# BIO: Walter E. Baker

Walter E. Baker, CEO and co-founder, Gradient Systems

Walter (*www.linkedin.com/pub/walter-e-baker/75/728/7b9/*) has been involved with the database, server and storage industries for 35 years. During that time, Walter worked in various teaching, senior technical and executive management positions at multiple academic institutions, end-user corporations and technology corporations. Walter is also the auditor, administrator and a co-founder of the Storage Performance Council (*www.storageperformance.org*).

# Industry Standard Benchmarks for Flash


Storage Performance Council (SPC)

*(www.StoragePerformance.org)*

Walter E. Baker

SPC Administrator and Auditor

# Successful Storage Products

- **Performance**, **price-performance** and **power/energy consumption** are three key measurements for:
  - Successful development of a storage product *(vendor perspective).*
  - Successful purchase or upgrade *(end-user/customer perspective)*.

# Performance – Vendor Perspective

- **A "measure of success" during product development.**
  *(Are performance targets maintained during development?)*
- **A factor in internal product positioning.**
  *(Where should the product be positioned and marketed within a product family?)*
- **A key differentiator in competitive positioning.**
  *(How should the product be positioned and marketed against competitors?)*


# Performance – End-User Perspective

- I/O performance is a key factor for successful application performance.
  - **Throughput**
    - IOPS needed to support required OLTP application performance requirements.
    - Data throughput needed to support sequential application performance requirements
  - **Response Time:** IOPS response time required OLTP application performance requirements.

# Price-Performance

- Vendor Perspective:
  - A key differentiator in competitive positioning *(How should the product be positioned and marketed against competitors?)*.
- End-User/Customer Perspective:
  - What is the realistic cost, including hardware maintenance and software support, for a product that meets performance and power/energy consumption requirements?

# Power/Energy Consumption

- An increasingly important factor for consideration along with **performance** and ‘traditional’ **price-performance**.
- End-users/customers are developing energy ‘budgets’ during data center planning to consider:
  - Increasing cost of finite energy sources:  coal, petroleum products, etc.
  - Ecological impact of increasing energy use.

# Storage Performance Council (SPC)

The SPC provides the means to accurately assess and compare **storage performance**, **price-performance** and **power/energy consumption** for both storage vendors and end-users/customers.


# SPC Objectives

- Provide an incentive for storage performance improvements in the storage industry.
- Enable end-users/customers to accurately compare storage product performance.
- Establish a “level playing field” for storage vendors to differentiate products.
- Publicize storage performance results.
- Ensure accuracy and authenticity of those results.

# SPC Membership






**EMC Corporation**

















# SPC Membership

NEC

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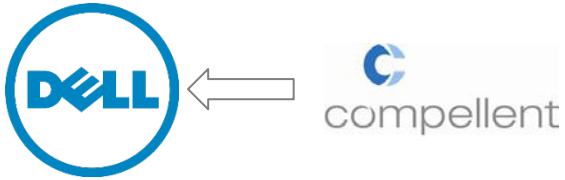
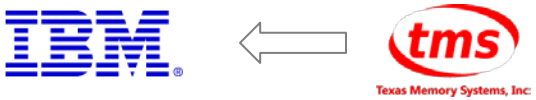
# SPC Membership Consolidation

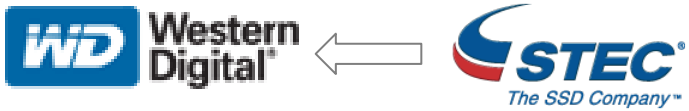




**EMC Corporation** ⇦ XtremIO




# SPC Benchmarks

- SPC Benchmark 1™ (SPC-1™)
- SPC Benchmark 2™ (SPC-2™)
- SPC-1 and SPC-2 are the two “core” benchmarks of the SPC.
- From those two “core” benchmarks:
  - Component-level benchmarks
  - Energy extensions to measure power/energy consumption


# SPC Benchmark 1 (SPC-1)

- SPC-1 consists of a single workload that measures the storage performance of business critical application types.
- Those applications are characterized by predominately random I/O requests, requiring query, update and logging operations.
- Examples of those types of applications include OLTP, database operations and mail server implementations.


# SPC Benchmark 2 (SPC-2)

- SPC-2 consists of three distinct workloads to demonstrate the storage subsystem performance of business critical application that require large-scale, sequential movement of data.
- Those applications are characterized by predominately large I/Os organized into one or more concurrent sequential patterns.

