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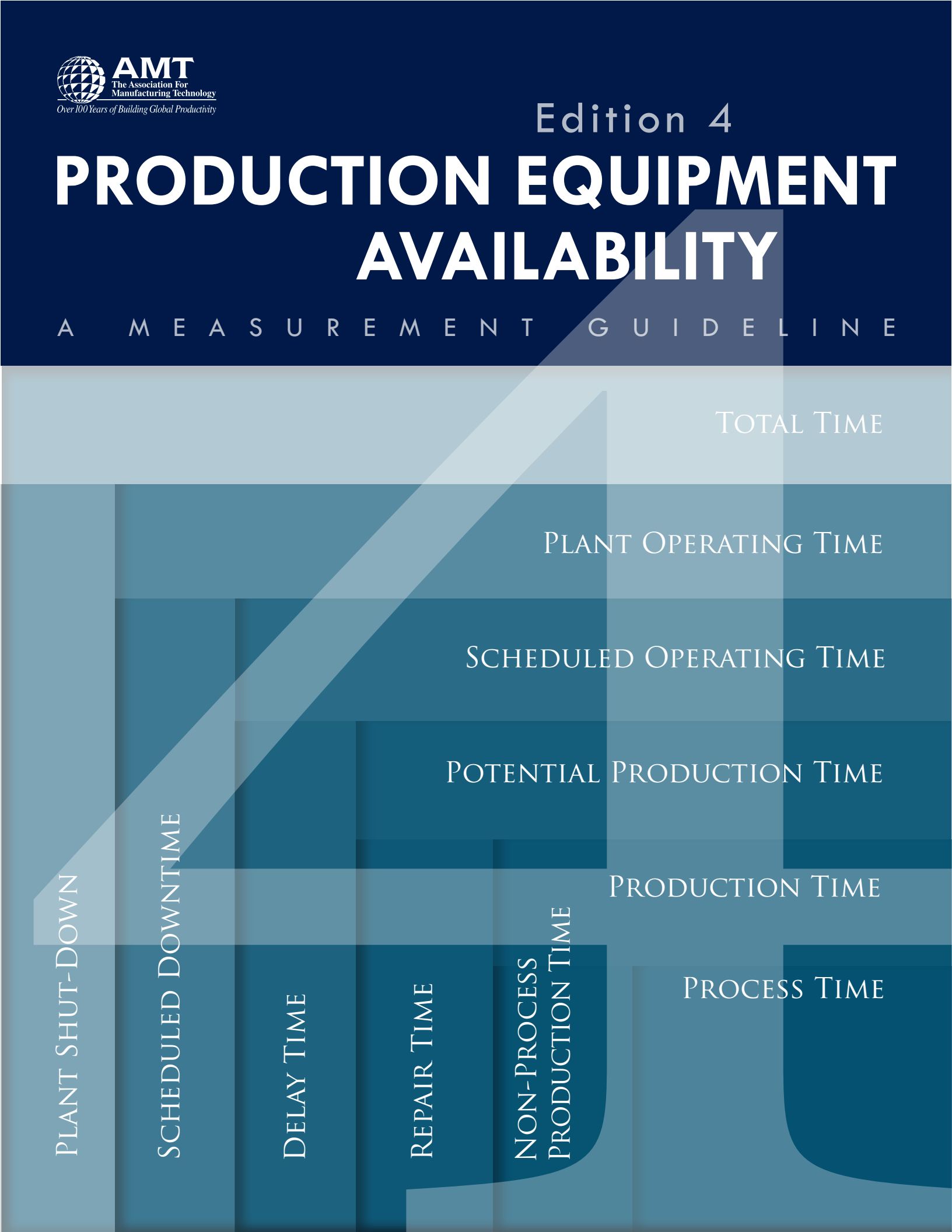
Edition 4

PRODUCTION EQUIPMENT AVAILABILITY

A MEASUREMENT GUIDELINE



PRODUCTION EQUIPMENT AVAILABILITY
A Measurement Guideline

Fourth Edition

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FOREWORD

A clear, simple, usable definition of, and a uniform procedure for, the measurement and reporting of *Production Equipment Availability* is presented primarily to determine the acceptability of *equipment*.

Terms, such as "uptime," "downtime," "reliability," "net available time," "total available time," "utilization," “in-cycle” and other terms, are traditionally used to determine a "figure of merit" for equipment operating characteristics. Inconsistent use of these terms, however, creates confusion. “Up-time” is not consistently defined and its use should not be continued. Additionally, “in-cycle” is another such term that is the source of some confusion and means different things depending on where and how it is used. This edition eliminates the use of the term “in-cycle” and illustrates that “PRODUCTION TIME” contains both “process” and “non-process” activities that encompass the conventional concept of “in-cycle.”

This guideline is designed to eliminate some of the confusion relating to these terms by defining a consistent set of figures of merit relating to manufacturing equipment. This document contains two parts (See Figure 1). Part 1 focuses on defining the term “Equipment Availability” while Part 2 addresses the composition of “PRODUCTION TIME.”

