SAND2016-8961PE

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Sandia National Laboratories

GRANTA
MATERIAL INTELLIGENCE

GRANTA MATERIAL DATABASE EFFORTS @ SNL : AM Schema & Data Population

J. Madison, L. Serna, R. Karnesky, M. Kinnan, J. Koepke, A. Baca, D. Hirschfeld

19 July 2016

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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GRANTA @ SNL – Team Members

Deidre Hirschfeld, Ph.D.
Manager (1832) –
Coatings & Additive
Manufacturing

Joshua Koepke
Intern (1832)
Coatings & Additive Manufacturing

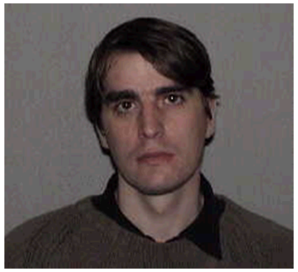
- *Data Entry*
- *Importer Creator*

Ana Baca
Technologist (1819)
Materials Characterization & Performance

- *Data Entry*
- *Importer Implementation Testing*

Mark H. Baumgardner
PO Contractor (9324)
Infrastructure Computing Systems

- *Application Maintenance*
- *Server Management*

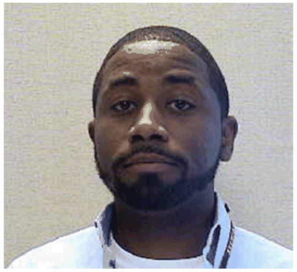


Rick Karnesky, Ph.D.
Staff Member (8367)
Hydrogen & Combustion Technologies

- *Granta Application Admin*
- *Customer Development & Technical Partnerships*
- *Hydrogen Compatibility Database*
- *Hydrogen Effects* *

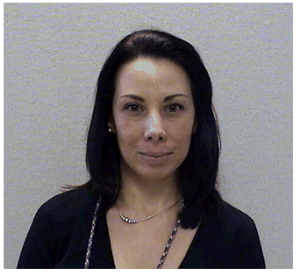
Mark Kinnan, Ph.D.
Staff Member (6632)
Chemical & Biological Systems

- *Importer & Schema Development*
- *Decontamination Foams* *



Jonathan D. Madison, Ph.D.
Staff Member (1851)
Materials Mechanics & Tribology

- *Granta Application Admin*
- *Customer Development & Technical Partnerships*
- *Sandia Materials Database*
- *Additive Manufacturing Database*
- *Metallurgy* *



Lysle Serna, M.S.
Staff Member (1852)

- *Customer Development & Technical Partnerships*
- *Material Listings Nomenclature*
- *Material Compatibility* *
- *Corrosion* *

Additive Manufacturing

AM Needs

- Traceable, digital data capture for entire part optimization and life cycles
- Method for validating virtual data
- Standards (MMPDS, ASTM, ISO, MatML)

How GRANTA Supports AM

- Proven enabling technology, collaborative platform
- Experience in implementing best practices for managing complex material-process pedigree and data
- MDMC expertise in materials, manufacturing, and data management
  - Granta MI – Industry consulting projects in Europe and US
  - Membership – Network of corporate, government & academic funded projects

MDMC AM Working Group

Sandia National Laboratories

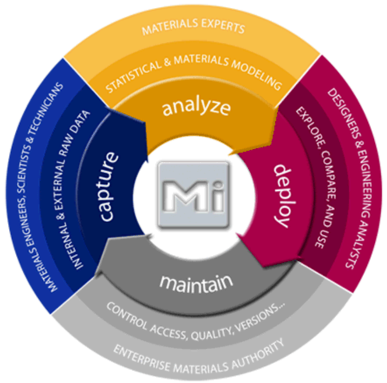
MDMC.net

Leverage core expertise of MDMC members

- Materials, manufacturing, data management
- Software infrastructure and networks

Focus

- Schema development
- Software & network integration
- Standards
- Interfacing with AM initiatives

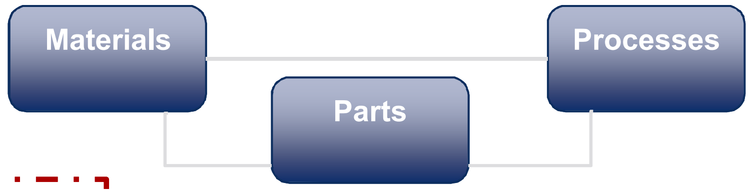


BOEING
Honeywell
UTC Aerospace Systems
Pratt & Whitney
A United Technologies Company
LOCKHEED MARTIN
NORTHROP GRUMMAN

U.S. ARMY
ARL
NASA
OAK RIDGE National Laboratory

and others….

Schema Requirements



Feed materials

- Bulk properties
- Simulation input data
- Microstructure

Polymers
Low density alloys
High temp alloys
Medical alloys
Innovative alloys…

Processes (Machines and simulations)

- Type and capabilities details
- Processing parameters stores
- Project-specific data

Direct laser deposition
Laser sintering
Electron beam deposition
Electro-mechanical…

Fabricated parts

- Characterization and measurements

Mechanical testing
Ultrasonic inspection
Computed Tomography
Metallography
Microscopy…

