The Extreme Cache feature provides the ETERNUS® DX500 S3 and DX600 S3 Storage Arrays with an effective flash based performance accelerator for regions of hot data within the storage array. The Extreme Cache expands the primary cache memory within the controllers in the storage arrays providing very quick access to a much larger portion of the data than is typically available, due to limitations in the primary cache size.
1 Introduction

The Extreme Cache (EXC) is made up of two or four modules of flash storage (PCIe Flash Module or PFM) that are directly connected to the Controller Modules (CM) in the ETERNUS DX500 S3 and DX600 S3 storage arrays. The Performance Guide provides some data on the performance impact of EXC, but does not guide the user in considerations regarding best practice. It also does not provide information on the impacts of the use of EXC on performance during periods of transition in the workload demand. This paper is intended to provide the user with a better understanding of the operation of EXC and provide guidance in the application of this feature within customer environments. It also provides the user with performance information when the active storage set exceeds the capacity of the EXC.

A key to effective use and sizing of the EXC is in understanding the size of the active storage set used by the applications. If the active set size is less than the capacity of the EXC then the boost in storage performance is huge, but if the active set size is larger than the capacity of the EXC then there may be very little performance gain from the EXC.

1.1 Extreme Cache Installation

The EXC is installed, without any system down time, in the front of the ETERNUS DX500 S3 or DX600 S3 Control Enclosure. In the front side of the system on the left side is the optional Extreme Cache cage (or PFM cage). The cage provides four slots for installing the EXC modules. The lower two slots belong to CM0 and the upper two slots belong to CM1.

2 Background

A Proof of Concept (PoC) test was run by a customer on an ETERNUS DX600 S3 with EXC to evaluate the effectiveness of the EXC in an internet video-on-demand delivery service environment. Although the testing methodology was only a rough simulation of the demand profile within the operational environment, it illustrated use of the EXC while revealing some unexpected aspects. This paper provides greater understanding into the issues that were revealed in the PoC testing, and provides insight into some aspects of usage.

There were two aspects in the PoC testing that were somewhat unexpected, were poorly understood and are not addressed in other papers on EXC.

- Behavior during the loading of data into the EXC.
- Behavior when the active data set exceeds the capacity of the EXC.

The customer application involved serving video files over the internet to a wide range of subscribers. The library of available video files is very large, but there is a smaller subset of the files that are active at any one period of time. The files in the Active Set change as the interests of the subscribers change and the volume of these active files also changes – both growing and shrinking from day to day. This paper investigates these behaviors revealed by the PoC.

3 Definitions

In the context of this paper, there are several definitions that the reader needs to understand to get the full meaning of the information provided.

- **Hot Spot** – a region of storage that has significantly higher rates of access than other regions within the storage space.
- **Eligible Files** – the set of data files (ETERNUS Logical Volumes – LUNs) that are authorized to use EXC resources. That is, the Logical Volumes have Extreme Cache Enabled.
- **Active Eligible Files** – a set of data files that are actively being used by the applications and that are eligible for EXC support. The activity may be dominated by reading or have both Read and Write accesses. Usually these active files represent only a small portion of the total set of data within the storage array.
- **Inactive Eligible Files** – the set of data files that are available for use by the applications and that are eligible for EXC support, but which have only occasional accesses.
- **Ineligible Files** – the set of data files (LUNs) that have not been made eligible for EXC support. That is, the Logical Volumes have Extreme Cache Disabled.
- **Initial Caching Threshold** – access count threshold used on primary cache purged blocks to qualify blocks for promotion into EXC, used until the EXC is fully occupied.
- **Caching Threshold** – access count threshold used like Initial Caching Threshold when the EXC is full.
- **Active Set** – the set of files (or LUNs) that currently make up the Active Eligible Files that are supporting host traffic at a given point in time. The areas of storage within the Active Set change with time, which is simulated in this testing by the different tests which access different sets of LUNs.

4 Operation of the Extreme Cache

The EXC serves to accelerate Read accesses, but does not participate in Write operations. When storage space that has been promoted to the EXC is accessed by a host Write operation, the EXC cache line is marked as invalid. Data is moved into the EXC from the HDDs in large cache lines (1 MB), using a dedicated buffer area in the primary cache. Only the selected LUNs are considered eligible for promotion to EXC.

