

# TEST CASE DOCUMENTATION AND TESTING RESULTS

LSTC-QA-LS-DYNA-AWG-ERIF-17-4

TEST CASE ID AWG-ERIF-17

\*MAT\_224\_Temperature Initialization

Tested with LS-DYNA® R11.1 Revision 139325

Tuesday 13<sup>th</sup> August, 2019

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# **1 Introduction**

## **1.1 Purpose of this Document**

The purpose of this test case is the demonstration of the temperature initialization for \*MAT\_224 in LS-DYNA® . The reliability and consistency of LS-DYNA® as a finite element solver for this test case is evaluated by performing analyses on different cpu architecture platforms.

## 2 Test Case Information

| Test Case Summary        |                                                        |
|--------------------------|--------------------------------------------------------|
| Confidentiality          | external use                                           |
| Test Case Name           | *MAT_224_Temperature Initialization                    |
| Test Case ID             | AWG-ERIF-17                                            |
| Test Case Status         | active                                                 |
| Test Case Classification | Example                                                |
| Test Case Source         | LSTC                                                   |
| Tested Keyword           | *MAT_224, *INITIAL_STRESS_SOLID, *INITIAL_STRESS_SHELL |
| Member of Test Suite     | AWG ERIF SUITE                                         |
| Metadata                 | AWG ERIF                                               |

Table 1: Test Case Summary

### **3 Test Case Specification**

#### **3.1 Test Case Purpose**

The purpose of Test Case ID AWG-ERIF-17 is to verify that \*MAT\_224 temperature can be initialized using history variable 10 for shells and history variable 14 for solids.

### **3.2 Test Case Description**

Using \*MAT\_224, one shell element and one solid element are loaded in uniaxial compression and the temperature is initialized to 500 degrees F using history variable 10 for shells and history variable 14 for solids.



### 3.3 Model Description

Using \*MAT\_224 one solid element (element ID 4) and one shell element (element ID 14) are loaded in uniaxial compression (Figure 1). The temperature is initialized to 500 degrees F using history variable 10 for the shell element and history variable 14 for the solid element. Two subcases are defined with different values of beta, the fraction of plastic work converted to heat. In Subcase 1, beta is set to a very small number so that the temperature remains constant as the elements deform. In Subcase 2, beta is set to set to 1.0 so that all the plastic work is converted to heat and the material heats up as the elements deform.

The model specifications can be found in Table 2. The material definitions and their parameters can be found in the input deck. A summary of the sub test cases can be found in Table 3.

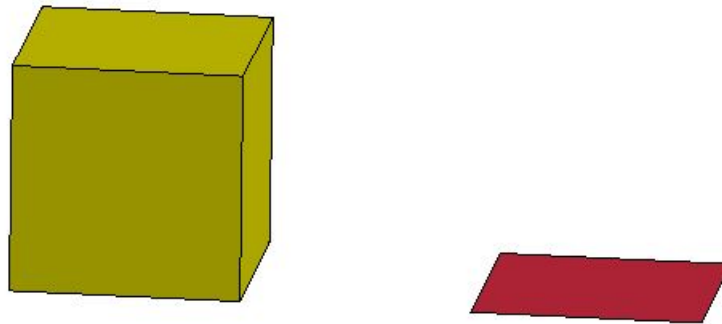


Figure 1: One solid element (ID 4) and one shell element (ID 14) using \*MAT\_224

| FEA Model information |                                                                                                          |
|-----------------------|----------------------------------------------------------------------------------------------------------|
| Nodes                 | 12                                                                                                       |
| Solid Elements        | 1                                                                                                        |
| Shell Elements        | 1                                                                                                        |
| Materials             | 1                                                                                                        |
| Parts                 | 2                                                                                                        |
| Units                 | in (length), s (time), lbf-s <sup>2</sup> /in (mass), lbf (force), psi (stress), degrees F (temperature) |