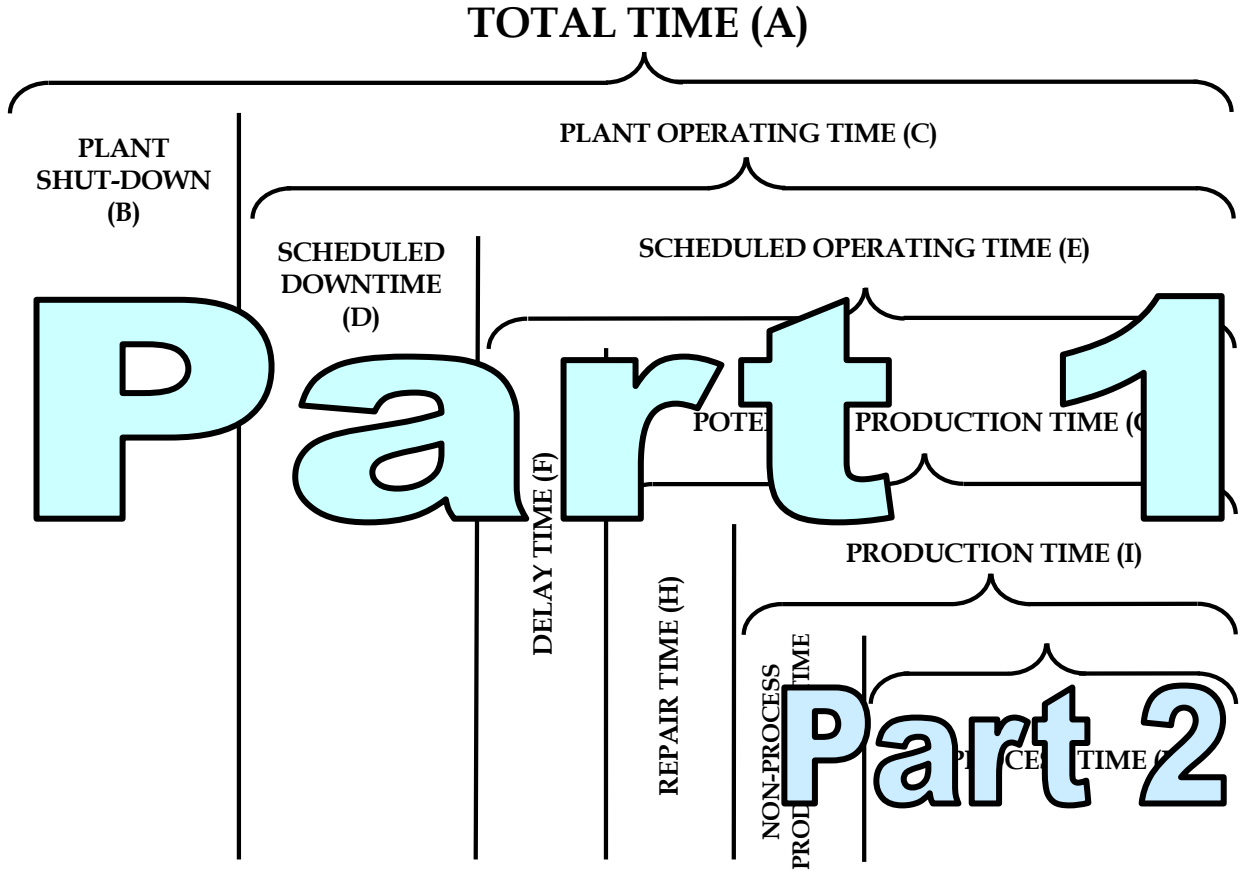


Figure 1 – Document Structure

In Part 1, the term "Equipment Availability" is defined. It represents the percentage of available operating time during which the operation of equipment is not prevented by an *equipment* malfunction. It has the advantage of simplicity, yet takes into account both the frequency and seriousness of equipment malfunctions and separates them from non-equipment-caused interruptions during operation.

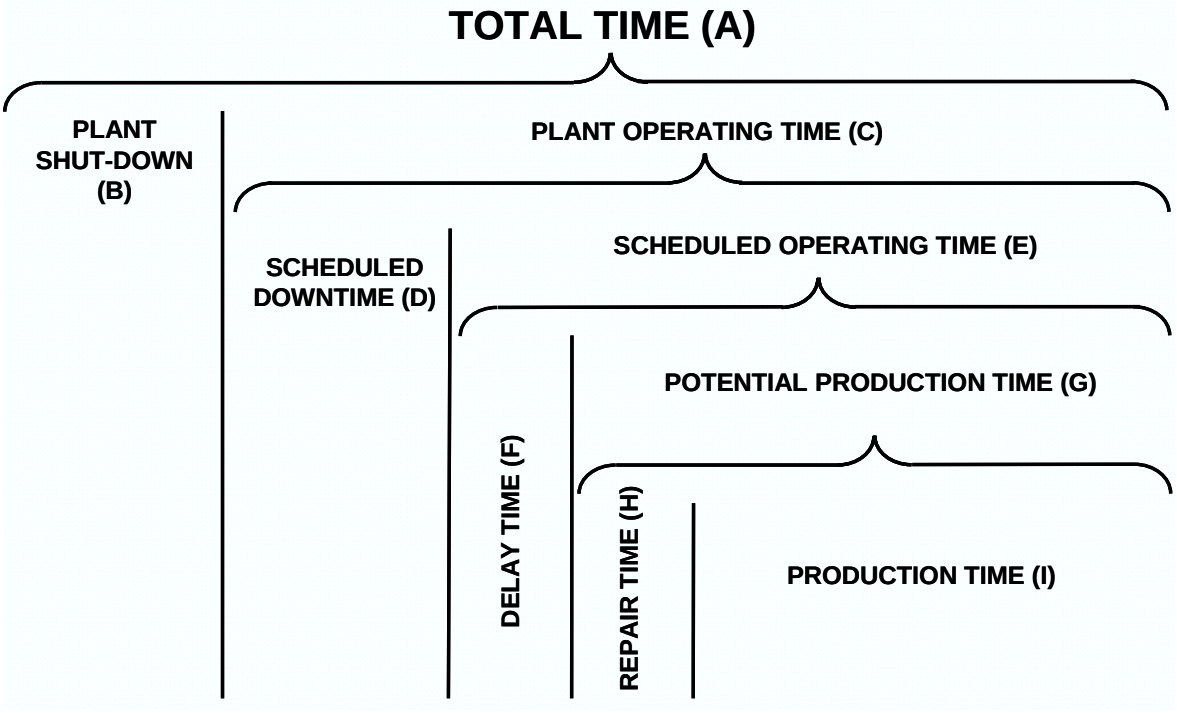
Equipment Availability is measured to determine the acceptability of production equipment, as opposed to its statistical or probabilistic *prediction.* The method for measurement uses data that can be readily collected, in a reasonable time, and under practical conditions, making it suitable for use during equipment run-off/start-up, as well as continued production.

NOTE: The term *Availability* is increasingly used to refer to a manufacturing asset or system without a specific limit on the nature of the asset. It could be a single machine or a complete facility. The term is applied to a piece of manufacturing equipment acting as a unit—usually one machine, but could also include several machines if they produce as a unit, and can consider all supporting elements.

Equipment Availability isolates the equipment-related component of *Availability* so that it may be separately examined. The calculation of *Equipment Availability* may produce a different answer from a calculation involving all the support services (power outage, for instance) required.

More complex and rigorous Reliability and Maintainability Engineering analyses exist which have great usefulness in improving future designs and in diagnosing production problems. The intent here is to provide a common, readily understandable reference point of measure by which equipment builders, users and other parties can agree.

The method of measurement enables the evaluation of equipment *Availability* in comparison with other equipment in a facility and with other installations - measured on a similar basis throughout industry.



The new Part 2 addresses the definition of elements comprising "PRODUCTION TIME" and a methodology for determining the amount of time an asset is performing the necessary activities or functions required for processing parts.

Also included in this guide are other definitions of terms that may be beneficial to users and builders in analyzing equipment use. These are Equipment Utilization and Potential Equipment Utilization (See Part 1, Section 1.2), as well as Process Equipment Utilization (See Part 2, Section 2.1.4).

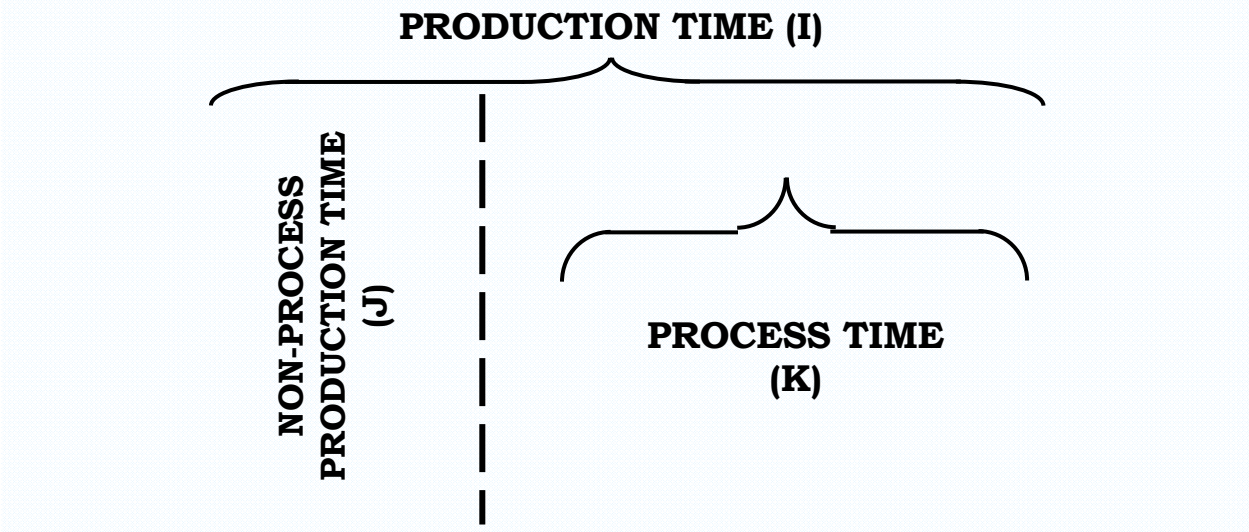
NOTE: "Equipment" refers to a stand-alone machine tool, a station in an automated line, a cell, or an entire line or system. Persons concerned with a specific Availability measurement should understand and agree upon the boundaries of the system/machine to be measured beforehand.