Depending upon the setting of “Initial Caching Threshold” and “Caching Threshold”, when a cache line of one of the eligible LUNs is aged out of the primary cache, it may be promoted to the EXC. The promotion involves reading the appropriate HDD section (EXC cache line) into a dedicated buffer, and subsequent transfer into the EXC. The values for these thresholds range from 1 to 16. The default value for Initial Caching Threshold is 1. For Caching Threshold the default value is 5.

In all the test runs reported, the Initial Caching Threshold is 1. Test runs with Caching Threshold of both 5 and 16 are included. The effect of the larger value of Caching Threshold is to make the EXC react more slowly to changes in the access profile.
5 Testing Methodology and Environment

To gain understanding into the behavior of the EXC during initial loading and during operations when the active data exceeds the capacity of the EXC a number of tests were conducted. Figure 1 provides a block diagram of the test configuration. There were a set of 16 Logical Volumes defined, each 64GB, and mapped for access from the VMs in the RX300 S8 servers. In some of the Test Run Sets these LUNs were assigned in the 3TB NL-SAS drives and in other Test Run Sets they were assigned in the 600GB 10krpm SAS drives. The volume content was the same in both cases. The full data set was loaded on one set of drives and then was migrated to the other set of drives for some of the tests. Note from the block diagram that only one CM was used in these tests, as the operation of EXC is separate and independent on each of the CMs. Only data for RAID groups owned by a CM is promoted to the EXC on that CM.

![Test Configuration Diagram]

Figure 1 - Test Configuration

Fourteen different tests were defined, with most of them run in all of the Test Run Sets. Each of the tests used different combinations of the 16 LUNs to provide different ranges of active space over which the application provided Read accesses. In this set of tests, Write impacts and the effect of EXC on other storage traffic was not included – only the traffic profiles for Read accesses to the active portions of the storage are considered. In the customer PoC it was observed that the effect of EXC was reduced significantly when the active space exceeded the available EXC space. In this test environment, the full complement of 16 LUNs provides 146% of the capacity of the EXC to enable evaluation of the behavior when the active area exceeds the capacity of the EXC.

Iometer was used as the test application with random 64K Read accesses over the entire set of LUNs in each particular test. The Iometer average test results are of little value, due to the drastic changes in data rate through the test interval, so they are not included in this paper. A Queue Depth of 32 was used for all of these tests to saturate the storage in order to see the limits to which the configurations could perform. PMCC data is charted to reveal the behavior of the EXC under the various tests.

5.1 The Tests

Each of the tests in this list was run following one another, so one test builds upon the previous. LUNs are added and removed from the Active Set from one test to the next.

- **Test 1** – this test was run once with all 16 LUNs active and the EXC disabled to establish the basic Read Throughput for the NL-SAS drives under the Iometer Random Read workload. This shows in Figure 8 that the basic throughput for the configuration is 140MB/s using the 16 defined LUNs on the 4 RAID1 groups with the 3TB NL-SAS disk drives. This baseline level of capability is important to realizing the performance impact of the EXC when used in conjunction with these types of large capacity drives. It was also run with 4 LUNs on the 10krpm drives to establish the 10k HDD basic throughput of 223MB/s.

- **Test 2** – in the first Test Run Set, the EXC was not yet enabled at the beginning, but was enabled part way through the test. In the later Test Run Sets, the EXC was enabled before the Test Run Set started, and this was the first test in the run set. This test had 4 of the 16 defined LUNs making up the Active Eligible Files, and the other 12 LUNs as Inactive Eligible Files. In this test only 37% of the EXC capacity is included in the Active Set.

- **Test 3** – this test changes 2 LUNs from Inactive Eligible Files to Active Eligible Files, changing the Active Set to 55% of the EXC capacity.

- **Test 4** – this test adds 2 more LUNs to the Active Set, changing the Active Set to 73% of the EXC capacity.

- **Test 5** – this test adds 2 more LUNs to the Active Set, changing the Active Set to 91% of the EXC capacity.

- **Test 6** – this test adds 2 more LUNs (for a total of 12 of the 16 LUNs) to the Active Set, changing the Active Set to 110% of the EXC capacity. The running time was extended for this test to better see the behavior when the Active Set exceeds the capacity of the EXC.

- **Test 7** – this test removes 4 of the LUNs from the Active Set, changing the Active Set down to 73% of the EXC capacity.

- **Test 8** – this test adds 2 LUNs that had not previously been included in the Active Set, changing the Active Set up to 91% of the EXC capacity.