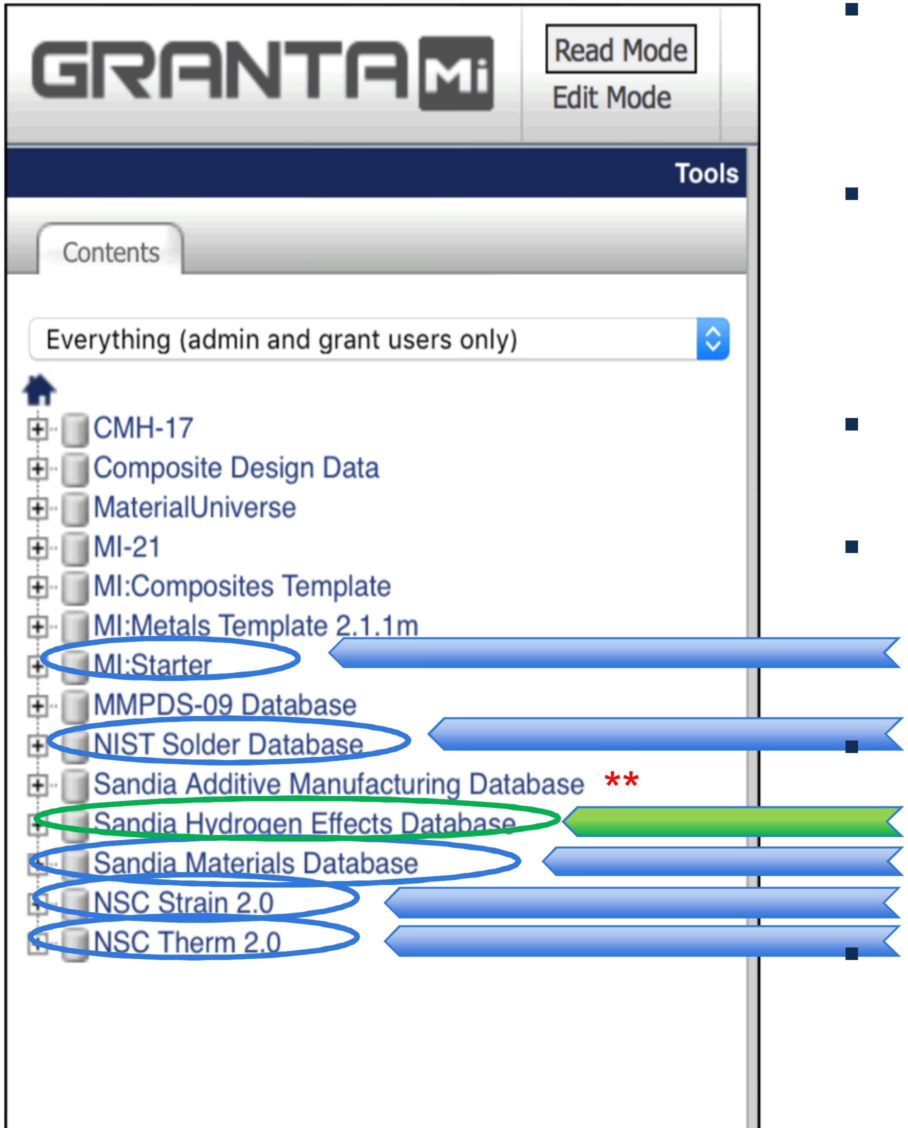
Schema Inclusion

Granta MI, AM Schema Layout Headings

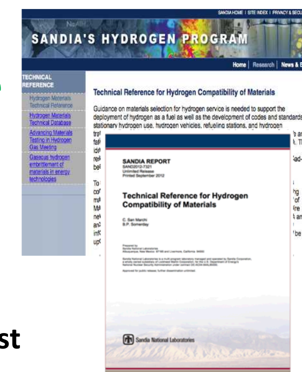
- Currently Includes 800+ attributes

Layout Headings - Granta AM Schema v1.01					
Machines	Materials	Part Design	Material Batches	Builds	Parts
General Information	General Information	General Information	Project Information	Project Information	Project Information
Calibration	General Properties	Original Design	General Batch Information	General Information	Part Information
Machine Specifications	Composition overview	Re-Design	Manufacturing	Build Information	Part Specifications
Material	Bulk Mechanical Properties	Dimensions	Material Quality	General Build Parameters	Samples
Machine Properties	Bulk Thermal Properties	General Material Properties	Particle Properties and Size Distribution	Build Atmosphere	Visual Inspection
Build Environment	Bulk Electrical Properties	Processing	Interstitial contamination	Material Used	Accuracy Testing
Laser Properties	Biological	Static Tensile Properties	Flowability	Support	NDT Testing
Electron Beam Properties	Chemical	High-cycle fatigue properties	Wire Properties	Filament Information	Post Processing
	Eco	Fracture Toughness	Chemical Analysis and Composition	Substrate	Heat Treatment
	Cost	Fatigue Crack Growth		Quality of Welding Consumables	HIP
	Safety and Handling	Surface Roughness Requested		Build Alarms	Machining
	General Information	Other Requested Properties		Themes Used	Laser Polishing
	Requirements	Final Part Details		Powder Build Parameters	Other Post Processing
	Composition	Quality Assurance		Wire Build Parameters	
	Physical Properties	Key Benefits		Laser Properties	
	Further Information			Electron Beam Properties	
				Arc Properties	
				In-Process Rolling	
				In-Process Analysis	

