big losses of total productive maintenance (TPM).

The E10 version of CUBES is used for 1 and its OEE version is used for 2 and 3. For the efficiency numbers of both versions to be the same, i.e., CUBES Efficiency = OEE, the following must be true:

– *Theoretical Tool Speed = Plan Tool Speed*

– The OEE Optional Inputs are set to their default answers: Part 1: YES, YES
Part 2: NO, NO, NO.

Table 6 shows the connections between the two sets of terminology.

Table 6 OEE to SEMI E10 Conversion Table

CUBES: OEE to SEMI E10 Conversion Table		
OEE EFFICIENCY CALCULATIONS	**OEE LOSSES**	**TOTAL EQUIPMENT EFFECTIVENESS E-10 EFFICIENCY CALCULATIONS**
AVAILABLILITY	Setups/Adjustments	Non-Scheduled Time Scheduled Downtime
PERFORMANCE	Breakdowns Idling/Minor Stoppages	Unscheduled Downtime Engineering Time Standby/Idle Time Other Time Losses
	Reduced Speed	Tool Speed Losses Average Batch Size
QUALITY	Defects/Rework Yield	Quality Losses

5 REFERENCES

1. Konopka, J., “Capacity Utilization Bottleneck Efficiency System (CUBES)—A New Model to Analyze Tool Efficiency and Throughput—An Overview,” working paper, 1994.
2. Konopka, J., “CUBES: A New Model to Analyze Tool Efficiency,” SEMATECH November/December 1993 Communiqué.
3. Konopka, J. and J. Fowler, “A TPM-Inspired Factory Throughput Analysis Tool,” Proceedings of International Symposium on Semiconductor Manufacturing (ISSM), Tokyo, Japan, 1994.
4. Nakajima, S., *Introduction to TPM: Total Productive Maintenance*, Productivity Press, Cambridge, MA, 1988.
5. Trybula, W. and M. Pratt, “Applying SEMI E10 Guidelines to Manufacturing,” *Proceedings of 1994 IEEE International Electronics Manufacturing Technology (IEMT*), Piscataway, NJ, 1994.
6. *SEMI E10-92 Guideline for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM).*

APPENDIX A — OEE FORMULATIONS

(for E10 and Speed inputs and possible Gross Time adjustments made according to OEE Optional Inputs, Part 1)

PART 1 - Availability Adjustment

INCLUDE IN OEE AVAILABILITY CALCULATION: (Default is YES in

NONSCHEDULED HRS(YES OR	**YES**
PLANNED DOWNTIME (YES OR NO)	**YES**

AVAILABILITY EFFICIENCY =

$$\frac{(\text{TotalTime} - \text{NonS} - \text{Unsch})}{(\text{Total Time} \quad - \textit{NonS} \text{ if "NO" to including in OEE calculation} \quad - \textit{Sch} \text{ if "NO" to including in OEE calculation})}$$

PERFORMANCE EFFICIENCY =

$$\left[\frac{(\text{Total Time} - \text{NonS} - \text{Sch} - \text{Unsch} - \text{Eng} - \text{Standby} - \text{Other})}{(\text{Total Time} - \text{NonS} - \text{Sch} - \text{Unsch})}\right] \times \left[\frac{(\text{AvgBatching \%}) * (\text{ActToolSpeed})}{\text{PlanToolSpeed}}\right]$$

QUALITY EFFICIENCY =

$$\frac{\left[\begin{array}{l}(\text{Total Time} - \text{NonS} - \text{Sch} - \text{Unsch} \\ - \text{Eng} - \text{Standby} - \text{Other})\end{array}\right] - \left[\begin{array}{l}\text{Quality Losses} * (\text{Total Time} - \text{NonS} - \text{Sch} - \text{Unsch} \\ - \text{Eng} - \text{Standby} - \text{Other})\end{array}\right]}{(\text{Total Time} - \text{NonS} - \text{Sch} - \text{Unsch} - \text{Eng} - \text{Standby} - \text{Other})}$$

Which Simplifies to:

(1 - Quality Losses)

SETUP/ADJUSTMENT LOSSES =

$$\frac{(\text{NonS if "YES" to including in OEE calculation} + \text{Sch if "YES" to including in OEE calculation})}{(\text{Total Time} - (\text{NonS}_{\text{if "NO"}}) - (\text{Sch} -_{\text{if "NO"}})}$$

BREAKDOWN LOSSES =

$$\frac{\text{Unsch}}{(\text{Total Time} - \text{NonS} - \text{Sch})}$$

IDLING / MINOR STOPPAGES LOSSES =

$$\frac{(\text{Eng} + \text{Standby} + \text{Other})}{(\text{Total Time} - \text{NonS} - \text{Sch} - \text{Unsch})}$$