- **Test 9** – this test removes 2 of the LUNs and adds 2 other LUNs to the Active Set, simulating a change in the active portion of the eligible file set, which does not change the 91% of the EXC capacity that is used. However it does require changes in the content of the EXC.

- **Test 10** – this test removes 4 of the LUNs from the Active Set, reducing the Active Set to 55% of the EXC capacity.

- **Test 11** – this test removes 2 more of the LUNs from the Active Set, reducing the Active Set to just 37% of the EXC capacity.

- **Test 12** – this test removes 2 of the LUNs and adds 2 other LUNs to the Active Set, but at the same time only has traffic demands from half of the VMs, reducing the load as well. This keeps the Active Set at just 37% of the EXC capacity, but does require changes in the content of the EXC.

- **Test 13** – this test adds 4 LUNs to the Active Set, changing the Active Set to 73% of the EXC capacity, while still only driving traffic from half of the VMs.

- **Test 14** – this test removes 4 LUNs and adds 4 other LUNs to the Active Set, as well as activating all four of the VMs to supply full load with 73% of the EXC capacity included in the Active Set.
5.2 The Test Run Sets

There were a number of test run sets conducted, with both NL-SAS HDDs and 10krpm HDDs that are reported in this paper. Charts of the run sets are provided in section 8 for review by the reader.

- **Test Run Set R-NL-1** - this first run set was manually controlled, which resulted in short breaks between the tests. These show up in the charts as drops in throughput to near zero and are not of specific meaning to interpreting the test results. This run set was made using the LUNs assigned to the 3TB NL-SAS disk drives. It includes Test 1 which provides the basic data rate for the NL-SAS HDDs under this workload of 140MB/s. A random workload was utilized on all of the LUNs included in each of the different tests. The Caching Threshold was set to the default value of 5 for this test run set.

- **Test Run Set R-NL-2** - this run set used scripting to move from one test to the next and was run with extended run times on each of the tests – most were 1 hour, with Test 6 run for 4 hours to obtain a more complete profile of the behavior when the Active Set is greater than the capacity of the EXC. The Caching Threshold was set to the value of 16 for this test run set.

- **Test Run Set S-NL-1** - this run set used sequential instead of random access patterns to see how the EXC behaved if such a pattern was applied. This set used the default settings for Pre-fetch, and it is noted that EXC is not expected to support sequential accesses, which is illustrated in this run set. The Caching Threshold was set to the value of 16 for this test run set.

- **Test Run Set S-NL-2** - this run set also used sequential access patterns, but with Pre-fetch disabled. This shows support by the EXC when the Active Set is less than the capacity of the EXC, which is useful to consider. The Caching Threshold was set to the value of 16 for this test run set.

- **Test Run Set R-10k-1** - this run set was conducted after the full set of eligible files (LUNs) was migrated from the NL-SAS drives to the 10krpm SAS drives. It illustrates the operation of EXC in conjunction with the higher speed drives. The Caching Threshold was set to the default value of 5 for this test run set.

6 Analysis of Test Results

The sets of tests that were run show a good deal about the behavior of the EXC under different situations. This analysis presents information from selected portions of the tests that illustrate specific characteristics to be aware of in using the EXC. The discussions in these sections are intended to aid the reader in considering the whole of the results charted in the section 8.

6.1 Initial Loading of EXC Space

When the EXC is disabled, then it is viewed as empty with no valid active data. During Test 2 in Test Run Set R-NL-1 the EXC was enabled while there was random Read activity on 4 of the LUNs. This corresponds to 37% of the EXC capacity. Figure 2 illustrates the operations during this portion of the activity. In the early portion of the test, prior to enabling the EXC, the throughput was the only base 140MB/s limited by the NL-SAS drives. At 8:06 the EXC was enabled and data began to be staged into the EXC to support the activity. In about 12 minutes at 8:18 the data for the 4 active LUNs had been transferred to the EXC, at which point the throughput rose abruptly to 3,100MB/s – over 22 times the rate provided by the NL-SAS drives. In the test configuration with 4 x 8Gbps FC Host Ports in use, this is the maximum data rate that the ports can sustain at the 64KiB block size used. This clearly illustrates the effect of EXC on the data rate when the EXC capacity is not exceeded. However it did take time for the EXC to get loaded, and during this time the traffic rate varied somewhat. Notice that as the data gets loaded into the EXC the EXC Hit Rate increases until it reaches nearly 95%. It does not reach 100% because only a small portion of the EXC space is active.