Sandia Databases

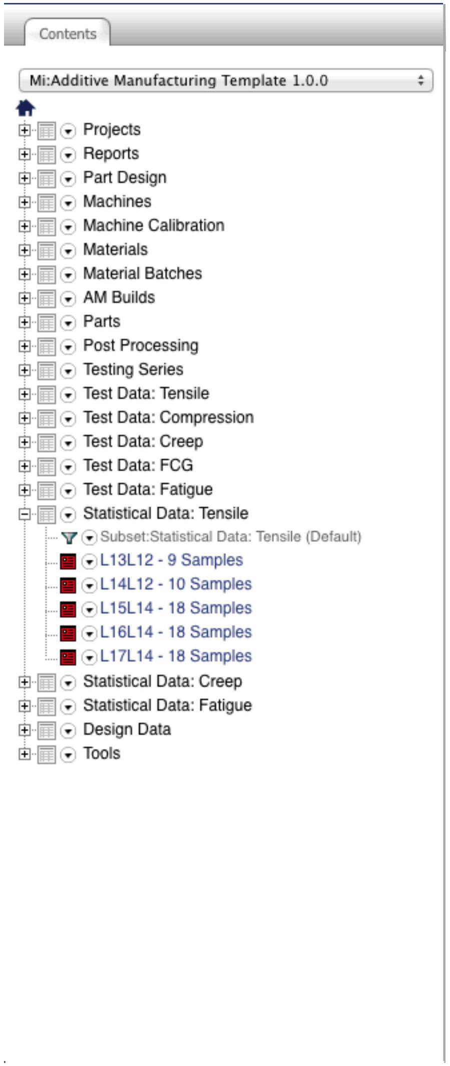


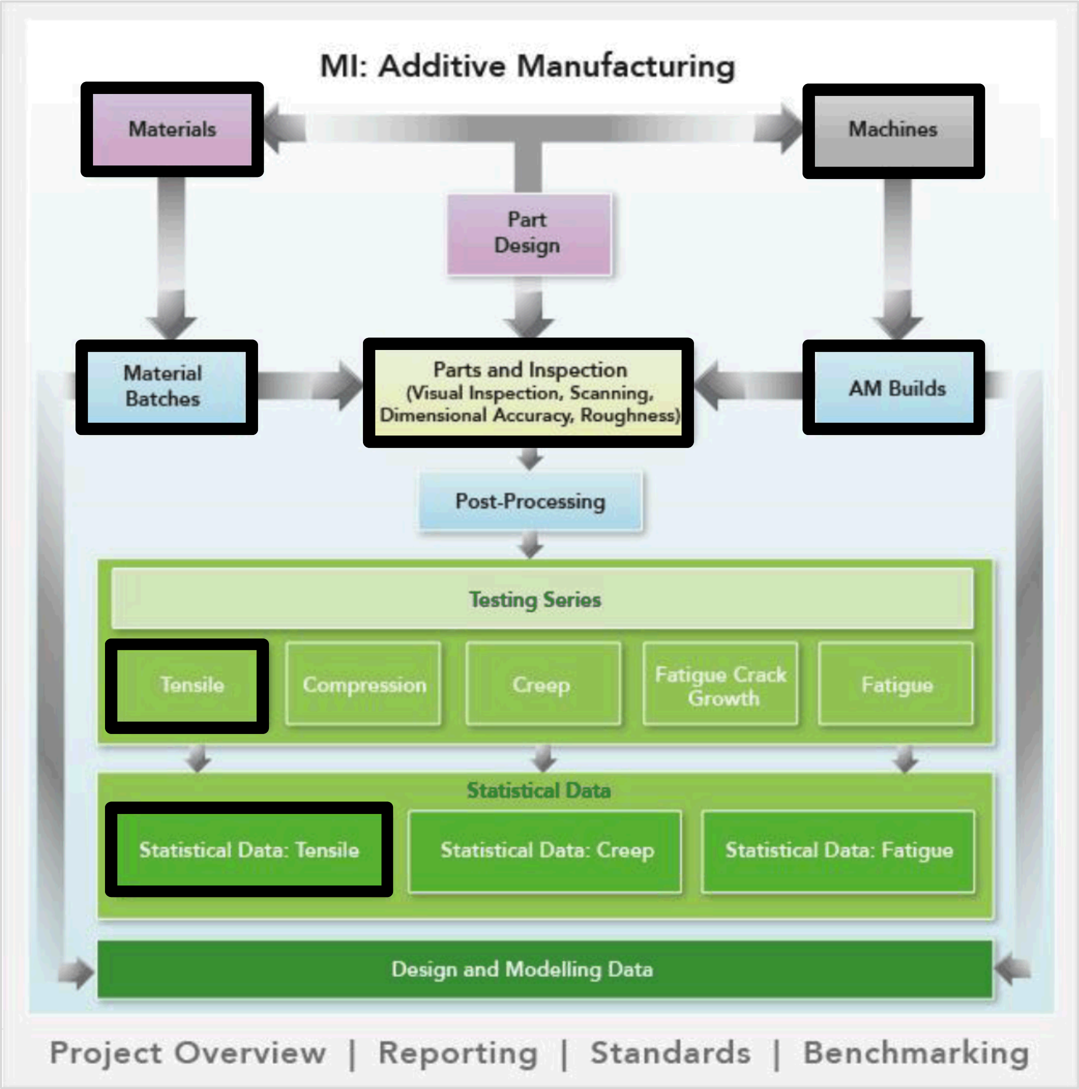
- **MI: Starter**
  - **Training**
- **NIST Solder Database**
  - http://www.nist.gov/mml/msed/solder.cfm
  - http://www.msed.nist.gov/solder/NIST_LeadfreeSolder_v4.pdf
- **Sandia Additive Manufacturing Database**
- **Sandia Hydrogen Effects Database**
  - **http://granta-mi.sandia.gov**



- **Sandia Materials Database**
  - **Material Systems of Specific SNL Interest**
  - **Epoxies, Blast Foams, Connectors & Cables**
- **NSC Strain 2.0 & Therm 2.0**
  - **Mechancial & Thermal Properties**

GRANTA MI AM Schema v 1.0.0

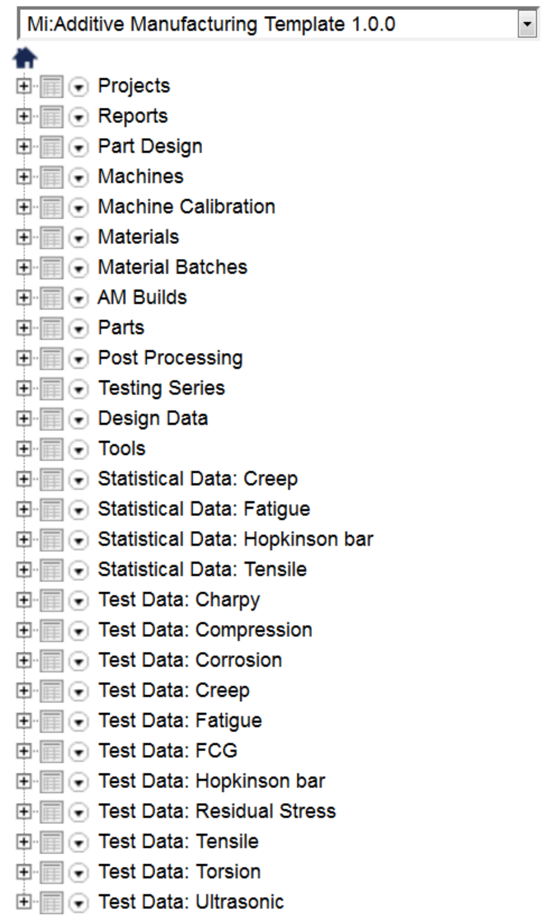




Sandia AM Database

Sandia National Laboratories

- Projects
- Reports
- Machines
- Materials
- AM Builds
- Test Data
- Statistical Data