Table 2: FEA Model Information

| Specification of sub test cases |        |                                                   |
|---------------------------------|--------|---------------------------------------------------|
| Test Case ID                    | Beta   | Input Deck Name                                   |
| 1                               | 1.0e-6 | mat224_inittemp_newformat_rev.incl.shells_beta0.k |
| 2                               | 1      | mat224_inittemp_newformat_rev.incl.shells_beta1.k |

Table 3: Specification of sub test cases

## 4 Test Specifications

### 4.1 Test Case Targets

Table 4 displays the test case targets. The test case targets specify values or a series of values taken from the finite element analysis solution of the test case and they are used in a comparison of analysis results on different cpu architectures. They are chosen in a way that they are representative of the numerical model.

| Test Case Targets |                  |        |                                   |               |                   |
|-------------------|------------------|--------|-----------------------------------|---------------|-------------------|
| Target number     | Sub Test Case ID | output | component type                    | components id | retrieved from    |
| 1                 | 1,2              | elout  | Von Mises Stress                  | 4             | binout/elout file |
| 2                 | 1,2              | elout  | Effective Plastic Strain          | 4             | binout/elout file |
| 3                 | 1,2              | elout  | History Variable 14 (temperature) | 4             | binout/elout file |
| 4                 | 1,2              | elout  | Von Mises Stress                  | 14            | binout/elout file |
| 5                 | 1,2              | elout  | Effective Plastic Strain          | 14            | binout/elout file |
| 6                 | 1,2              | elout  | History Variable 10 (temperature) | 14            | binout/elout file |

Table 4: Test Case targets for Test Case ID AWG-ERIF-17

Test case targets are used to evaluate the cross cpu architecture consistency (see section 4.2).

## 4.2 Pass/Fail Criteria

These are the Pass/Fail criteria used for the cross cpu architecture consistency test of the Test Case ID AWG-ERIF-17.

The sub test case passes if the test case target data falls within the corridor bounds. Otherwise the test fails.

The test case corridors are upper and lower bounds for the test case targets. They were defined based on the test target data obtained with LS-DYNA® R10.1 Revision 123136 binaries by the following process:

- For a specific test case target, interpolate the data from different platform and executable (R10.1 Revision 123136) combinations, so that the time domain is the same.
- Calculate the upper and lower bounds by:

$$bound_{up}(i) = max(i) + 0.2 \times [max(i) - min(i)] + 0.05 \times peak$$

$$bound_{low}(i) = min(i) - 0.2 \times [max(i) - min(i)] - 0.05 \times peak$$

where  $max(i)$ ,  $min(i)$  are the maximum and minimum values at the  $i_{th}$  time step across all platforms and executable (R10.1 Revision 123136) combinations the test case was calculated with,  $peak$  is the maximum absolute y value across the whole time domain,  $bound_{up}(i)$  and  $bound_{low}(i)$  are the upper and lower bounds for the  $i_{th}$  time step.

## 5 Test Case Results

### 5.1 Software and Hardware Specifications

In order to ensure cross-platform consistency, the herein mentioned sub test cases are run on platforms specified in table 5 and the results are calculated with software versions defined in table 6.

| Platform Name | Operating system | CPU type                        | MPI-Protocol         | Number of cpu's <sup>1</sup> |
|---------------|------------------|---------------------------------|----------------------|------------------------------|
| mars          | CentOS 6.5       | Intel® Xeon® E5- 2640 @ 2.50GHz | Platform MPI 8.2.0.0 | 4                            |
| dinar3b       | SUSE LES 11      | AMD® Opteron® 6276 @ 2300MHz    | Platform MPI 8.2.0.0 | 4                            |

<sup>1</sup> Number of cpu's used for calculation of the test case

Table 5: Used Platforms and CPU Type's

| Product  | Version | Release | Revision | Parallel type <sup>1</sup> | Precision <sup>2</sup> | executable          |
|----------|---------|---------|----------|----------------------------|------------------------|---------------------|
| LS-DYNA® | 971     | R11.1   | 139325   | SMP                        | SP                     | ls971.139325.R11.1  |
| LS-DYNA® | 971     | R11.1   | 139325   | SMP                        | DP                     | ld971.139325.R11.1  |
| LS-DYNA® | 971     | R11.1   | 139325   | MPP                        | SP                     | mpp971.139325.R11.1 |
| LS-DYNA® | 971     | R11.1   | 139325   | MPP                        | DP                     | mpd971.139325.R11.1 |