![Figure 2 - Initial Loading of EXC](image-url)
6.2 Additional Loading of EXC Space

As the application accesses additional space in the Active Set, more data will be loaded into the EXC to support the accesses. Figure 3 illustrates operations as additional space joins the Active Set. In this case 2 LUNs were added to the 8 LUNs already within the Active Set, bringing the total up to 91% of the EXC space.

![Figure 3 - Additional Loading of EXC](image)

As additional areas are addressed that are not in the EXC, the data must be obtained from the NL-SAS HDDs. It is recognized that there is space available in the EXC for this data, so it is promoted to the EXC. However, during the time it takes for this data to be moved from the HDDs to the EXC, the overall performance drops significantly from what it had been, and what it returns to after the data is moved to the EXC. A review of Figure 9 - Test Run Set R-NL-2 Traffic and EXC Operations shows that as the EXC is loaded up in stages through Tests 2-5, once the data is promoted to EXC the throughput pops right up to the same high level. (This level was limited by the bandwidth of the host connections and not by the storage array.)

6.3 Accesses to More Space than will fit in the EXC

Test 6 illustrates what happens when the Active Eligible File space exceeds the capacity of the EXC. This is a situation where the Cache Threshold comes into play. Two values of Cache Threshold were tested – the default value of 5 and the maximum value of 16. In Test Run R-NL-1 (Figure 8) the default Cache Threshold value of 5 was used and is detailed in Figure 4. The test run duration was about one hour during which time the throughput dropped to only 13% of the previous level within the first 45 minutes. This reflects the continuing changes in the content of the EXC as illustrated by the continued rising of the EXC Stage Count and the reduction in the EXC Read Hit percentage. There were continuing changes in the content of the EXC that drastically reduced the throughput from what it was before the Active Set exceeded the capacity of the EXC.

![Figure 4 - Loading Beyond Capacity with Cache Threshold = 5](image)
In Test Run R-NL-2 (Figure 9) the Cache Threshold value was set to 16, and the test run duration was extended to four hours. As Figure 5 shows, the throughput dropped to about 19% of the previous level, but the drop occurred over a three hour period. This indicates that the higher value of Cache Threshold makes the replacement of data within EXC require more accesses. Notice that with the higher Cache Threshold value, there is not nearly as much data being staged by the EXC. This means there is a lower level of cache thrashing which keeps the throughput up to a higher level for a longer time.

Figure 5 – Loading Beyond Capacity with Cache Threshold = 16

This effect of the drop in throughput when the Active Set size exceeded the capacity of the EXC was observed in the customer PoC testing that was performed. It emphasizes the need to carefully consider the capacities of the active files that are to be accelerated by the EXC. If possible, the active file set needs to be kept smaller than the capacity of the EXC.

6.4 Reduction of Active Set Size and Recovery of Performance

This test immediately followed the over capacity test in Test Run R-NL-2 (Figure 9) and illustrates the recovery of performance once the smaller Active Set is recognized and the appropriate data promoted to the EXC. The Cache Threshold remained at 16 through this test.

Figure 6 - Performance Recovery with Reduced Active Data Size

Although it took 25 minutes to resolve the reduced Active Set within the EXC, performance returned to a high level when the amount of active data was reduced to less than EXC capacity. In this test case it was reduced to 73% of EXC capacity. However, notice that the performance level reached is only ~95% of the performance seen before the EXC capacity was exceeded. Prior to the capacity being exceeded, the EXC hit ratio was 97.8, but after recovery is at 97.3. This indicates that there are some areas of the EXC that are occupied with data that is no longer being accessed, but they are not being replaced either, so the EXC is somewhat less effective. There may be some housekeeping necessary within the EXC that has not yet taken place.
6.5 Changes in Active Set Areas

In the normal course of operations it can be expected that after the EXC has become fully occupied with valid data, the areas represented in the Active Set will change. Test 9 was included to explore this type of transition. Two LUNs were dropped from the Active Set and two other LUNs were added, while the Cache Threshold remained set to 16. Test Run R-NL-2 (Figure 9) illustrates where this test occurred in the sequence of tests.

![Test 9 - Change in Active Set Areas](image)

Notice that it took some time for the access changes to be recognized, and then the appropriate data was staged for promotion to the EXC. Again during this transition, the performance dropped significantly for nearly 25 minutes, but then resumed at the high level of throughput. Note that Test 9 in Test Run R-NL-1 (Figure 8) has a very similar transition profile, but over a shorter time. This is due to the Cache Threshold setting, which was the default value 5 in R-NL-1 and set to the value 16 in R-NL-2.