Another objective is to improve communication and understanding between equipment builders* and users.

This document discusses the methodology for determining *Equipment Availability* and offers an example in Appendix B for performing this calculation. Appendix C provides a brief overview of Overall Equipment Effectiveness (OEE) only as reference information. Appendix D offers insight into the importance of organizing any information being collected for future use in improving its design and resultant Reliability and Maintainability.

This Fourth Edition was developed over a period of time to better organize information contained in the previous version and incorporate additional definitions for clarity. It very specifically addresses the deletion of the term "in-cycle" and uses "PROCESS TIME" and "NON-PROCESS PRODUCTION TIME" to constitute total "PRODUCTION TIME."

This document replaces the "NMTBA Guidelines for the Measurement of Machine Tool Utilization" dated June 1975, published by AMT - The Association For Manufacturing Technology and all previous editions of this same document.



* Equipment builders include builders of stand-alone machine tools, standard or special; automated lines or stations thereof; cells; or entire manufacturing systems, used for machining, forming, assembly, inspection, or testing of components.

ACKNOWLEDGMENTS

AMT TECHNOLOGY ISSUES COMMITTEE

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PART 1 - EQUIPMENT AVAILABILITY

Section 1.1 - EQUIPMENT AVAILABILITY

1.1.1 INTRODUCTION

1.1.1.1 This document can be used to determine the acceptability of a wide variety of production equipment and its related accessories (i.e. coolant, chucks, etc.). It is versatile enough to be used in all sizes of manufacturing facilities operating any of the foregoing equipment, individually or in groups.

1.1.1.2 Availability for production equipment (*Equipment Availability*) is herein defined and a consistent method for its evaluation is established. The techniques established in this document can be used on a continuing basis, or they can be applied on a periodic basis to investigate the acceptability of the equipment and to identify specific current problem areas.

1.1.1.3 *Availability* has various meanings and ways of being computed depending upon its use. Availability is defined as "a percentage measure of the degree to which machinery and equipment is in an operable and committable state at the point in time when it is needed." This definition includes operable and committable factors that are contributed to the equipment itself, the process being performed and the surrounding facilities and operations.

1.1.1.4 *Equipment Availability* is defined as it relates to the acceptability of production equipment. Definitions of associated terms, a structured approach to the logging of data and a systematic method of analyzing the data for proper evaluation are provided. Typical forms are also provided for use in data logging and analysis. Figure 1 is a graphical representation of the relationships described.

1.1.1.5 The analyses presented in this document are designed to identify deficiencies in equipment support resources, as well as in the equipment itself. The data collected and its analysis will indicate to the user whether the necessary resources are available in a timely fashion for equipment support and whether the equipment is operable.

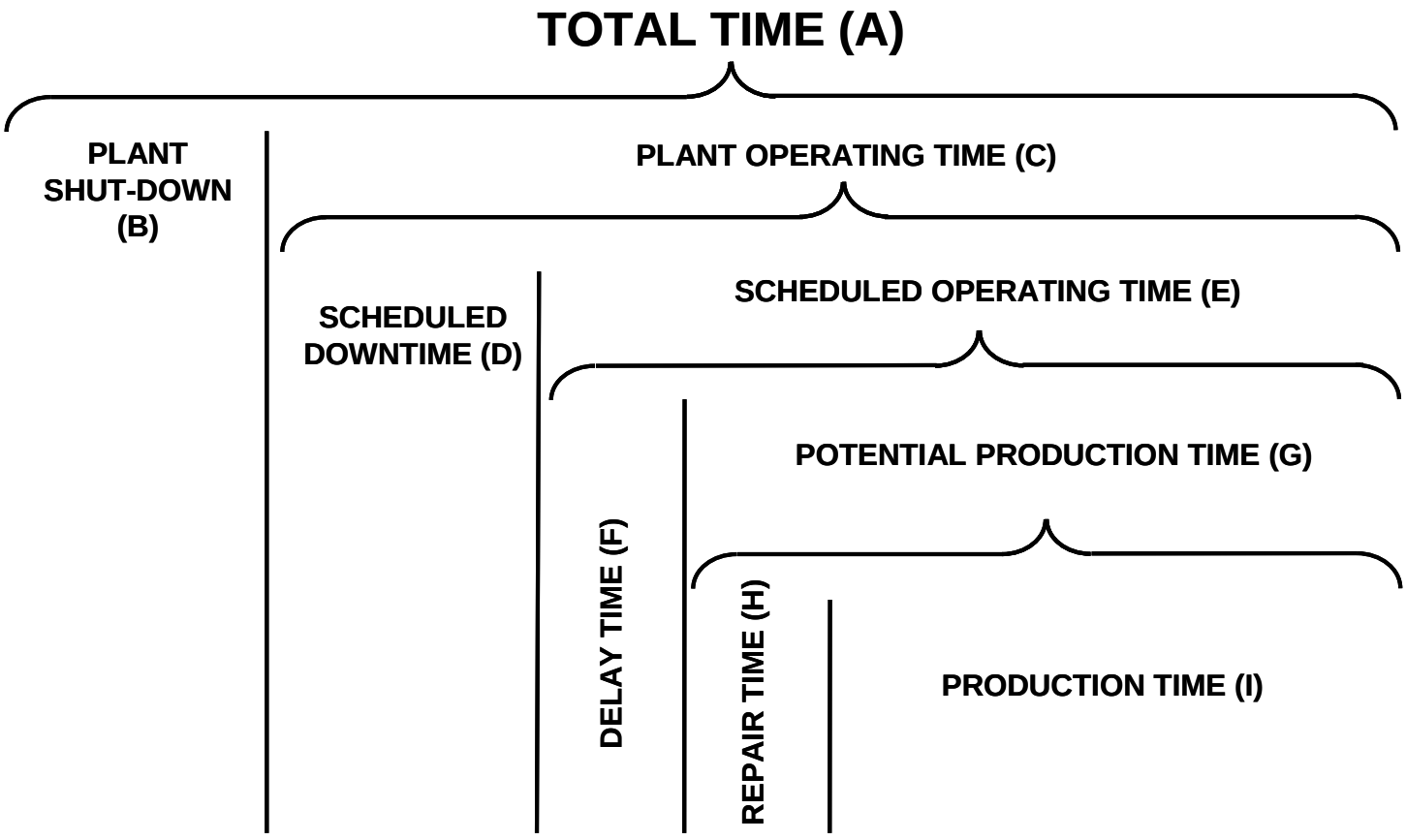

Figure 1.1 - Chart of Equipment Availability Parameters

1.1.2 TIME ALLOCATION DEFINITIONS

1.1.2.1 TOTAL TIME (A)

- time (maximum amount) available (at 24 hours per day and 7 days per week) in the observation period as agreed to in a test plan (i.e. Calendar Time)

1.1.2.2 PLANT SHUT-DOWN (B)

- time that the facility is closed and unavailable for equipment operation

1.1.2.3 PLANT OPERATING TIME (C)

- time the facility is open and capable of equipment operation

1.1.2.4 SCHEDULED DOWNTIME (D)

- time scheduled for planned maintenance, part prove-out, testing, or experiments. This is time in which any predictable repairs are performed, time during which operators, parts and supplies are not scheduled to be available; any time the facility is open, but during which a machine is not scheduled for normal operation. Time when expected stoppages in production occur, such as breaks, lunch, meetings, etc.