<sup>1</sup> MPP = Massively Parallel Processing, SMP = Symmetric Multiprocessing

<sup>2</sup> SP = single precision, DP = double precision

Table 6: Tested LS-DYNA® version

## 5.2 Results Summary

Table 7 contains the results of the Test Case ID AWG-ERIF-17 completed with all combinations of software and hardware defined in section 5.1.

Details on the test results can be found in the section 5.3.

The table 7 cross cpu architecture consistency summary is:

- **PASS** - Pass criteria in section 4.2 is attained.
- **FAILED** - Pass criteria in section 4.2 is not attained.
- **ERROR** - sub test case terminates due to error.
- **N/A** - sub test case was not calculated.

| Sub Test Case ID | PASS/FAILED |
|------------------|-------------|
| 1                | <b>PASS</b> |
| 2                | <b>PASS</b> |

Table 7: Results summary for Test Case ID AWG-ERIF-17

### 5.3 Result Details

The following subsections contain detailed results for the Test Case ID AWG-ERIF-17 for LS-DYNA® R11.1 Revision 139325.

For each sub test case defined in section 3.3 there is a graph displaying the time history of the result target defined in section 4.1 for the platform and software version combinations defined in section 5.1.

The title of the graph states the test case ID and the name of input deck. The legend contains the result file name, output, platform, executable and number of cpu's separated by comma. A minus sign before the number of cpu's refers to the compatibility option for SMP calculations (see [1] for details on this option).

#### Example for title and legend:

##### *Title:*

'AWG\_ERIF\_TEST\_CASE\_17: mat224\_inittemp\_newformat\_rev.incl.shells.beta0.k' states the test case ID 17 and name of the input deck for sub test case 1.

##### *Legend:*

'elout\_effsg\_4\_4\_1,mars,ls971.139325.R11.1,4' states that the graph shows the Von Mises Stress (effective stress) of element ID 4 derived from the 'elout' output file for an input deck which was calculated on the 'mars' platform with a LS-DYNA® R11.1 Revision 139325 binary (SMP, single precision) on four processors.

### 5.3.1 Sub Test Case ID 1, 2- Test Target 1

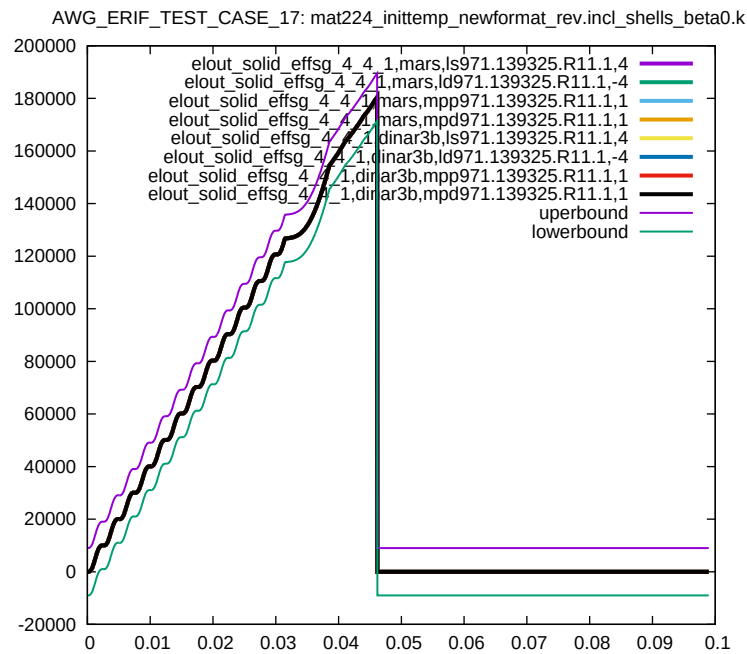


Figure 2: Cross platform results, Von Mises Stress, element ID 4, sub test case ID 1