# SPC Benchmark 2 (SPC-2)

- SPC-2 Workloads:
  - **Large File Processing** *(LFP)*: Simple sequential processing of one or more large files *(scientific computing, large-scale financial processing, etc.)*.
  - **Large Database Query** *(LDQ)*: Scans or joins of large relational tables *(data mining, business intelligence, etc.)*.
  - **Video on Demand (VOD):** Delivery of individualized video entertainment to a community of subscribers from a digital film library.


# SPC Component Benchmarks

- There is a distinct need to provide objective and verifiable performance measurement and comparisons of individual storage components such as storage devices *(HDDs, SSDs and Hybrids)*, HBAs/controllers, small storage subsystems, storage software, etc.
- SPC-1 and SPC-2 provide that type of performance measurement and comparison, but are used for large complex storage configurations.


# SPC Component Benchmarks

- SPC Benchmark 1C™ (SPC-1C™)
  - SPC-1C is based on the SPC-1 benchmark specification and utilizes the single SPC-1 workload.
- SPC Benchmark 2C™ (SPC-2C™)
  - SPC-2C is based on the SPC-2 benchmark specification and utilizes the three SPC-2 workloads.


# SPC Component Benchmarks

- SPC-1C and SPC-2C provide performance measurement and comparison for storage components such as:
  - Storage devices such as HDDs, SSDs and Hybrid devices.
  - HBAs/controllers
  - Small storage subsystems (single enclosure)
  - Processors used in the above components
  - Storage software such as snapshots, adaptive data migration, logical volume managers, etc.


# SPC Energy Extensions

- SPC Benchmark 1/Energy™ (SPC-1/E™)
- SPC Benchmark 2/Energy™ (SPC-2/E™)
- SPC Benchmark 1C/Energy™ (SPC-1C/E™)
- SPC Benchmark 2C/Energy™ (SPC-2C/E™)
- Each SPC benchmark includes an optional energy extension, which includes power/energy measurement and reporting.


# SPC Benchmarks are “Agnostic”

- SPC benchmarks are storage technology “agnostic”.
  - SPC benchmarks are implemented at the end-user application level.
  - As such, like end-user applications, there is no “awareness” of the storage technology that is the target of the I/O requests generated by the benchmark.


# SPC Benchmarks are “Agnostic”

- The technology “agnostic” nature of SPC benchmarks allows direct comparison of:
  - Various storage interfaces:  FC, SAS, SATA, iSCSI, FCoE, Infiniband, etc.
  - Various storage devices and storage configurations:  HDDs, SSDs, Hybrid devices, HDD/SSD tiered configurations


# SPC Benchmarks for SSD/Flash

- SPC benchmarks address, directly and indirectly, the “Fresh-Out-of-Box” (FOB) and preconditioning performance of SSD/Flash storage devices as a result of the following:
  - The execution profile for each SPC benchmark
  - The iterative nature of “internal” SPC measurements prior to audited measurements.


# SPC-1 Execution Profile

- The SPC-1 execution profile consists of the following in an uninterrupted sequence:
  - **Application storage pre-fill:** All of storage that will be used by the benchmark is “pre-filled” with sequential write of pre-defined data content.
  - **Sustainability Test Run:** A Test Run at 100% of the specified offered load with a minimum of an 8-hour Measurement Interval in “steady state”.

# SPC-1 Execution Profile *(continued)*

- **IOPS Test Run:** A Test Run at 100% of the specified offered load with a minimum of a 10 minute Measurement Interval in “steady state”. This Test Run produces the reported SPC-1 IOPS.
- **Response Time Ramp Test Runs:** A series of five Test Runs at 95%, 90%, 80%, 50% and 10% of the specified offered load with a minimum of a 10 minute Measurement Interval for each Test Run.
- **Repeatability Test Runs:** A series of four Test Runs at 10%, 100%, 10% and 100% of the specified offered load with a minimum of a 10 minute Measurement Interval for each Test Run.

# SPC-1 Execution Profile *(continued)*

- **Persistence Test:** This is a test to ensure that data written to persistent storage is intact after a normal power off/power on cycle.
  - **Test Run 1 *(write phase)*:** A pre-defined pattern is written to randomly selected storage locations that were used by the previous Test Run.
  - **Power Off/Power On Cycle:** The storage configuration is powered off after completion of Test Run 1, then powered on.
  - **Test Run 2 (read phase):** The content of the previously selected storage locations is verified to be what was written in Test Run 1.