1.1.2.4.1 Major equipment changeover time (e.g. retooling, cell reconfiguration) is included in SCHEDULED DOWNTIME (D) unless specifically excluded by mutual agreement (i.e. turnkey systems).

1.1.2.5 SCHEDULED OPERATING TIME (E)

- time available for normal equipment operation

1.1.2.6 DELAY TIME (F)

- time consumed by unexpected events which keep the equipment from operating, but which are not equipment malfunctions. These include, but are not limited to, process difficulties and unplanned activities executed to address the difficulties, such as unexpected burr formation and removal (unless a turnkey system), operational or programming errors, lack of or incorrectly set-up cutting tools, disruption of material flow (blockage or shortage), out-of-specification incoming material or unavailability of user supplied operating or maintenance personnel, as well as user supplied parts or materials. A subset of DELAY TIME is RESPONSE TIME, which is time specifically waiting for personnel available on the premises for equipment operation, programming, maintenance or other personnel needs.

1.1.2.7 POTENTIAL PRODUCTION TIME (G)

- time the equipment is expected to run, or the SCHEDULED OPERATING TIME (E) minus any DELAY TIME (F)

1.1.2.8 REPAIR TIME (H)

- time the equipment is incapable of operation due to an equipment malfunction and subsequent repair of one or more of its components, sub-units or units

> **NOTE**: Equipment malfunction is any spontaneously occurring or unplanned condition, which causes the equipment to cease operation or if left unaddressed would cause an equipment malfunction. Equipment malfunction includes the malfunction of equipment designed and manufactured by the builder and used as intended; accessory equipment specified and purchased, or otherwise provided by the builder; equipment specified by the user and purchased by the builder (with written acceptance of responsibility by the builder); and equipment provided by the user (with written acceptance of responsibility by the builder).
>
> Equipment malfunction does **not** include a process malfunction or any unplanned activities arising from the malfunction (unless a turnkey system), normal housekeeping (clearing scrap, chips, unexpected burr removal, weld spatter, and other housekeeping activities), adjustments (for which operator controls have been provided by design), lack of or incorrectly set-up cutting tools, gauging/inspection, replacement of perishable tooling or consumable supplies (coolant replacement), disruption in the flow of process material(s), out-of-spec process materials, utility failures, unavailability of operator(s), or the like.

1.1.2.8.1 For purposes of calculating Equipment Availability, time waiting for off-site builder field service or other personnel or off-site repair parts needed from the equipment supplier or other source is included in REPAIR TIME (H).

1.1.2.8.2 For purposes of calculating Equipment Availability, time waiting for maintenance, programmer, or other personnel or repair parts available on the premises or equipment-specific on-site spare parts is included in DELAY TIME (F) and should be documented separately as RESPONSE TIME – a subset of DELAY TIME (F).

1.1.2.9 PRODUCTION TIME (I)

- time the equipment is running, producing parts, or in the process of producing parts, or the POTENTIAL PRODUCTION TIME (G) minus REPAIR TIME (H).

NOTE: Constructing a table similar to Table 1.2, identifying how occurrences are to be listed, will assist in understanding where events are to be assigned. Items listed in this table are not meant to be an exhaustive list of all types of occurrences.

SCHEDULED DOWNTIME	DELAY TIME	REPAIR TIME	NON-PROCESS PRODUCTION TIME*
EQUIPMENT -			
Planned maintenance	Waiting for repair parts (located in plant)	Equipment repair due to a malfunction	
Testing		Malfunction diagnosis	
Preventive and predictive maintenance		Waiting for outside specially skilled personnel (e.g. builder field service, etc.)	
		Waiting for repair parts (required from builder)	
PROCESS -			
Part prove-out (i.e. program, tooling, fixturing)	Operational error	Tooling/fixture repair on equipment due to equipment malfunction	Part setup
Experiments	Unplanned gauging		Planned manual gauging
Major equipment changeover	Unplanned inspection		Planned manual in-process inspection
	Out-of-specification incoming material		Replacement of dull tooling
	Disruption of material flow or no parts		Load and unload parts
	Wrong part number		Exceeding planned manual gauging time
	Awaiting information (i.e. NC tape)		
	Replacement of perishable tools/supplies		
	Unplanned burr removal		
FACILITIES -			
Resources not scheduled (operators, parts, supplies, etc.)	Waiting for internal specially skilled personnel (e.g. operator, maintenance, programming, etc.)		
Other miscellaneous scheduled stoppages (breaks, meals, meetings, etc.)	Utility outage		
Shift change	Network failure		
	Housekeeping and unplanned meetings		

***Section 2.1.2.2 outlines NON-PROCESS PRODUCTION TIME in greater detail.**

Table 1.2 – Occurrence Chart (not all inclusive)

1.1.3 EQUIPMENT AVAILABILITY FORMULA

Equipment Availability is defined as the percentage of POTENTIAL PRODUCTION TIME (G) during which equipment is operable, that is, operation is not prevented by equipment malfunction (or process difficulties for turnkey systems):

$$\text{EQUIPMENT AVAILABILITY} = \frac{\text{PRODUCTION TIME (I)}}{\text{POTENTIAL PRODUCTION TIME (G)}} \times 100$$

NOTE 1: In this calculation, *Equipment Availability* is applied to a piece of manufacturing equipment acting as a unit—usually one machine, but several machines if they produce as a unit, and does not consider all the supporting elements. For this very reason, the calculation of *Equipment Availability,* as performed, may produce a different answer from a calculation of *Overall Availability* (See C.2.1.1), which considers PRODUCTION TIME (I) divided by SCHEDULED OPERATING TIME (E). DELAY TIME (F) in the plant operation is not considered in *Equipment Availability,* but is considered in *Overall Availability*. *Equipment Availability* is intended to isolate the equipment-related component of *Availability* so that it may be separately examined.

NOTE 2: A definition for "up-time" is not provided in this document and its use should be discontinued. Due to differences in usage of this term in industry, it is no longer considered appropriate for determining the acceptance of production equipment. Instead, it is highly recommended that the definition for *Equipment Availability* given here be used when assessing production equipment acceptability.

Section 1.2 - ASSOCIATED TERMS

1.2.1 EQUIPMENT UTILIZATION

Equipment Utilization is defined as the percentage of PLANT OPERATING TIME (C) during which equipment is in production (PRODUCTION TIME [I]) that is, production is not prevented by equipment malfunction, operating delays, or SCHEDULED DOWNTIME.

$$\text{EQUIPMENT UTILIZATION} = \frac{\text{PRODUCTION TIME (I)}}{\text{PLANT OPERATING TIME (C)}} \times 100$$

1.2.2 POTENTIAL EQUIPMENT UTILIZATION

Potential Equipment Utilization is defined as the percentage of PLANT OPERATING TIME (C) during which equipment is scheduled for production, that is, production is not prevented by SCHEDULED DOWNTIME.

$$\text{POTENTIAL EQUIPMENT UTILIZATION} = \frac{\text{SCHEDULED OPERATING TIME (E)}}{\text{PLANT OPERATING TIME (C)}} \times 100$$

PART 2 – PRODUCTION TIME

Section 2.1 - PRODUCTION TIME

2.1.1 INTRODUCTION

2.1.1.1 In determining productivity of a piece of capital equipment or production equipment, figures of merit such as "In-cycle" have been used in the past with mixed results. However, since there is no clear and consistent definition of what constitutes a piece of machinery being "In-cycle," this leads to confusion when trying to use such data to analyze productivity. Therefore, this section defines an alternative and more acceptable approach to machine tool builders and users of the machines.