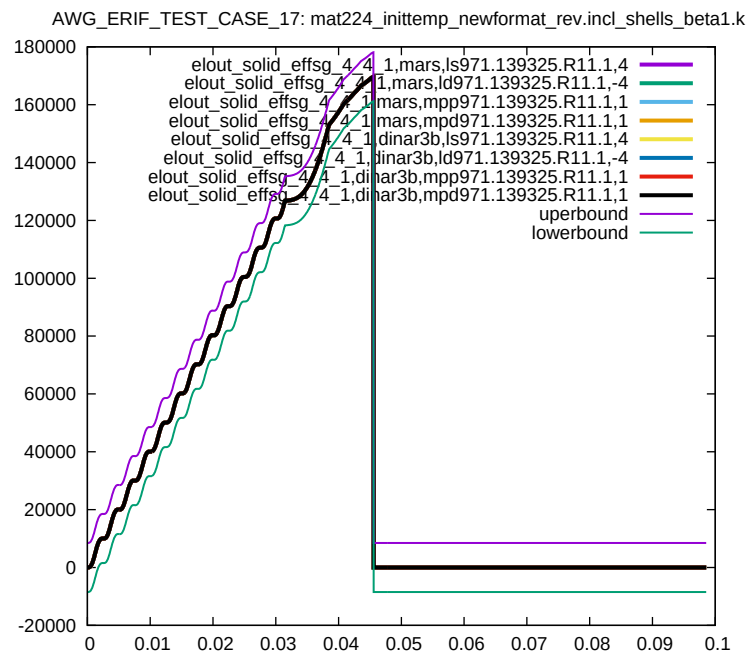


Figure 3: Cross platform results, Von Mises Stress, element ID 4, sub test case ID 2



### 5.3.2 Sub Test Case ID 1, 2- Test Target 2

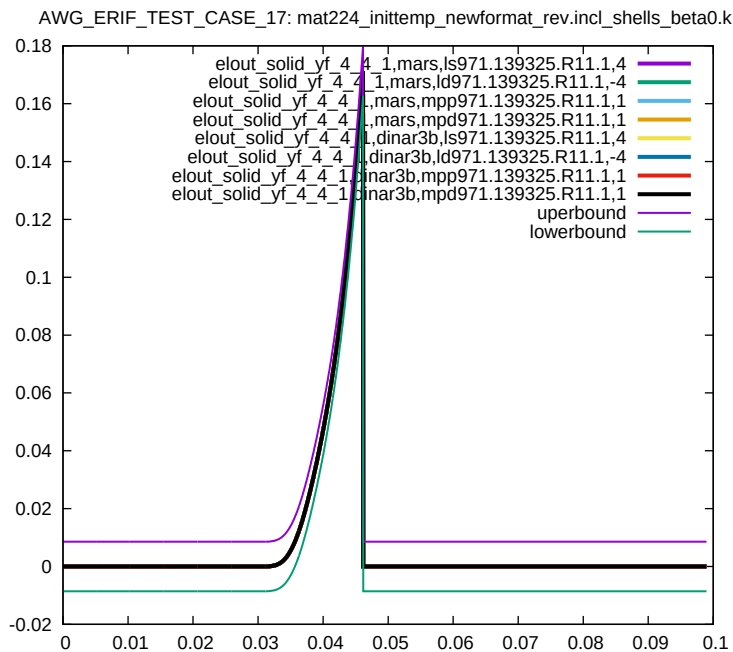


Figure 4: Cross platform results, Effective Plastic Strain, element ID 4, sub test case ID 1