6.6 EXC Operation with 10krpm SAS Drives

Test Run Set R-10k (Figure 10) was made to illustrate the behavior of EXC when the primary storage is on 10krpm SAS drives instead of NL-SAS drives. These drives have better response times and so it may be expected that the EXC would be less effective. On the contrary, the higher speed of the 10krpm SAS drives enable the data to be loaded into the EXC much more quickly and so the drops in performance when the Active Set area changes is much less dramatic. There is still the impact of recognition of different regions and the time required to move the active data from the drives to the EXC, but then the operation is very much the same. Without use of the EXC the throughput for the 10krpm drives is only 220MB/s, while with the EXC the tests ran at the rate limited by the capability of the host connection channels.

6.7 EXC Operation with Sequential Accesses

It is clearly stated that EXC is not intended to support data that is being accessed sequentially as the primary cache through Pre-fetch enhances the throughput of this type of access profile. However, there are times when data that is normally accessed randomly and which needs the enhanced response time offered by the EXC, can be accessed in a sequential manner. Two test run sets were made to gain insight into how the EXC reacts to this type of access pattern.

Test Run Set S-NL-1 (Figure 11) was accessed sequentially with the normal Pre-fetch settings active. The throughput rate clearly shows that the primary cache provides significant improvement over the raw data rate of the drives, and that it is limited by the number of drives supporting the Active Set. Although there is a small burst of EXC activity at the very beginning, it is clear that the EXC is not active under this test scenario.

On the other hand, Test Run Set S-NL-2 (Figure 12) was conducted with Pre-fetch disabled, which changed the apparent access profile. In this situation, the EXC became involved and up to the point where the Active Set size exceeded the EXC capacity, the EXC supported the accesses with double the throughput of the previous Test Run Set. However, once the capacity of the EXC was exceeded, then the EXC was much less effective.

These tests were not conducted to support any recommendation to utilize EXC in sequential environments, but rather to show that such operation is not recommended. It would be most difficult to predict the effective throughput in an environment where the dominate accesses are sequential and the files are made eligible for promotion into the EXC.
7 Conclusions and Recommendations

7.1 Extreme Cache Provides Huge Performance Boost

It is clear from this testing that EXC is capable of providing a huge performance boost to the active data within the ETERNUS storage array. The boost is nearly 15 times for 10k rpm HDDs and over 20 times for NL-SAS HDDs. This boost is provided, as long as the Active Set size remains smaller than the capacity of the EXC. However it does take time for the performance boost to be realized. The user needs to plan that it can take several minutes for the performance to reach the maximum level.

7.2 Primary Recommendation

It is very clear from this testing that the best way to get the most benefit from the Extreme Cache is to keep the total volume that may be active in the EXC to less than the capacity of the EXC. Exceed the capacity of the EXC and a much smaller performance boost will be seen. A mechanism is provided to select the Logical Volumes that have the critical Hot Spot data for use of the EXC.

7.3 Logical Volume Selection

Care needs to be taken in selecting the Logical Volumes that are eligible for support by the EXC. These should be volumes that are critical to the overall application environment and that can benefit from very short response times. However, it is important to understand that the total active space among all of the eligible volumes should be kept less than the capacity of the EXC. The test results in this paper indicate that there is a performance boost provided by the EXC even when the active space exceeds the capacity of the EXC, but the boost can be much less than when there is extra available capacity in the EXC.

7.4 Extreme Cache Tuning

The two EXC threshold parameters can be used for tuning the responsiveness of the EXC to changes in the workload profile. The Initial Caching Threshold parameter determines how quickly an empty EXC will be loaded in response to accesses within the eligible volumes. The default value of 1 for this parameter provides the most rapid loading of the accessed storage areas into the EXC, and is recommended for most environments.

The Caching Threshold parameter determines how rapidly the EXC content will be changed when the access profile changes, after the EXC has reached full capacity. The default value of 5 should be suitable for most environments. However, if the access profile is changing several times in the course of a day, it may be better to reduce the value. On the other hand, if there is a basic set of accesses that need the fast response, but at the same time are other accesses that change quite frequently, then it may be better to increase the Caching Threshold. Increasing the Caching Threshold will make the response to changes take longer, require more accesses, to change the contents within the EXC, and thereby reduce the response time on accesses to those areas.