# SPC-1 Measurement Constraints

- **Sustainability Performance:**

  The measured Sustainability SPC-1 IOPS must be at least 95% of the reported SPC-1 IOPS generated by the IOPS Test Run.

- **Repeatability Performance:**

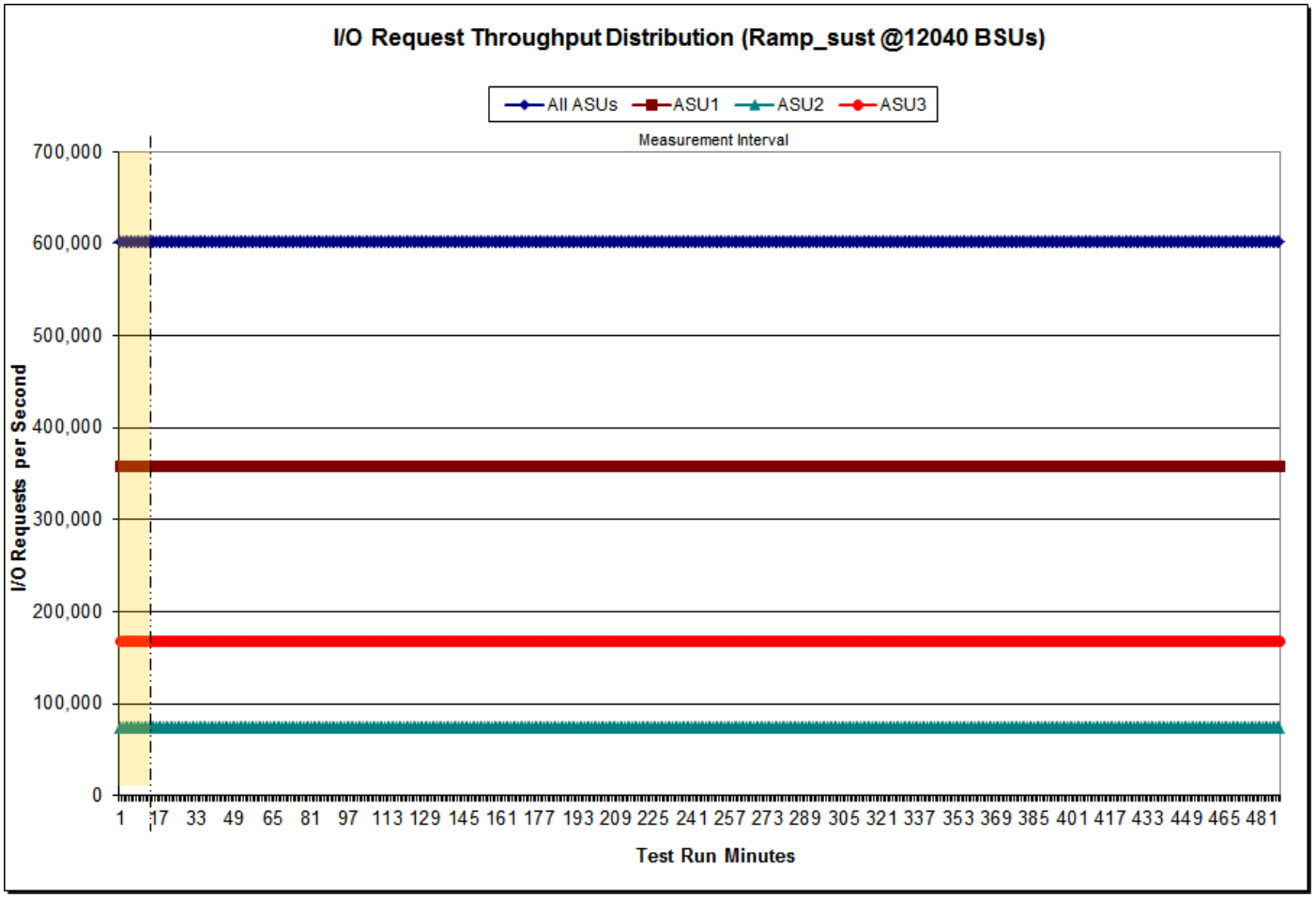
The measured SPC-1 IOPS from the two 100% Repeatability Test Runs must be at least 95% of the reported SPC-1 IOPS generated by the IOPS Test Run.