2.1.1.2 This document can be used to further refine the acceptability of a wide variety of production equipment and its related accessories (i.e. coolant, chucks, etc.,) based on the types of activities engaged by the equipment during production periods.

2.1.1.3 The PRODUCTION TIME for a device is herein analyzed and is divided into "PROCESS TIME" and "Non-Process PRODUCTION TIME." The distinction between these two is illustrated using a series of examples based on specific use cases of production equipment. Depending on how the production equipment is being applied, the events that are considered under PROCESS TIME and NON-PROCESS PRODUCTION TIME can be varied.

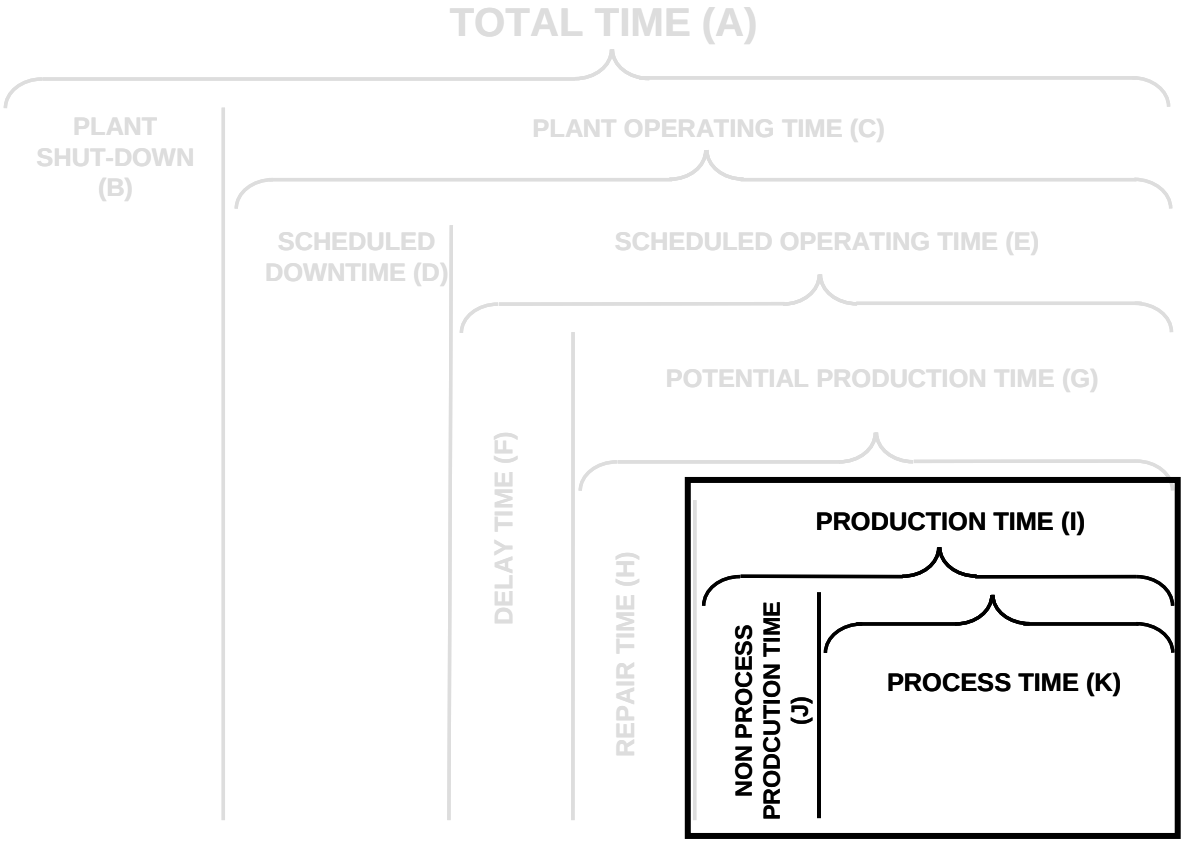

Figure 2.1 – PRODUCTION TIME

2.1.2 PRODUCTION TIME

2.1.2.1 PRODUCTION TIME (I)

- time the equipment is running, producing parts, or in the process of producing parts, or the POTENTIAL PRODUCTION TIME (G) minus REPAIR TIME (H)

2.1.2.2 NON–PROCESS PRODUCTION TIME (J)

- time comprised of activities **necessary** in the processing of parts, but is ancillary to the specific act of processing the part. These activities are performed independently of the process.

> **NOTE**: NON-PROCESS PRODUCTION TIME activities includes preparation of the machine (part setup) for running and producing parts, manual gauging of parts, manual in-process inspections, planned operator adjustments, replacement of perishable tooling and/or consumable supplies, and housekeeping (such as scrap removal, chip clearing, burr removal, weld spatter removal, etc.). In addition, this time includes activities that exceed the total allocated duration for NON-PROCESS PRODUCTION TIME activities.

2.1.2.3 PROCESS TIME (K)

- time the equipment is performing functions necessary for running and producing parts, or the PRODUCTION TIME (I) minus NON-PROCESS PRODUCTION TIME (J)

> **NOTE**: This includes the time for PROCESS TIME activities, in addition to exceeding the time allocated to PROCESS TIME activities. The events that are considered as belonging to PROCESS TIME are based on the type of analysis that needs to be performed using the measured data from the process equipment data. Example events are outlined in 2.1.2.4 of how to define PROCESS TIME.

2.1.2.4 TABLES

Constructing a listing beforehand, identifying how PRODUCTION TIME events are to be treated and tabulated will assist in understanding where these events are to be assigned. Depending on the specific situation, NON-PROCESS PRODUCTION TIME can be very minimal if the plan is very detailed and precisely followed, and some events are moved to either DELAY TIME or REPAIR TIME. Similarly, in the case of processes with extensive manual activities, NON-PROCESS PRODUCTION TIME can be significant.

However, care must be exercised in moving some events in this way as this may affect the calculations associated with Equipment Availability. It is advisable to use an excel spreadsheet to perform a variety of "what if" calculations to get a better understanding of how DELAY TIME, REPAIR TIME, and PROCESS TIME affect *Equipment Availability*.

Examples of these events and which can include both automatic or manual:

Program Code Execution
Faults
Part Setup
Overrides
Process Gauging
Tool Change
Offset Measurements and Corrections
Resets
Pallet Shuttle Movements
Probing
Part Handling / Loading
Warnings
Pauses

2.1.3 USE OF THE TERM "IN-CYCLE"

"In-Cycle" has caused much confusion over the years. Its meaning is often different depending on where and how it is used and even within the context of a discussion. As such, when the term "In-Cycle" is written into instructions its meaning is very often misconstrued by either end of a communication. This edition offers to outline a distinctive methodology that replaces this term with the more widely accepted "PROCESS TIME." However, this is not to mean that "PROCESS TIME" is a simple swap for "In-Cycle" since "In-Cycle" is not consistently defined. It is recommended that the term "In-Cycle" be discontinued and no longer used and replaced with the current usage contained within this document.

"There is no absolute definition, customers have their points of view, and different machines and part programming styles can also change that definition."