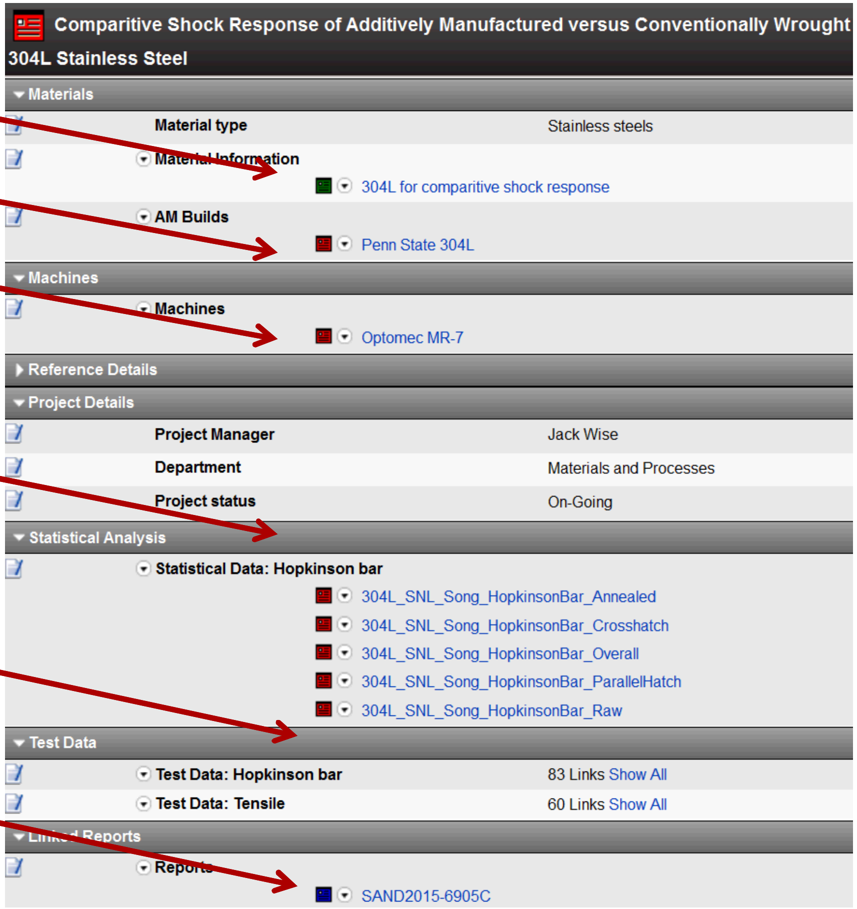


Data

Material System	Test Types	Material Properties	Amount
AlSi10Mg	Charpy	Charpy impact vs Angle	1
		Charpy impact vs distance	
	Corrosion	Electrochemical impedance	1
		Open circuit potential	1
		Polarization test	1
	Creep	Strain	4
	Residual Stress	Residual stress bulk	1
		Residual stress corner	
	Tensile	Ductility	112
		Yield Stress	112
		Young's modulus	112
		Ultimate tensile strength	93
		Tensile response	29
	Torsion	Torsion	1
	Ultrasonic	Poisson's ratio	1
		Young's modulus	
304L	Hopkinson bar	Stress vs strain	83
	Tensile	Strain rate	91
		Proportion limit	60
		Ultimate tensile strength	60
		Tensile failure stress	60
		Load vs displacement	31
Ti6Al4V	Tensile	Yield stress	74
		Ultimate tensile strength	74
		Ductility	74

Projects

- Auto linking between:
  - Materials
  - AM Builds
  - Machines
  - Statistical Data
  - Test Data
  - Reports



Project to Report

- Sandia Additive Manufacturing Database
  - Projects
    - Subset:Projects (Default)
    - Comparitive Shock Response of Additively Manufactured versus Conventionally Wrought 304L Stainless Steel
    - GTS Round Robin
    - Mechanical Benchmarking Project
    - Properties of Laser Bed Manufactured AlSi10Mg

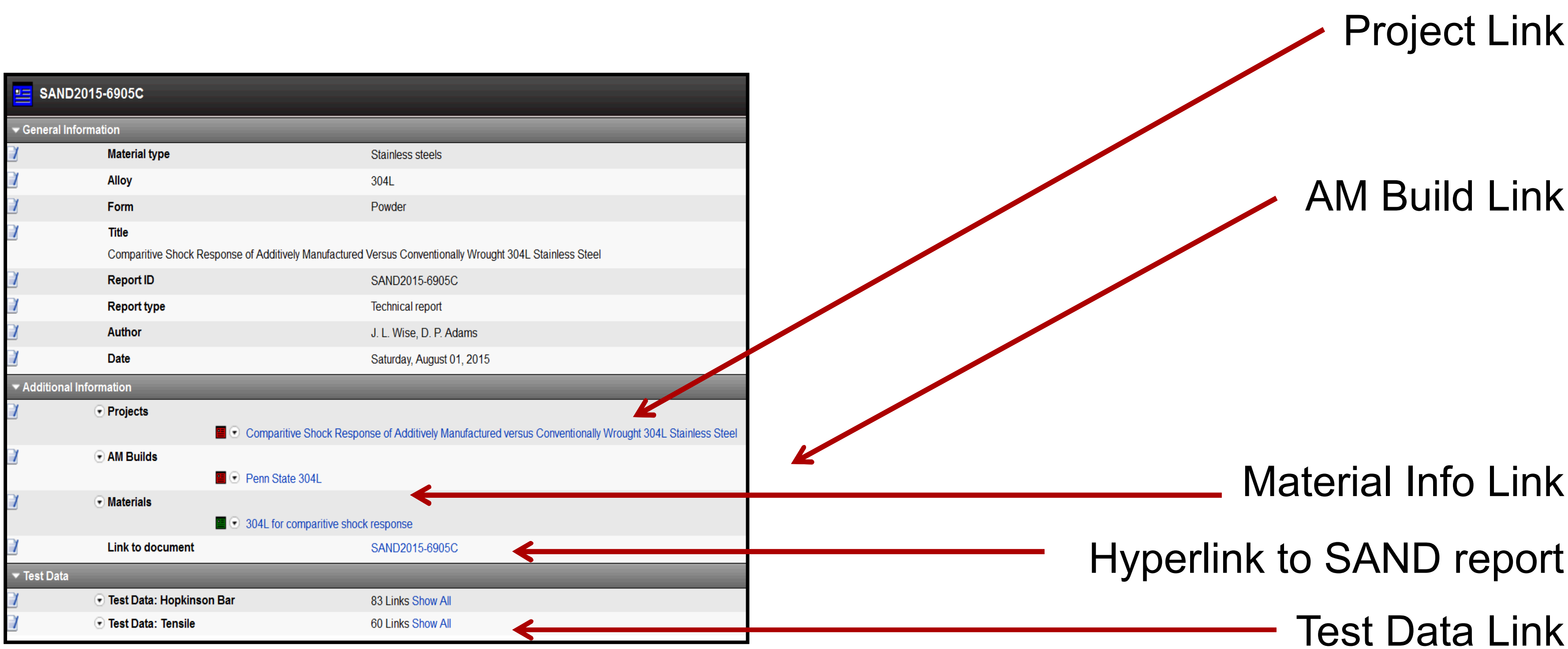
Comparitive Shock Response of Additively Manufactured versus Conventionally Wrought 304L Stainless Steel