# SPC-1 Measurement Constraints

- **Repeatability Average Response Time:** The average response time from the two Repeatability 10% Test Runs must meet one of the two following constraints:
  - Less than 105% of the average response time of the Response Time Ramp 10% Test Run.
  - Less than the average response time of the Response Time Ramp 10% Test Run plus 1 millisecond.

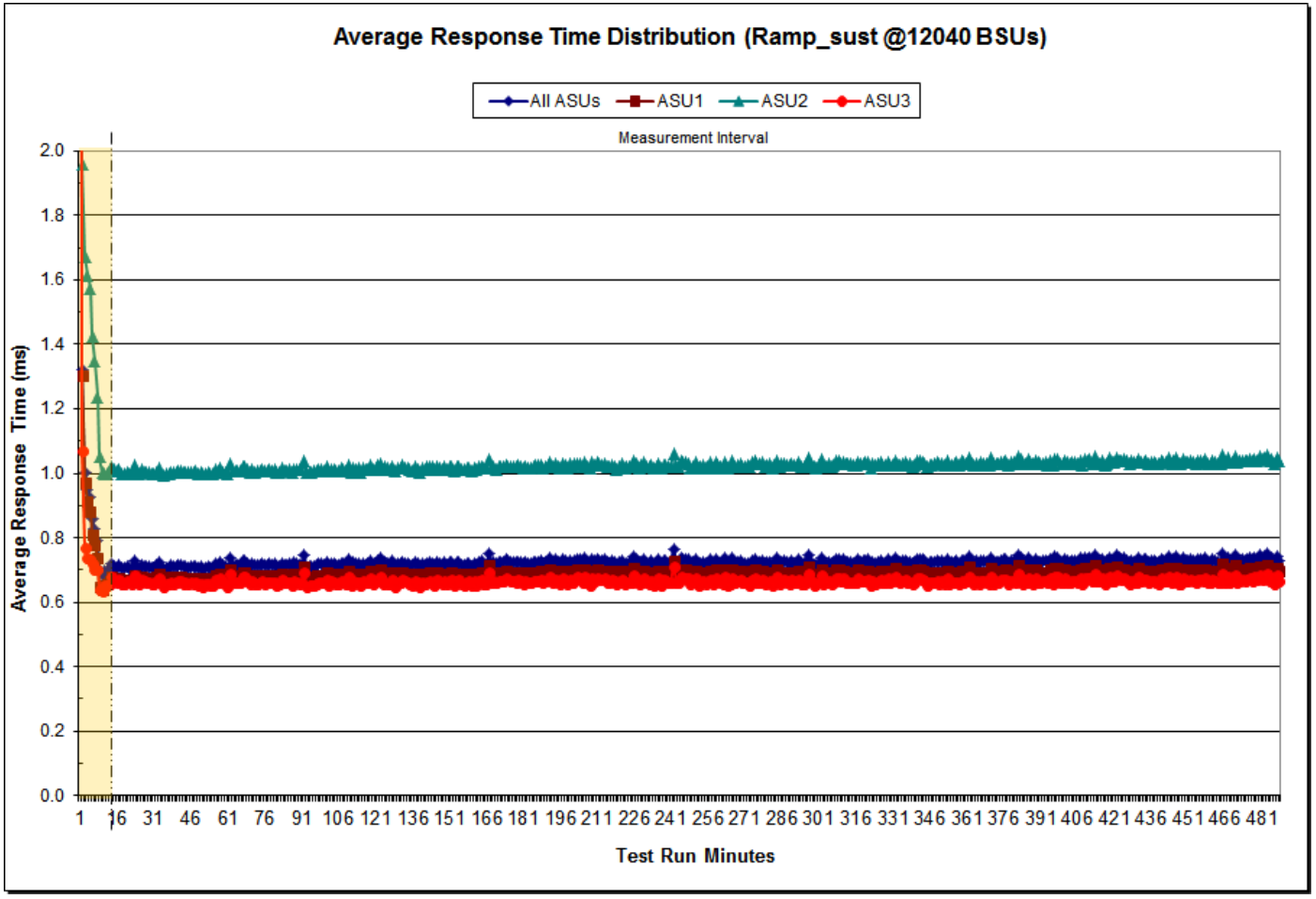
# SPC-1 Sustainability Performance

- 24 SSDs
- 43,550.927 GB Configured
- 24,551.412 GB Used
- 18,999.541 GB Unused
- 8-hour Measurement Interval
- 601,990.38 Sustainability SPC-1 IOPS
- 602,091.47 Reported SPC-1 IOPS