--- A Machine Tool Builder

Section 2.2 - ASSOCIATED TERMS

2.2.1 PROCESS EQUIPMENT UTILIZATION

Process Equipment Utilization is defined as the percentage of PLANT OPERATING TIME (C) during which equipment is actually producing parts (PROCESS TIME [K]). This excludes non-process production activities required as part of the production operation.

$$\text{PROCESS EQUIPMENT UTILIZATION} = \frac{\text{PROCESS TIME (K)}}{\text{PLANT OPERATING TIME (C)}} \text{ X 100}$$

2.2.2 LOST CAPACITY

A theoretical limit of zero - the percentage of the SCHEDULED OPERATING TIME (E) lost to REPAIR TIME (H), DELAY TIME (F) and NON-PROCESS PRODUCTION TIME (J) as it was encountered.

$$\text{LOST CAPACITY} = \frac{\left(\begin{array}{l}\text{DELAY TIME (F)} \\ \text{+ REPAIR TIME (H)} \\ \text{+ NON-PROCESS PRODUCTION TIME (J)}\end{array}\right)}{\text{SCHEDULED OPERATING TIME (E)}} \text{ X 100}$$

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APPENDIX A – DATA LOGGING AND ANALYSIS

A.1 DATA LOGGING

A.1.1 General

A.1.1.1 To measure production *Equipment Availability*, an accurate log of time for the equipment must be maintained. The purpose of the log is to record time in five basic categories: PLANT SHUT-DOWN (B), SCHEDULED DOWNTIME (D), DELAY TIME (F), REPAIR TIME (H) and NON-PROCESS PRODUCTION TIME (J). Two of these categories, PLANT SHUT-DOWN (B) and SCHEDULED DOWNTIME (D), are usually known in advance.

A.1.1.2 A mutually agreed upon time period must be defined for the logging of data.

A.1.2 Logging Format and Forms

A.1.2.1 The Equipment Availability Log (Figure A.1) is used to record start and stop times in the five categories as detailed in the Time Allocation Definitions portion of Section 1 above.

A.1.2.2 With PLANT SHUT-DOWN (B) and SCHEDULED DOWNTIME (D) known, the logging of only three basic categories is needed to calculate *Equipment Availability*.

A.1.2.3 The logged data may be recorded in any time units (seconds, hours, minutes, etc.), so long as they are consistent, depending on the user's preference.

A.1.3 Consistency of Procedures

A.1.3.1 Consistent procedures and interpretations are essential. It is very important that the same category code to log the same event must be used by all individuals recording data to evaluate both equipment and system operation.

A.1.3.1.1 Precedence: In the event of a categorization conflict between legitimate events, the event having the greatest effect on product output shall be recorded.

A.1.3.2 Allocation of Time

A.1.3.2.1 All TOTAL TIME must be accounted for.

Note: In the logging of occurrences, an accurate description of each occurrence is necessary for post event analysis, such as those listed in Table D.1.

A.1.3.2.2 All time during which the machine is manned (SCHEDULED OPERATING TIME [E]) or being repaired (REPAIR TIME [H]) must be accounted for, whether scheduled or not. For example, repair performed after scheduled hours is logged as "REPAIR TIME (H)," and that (after hours portion of) "REPAIR TIME (H)" deducted from either the PLANT SHUT-DOWN (B) time or the SCHEDULED DOWNTIME (D) category.

A.2 DATA ANALYSIS

A.2.1 General

A.2.1.1 To evaluate *Equipment Availability*, the logged data must be properly analyzed.

Note: The example in Appendix B illustrates a technique for recording information and its analysis.

A.2.2 Forms

A.2.2.1 The time intervals shall be calculated and entered into an Equipment Availability Log (Refer to Figure A.1 for a sample log sheet). They shall be totaled and entered on an Equipment Availability Analysis Worksheet (See sample in Figure A.2) in the corresponding categories.

A.2.2.2 Percent calculation is done on the Equipment Availability Analysis Worksheet (Figure A.2).

A.2.2.3 The percent of logged time for each of the categories may be useful for identifying problem areas. Also, these percentages may be calculated for any period of time desired. The formulas are set up to automatically accommodate any desired TOTAL TIME period simply by filling in the proper number of time units.

A.2.3 Analysis Results

A.2.3.1 A pass/fail **Equipment Availability** value shall be established during the development of an acceptance test plan for use in this analysis.

Log Sheet # _____

Equipment Availability Log

Equipment Identification _____

_____

Time Period (Dates Inclusive)
From _____ To _____
Time Units _____
Approved by _____

Start Time (Ts)	Finish Time (Tf)	B - Plant Shut-Down	D - Scheduled Downtime	F - Delay Time	H - Repair Time	J - Non - Process Production Time	Logged By	Remarks
Totals								
							Total Time	

Category Codes

- **B** **PLANT SHUT-DOWN** - Facility closed (See 1.1.2.2)
- **D** **SCHEDULED DOWNTIME** - Planned maintenance, breaks, meetings, etc. (See 1.1.2.4)
- **F** **DELAY TIME** - Delays which are not equipment malfunctions (See 1.1.2.6)
- **H** **REPAIR TIME** - Finding and repairing equipment malfunctions (See 1.1.2.8)
- **J** **NON-PROCESS PRODUCTION TIME** – Part setup, planned gauging of parts, housekeeping (See 2.1.2.2)

Start time and finish time may not occur on the same date.

Page _____ of _____

Figure A.1 - Typical Equipment Availability Log (Sample)

Log Sheets # ___ to # ___

Equipment Availability Analysis Worksheet

Equipment Identification _____
_____

Time Period (Dates Inclusive)
From _____ To _____

CATEGORY	SYMBOL		TIME	% OF TOTAL TIME
Total Time	A		_____	100
Plant Shut-Down	B		_____	_____
Plant Operating Time	C	*(CALCULATED)*	_____	_____
Scheduled Downtime	D		_____	_____
Scheduled Operating Time	E	*(CALCULATED)*	_____	_____
Delay Time	F		_____	_____
Potential Production Time	G	*(CALCULATED)*	_____	_____
Repair Time	H		_____	_____
Production Time	I	*(CALCULATED)*	_____	_____
Non-Process Production Time	J		_____	_____
Process Time	K	*(CALCULATED)*	_____	_____

Note: Be sure consistent time units are used.

C = A - B = _____ - _____ = _____

E = C - D = _____ - _____ = _____

G = E - F = _____ - _____ = _____

I = G - H = _____ - _____ = _____

K = I - J = _____ - _____ = _____

EQUIPMENT AVAILABILITY = $\frac{I}{G}$ x 100 = _____%

Compiled By _____
Date _____

Figure A.2 - Typical Equipment Availability Analysis Worksheet (Sample)

APPENDIX B – EXAMPLE CALCULATING EQUIPMENT AVAILABILITY AND UTILIZATION

B.1 Example Scenario

The following outlines what to expect and plan for when beginning an analysis.

On Aug. 20 and Aug. 21, Brand A—Model 30, with a planned design cycle time of 2.0 minutes (120 seconds), was to be tested for **Equipment Availability** over a 48-hour time frame (2,880 minutes). Over the 48 hours, the Plant would be closed for 14 hours (840 minutes). There are two shifts each day during the test period. Data was logged by Lynn, the Day Shift Operator, and by Chris, the Night Shift Operator. Day shift was 7:00 a.m. to 3:30 p.m., night shift was 3:30 p.m. to midnight, each with a ½-hour lunch break. Over the 2 days, these two shifts operated for a total of 34 hours – 17 hours each day.

At 9:00 a.m. on Aug. 20, Lynn was paged by the Plant Manager for a scheduled meeting which lasted 35 minutes. At 2:00 p.m., coolant was replenished, taking 14 minutes --- this was a planned 10-minute event.

On the evening of Aug. 20 at 9:00 p.m., the machine registered a warning: a bearing was running slightly over maximum allowable temperature. Chris decided to continue process operations but called the Maintenance Office. The Repair Team arrived at 10:30 p.m. and the repair took a total of 1-1/2 hours.

The next morning, the run was resumed at 7:00 a.m. but at 8:15 a.m. a belt failed. It took 15 minutes to remove the belt and 15 minutes to replace it, but Lynn had to drive to a local supply house, since the plant had none in stock. This took 2 hours and 15 minutes.