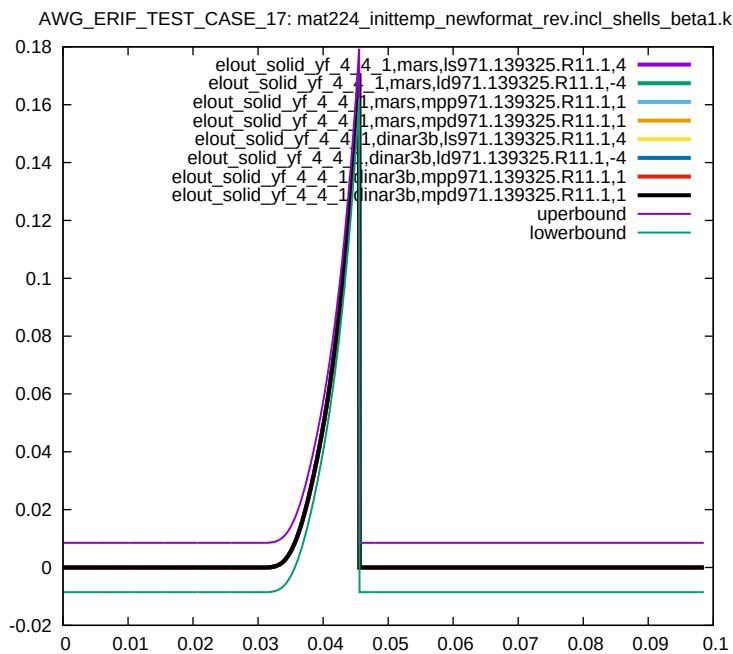


Figure 5: Cross platform results, Effective Plastic Strain, element ID 4, sub test case ID 2

### 5.3.3 Sub Test Case ID 1, 2- Test Target 3

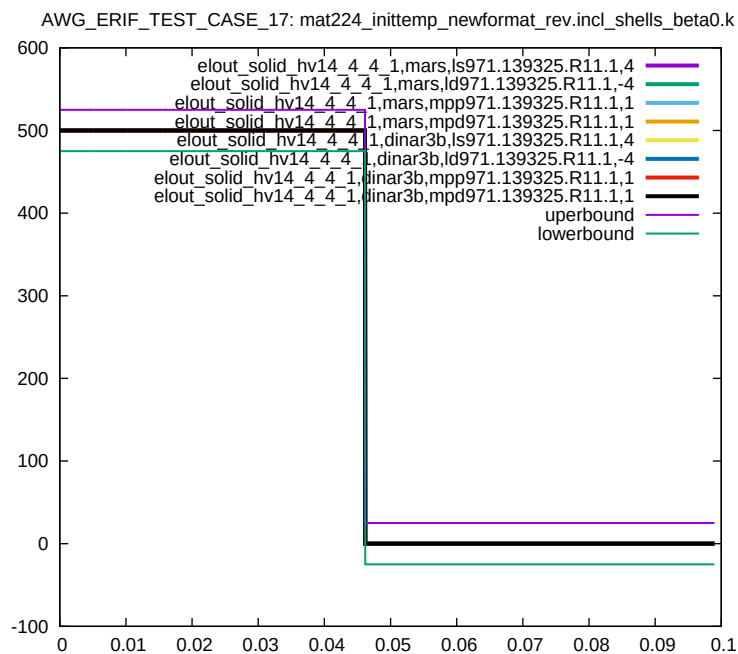


Figure 6: Cross platform results, History Variable 14 (temperature), element ID 4, sub test case ID 1