Materials	
Material type	Stainless steels
Material Information	304L for comparitive shock response
AM Builds	Penn State 304L
Machines	
Machines	Optomec MR-7
Reference Details	
Project Details	
Project Manager	Jack Wise
Department	Materials and Processes
Project status	On-Going
Statistical Analysis	
Statistical Data: Hopkinson bar	304L_SNL_Song_HopkinsonBar_Annealed 304L_SNL_Song_HopkinsonBar_Crosshatch 304L_SNL_Song_HopkinsonBar_Overall 304L_SNL_Song_HopkinsonBar_ParallelHatch 304L_SNL_Song_HopkinsonBar_Raw
Test Data	
Test Data: Hopkinson bar	83 Links Show All
Test Data: Tensile	60 Links Show All
Linked Reports	
Reports	SAND2015-6905C

SAND2015-6905C

General Information	
Material type	Stainless steels
Alloy	304L
Form	Powder
Title	Comparitive Shock Response of Additively Manufactured Versus Conventionally Wrought 304L Stainless Steel
Report ID	SAND2015-6905C
Report type	Technical report
Author	J. L. Wise, D. P. Adams
Date	Saturday, August 01, 2015
Additional Information	
Projects	Comparitive Shock Response of Additively Manufactured versus Conventionally Wrought 304L Stainless Steel
AM Builds	Penn State 304L
Materials	304L for comparitive shock response
Link to document	SAND2015-6905C
Test Data	
Test Data: Hopkinson Bar	83 Links Show All
Test Data: Tensile	60 Links Show All

Report Record



Machines


SYSTEMS

LENS® MR-7

Breakthrough additive manufacturing technology for the fabrication & repair of high performance metal components

LENS systems are used in the repair and rapid manufacturing of metal components in state-of-the-art materials such as titanium, stainless steel, and Inconel®. Use the LENS MR-7 System to rapidly create materials of exceptional quality.

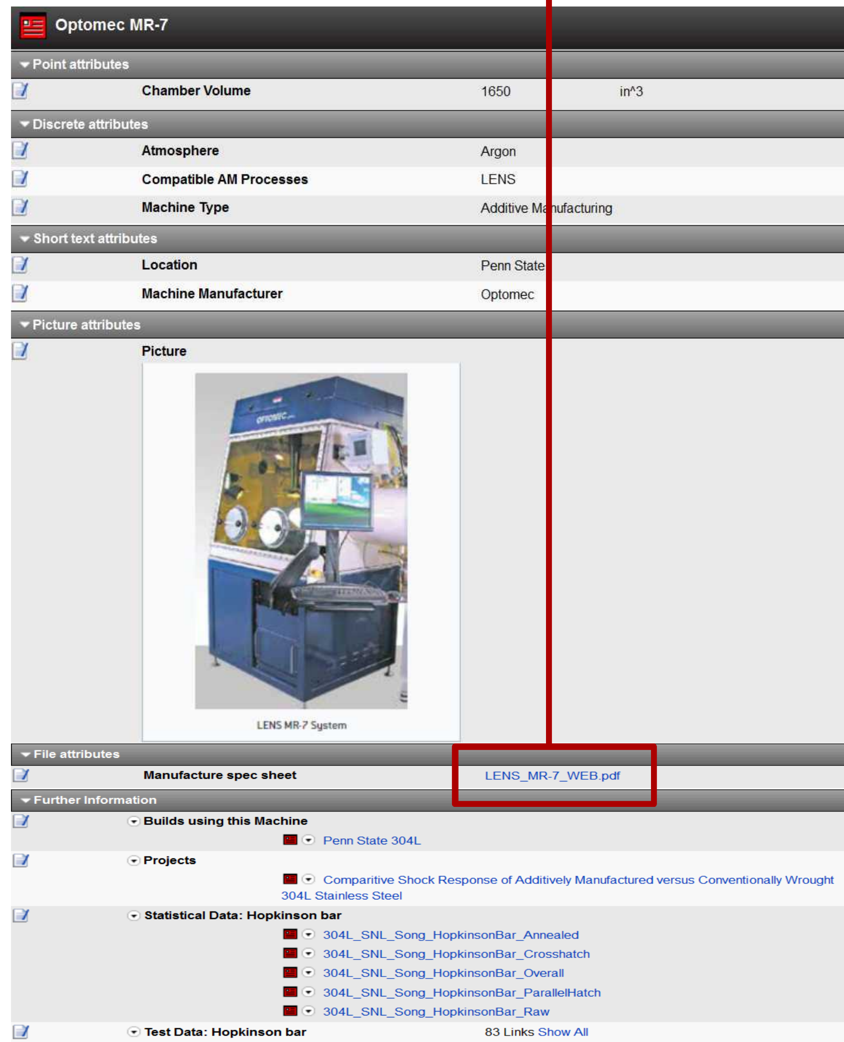
Novel structures created by LENS

LENS MR-7 System

The LENS MR-7 system offers a 300mm cubed work envelope, making it ideal for the manufacture or repair of smaller components. LENS systems use energy from a high-power Fiber Laser to build up structures one layer at a time directly from metal powders, alloys, ceramics or composites. The two powder feeders allow gradient materials to be made – every layer can have a different chemistry. This enables new materials to be made and analyzed with extraordinary speed. LENS systems are used throughout the entire product lifecycle for applications ranging from rapid alloy development and functional prototyping to rapid manufacturing or repair.

