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# STATUS OF EXPLOSIVE D RECOVERED FROM NAVAL 6-INCH SHELLS AFTER BEING BURIED FOR 93 YEARS

Brian Fuchs
Henry Grau
Jeff Ranu
Gerald Schreck Jr.
Brian Disalle

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U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND ARMAMENTS CENTER

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Picatinny Arsenal, New Jersey



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**6. AUTHOR(S)**
Brian Fuchs, Henry Grau, Jeff Ranu, Gerald Schreck Jr., and Brian Disalle

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
U.S. Army DEVCOM AC
Senior Research Scientist for Insensitive Munitions
(FCDD-ACD-STM)
Picatinny Arsenal, NJ 07806-5000

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Picatinny Arsenal, located in New Jersey, has had a long history of explosives–research, development, storage, and production. The U.S. Navy once had a large depot on what is now Navy Hill, the Lake Denmark Naval Ammunition Storage Depot. During a lightning storm in 1926, a large portion of the stored items burned and detonated, including unexpended munitions from World War I. The cleanup involved on-site burial, and many munitions were thrown and buried within the surrounding countryside. In a water line construction on Navy Hill in 2019, seven 6-in. U.S. Navy rounds (Explosive D fill with a base fuze) were found and destroyed by the Explosive Ordnance Disposal. One of these rounds mostly reacted but did not fully detonate in the disposal. This provided an opportunity to sample the material inside for the purpose of evaluating the aged condition of the explosives buried at Picatinny Arsenal.

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| Brian Fuchs | (973) 724-4772 |

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## INTRODUCTION

Handling and disposing of an unexploded ordnance is a hazardous job performed by ordnance and explosive safety specialists (OESSE), unexploded ordnance (UXO), and Explosive Ordnance Disposal (EOD) personnel. Protection of critical infrastructure is important, and safety of the disposal personnel and the public is of the greatest priority. Experimenting with, sampling, and examining beyond what is needed to safely perform the disposal is generally not conducted. The materials are detonated in place whenever the area can withstand a high order detonation or when the item is too dangerous to move, as that is considered the safest method. Determining if an item can be moved is based upon fuze condition and filler. If amenable, the item is moved to a remote location and then detonated. Blocks of C-4 explosive or other detonating warheads are typically utilized. The sensitivity, propensity to explode, and overall condition of munitions found buried in the ground over many years is unknown. Therefore, UXO can pose a threat for a very long time. In 2008, a black powder cannonball from the civil war killed a collector while attempting to remove the fill (ref. 1).

In the year 2019, during the installation of a water line, seven 6-in. U.S. Navy rounds were found buried in the ground at the U.S. Army Combat Capabilities Development Command (DEVCOM) Armaments Center (AC), Picatinny Arsenal, NJ. The rounds were located on Navy Hill, which houses the DEVCOM AC machine shop and a gymnasium. The location is called Navy Hill as it is at the site of the former Lake Denmark Naval Ammunition Storage Depot, which closed in July 1960 (ref. 2). It is also the location of the Lake Denmark explosives accident where a large quantity of stored munitions detonated on Saturday, 10 July 1926.

## LAKE DENMARK NAVAL AMMUNITION STORAGE DEPOT ACCIDENT

The cause of the accident was attributed to a lightning strike exacerbated by close storage and inappropriate building construction. The event was devastating, with 19 fatalities and extensive damage to the facility and the neighboring U.S. Army arsenal (ref. 3) [figs. 1 (ref. 4) and 2 (ref. 5)]. The accident involved over 600,000 tons of explosives, much of which were left over from World War I (WWI). A study reported four major blasts over 30 min. The report determined that “it is difficult to avoid the conclusion that the storage of amounts of explosives, in excess of say one-half million pounds in one building is most assuredly undesirable.” Also noted was “although the loss of life was great, it was only a small proportion of that which would have occurred if the explosion had occurred at a time when all the employees of both stations were on duty” (ref. 6).