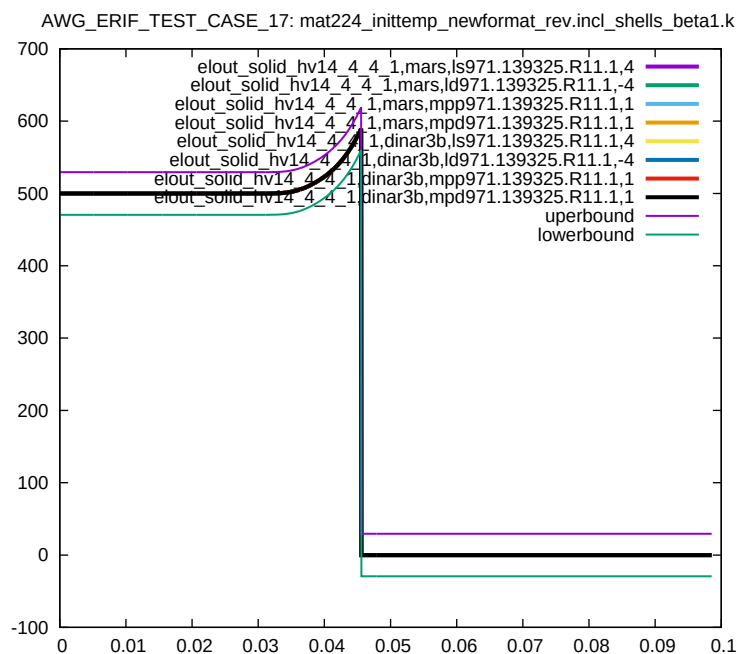


Figure 7: Cross platform results, History Variable 14 (temperature), element ID 4, sub test case ID 2

### 5.3.4 Sub Test Case ID 1, 2- Test Target 4

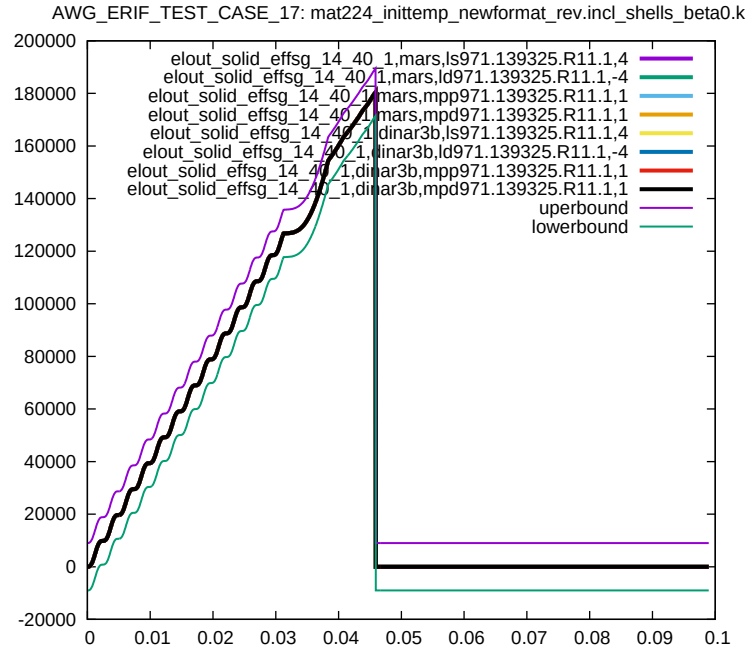


Figure 8: Cross platform results, Von Mises Stress, element ID 14, sub test case ID 1