# SPC-1 Sustainability Response Time

- 24 SSDs
- 43,550.927 GB Configured
- 24,551.412 GB Used
- 18,999.541 GB Unused
- 8-hour Measurement Interval
- 0.72 ms Sustainability and SPC-1 IOPS Response Time



# SPC-1 Sustainability Performance

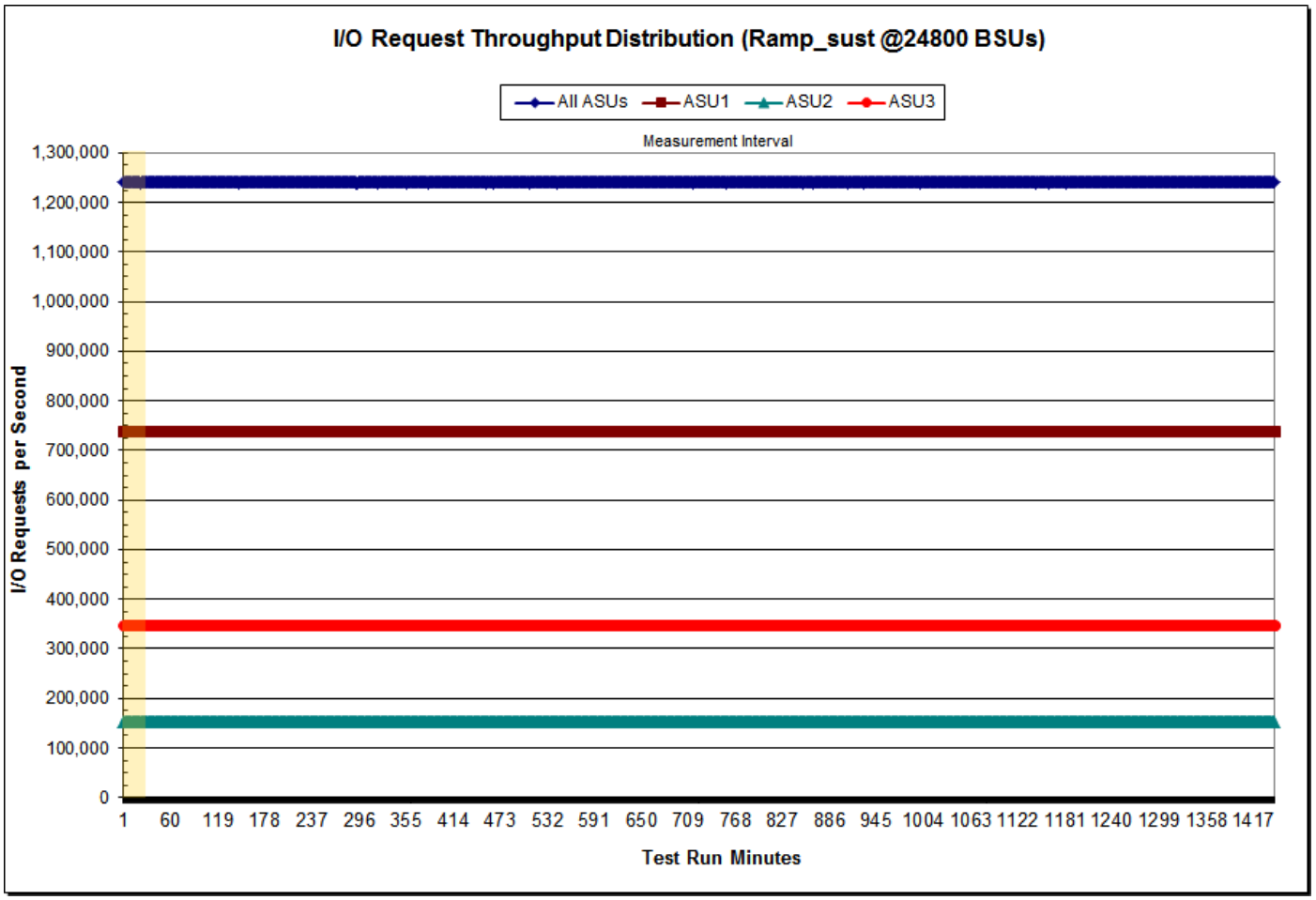
224 SSDs

196,491.768 GB Configured
137,564.817 GB Used
58,926.951 GB Unused