Figure 1
Aerial view of devastation

Figure 2
Damaged naval shells

## AFTER THE ACCIDENT

The accident has a particular historic significance beyond the damage and loss of life. Post-accident reviews led to improvements in munitions storage and handling at the national and international level. These reviews found the depot severely lacking in its construction and layout. For example, a storage building containing 1,691,000 tons of 2,4,6-trinitrotoluene (TNT) was located 80 ft from a neighboring building containing 789,400 tons of TNT (ref. 7). The detonation of one magazine caused the nearby magazines to “sympathetically detonate” (the technical term used by explosive safety experts). The result was a large quantity of munitions detonating and damaged munitions being thrown large distances. Subsequent actions taken looked at not only preventing the lightning strike, but also the cascading of sympathetic detonations:

- Congress to establish a permanent board to develop explosives safety standards and ensure compliance in 1928. This has evolved into the Department of Defense Explosives Safety Board (DDESB) (ref. 3).
- Lightning protection systems were greatly improved, and the regulations have evolved into a comprehensive system of lightning safety standards (ref. 8).
- Earth covered magazine “igloos” were improved and standardized to prevent fragments and blast from a neighboring site from detonating internally stored munitions (refs. 7 and 9).
- Tables were improved that established uniform safe inter-magazine distances as well as distances to the public, structures, and motorways.

Some of the damaged and undetonated munitions were lost after being thrown large distances. These munitions are frequently found to this day, requiring EOD disposal. Overwhelmed by the quantity of leftover and damaged munitions, the remainder were buried on site in a number of pits. Construction operations at the site follow special safety precautions. The Department of Defense is still looking for munitions that left the government facility and landed on private property (ref. 10).

## WATER LINE CONSTRUCTION

A new water line was being constructed on Navy Hill, the former location of the Lake Denmark Naval Ammunition Storage Deport (figs. 3 and 4). The water line was being constructed near but not over the known location of an explosives burial pit. The ground is in a rugged region, with large rocks being dug up with the munitions (fig. 5).

Figure 3
Water line construction

Figure 4
Dug pit for water line

Figure 5
Large rocks dug up during construction

During the construction, seven 6-in. U.S. Navy rounds (Explosive D fill with a base fuze) were found and destroyed by the EOD. One of these rounds did not fully detonate in the disposal operation, leaving a residue. This provided an opportunity to sample the material inside for the purpose of evaluating the aged condition of the explosives buried at Picatinny Arsenal.

## 6-INCH NAVAL ROUNDS LOADED WITH EXPLOSIVE D

The Naval 6-inch shell found (fig. 6) was designed to penetrate the armor of a war ship and then detonate. The steel casing was much thicker than warheads designed for fragmentation leading to a relatively small explosive charge. When the warhead detonated, there would be large fragments with a reduced velocity, but its operation within the confined spaces of a warship was devastating.

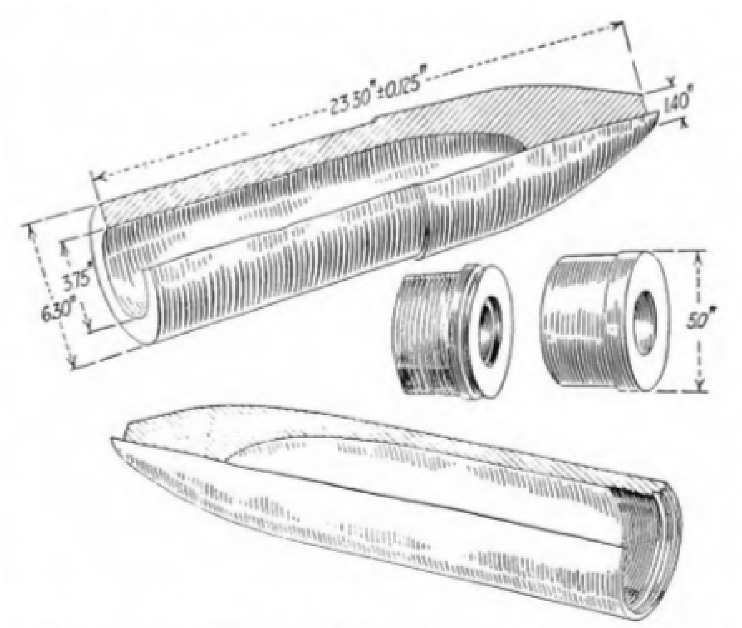


Figure 6
Naval 6-in. shells rough forged and finished

### Fuze

The munition has a base fuze, Mark III [fig. 7 (ref. 11)], to allow for a heavy penetrating steel nose. The fuze required both set-back (the force on the munition from being fired out of a gun) and spin (caused by the barrel rifling) (ref. 12). These two independent environments are common for modern artillery but were advanced for the time. It was these safety features that provided some confidence to the responding EOD personnel that if the aged sensitive fulminate initiator charge detonated, the whole munition would not.