7.5 Extreme Cache Management

The Extreme Cache can be managed from a number of the management platform interfaces available for the ETERNUS storage arrays. Some of the controls require use of the hardware GUI, while others are also supported from the ETERNUS SF tool set. System performance can be viewed with the ETERNUS SF tool set to monitor the effectiveness of EXC selections.

The use of the EXC can be Disabled/Enabled as an entire function. When the EXC is disabled, then all of the EXC cache lines are set to invalid. When it is enabled again, then it will load under control of the Initial Caching Threshold until all of the EXC cache lines have been loaded with content. It is in this phase that it is most responsive to the currently active workload profile.

The content of the EXC is preserved during Power Cycles, so that after a power interruption, it is not necessary to reload the EXC, assuming that the workload profile has not changed a great deal. If the system is undergoing maintenance and the workload profile is expected to change, then it is recommended that the EXC be Disabled and then Enabled to give it a fresh start.

7.6 Extreme Cache Loading Expectation (Caution)

Unlike the primary DRAM cache within the ETERNUS storage arrays, the EXC requires time for the data to be staged from the HDDs into the EXC. The cache lines in the EXC are large (1MB) and the data has to be moved from the HDDs to the EXC through the primary cache buffer, once it is recognized that a portion of the storage should be moved. When this moving action takes place, it impacts the ongoing accesses into that space. It should be expected that other accesses may be impacted as well, as loading the EXC requires back-end system resources. Reading the appropriate EXC cache lines from the HDDs via the back-end SAS paths impacts the HDDs involved. The buffer in the primary cache is reserved space, so does not impact the available primary cache for normal operations, but still it consumes memory bandwidth, both on the transfer into the memory from the HDDs and on the transfer from the memory to the EXC. Our testing has shown that it can take tens of minutes to load up a large active set.
This first Test Run Set was manually controlled and that is clearly evident in the traffic throughput which drops to nothing between the tests. These tests used the NL-SAS HDDs for primary storage. The EXC parameters were Initial Caching Threshold = 1 and Caching Threshold = 5 (both default values). The test durations varied, based on the apparent stability of the throughput observed as the tests were running.

This Test Run Set was script controlled with basic test durations of one hour, but with Test 6 extended to four hours. These tests used the NL-SAS HDDs for primary storage. The EXC parameters were: Initial Caching Threshold = 1 (default) and Caching Threshold = 16.
This Test Run Set was run from a script with all the tests running for 30 minutes, except Test 6 which ran for 2 hours. This Test Run Set was performed using 10krpm SAS HDDs instead of the NL-SAS HDDs. This shows that even with the higher speed drives, the EXC still can provide a great boost to the performance, as long as the Active Set remains within the capacity of the EXC. The EXC parameters were Initial Caching Threshold = 1 and Caching Threshold = 5 (both default values).

Throughput values marked above:

- A – throughput without EXC enabled = 222MB/s
- B – throughput with EXC enabled and Active Set smaller than capacity of EXC and all CA ports connected = 3110MB/s
- C – throughput with EXC enabled and Active Set larger than capacity of EXC = 384MB/s
- D – throughput with EXC enabled and Active Set smaller than capacity of EXC with only half the CA ports connected = 1570MB/s

The performance gain from EXC with 10krpm SAS HDDs is seen from the above charts to be 14 times (3110/222) when the Active Set is smaller than the capacity of the EXC and all the CA ports are in use. However when the Active Set is larger than the capacity of the EXC, the performance gain drops to only 1.7 times (384/222). Another aspect of system throughput is the capability between the server(s) and the storage array, which is illustrated in this testing as well. With only half of the CA ports in use, shown in Tests 12 and 13, the performance gain is reduced to 7 times (1570/222).
This Test Run Set illustrates operations when sequential accesses are encountered in the Active Set for Eligible Files and shows that the EXC is not active in such a situation with the standard default settings for Pre-fetch.

This Test Run Set illustrates operations when sequential accesses for Eligible Files are encountered with Pre-fetch NOT enabled (not the normal default). This shows that EXC does become active and can enhance throughput when the Active Set is smaller than the EXC capacity. However, it also shows that the EXC is much less effective when the Active Set exceeds the EXC capacity, even after the Active Set size is reduced, as shown in Test 7 at the end of the above test run set.