KEY FEATURES

APPLICATIONS



AM Builds link

Projects link

Statistical data links

Test data link

Materials

GPI EOS Aluminum AlSi10Mg

General Information

Material Type	Aluminum alloys
Alloy	AlSi10Mg
Available Forms	Powder
Used in Process	Powder bed (Laser beam)
Used in Project	Properties of Laser Bed Manufactured AlSi10Mg
Suppliers	EOS
Material Data	GPI EOS AlSi10Mg spec.pdf
Machines	GPI EOS M280
Reports	SAND2015-8981 "Properties of laser powder bed manufactured AlSi10Mg"
AM Builds	GPI 1 Fall 2014 GPI 2 Jan 2015 GPI 3 Mar 2015

Chemical Analysis and Composition

Test Data

Test Data: Charpy	GPI_EOS_IMR_Deibler
Test Data: Corrosion	AlSi10Mg_SNL_Serna_Corrosion (Electrochemical Impeadance Test) AlSi10Mg_SNL_Serna_Corrosion (Polarization Test) AlSi10Mg_SNL_Serna_Corrosion (Open Circuit Potential)
Test Data: Creep	AlSi10Mg creep_152MPa_0.59Yield_0.36Ultimate AlSi10Mg creep_278MPa_1.08Yield_0.65Ultimate AlSi10Mg creep_322MPa_1.25Yield_0.75Ultimate AlSi10Mg creep_356MPa_1.38Yield_0.83Ultimate
Test Data: Residual Stress	AlSi10Mg_SNL_ Rodriguez_ResidualStress (Residual Stress)
Test Data: Tensile	48 Links Show All
Test Data: Torsion	AlSi10mg_SNL_Lu_TorsionShear (Torsion Shear)
Test Data: Ultrasonic modulus	AlSi10Mg_SNL_Carroll_UltrasonicModulus (Ultrasonic Modulus)

Project link

Specification sheet

Machine link

Report link

AM Builds links

Test data

eos

Material data sheet

EOS Aluminium AlSi10Mg

EOS Aluminium AlSi10Mg is an aluminium alloy in fine powder form which has been specially optimised for processing on EOSINT M systems

This document provides information and data for parts built using EOS Aluminium AlSi10Mg powder (EOS art.-no. 9011-0024) on the following system specifications:

- EOSINT M 280
  with PSW 3.6 and Original EOS Parameterset AlSi10Mg_Speed 1.0
- EOS M 290 400Watt
  with EOSPRINT 1.0 and Original EOS Parameterset AlSi10Mg_Speed 1.0

Description

AlSi10Mg is a typical casting alloy with good casting properties and is typically used for cast parts with thin walls and complex geometry. It offers good strength, hardness and dynamic properties and is therefore also used for parts subject to high loads. Parts in EOS Aluminium AlSi10Mg are ideal for applications which require a combination of good thermal properties and low weight. They can be machined, spark-eroded, welded, micro shot-peened, polished and coated if required.

Conventionally cast components in this type of aluminium alloy are often heat treated to improve the mechanical properties, for example using the T6 cycle of solution annealing, quenching and age hardening. The laser-sintering process is characterized by extremely rapid melting and re-solidification . This produces a metallurgy and corresponding mechanical properties in the as-built condition which is similar to T6 heat-treated cast parts. Therefore such hardening heat treatments are not recommended for laser-sintered parts, but rather a stress relieving cycle of 2 hours at 300 °C (572 °F). Due to the layerwise building method, the parts have a certain anisotropy, which can be reduced or removed by appropriate heat treatment - see Technical Data for examples.

AM Build

- Projects link
- Reports link
- Build layout file
- Machine link
- Material link

GPI 2 Jan 2015

General Information

Projects
Properties of Laser Bed Manufactured AlSi10Mg

Reports
SAND2015-8981 "Properties of laser powder bed manufactured AlSi10Mg"

Build ID	GPI 2
Date of Build	Monday, January 26, 2015
Drawing File	GPI Build layout 63941_SNL_Digital SetUp and Orientation_Update_1-26-2015 (2).pdf

Notes on Build
Build was in January 2015. Build includes 36 tensile samples, 40 Charpy samples, 8 residual stress samples, 16 creep samples, 10 torsion tube samples, and 25 corrosion cube samples.

Build Information

Process	Powder bed (Laser beam)

Machine used in this build
GPI EOS M280

Material Information
GPI EOS Aluminum AlSi10Mg

Test Data

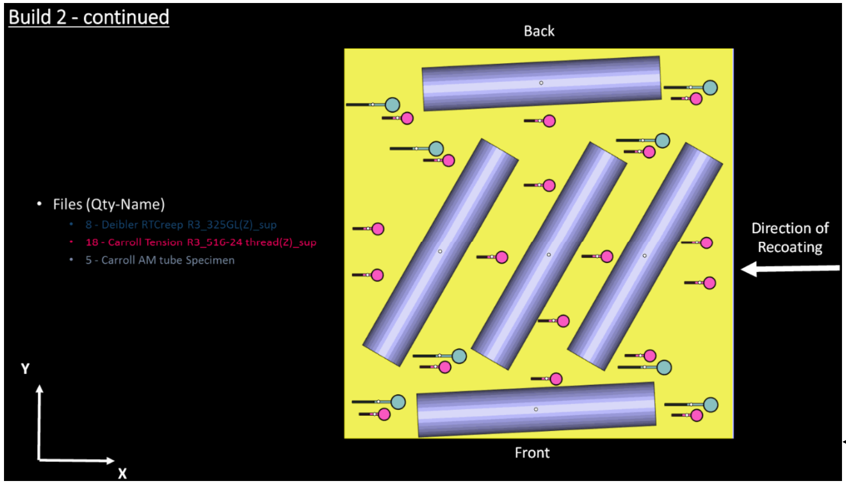
Test Data: Charpy
GPI_EOS_IMR_Deibler

Test Data: Corrosion
AlSi10Mg_SNL_Serna_Corrosion (Electrochemical Impeadance Test)
AlSi10Mg_SNL_Serna_Corrosion (Polarization Test)
AlSi10Mg_SNL_Serna_Corrosion (Open Circuit Potential)