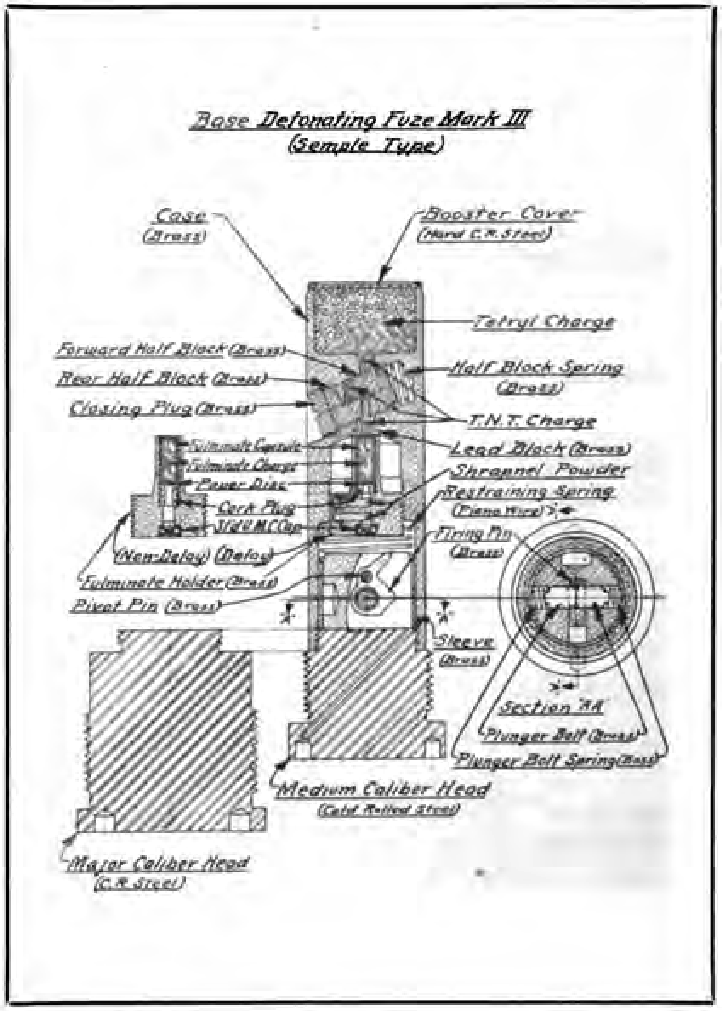


Figure 7
Mark III (sample type) base-detonating fuze

**Explosive Fill**

The 6-in. shell was filled with Ammonium Picrate, $C_6H_6N_4O_7$, the chemical name for Explosive D. Originally developed by Lt. Col. Dunn of the U.S. Army as a more insensitive and higher performing explosive than the materials in use at the time, such as picric acid, the material could survive gun launch and the penetration of steel armor before being detonated by the fuze. This explosive had a long usage by the U.S. Navy. The last munitions filled with Explosive D used Canadian-produced explosive due to the loss of domestic capability (ref. 13). Production ended in the U.S. in 1946, with the stockpiles lasting until 1969. It appears that the use of Explosive D stopped when the U.S. Navy started the insensitive munitions program after several disastrous ship accidents and a series of munitions exploding in the gun barrels (ref. 14).

Ammonium picrate is a salt of picric acid made by ammoniating picric acid with either ammonia or ammonium hydroxide. Beauregard (ref. 13) notes two forms of the material–a bright yellow stable form and a red meta-stable form. It has a density of 1,720 kg/m$^3$ and decomposes at 265°C (ref. 15). The standard enthalpy of formation has been measured as 385.44 kJ/mole using bomb calorimetry (ref. 16). The material is yellow in color and was known to turn the workers' skin and clothes yellow. Explosive D is known to be thermally stable but has significant aging issues. The Encyclopedia of Explosives states (ref. 17):

> "Explosive D should not be exposed to moisture since w(SIC) reduces its strength and sensitivity. Moisture also increases its reactivity with metals such as Pb, K, Cu, Fe, etc. to form extremely sensitive compounds."

It should be noted that the Lake Denmark Naval Ammunition Storage Depot was located in an area with a rich history of iron ore mining, with moderate to high rainfall. The reaction of Explosive D with the iron in the steel warhead required an engineering solution for the production of munitions. The solution was to use a protective layer between the explosive and shell. A black lacquer was poured in hot, the shell was revolved, and the lacquer was then poured out, leaving an even coat on the inside wall of the munition (ref. 18).