At 5:30 p.m. on Aug. 21, the equipment ran out of work parts to process. Another tray of parts was delivered at 5:50 p.m. The remainder of the run was uneventful.

Over the course of the entire run, 15 parts were rejected as a result of this operation out of 760 parts introduced and processed. Actual PROCESS TIME for all parts was 2 minutes and 6 seconds per part (126 seconds). (This was a calculated number.)

B.2 Log Sheet Note Explanations

Figure B.1 shows an Equipment Availability Log sheet filled out for this period of equipment operation.

B.2.1 Note in the example that time for lunches (four lunches) was logged as SCHEDULED DOWNTIME (D) - one lunch for each shift. Also, the Plant Manager meeting was a regular event and the plan had this accounted for in SCHEDULED DOWNTIME (D).

B.2.2 The repair of the bearing was performed during scheduled hours and was logged as REPAIR TIME (H) and not deducted from SCHEDULED DOWNTIME (D). However, had the repair occurred during SCHEDULED DOWNTIME (D) there would have been no reduction to Equipment Availability. Had there been a third shift, so that the repair had taken place during SCHEDULED OPERATING TIME (E), then the repair would also have been logged as REPAIR TIME (H).

B.2.3 Since the "coolant replacement" was a **planned** activity, it was logged as NON-PROCESS PRODUCTION TIME (J) as a housekeeping event. Had "coolant replacement" not been a planned event, it would be captured as DELAY TIME (F).

B.3 Equipment Availability Analysis

Figure B.2 shows the analysis of the operation of the equipment for the TOTAL TIME (A). In the example, daily times were summarized for each major category in minutes, and entered on the Equipment Availability Analysis Worksheet. It is important to be as detailed as possible for analysis.

B.4 Utilization Analysis

Figure B.3 shows the analysis of the utilization factors for the operation of the equipment for the TOTAL TIME.

The following can be generalized from the example scenario:

Actual PROCESS TIME per part is 2 minutes and 6 seconds, whereas Planned PROCESS TIME is 2 minutes per part. This was calculated.

The planned coolant replacement should have taken 10 minutes, but the operator indicated that it took 14 minutes. These additional 4 minutes are considered as unplanned NON-PROCESS PRODUCTION TIME and will be considered for later analysis and plan improvements.

From 1.1.2.8.1 and the Example - Had the replacement belt been available in-stock/in-house, the 135 minutes – 1) could have probably been reduced in time, but 2) and more importantly, those minutes would have moved from REPAIR TIME (H) to DELAY TIME (F) and increased the overall Equipment Availability calculations. That difference would change *Equipment Availability* from **~86%** to more than **93%** by simply having replacement parts on-site.

Lastly, had the repair of the bearing occurred during the SCHEDULED DOWNTIME (D) and the replacement of the belt been moved to DELAY TIME (F) by having the replacement parts on-site, *Equipment Availability* could be pushed to **over 98%** and Lost Capacity could be reduced by 5%.

EQUIPMENT AVAILABILITY LOG

Time Period (Dates Inclusive)
From AUG 20 To AUG 21

Equipment Identification Brand A – Model 30c

TIME UNITS MINUTES
(Seconds or Minutes)

Approved By JJB

Start Time (Ts)	Finish Time (Tf)	B - Plant Shut-Down	D - Scheduled Downtime	F - Delay Time	H - Repair Time	J - Non-Process Production Time	Logged By	Notes and Remarks
7AM	9am						Lynn	Start Test
9am	9:35A		35				"	Plant Mgr Meeting
9:35A	11am						"	Resume Run
11am	11:30A		30				"	Lunch
11:30A	2pm						"	Resume Run - no issues
2pm	2:14pm					14	"	Added additional coolant
2:14p	6:30p						"	Resume Run
6:30p	7PM		30				Chris	Lunch
7PM	9pm						"	Resume Run
9pm	10:30pm						"	Bearing Hot - continued operation (MAINT called)
10:30pm	1ZM				90		**Maint**	Replaced/Reset out of spec bearing
1ZM	7AM	420					Lynn	Shift End
7AM	8:15a						"	Resume Run
8:15a	8:30a				15		"	Belt Broken - Removed Belt
8:30a	10:45a				135		"	Waiting for Replacement Belt
10:45a	11:00a				15		"	Replaced Belt
11:05a	11:30a		30				"	Lunch
11:30a	5:30p						"	Resume Run
5:30p	5:50p			20			Chris	No-parts --- waiting for parts (swept floor)
5:50p	6:30p						"	Resume Run
6:30p	7PM		30				"	Lunch
7pm	1ZM						"	Resume Run
1ZM	7AM	420						Shift End - End Test
TOTALS		840	155	20	255	14		
							TOTAL TIME	2880

Category Codes:

B - Plant Shut Down --- Facility closed (Section Section 1.1.2.2)

D - Scheduled Downtime --- Planned maintenance, breaks, meetings (Section Section 1.1.2.4)

F - Delay Time --- Delays which are not equipment malfunctions (Section Section 1.1.2.6)

H - Repair Time --- Finding and Repairing Equipment Malfunctions (Section 1.1.2.8)

J - Non-Process Production Time --- Part Set-up, Planned Gauging of Parts, Housekeeping (Section 2.1.2.2)

Note: Start Time and Finish Time must reflect when each instance occurs

Figure B.1 - Typical Equipment Availability Log (Example)

Total Time	A		2880	100.0%
Plant Shut-Down	B		840	29.2%
Plant Operating Time	C	(calculated)	2040	70.8%
Scheduled Down Time	D		155	5.4%
Scheduled Operating Time	E	(calculated)	1885	65.5%
Delay Time	F		20	0.7%
Potential Production Time	G	(calculated)	1865	64.8%
Repair Time	H		255	8.9%
Production Time	I	(calculated)	1610	55.9%
Non-Process Production Time	J		14	0.5%
Process Time	K	(calculated)	1596	55.4%

Equipment Availability	**=**	**86.3%**
Equipment Utilization	**=**	**78.9%**
Process Equipment Utilization	**=**	**78.2%**
Potential Equipment Utilization	**=**	**92.4%**
Overall Availability	**=**	**85.4%**

Performance Efficiency	**=**	**95.2%**
Quality	**=**	**98.0%**
Overall Equipment Effectiveness	**=**	**79.7%**

Number of Parts Introduced during Test Run	760	
Number of Parts Rejected during Test Run	15	
Planned Process Time per Part	2	minutes
	120	seconds
Actual Process Time per Part	2.10	minutes
	126.00	seconds

Figure B.2 - Typical Equipment Availability Analysis Worksheet (Example)

Additional formulas that may be considered useful:

$$\text{EQUIPMENT UTILIZATION} = \frac{I}{C} \times 100 = \frac{1610}{2040} \times 100 = 78.9\%$$

$$\text{PROCESS EQUIPMENT UTILIZATION} = \frac{K}{C} \times 100 = \frac{1596}{2040} \times 100 = 78.2\%$$

$$\text{POTENTIAL EQUIPMENT UTILIZATION} = \frac{E}{C} \times 100 = \frac{1885}{2040} \times 100 = 92.4\%$$

$$\text{LOST CAPACITY} = \frac{(F+H+J)}{E} \times 100 = \frac{(20+255+14)}{1885} \times 100 = 15.3\%$$

Figure B.3 - Typical Utilization Calculations (Example)

APPENDIX C – OVERALL EQUIPMENT EFFECTIVENESS (OEE)

NOTE: The following is included primarily for reference purposes only.