REDUCED SPEED LOSSES =

$$\frac{1 - (\text{AvgBatching \%}) * (\text{ActToolSpeed})}{\text{PlanToolSpeed}}$$

DEFECTS/REWORK LOSSES =

$$\left[1 - \sqrt{(1 - \frac{\text{Quality Losses})}{100}}\right] \times \left[\frac{\text{Defect / Rework \%}}{50}\right]$$

YIELD LOSSES =

$$\left[1 - \sqrt{(1 - \frac{\text{Quality Losses})}{100}}\right] \times \left[\frac{\text{Scrap \%}}{50}\right]$$

APPENDIX B — SAMPLE OUTPUT

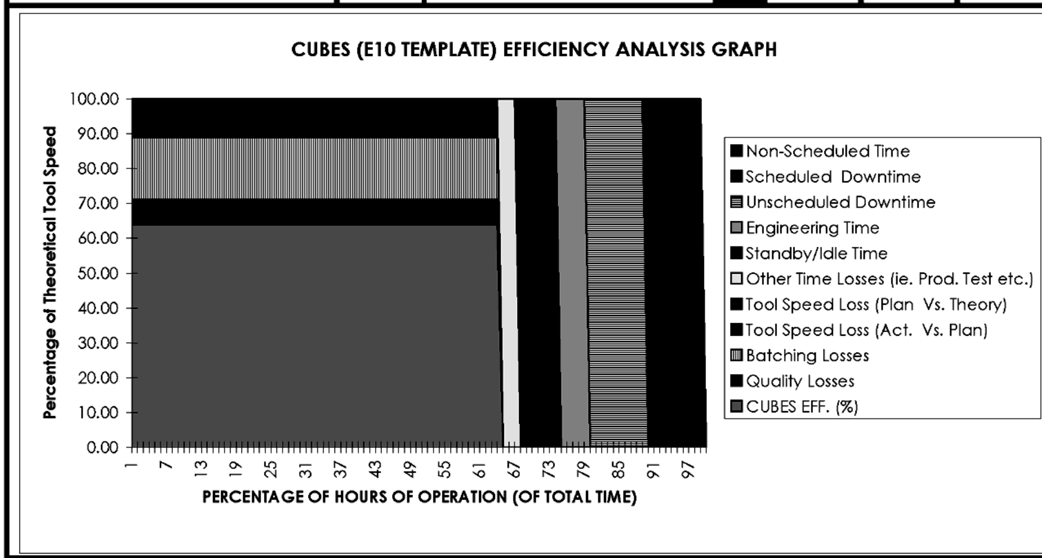
OUTPUT - CUBES (E10 TEMPLATE) EFFICIENCY ANALYSIS TOOL

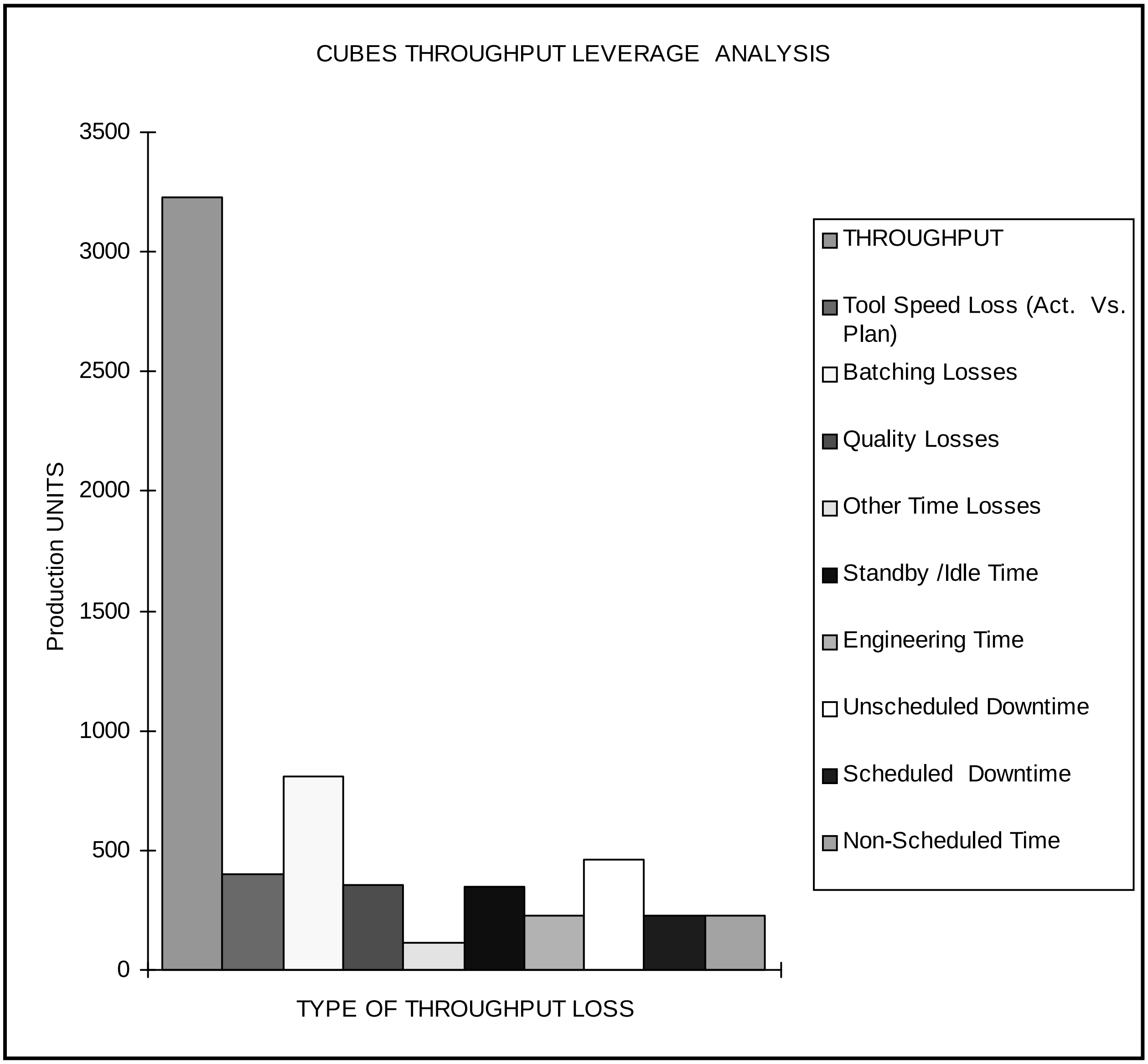
INPUTS | OEE TEMPLATE | E10 BENCHMARK DATA | PRINT E10 TEMPLATE

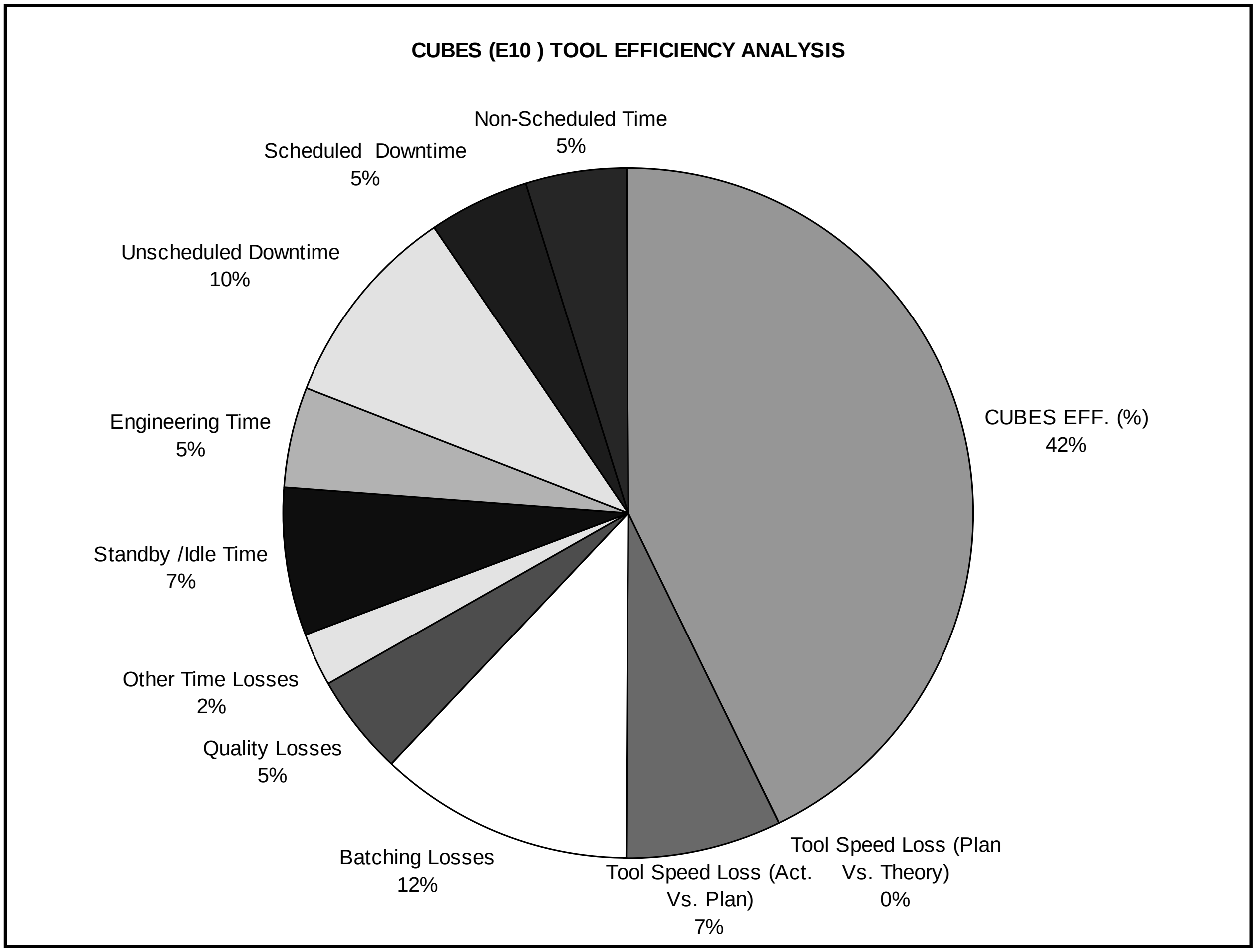
CUBES v. 2.5 (E10 TEMPLATE) EFFICIENCY ANALYSIS TOOL 11/13/95