The loading of Explosive D was initially conducted by hand with wooden rammers, obtaining a density of approximately 1.32 (ref. 13). The report did not provide the units of the density; however, for consistency with the era of the measurement and the magnitude, it appears to be a measurement of specific gravity. This is nearly equivalent to a more modern conventional units of $g/cm^3$ for a density of 1,320 $kg/m^3$. The percentage of the theoretical maximum density (TMD) was then 76.7%, relatively low which would be expected from hand pressing. Low densities were determined to be associated with set-back accidents (explosions of the munition in the gun barrel during firing) and more modern hydraulic press loading was introduced in 1916-17 obtaining densities of 1,480 $kg/m^3$ (86% TMD). This is still relatively low as the rule of thumb is shock sensitivity (this is not sensitivity to set-back) is a maximum at approximately 80% TMD. As the U.S. entered WWI in 1917, and was poorly prepared for war, it is assumed that the rounds recovered are at the higher, hydraulic-pressed density.

The thermo-chemical code Cheetah (ref. 19) was used to compute the detonation properties of Explosive D at the 1,480 $kg/m^3$ density. The explosive is computed to have a detonation velocity of 6,618 m/s and a detonation pressure of 15.721 GPa. Explosive D has a computed TNT equivalence of 0.87 (mechanical energy) by weight. Most modern explosives exceed the performance of TNT.

## Observations for Explosive Ordnance Disposal

A review of the construction of the rounds lead to several observations important for EOD personnel:

- The fuze, requiring both set-back and spin to arm, is unlikely to have armed in the accident.
- Explosive D, when stored away from moisture and high heat, is very stable.
- Explosive D is degraded by moisture, becoming less energetic.
- Explosive D reacts poorly with metals, forming sensitive compounds. These reactions increase with moisture.
- Explosive D has two forms–a red meta-stable form and a yellow stable form. The color can only be ascertained if the munitions are broken or cut open.

In conclusion, there will be a large variation on the status of the munitions. Some rounds will be pristine, some degraded (possible nondetonable or ignitable), and some rounds will have become extremely sensitive. The status of the explosive cannot be ascertained by a visual inspection of the outside of the shell. Because of the thermal stability of the explosive, the burial site is and will remain hazardous.

## SYNTHESIS OF AMMONIUM PICRATE

In order to provide baseline data on unaged explosive, ammonium picrate was synthesized in the laboratory. The synthesis of ammonium picrate was carried out according to a procedure adapted from older references (refs. 17, 20, and 21). Specific volumes of solvent were not specified in historical procedures. Reaction concentration for this synthesis was chosen to increase safety of operators. Ammonium picrate was synthesized via the reaction of picric acid with aqueous ammonia at an elevated temperature. Lustrous yellow crystals formed upon cooling and were collected via filtration. A 53% yield of the reaction was lower than expected, likely due to a portion of the product remaining in solution. The authors hypothesize higher yields could be obtained by running the synthesis at higher concentrations of reagents. Proton and carbon nuclear magnetic resonances (NMR) were consistent with the desired product (figs. 8 and 9).