C.1 INTRODUCTION

C.1.1 Overall Equipment Effectiveness (OEE) is a term used to describe how effective equipment is at adding value to the components made in the manufacturing process. The calculation of OEE takes into account the availability of the equipment or asset, the efficient use of the equipment and the quality of the product produced. Since efficiency and quality factors play an important role in the calculation, the same piece of equipment may yield a different OEE as production requirements and resources change.

Note: Since OEE includes factors that are only under the control of the end user, its use is not recommended as an equipment acceptance criterion.

C.2 OEE - Overall Equipment Effectiveness Definition

C.2.1 Overall Equipment Effectiveness is defined as the algebraic product of Overall Availability, Performance Efficiency and Quality.

OEE = OVERALL AVAILABILITY X PERFORMANCE EFFICIENCY X QUALITY X 100

C.2.1.1 Overall Availability

C.2.1.1.1 Overall Availability is defined as the percentage of SCHEDULED OPERATING TIME (E) during which system operation is not prevented by malfunctions, including process difficulties, facility problems, equipment availability issues, etc.

C.2.1.1.2 The calculation for Overall Availability, as outlined in this document, is:

$$\textbf{OVERALL AVAILABILITY} = \frac{\textbf{PRODUCTION TIME (I)}}{\textbf{SCHEDULED OPERATING TIME (E)}}$$

C.2.1.2 Performance Efficiency

C.2.1.2.1 Performance Efficiency is defined as the ratio of planned process/cycle time (PROCESS TIME) to actual process/cycle time (PROCESS TIME) per part or unit, or as the measured output to the target output.

$$\text{PERFORMANCE EFFICIENCY} = \frac{\text{PLANNED PROCESS TIME}}{\text{ACTUAL PROCESS TIME}} \text{ or } \frac{\text{MEASURED OUTPUT}}{\text{TARGET OUTPUT}}$$

C.2.1.2.2 Performance Efficiency formula definitions:

a) Planned PROCESS TIME is defined as the target output cycle time of the process.

b) Actual PROCESS TIME is defined as the measured output cycle time of the process.

C.2.1.2.3 The term "Efficiency" is used to describe the net yield or output of a productive unit. While the foregoing Equipment Availability Analysis provides some of the input data required to calculate Efficiency, additional information must be logged. For example, equipment may be producing acceptable parts at a rate lower than the planned output, because it was found that the workpiece lacked sufficient structural rigidity to maintain geometric tolerances when processed at the planned cycle time. To calculate OEE, efficiency data must be recorded.

C.2.1.3 Quality

C.2.1.3.1 Quality is defined as the ratio of the number of good parts produced to the total number of parts introduced during a specified period of time.

$$\text{QUALITY} = \frac{\text{GOOD PARTS}}{\text{INTRODUCED PARTS}}$$

C.2.1.3.2 Quality formula definitions:

a) Good parts are the number of parts produced during the specified period of time that meet defined print requirements.

b) Introduced parts are the total number of parts processed during the specified period of time.

C.3 USE OF OEE

C.3.1 Overall Equipment Effectiveness can be used for capacity planning, process control, and process improvement. Because of the many factors involved in addition to the equipment in question, OEE is **not recommended** as an equipment acceptance criterion. OEE can be used for analysis and benchmarking exercises. There is sufficient literature, focus in the industry and other resources that outline OEE that additional coverage on its use is beyond the scope of this document.

APPENDIX D – USE OF DATA

D.1 INTRODUCTION

D.1.1 As a part of data logging and analysis, it is recommended that the data collected be logged in such a manner as to permit its use for various types of analysis efforts. These efforts can include more complex and rigorous Reliability and Maintainability Engineering analysis or in simple Pareto charts to determine occurrence information.

> **Note**: A Pareto Chart is a series of bars whose heights reflect the frequency or impact of problems. The bars are arranged in descending order of height from left to right. This means the categories represented by the tall bars on the left are relatively more significant than those on the right. This bar chart is used to separate the "vital few" from the "trivial many." These charts are based on the Pareto Principle which states that 80% of the problems come from 20% of the causes. Pareto Charts are extremely useful because they can be used to identify those factors that have the greatest cumulative effect on the system and thus screen out the less significant factors in an analysis. Ideally, this allows the user to focus attention on a few important factors in a process.

D.1.2 Types of analyses that can be performed on collected information are included in Table D.1 – Types of Failure Analysis.

TYPE OF ANALYSIS	PURPOSE
FMEA – Failure Mode and Effects Analysis	An analysis used to identify potential failure modes and their impact on the performance of equipment.
Fault Tree Analysis	A system analysis used to explore the possible occurrence of undesirable events (failures).
FRACAS – Failure Reporting, Analysis, and Corrective Action System	A process for reporting, recording, transmitting and using failure data.
Pareto Analysis	A tool to help prioritize data by ranking its occurrence.

Table D.1 – Types of Failure Analysis

D.2 CODING DATA

D.2.1 To facilitate the logging of data, it is often helpful to assign codes to events. This can assist in automating the collection of information and its analysis. An example of coding is illustrated in Table D.2 where occurrences outlined in Table 1.2 of Chapter 1 are numbered according to the events to be monitored and whether they are equipment, process or facilities related.

100 - SCHEDULED DOWNTIME	200 - DELAY TIME	300 - REPAIR TIME	400 - NON- PROCESS PRODUCTION TIME
EQUIPMENT -			
101 Planned maintenance	201 Waiting for repair parts (located in plant)	301 Equipment repair due to a malfunction	
102 Testing		302 Malfunction diagnostics	
103 Preventive and predictive maintenance		303 Waiting for outside specially skilled personnel	
		304 Waiting for repair parts (required from builder)	
PROCESS -			
111 Part prove-out (i.e. program, tooling, fixturing)	212 Operational error	311 Tooling/fixture repair on equipment due to equipment malfunction	411 Part setup
112 Experiments	213 Unplanned gauging		412 Planned gauging
113 Major equipment changeover	214 Unplanned inspection		413 Planned inspection
	215 Out-of-specification incoming material		414 Replacement of dull tooling
	216 Disruption of material flow or no parts		415 Load and unload parts
	217 Wrong part number		
	218 Awaiting information (i.e. NC tape)		
	219 Replacement of perishable tools/supplies		
FACILITIES -			
121 Resources not scheduled (operators, parts, supplies, etc.)	221 Waiting for specially skilled personnel (e.g. Operator, maintenance, etc.)		
122 Other miscellaneous scheduled stoppages (breaks, meetings, etc.)	222 Utility outage		
123 Shift change	223 Network failure		
	224 Housekeeping and unplanned meetings		

Figure D.2 – Example of Coding Events

GLOSSARY

AVAILABILITY
A percentage measure of the degree to which machinery and equipment is in an operable and committable state at the point in time when it is needed.[1] (This statement incorporates all aspects of malfunctions and delays relating to equipment, process and facility issues.)

AVAILABILITY, EQUIPMENT
The percentage of POTENTIAL PRODUCTION TIME (G) during which equipment is operable, that is, operation is not prevented by *equipment* malfunction.

MAINTAINABILITY
A characteristic of design, installation, and operation of machinery and equipment. Maintainability is usually expressed as the probability that a machine can be retained in or restored to specified operable condition within a specified interval of time, when maintenance is performed in accordance with prescribed procedures.[1]

RELIABILITY
The probability that machinery and equipment can perform continuously for a specified interval of time without failure, when operating under stated conditions.[1]

REFERENCES

[1] National Center for Manufacturing Sciences & Society of Automotive Engineers, Inc. *Reliability and Maintainability Guideline for Manufacturing Machinery and Equipment, Second Edition, M-110.2*. NCMS or SAE, August 1999.

NOTES:

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