Test Data: Creep
AlSi10Mg creep_152MPa_0.59Yield_0.36Ultimate
AlSi10Mg creep_278MPa_1.08Yield_0.65Ultimate
AlSi10Mg creep_322MPa_1.25Yield_0.75Ultimate
AlSi10Mg creep_356MPa_1.38Yield_0.83Ultimate

Test Data: Residual Stress
AlSi10Mg_SNL_ Rodriguez_ResidualStress (Residual Stress)

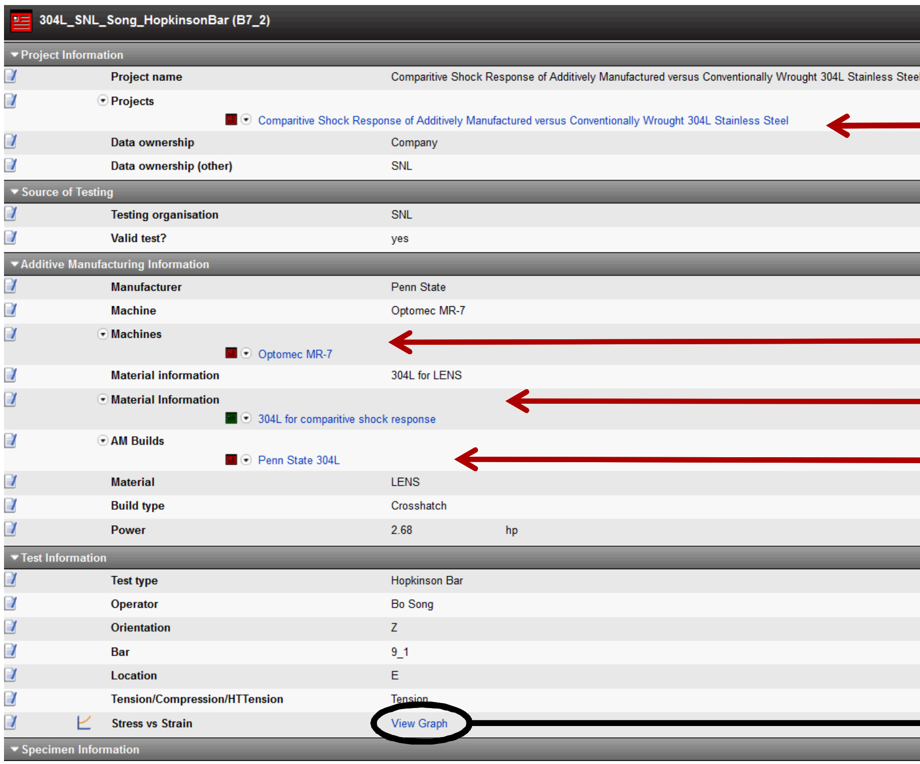
Test data



Test Data

- Test types with data
  - Charpy
  - Corrosion
  - Creep
  - Hopkinson bar
  - Residual Stress
  - Tensile
  - Torsion
  - Ultrasonic
- Auto linking to:
  - Projects
  - Reports
  - Machines
  - Materials
  - AM Builds
  - Statistical Data
- Can contain graphs, files, pictures, and tables of results

Test Data: Hopkinson Bar



304L_SNL_Song_HopkinsonBar (B7_2)

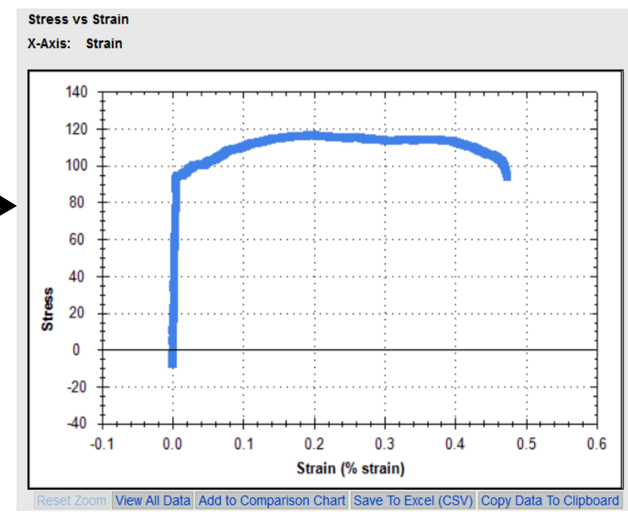
Project Information	
Project name	Comparitive Shock Response of Additively Manufactured versus Conventionally Wrought 304L Stainless Steel
Projects	Comparitive Shock Response of Additively Manufactured versus Conventionally Wrought 304L Stainless Steel
Data ownership	Company
Data ownership (other)	SNL
Source of Testing	
Testing organisation	SNL
Valid test?	yes
Additive Manufacturing Information	
Manufacturer	Penn State
Machine	Optomec MR-7
Machines	Optomec MR-7
Material information	304L for LENS
Material Information	304L for comparitive shock response
AM Builds	Penn State 304L
Material	LENS
Build type	Crosshatch
Power	2.68 hp
Test Information	
Test type	Hopkinson Bar
Operator	Bo Song
Orientation	Z
Bar	9_1
Location	E
Tension/Compression/HTTension	Tension
Stress vs Strain	View Graph
Specimen Information	