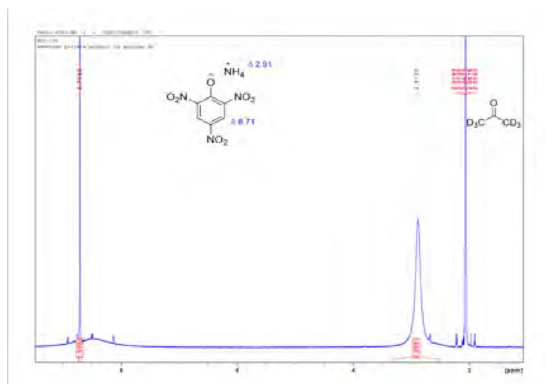

Figure 8

$^{1}$H NMR of synthesized ammonium picrate

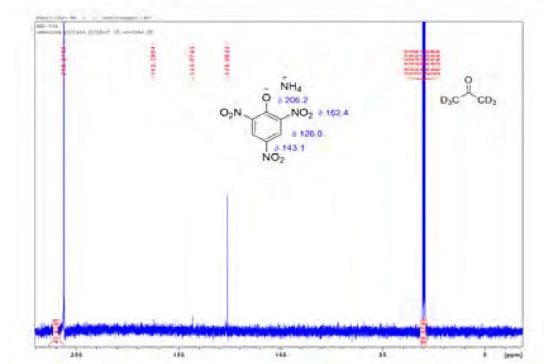

Figure 9

$^{13}$C NMR of synthesized ammonium picrate

In a 50-mL round bottomed flask, 1.43 g of wet picric acid [35% water ($H_2O$) Aldrich and 4.0 mmol 2,4,6-trinitrophenol] was suspended in 20 mL of $H_2O$. The mixture was slowly heated to 80°C in an oil bath. The solid was observed until it dissolved. 1.0 mL ammonium hydroxide solution (28% $NH_3$) was added dropwise to the mixture (3.5 equivalence NH3 ). The solution was stirred for 10 min and then allowed to cool to room temperature and the flask was transferred to an ice bath. Yellow precipitate formed upon cooling. The suspension was stirred at 0°C for 10 min and then vacuum filtered to obtain yellow crystals. Crystals were washed with cold water and allowed to dry at an ambient temperature for 12 hr Yield 0.53g 53%. The NMR analysis of the products is:

H NMR (400 MHz, CO(CD3)2) 2.91 (s,br 4H), 8.71 (s 2H)
C NMR (100 MHz, CO(CD3)2) 126.1 (s), 143.1 (s), 162.4 (s), 206.2 (s)

## RECOVERED ROUNDS

Figures 10 and 11 are typical of the rounds uncovered during water line construction. In figure 10, the extensive rust of the munitions is seen. Figure 11 shows damage caused by the accident with a large dent at the base, near the fuze, and a close up of this is seen in figure 12.

Figure 10
Rusted 6-in. shell

Figure 11
Damaged 6-in. shell

Figure 12
Close-up view of base from figure 11

The method employed by EOD personnel to destroy the munitions involves placing C-4 explosive blocks on top, which are then detonated (fig. 13). With a steel wall thickness of over 1 in., the explosive would have to be more sensitive than modern insensitive munitions to be detonated by this method.

Figure 13
6-in. shell prepared for destruction by detonation

## Sampling

In the destruction of the shells, one of the rounds did not fully detonate, with pieces of the yellow Explosive D visible. The shell is shown in figures 14 and 15 with a close-up view of the black lacquer in figure 16. The close-up view shows exposed steel through the lacquer. The shell interior was cleaned with an alcohol wipe in order to not damage the lacquer. It is believed that the lacquer was damaged by age and the steel had come in direct contact with the explosive.

Figure 14
Recovered 6-in. shell

Figure 15
Inside view

Figure 16
Close-up view of interior lacquer

The recovered samples of explosive were of a variety of colors, with a bright yellow, a yellow-orange, and grey-yellow colored samples present (fig. 17). The bright yellow samples are assumed to be the stable form, and the yellow-orange samples are assumed to contain the red meta-stable form of ammonium picrate. The samples are visibly damaged with age.