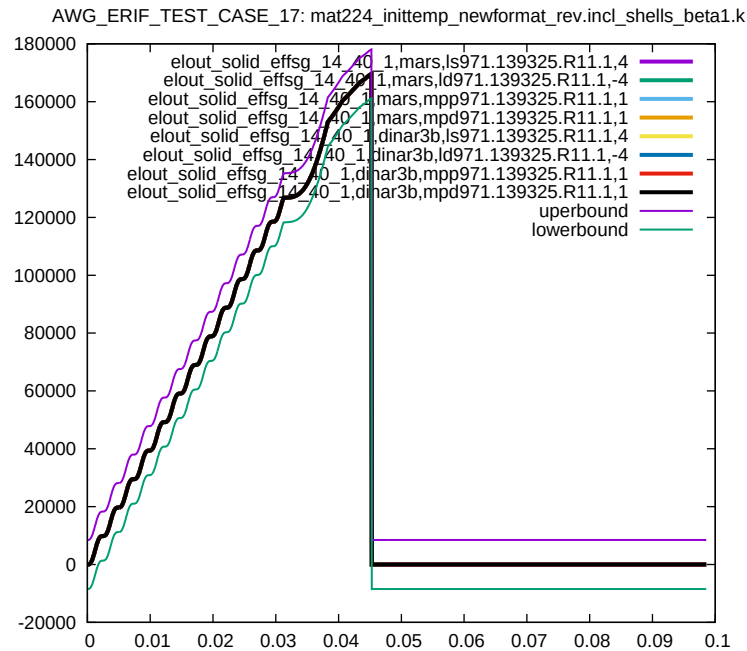


Figure 9: Cross platform results, Von Mises Stress, element ID 14, sub test case ID 2

### 5.3.5 Sub Test Case ID 1, 2- Test Target 5

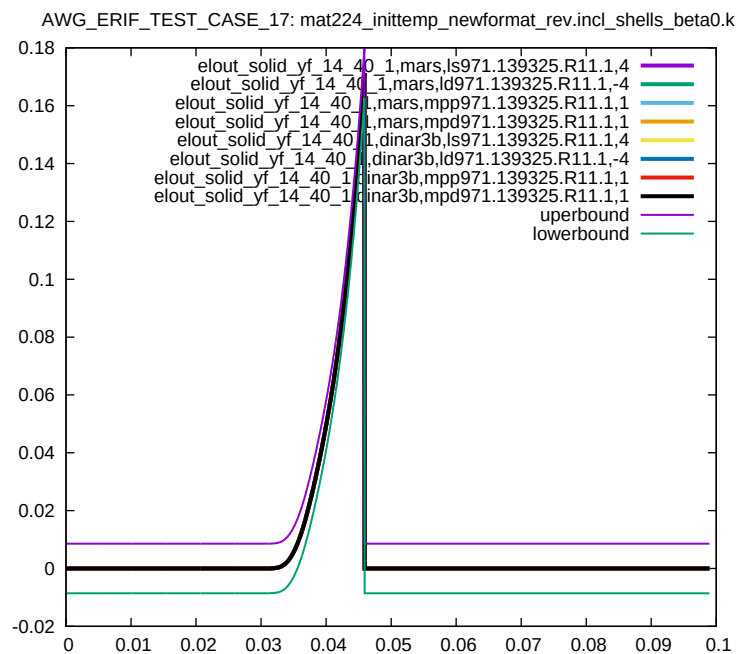


Figure 10: Cross platform results, Effective Plastic Strain, element ID 14, sub test case ID 1

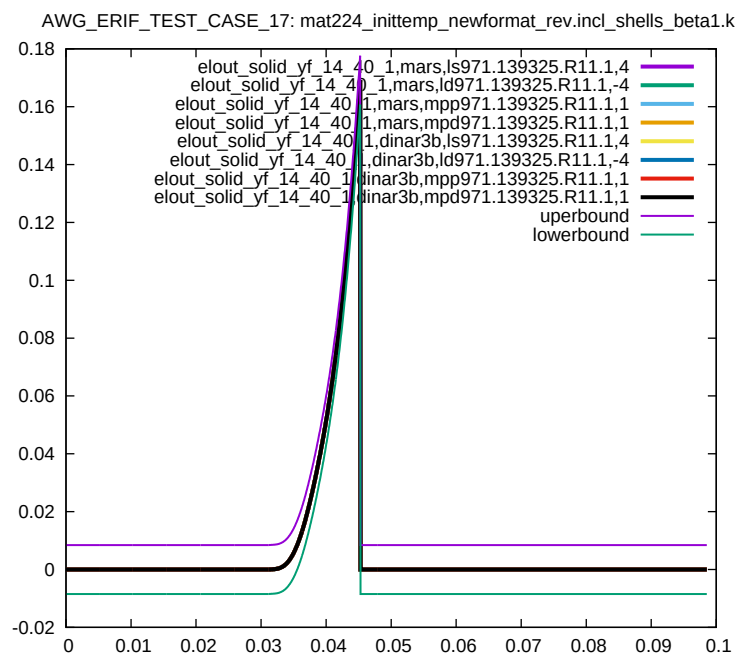


Figure 11: Cross platform results, Effective Plastic Strain, element ID 14, sub test case ID 2