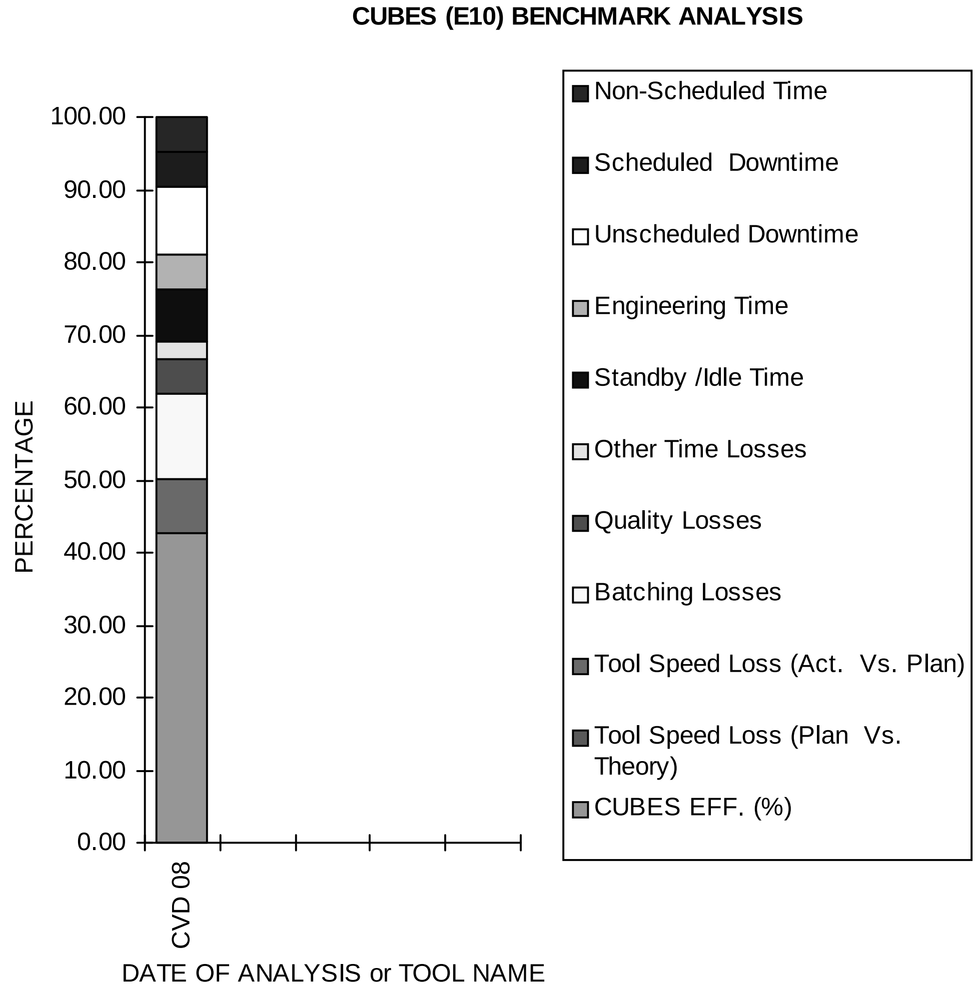
TOOL:	TOOL 1	SUPPLIER:	MODEL:	
TOOL ID:		SOURCE DATA DATE:		
BATCH SIZE:	1	SOURCE DATA FROM:		