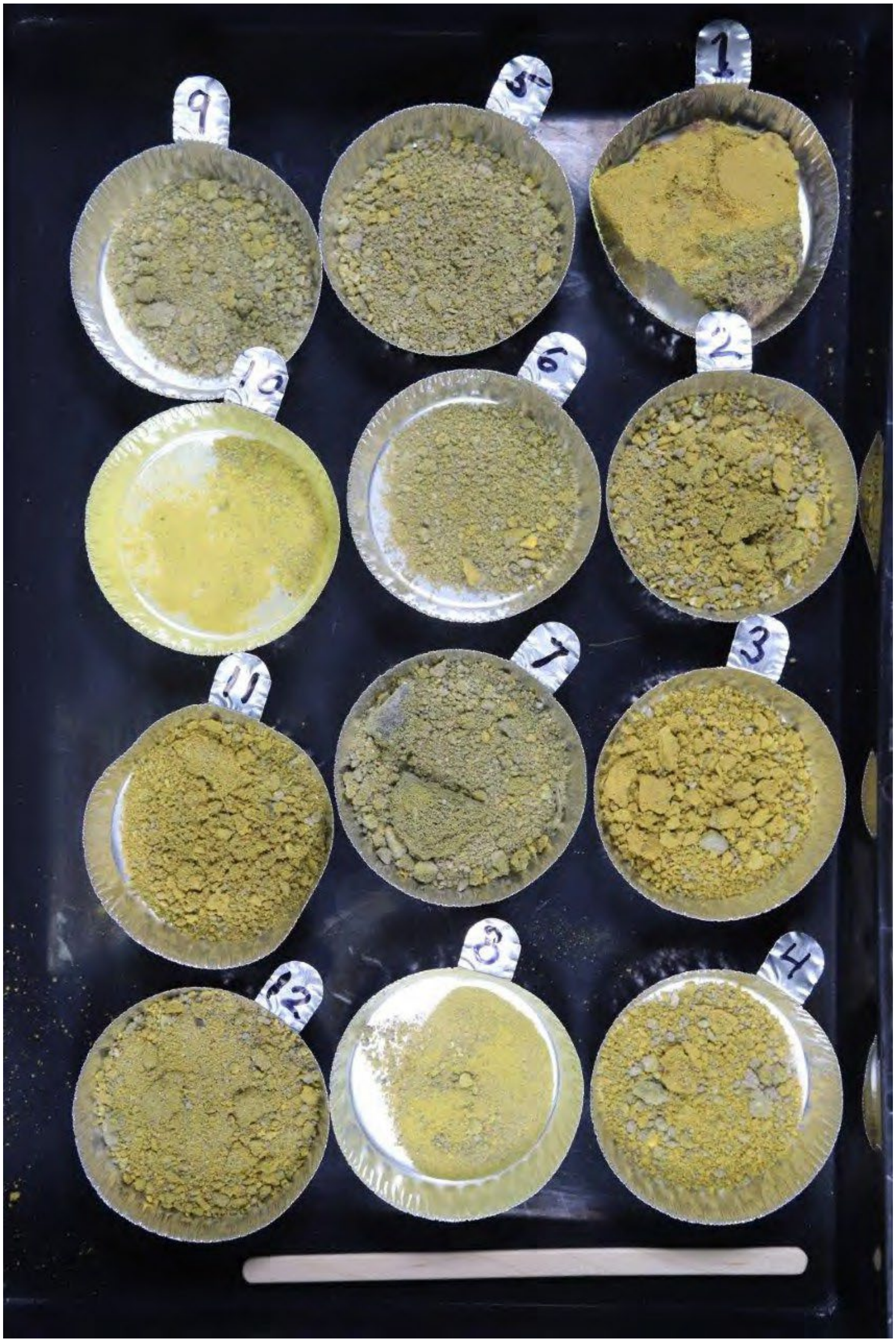


Figure 17
Recovered Explosive D samples

## Baseline Safety Testing

The Detonation Physics and Experimental Research Branch at DEVCOM AC requires all explosives be tested for sensitivity to impact, electrostatic discharge (ESD), and friction before operations begin. The details of the testing methods are in Allied Ordnance Publication (AOP)-7, U.S. National Section (ref. 22). These are the following results[1]:

### Explosives Research Laboratory (ERL) Impact Test

- This test uses a 2.2-kg weight dropped onto a sample sitting on 180-grit sandpaper.
- Definite reactions as low as 25.1 cm with obvious signs of jetting, heat transfer on the hammer, and charring of the sandpaper. No obvious audible or light signatures present. Small amounts of material consumed in reaction.

### BAM[2] Friction Test

- A powdered sample is scraped between a loaded porcelain plate and pin.
- No sparking, snapping, or obvious displacement of materials (due to jetting) seen at 360 N. Porcelain plate showed a black line with some browning along edges.
- Material in the immediate vicinity of porcelain pin was blackened. Small amounts of material blackened as low as 120 N.

### Allegany Ballistics Laboratory (ABL) ESD Test

- A charged needle dropped discharging the energy.
- Flame reactions as low as 0.031 J, no obvious reactions (out of 15 trials) shown at 0.025 J.

The results are within the expected range for secondary main charge explosives. There is no indication of undue age-induced sensitivity in this particular munition.

## Differential Scanning Calorimetry (DSC)

In DSC, a sample and a reference sample are both heated at the same rate, and the differences in the heat required are measured. If the reference sample has a known heat capacity, important thermal measurements can be obtained from the sample, such a phase changes, onset and peak temperatures for reactions, and the change in enthalpy. This test was conducted on the recovered samples, and the plots are in the appendix. Additionally, ammonia picrate was produced in the chemistry laboratory to provide a basis of comparison to the aged samples. The DSC testing was conducted twice on each test samples, with the designation “a” given for the first test and “b” given for the second repeated test. These results can be seen in table 1.

---

[1] email from Devin Alonso, lead technician for sensitivity testing of the Detonation Physics and Experimental Research Branch at the Armaments Center, dated 23 Mar. 2020.

[2] BAM stands for Bundesanstalt für Materialforschung und -prüfung.