### 5.3.6 Sub Test Case ID 1, 2- Test Target 6

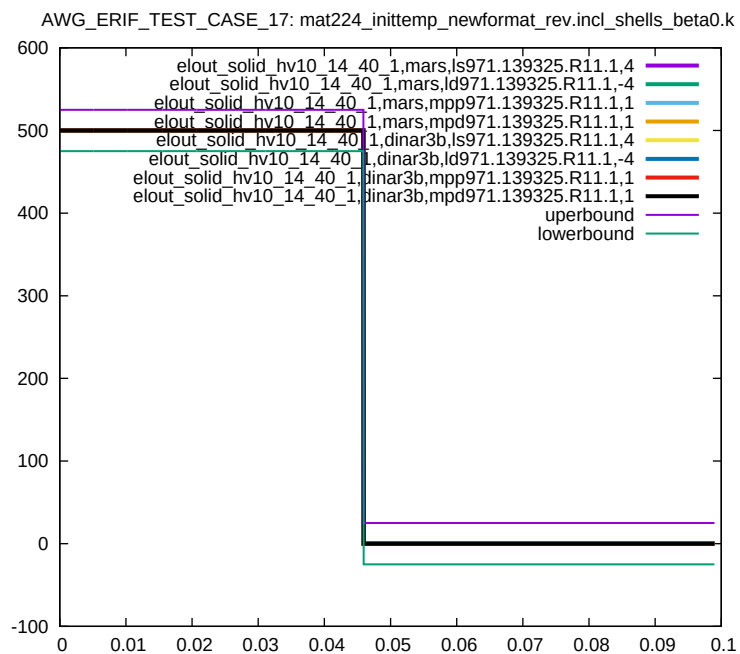


Figure 12: Cross platform results, History Variable 10 (temperature), element ID 14, sub test case ID 1

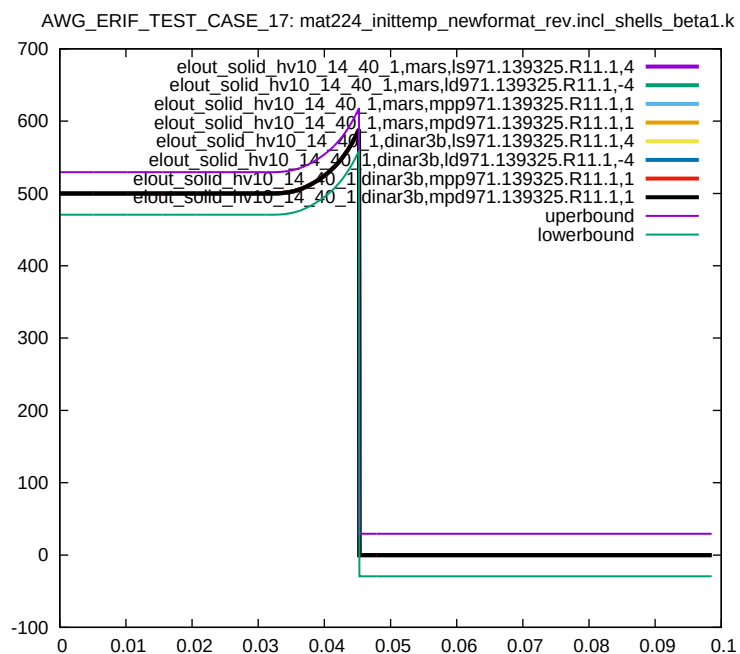


Figure 13: Cross platform results, History Variable 10 (temperature), element ID 14, sub test case ID 2

## References

- [1] LSTC, *LS-DYNA KEYWORD USER MANUAL*, 7374 Las Positas Road, Livermore, CA, 94551, USA, version 971 ed., May 2007.