SUMMARIZED INPUTS		INPUT CHECKS	SUMMARIZED OUTPUTS	CUBES EFFICIENCY (%)		THRUPUT
			Actual Production	42.67		3226
				OVERALL EFFECT (%)	INDIVIDUAL EFFECT (%)	THRUPUT INCREASE ANALYSIS IN UNITS
Theoretical Tool Speed (UPH)	45		Speed Efficiency (%) 64.00			
Total Time	168		Time Efficiency(%) 66.67			
Plan Tool Speed (UPH)	45	TRUE	Tool Speed Loss (Plan Vs. Theory)	0.00	0.00	
Actual Tool Speed (UPH)	40	TRUE	Tool Speed Loss (Act. Vs. Plan)	7.41	11.11	403
Average Batch Size (% Full)	80	TRUE	Batching Losses	11.85	20.00	806
Quality Losses (% Loss)	10	TRUE	Quality Losses	4.74	10.00	358
Other Time Losses (ie. Prod. Test etc.)	4.00	TRUE	Other Time Losses (ie. Prod. Test etc.)	2.38	3.45	115
Standby /Idle Time	12.00	TRUE	Standby/Idle Time	7.14	9.38	346
Engineering Time	8.00	TRUE	Engineering Time	4.76	5.88	230
Unscheduled Downtime	16.00	TRUE	Unscheduled Downtime	9.52	10.53	461
Scheduled Downtime	8.00	TRUE	Scheduled Downtime	4.76	5.00	230
Non-Scheduled Time	8.00	TRUE	Non-Scheduled Time	4.76	4.76	230




CUBES THROUGHPUT LEVERAGE ANALYSIS
Production UNITS
3500
3000
2500
2000
1500
1000
500
0
TYPE OF THROUGHPUT LOSS
THROUGHPUT
Tool Speed Loss (Act. Vs. Plan)
Batching Losses
Quality Losses
Other Time Losses
Standby /Idle Time
Engineering Time
Unscheduled Downtime
Scheduled Downtime
Non-Scheduled Time


CUBES (E10) TOOL EFFICIENCY ANALYSIS
Non-Scheduled Time 5%
Scheduled Downtime 5%
Unscheduled Downtime 10%
Engineering Time 5%
Standby /Idle Time 7%
Other Time Losses 2%
Quality Losses 5%
Batching Losses 12%
Tool Speed Loss (Act. Vs. Plan) 7%
Tool Speed Loss (Plan Vs. Theory) 0%
CUBES EFF. (%) 42%



Use Tool name (T) or Date (D) in plot? **T**

Tool	CVD 08				
Date	4/21/95				
INPUTS for Stacked BAR	CVD 08				
CUBES EFF. (%)	42.67				
Tool Speed Loss (Plan Vs. Theory)	0.00				
Tool Speed Loss (Act. Vs. Plan)	7.41				
Batching Losses	11.85				
Quality Losses	4.74				
Other Time Losses	2.38				
Standby /Idle Time	7.14				
Engineering Time	4.76				
Unscheduled Downtime	9.52				
Scheduled Downtime	4.76				
Non-Scheduled Time	4.76				