Table 1
DSC test results

| Sample | Onset temperature (°C) | Peak temperature (°C) | Change in enthalpy (J/g) |
|---|---|---|---|
| | | | |
| 1a | 274.75 | 276.73 | -1139.5287 |
| 1b | 270.54 | 276.59 | -1029.5458 |
| 2a | 263.66 | 270.67 | -232.5621 |
| 2b | 266.75 | 271.80 | -223.5723 |
| 3a | 269.82 | 276.51 | -711.4087 |
| 3b | 269.18 | 274.79 | -435.0390 |
| 4a | 272.21 | 278.31 | -635.3278 |
| 4b | 271.16 | 277.12 | -650.4680 |
| 5a | 257.16 | 262.72 | -37.0000 |
| 5b | 257.04 | 262.88 | -55.3067 |
| 6a | 255.82 | 262.89 | 45.5155 |
| 6b | 259.78 | 265.80 | -70.1340 |
| 7a | 256.60 | 262.24 | -33.8676 |
| 7b | 256.57 | 262.43 | -22.7088 |
| 8a | 262.52 | 262l43 | -22.7080 |
| 8b | 263.77 | 269.77 | -247.8974 |
| 9a | 243.85 | 249.97 | -10.4149 |
| 9b | 242.75 | 252.15 | -13.2401 |
| 10a | 269.18 | 275.03 | -571.8612 |
| 10b | 267.78 | 273.62 | -709.3977 |
| 11a | 268.53 | 274.96 | -520.3514 |
| 11b | 268.09 | 274.43 | -431.9201 |
| 12a | 261.99 | 268.09 | -183.0657 |
| 12b | 262.16 | 269.98 | -110.5796 |
| | | | |
| New_a | 283.34 | 286.63 | -740.461 |
| New_b | 277.69 | 280.83 | -392.2790 |

For the freshly produced explosive, the onset (~280°C) and peak of decomposition (~285°C) demonstrates a higher decomposition temperature than the material found in the UXO. This is indicative of age degradation, likely of the nitro groups. There is also an endotherm at ~220°C similar to that in the range for the UXO material, confirming the UXO material is most likely ammonium picrate. The samples subjected to thermal analysis also show the variation in the change of enthalpy, which is also an indication of random decomposition. The lower values of enthalpy may also take into account foreign debris such as soil and stone that may have been mixed with the energetic material. It is noted that all of the samples tested, regardless of the level of degradation, remain energetic.

## STABILITY OF THE MUNITIONS

There is little information on the long-term aging of the explosive. Explosive D has been found to be very thermally stable, with no evidence of deterioration at 50°C for more than five years (ref. 17). A standard method of evaluating the thermal degradation of materials is the Arrhenius equation:

$$\frac{dH}{dt} = -HZe^{-E_a/RT}$$

(1)

Where:

$E_a$ = Activation energy
$H$ = Heat of reaction
$R$ = Ideal gas constant
$t$ = Time
$T$ = Temperature
$Z$ = A time constant

Solving for the fraction of the heat of reaction lost, which will be assumed to be approximately equal the quantity of the material reacted (ref. 23), is shown in equation 2.

$$\frac{H}{H_{initial}} = e^{-tZe^{E_a/RT}}$$

(2)

Where:

$\frac{H}{H_{initial}}$=The fraction of the heat loss

There is little information available for the Arrhenius coefficients for Explosive D. Ross and Jayaweera (ref. 23) have reported values for ammonium picrate dissolved in water and liquid picric acid. Their values for ammonium picrate solutions within the temperature range of 180 to 325°C are $Z$ = 12.6 s$^{-1}$ and $E_a$ =41.2 kcal/mole. For liquid picric acid within the temperature range of 183 to 270°C, the values are $Z$ = 11.6 s$^{-1}$ and $E_a$ =38.6 kcal/mole. These values are comparatively close, implying similar chemical decomposition reactions (ref. 23). Using these values in the previous equation indicates virtually no degradation of the explosive. The environmental temperatures of New Jersey underground is an extrapolation far beyond where the measurements were taken. Additionally, advanced decomposition studies have used multiple Arrhenius equations for the same material, each for a different chemical decomposition path. Other decomposition paths are possible at the lower temperatures the 6-in. rounds have experienced. However, there are no indications that any of these situations have affected the explosive, and it is noted that six of the seven rounds were fully detonated by EOD. The conclusion is made that many of the rounds buried on Navy Hill are not degraded and will remain energetic for the foreseeable future.

The degradation of the tested recovered sample is probably due to water intrusion into the shell caused by damage to the seals from the accident and the incompatibility of the explosive with iron. The DSC and sensitivity test results should not be considered typical for the population. However, the results are indicative of the current status of some of the munitions. Bacteria is also known to degrade explosive (ref. 24); however, this would require a pathway for the entry of the bacteria.