24-hour Measurement Interval

1,240,000.52 Sustainability SPC-1 IOPS

1,239,898.00 Reported SPC-1 IOPS



# SPC-1 Sustainability Response Time

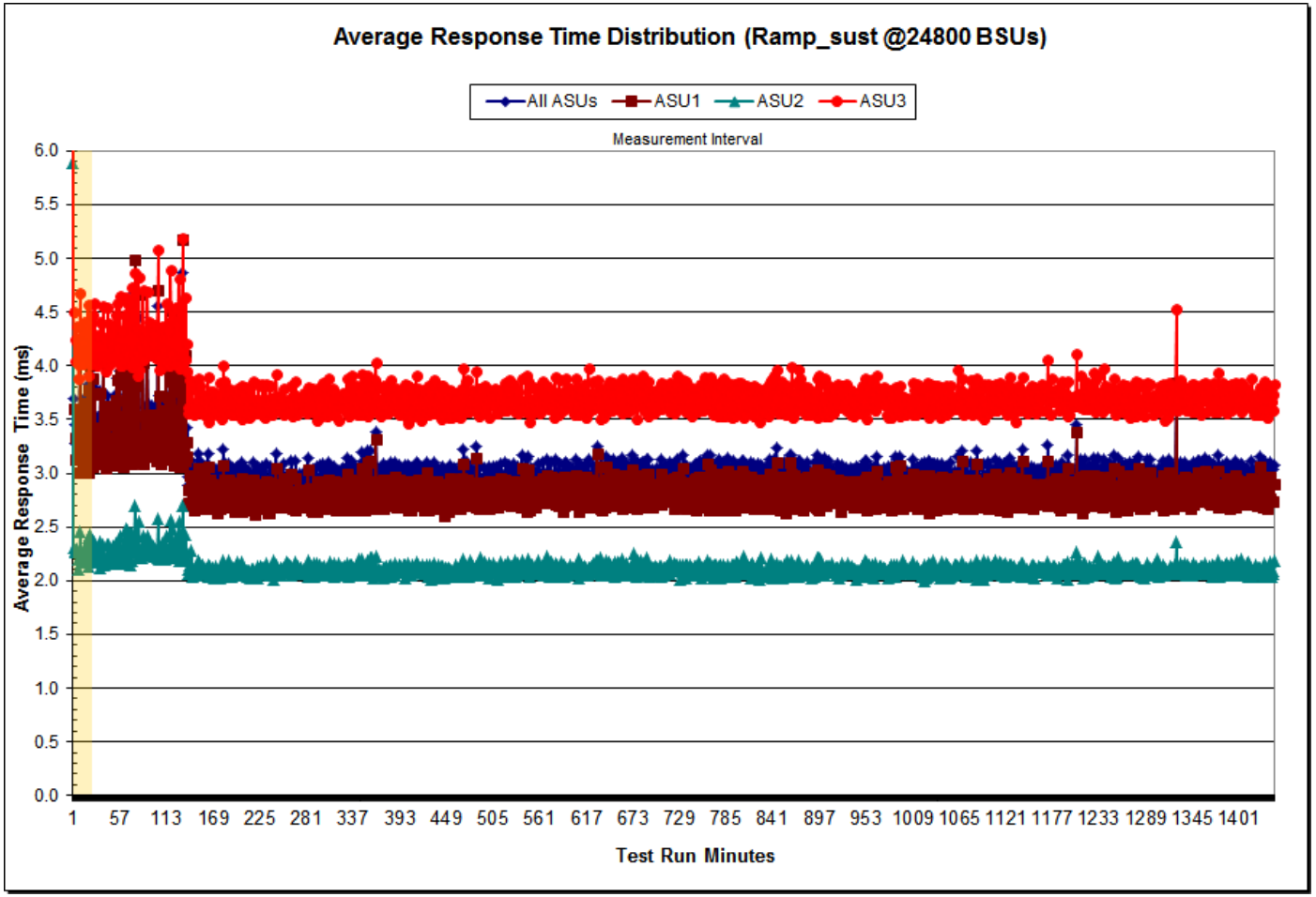
224 SSDs

196,491.768 GB Configured
137,564.817 GB Used
58,926.951 GB Unused

24-hour Measurement Interval

3.02 ms Sustainability Response Time

2.95 ms SPC-1 IOPS Response Time