TODAY'S CALCULATIONS
42.67
0.00
7.41
11.85
4.74
2.38
7.14
4.76
9.52
4.76
4.76

OUTPUT - CUBES (OEE) EFFICIENCY ANALYSIS TOOL

INPUTS | E10 TEMPLATE | OEE-TPM OPTIONAL INPUTS | OEE BENCHMARK DATA | PRINT OEE TEMPLATE

CUBES v. 2.5 (OEE) EFFICIENCY ANALYSIS TOOL

OEE & TPM'S 6 BIG LOSSES

11/13/95

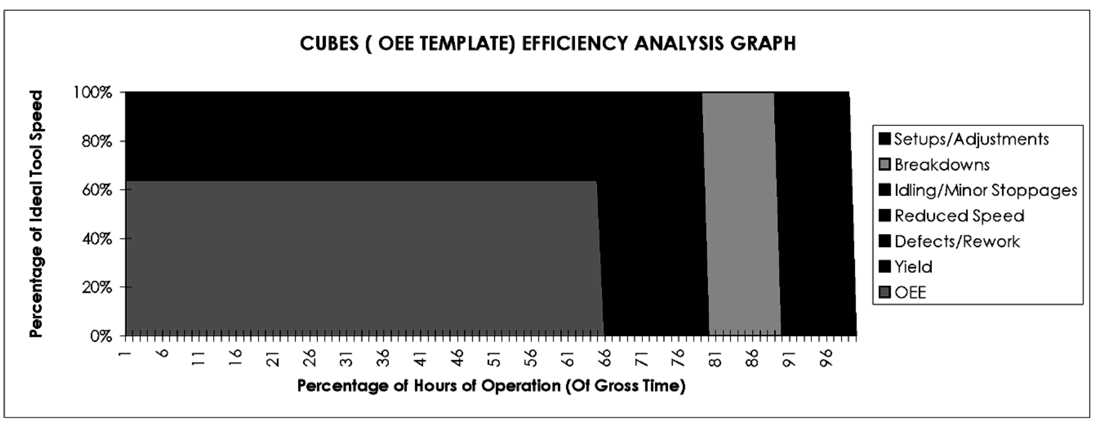
TOOL: TOOL 1
TOOL ID:
BATCH SIZE: 1

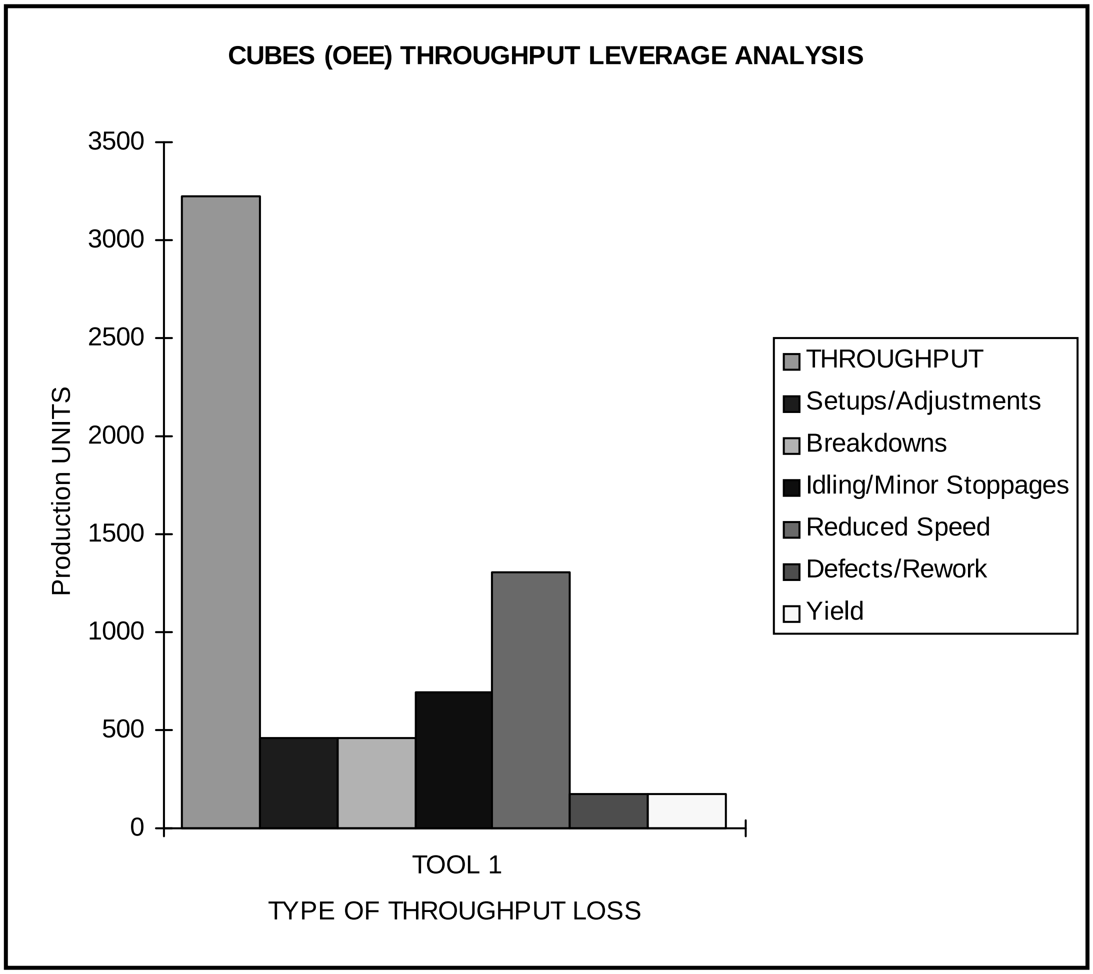
SUPPLIER:
SOURCE DATA DATE:
SOURCE DATA FROM:

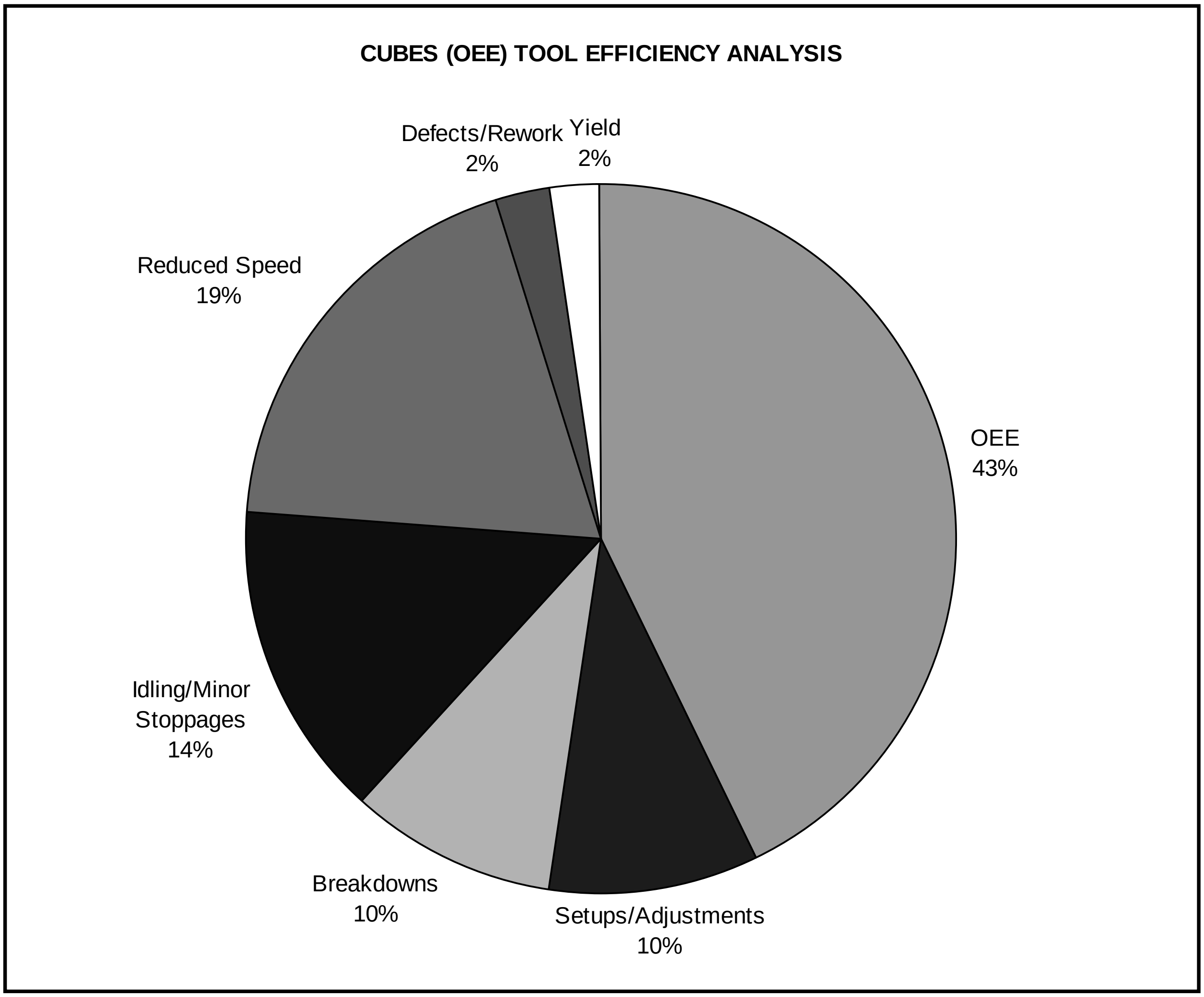
MODEL:

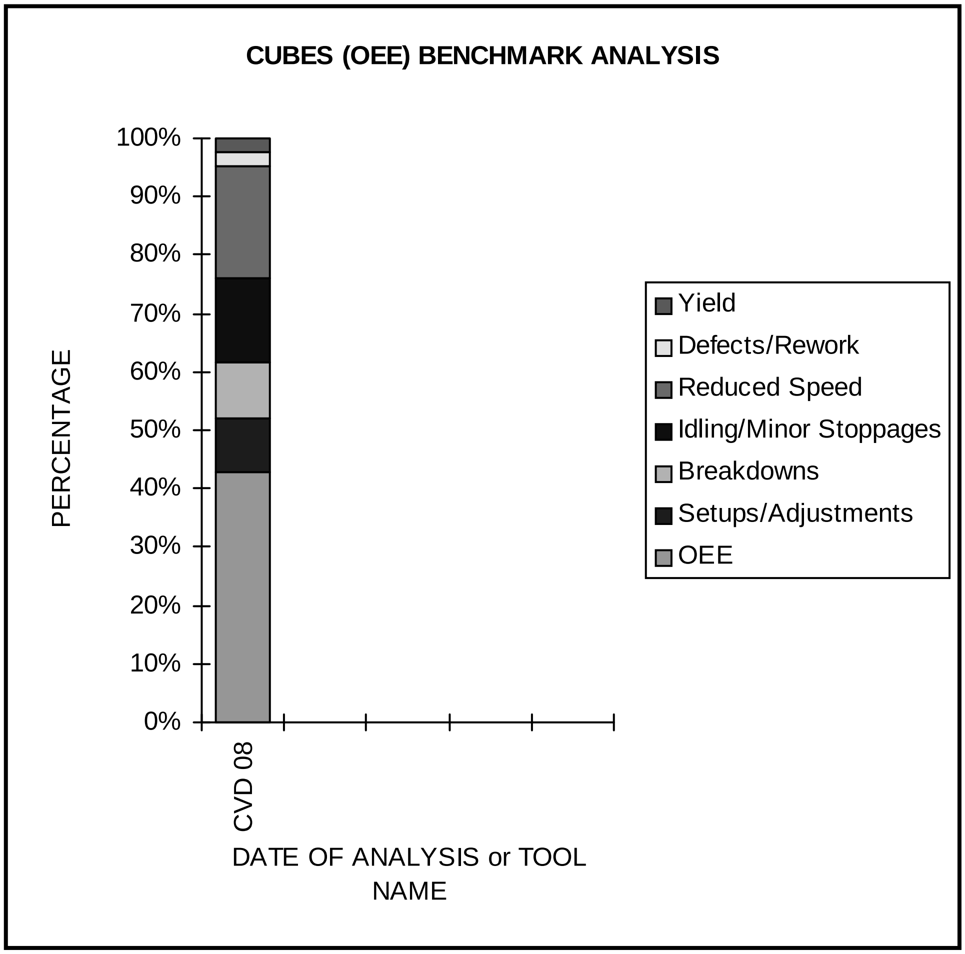
SUMMARIZED INPUTS		INPUT CHECKS
Total Time	168.00	
Gross Time	168.00	
Non-Scheduled Time	8.00	TRUE
Scheduled Downtime	8.00	TRUE
Engineering Time	8.00	TRUE
Unscheduled Downtime	16.00	TRUE
Standby/Idle Time	12.00	TRUE
Other Time Losses (ie. Prod. Test etc.)	4.00	TRUE
Ideal Tool Speed (UPH)	45.00	TRUE

SUMMARIZED OUTPUTS	OVERALL EFFECT (%)	INDIVIDUAL EFFECT (%)	THRUPUT INCREASE ANALYSIS IN UNITS
OVERALL EQUIPMENT EFFECTIVENESS — OEE (%)	42.67		THRUPUT 3226
EFFICIENCY RATINGS			
Availability Efficiency (due to losses 1&2 below)		80.95	922
Performance Efficiency (due to losses 3&4)		58.56	2282
Quality Efficiency (due to losses 5&6)(Rate of Quality)		90.00	358
LOSSES DUE TO:			
1) Setups/Adjustments	9.52	9.52	461
2) Breakdowns	9.52	10.53	461
3) Idling/Minor Stoppages	14.29	17.65	691
4) Reduced Speed	19.26	28.89	1310
5) Defects/Rework	2.43	5.13	174
6) Yield	2.31	5.13	174




CUBES (OEE) THROUGHPUT LEVERAGE ANALYSIS
3500
3000
2500
2000
1500
1000
500
0
Production UNITS
THROUGHPUT
Setups/Adjustments
Breakdowns
Idling/Minor Stoppages
Reduced Speed
Defects/Rework
Yield
TOOL 1
TYPE OF THROUGHPUT LOSS


CUBES (OEE) TOOL EFFICIENCY ANALYSIS
Defects/Rework 2%
Yield 2%
Reduced Speed 19%
OEE 43%
Idling/Minor Stoppages 14%
Breakdowns 10%
Setups/Adjustments 10%



Use Tool name (T) or Date (D) in plot? **T**

TODAY'S CALCULATIONS
42.67
9.52
9.52
14.29
19.26
2.43
2.31

Tool	CVD 08				
Date	4/21/95				
INPUTS for Stacked BAR	CVD 08				
OEE	42.67				
Setups/Adjustments	9.52				
Breakdowns	9.52				
Idling/Minor Stoppages	14.29				
Reduced Speed	19.26				
Defects/Rework	2.43				
Yield	2.31				

SEMATECH Technology Transfer
2706 Montopolis Drive
Austin, TX 78741

http://www.sematech.org
fax: (512) 356-3081
e-mail: info@sematech.org