Project link

Machine link

Material link

AM Build link



Not shown:

- Reports link
- Original data file
- Statistical data link

Test Data: Tensile

Sandia National Laboratories

TV24

Project Information		
Project name	Properties of Laser Bed Manufactured AlSi10Mg	
Projects	Properties of Laser Bed Manufactured AlSi10Mg	
Data ownership	Company	
Associated Statistical Data	Carroll_3000_overall Carroll_3000_Smoothed	
Source of Testing		
Additive Manufacturing Information		
Manufacturer	NSC	
Machine	Renishaw AM 250 with original software	
Machines	Renishaw AM 250 with original software	
Material information	LPW Standard AlSi10Mg	
Material Information	LPW Standard AlSi10Mg	
AM Build	NSC build 14	
AM Builds	NSC build 1	
Test Information		
Specimen Information		
Specimen ID	TV24	
Alloy	Aluminum	
Gauge thickness	0.0501	in
Gauge width	0.234	in
Effective thickness	0.0501	in
Effective width	0.234	in
Surface finish	Other	
Surface finish (other)	Smoothed	
Measurement		
Ductility	0.051	mm/mm
Yield Stress	20	ksi
Yield stress (based on unload Young's modulus)	19.9	ksi
Tensile Modulus Results		
Young's modulus (11-axis)	9.29	10^6 psi
Young's modulus (unloading)	9.39	Msi

Project link

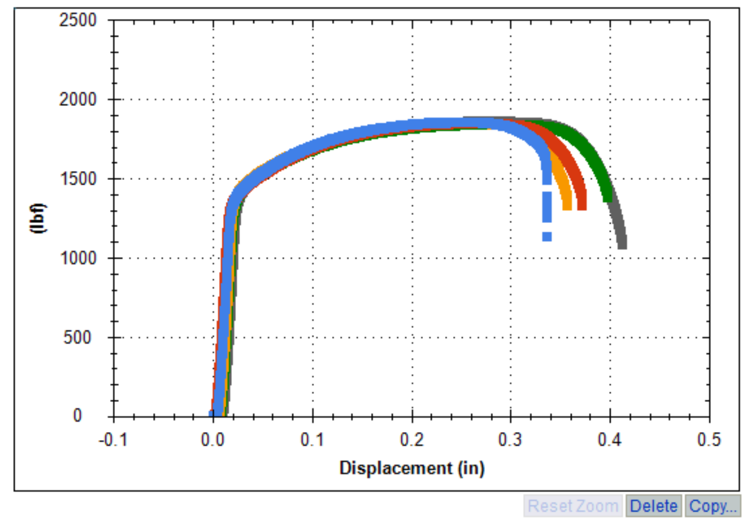
Statistical data links

Machine link

Material link

AM Build link

Comparison Chart



Statistical Data

- Statistical Data available
  - Tensile
  - Hopkinson bar
- Allows for user to examine
  - Average
  - Maximum
  - Minimum
  - Standard Deviation
- Can be used to find statistical data for specific attributes for comparison

- Auto linking to:
  - Projects
  - Reports
  - Machines
  - Materials
  - AM Builds
  - Test Data

Statistical Data: Hopkinson Bar

Sandia National Laboratories

304L_SNL_Song_HopkinsonBar_Crosshatch

Material Information

Project name	Comparitive Shock Response of Additively Manufactured versus Conventionally Wrought 304L Stainless Steel
Projects	Comparitive Shock Response of Additively Manufactured versus Conventionally Wrought 304L Stainless Steel
Material information	304L for LENS
Material Information	304L for comparitive shock response
AM Builds	Penn State 304L
Machines	Optomec MR-7
Machines	Optomec MR-7

Additional Information

Report ID	SAND2015-6905C
Reports	SAND2015-6905C

Project link

Material link

Machine link

AM Build link

Report link

Test Conditions

Strain rate average	1810	% strain/s
Maximum	2900	% strain/s
Minimum	440	% strain/s
Standard deviation	896	% strain/s

Tensile Results

Yield stress average	87.7	ksi
Maximum	107	ksi
Minimum	63.6	ksi
Standard deviation	11.7	ksi

Statisical Rollup

Hopkinson bar test data used in this rollup Hide table

Save To Excel (CSV) Copy To Clipboard

Yield Stress (ksi)	Rate (/s)	Linking value (Specimen ID)	Linked records found
78	2400	HB_B12_1	304L_SNL_Song_HopkinsonBar (B12_1)
63.6	2500	HB_B12_2	304L_SNL_Song_HopkinsonBar (B12_2)
78.3	2600	HB_B13_1	304L_SNL_Song_HopkinsonBar (B13_1)
90.2	2500	HB_B13_2	304L_SNL_Song_HopkinsonBar (B13_2)
76.3	540	HB_B14_1	304L_SNL_Song_HopkinsonBar (B14_1)
76.6	560	HB_B14_2	304L_SNL_Song_HopkinsonBar (B14_2)
77.8	560	HB_B14_3	304L_SNL_Song_HopkinsonBar (B14_3)
84.7	1500	HB_B14_4	304L_SNL_Song_HopkinsonBar (B14_4)
80	1500	HB_B14_5	304L_SNL_Song_HopkinsonBar (B14_5)
81.2	1500	HB_B14_6	304L_SNL_Song_HopkinsonBar (B14_6)
92.8	2800	HB_B14_7	304L_SNL_Song_HopkinsonBar (B14_7)
91	2800	HB_B14_8	304L_SNL_Song_HopkinsonBar (B14_8)
91.5	2700	HB_B14_9	304L_SNL_Song_HopkinsonBar (B14_9)
94.2	2900	HB_B3_1	304L_SNL_Song_HopkinsonBar (B3_1)
71.6	2500	HB_B3_2	304L_SNL_Song_HopkinsonBar (B3_2)
106	2500	HB_B4_1	304L_SNL_Song_HopkinsonBar (B4_1)
75.9	2500	HB_B4_2	304L_SNL_Song_HopkinsonBar (B4_2)
82.9	440	HB_B5_1	304L_SNL_Song_HopkinsonBar (B5_1)