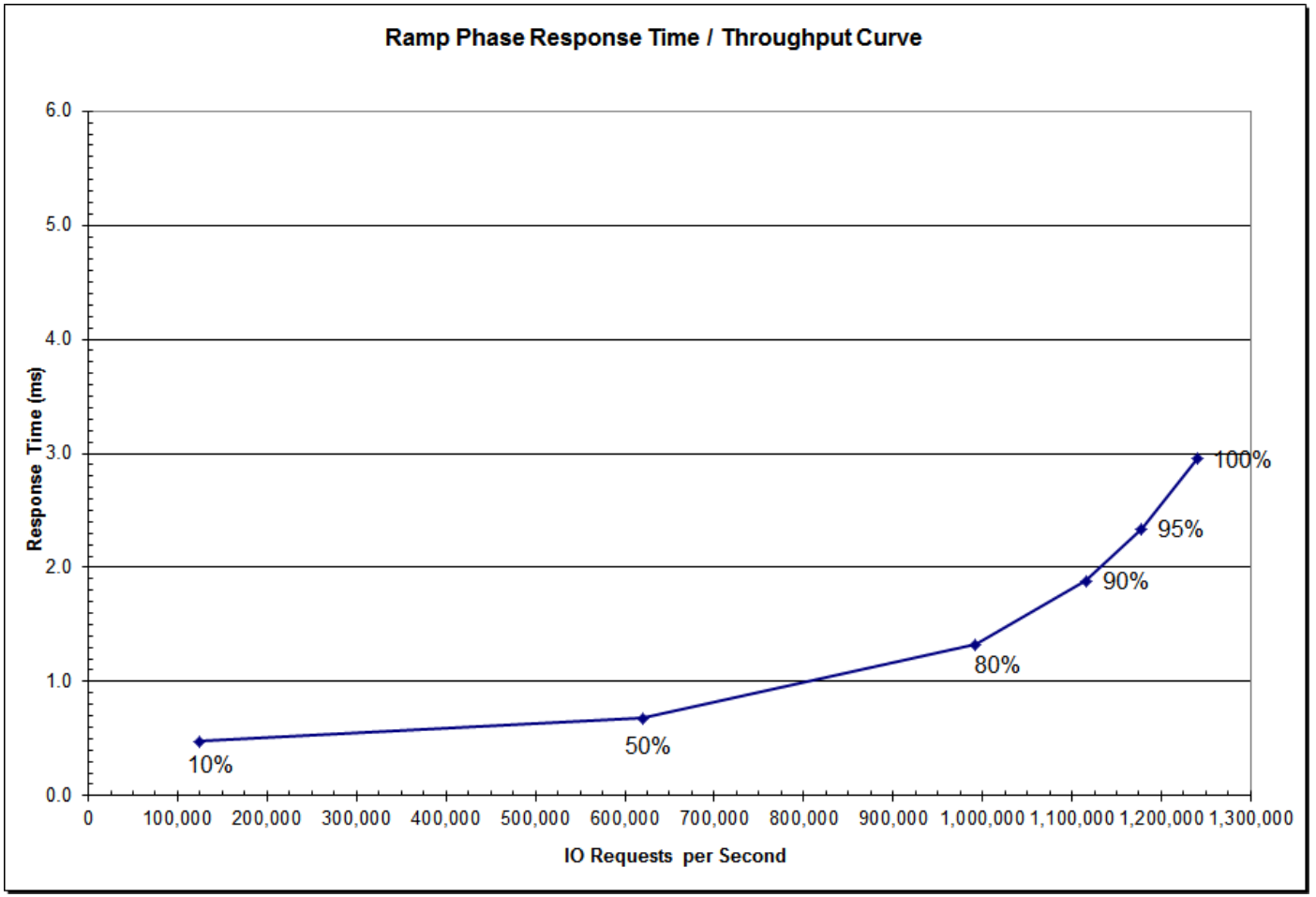


# SPC-1 Throughput Response Time

224 SSDs

196,491.768 GB Configured
137,564.817 GB Used
58,926.951 GB Unused

24-hour Sustainability Measurement Interval



# Storage Performance Council (SPC)

For SPC benchmark results, specifications and membership information, please visit:

www.storageperformance.org