## CONCLUSIONS

Many of the 6-in. Explosive D artillery munitions buried at Navy Hill at the U.S. Army Combat Capabilities Development Command (DEVCOM) Armaments Center (AC), Picatinny Arsenal, NJ, are still energetic and detonable. It should be assumed that in many cases, the explosives are most likely as powerful as the day of manufacture. Because of interactions with iron, some of these munitions are likely very sensitive. The damage experienced by some will have allowed water intrusion and degradation of the material, which will eventually make some of the shells nonenergetic. External examination of the shells cannot be used to definitively evaluate the status of the material. Eventually, oxidation of the shells will break the seal and expose the explosive to the environment, making it eventually nondetonable. However, the thick steel bodies and state of the current shells indicates that the 93 years of burial is only a small start of this process. This evaluation is only for the 6-in. shells found; there were many different munitions stored at Lake Denmark Naval Ammunitions Storage Depot.

## SUGGESTIONS FOR FUTURE WORK

The sampling and analysis on the Explosive D filled round is for the individual round, and care must be exercised in applying the results to the remaining rounds still buried. As it is the only round of the seven that did not fully detonate in the disposal and the testing clearly indicated degradation of the explosive, it is assumed that the round does not represent the typical buried round. Additionally, the round is one of many types known to have been involved in the accident, and the round was found individually and not in the burial pits.

A better analysis of the rounds can be made by sampling a more pristine sample. The added dangers this poses must be carefully considered. Fortunately, there is no urgent need to sample a munition, and the time exists to develop a test plan and procedure that can perform the operation when another round is discovered; although it also may be, in review, judged to be too hazardous of an operation to justify the benefits. One possible concept is to open the round and separate the fuzed portion using linear shaped charges. The fuzed portion (in this case, the base of the round) could be disposed of while the remainder of the round is sampled for analysis. The explosive and the condition of any protective lacquer should be evaluated.

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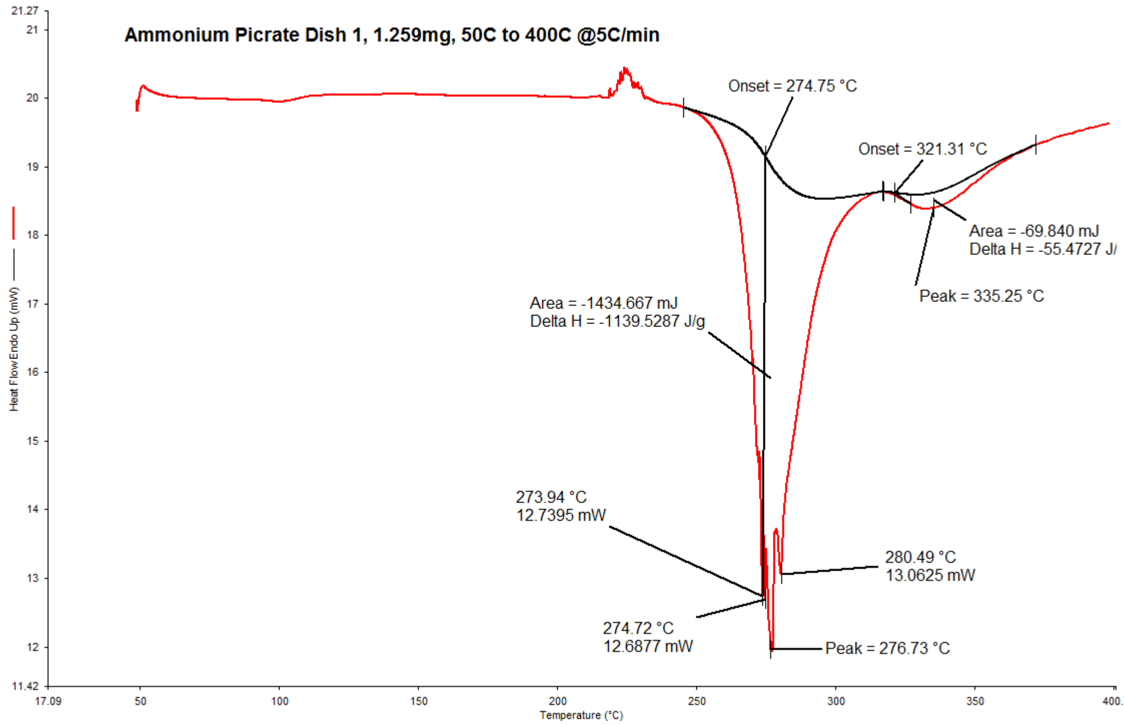
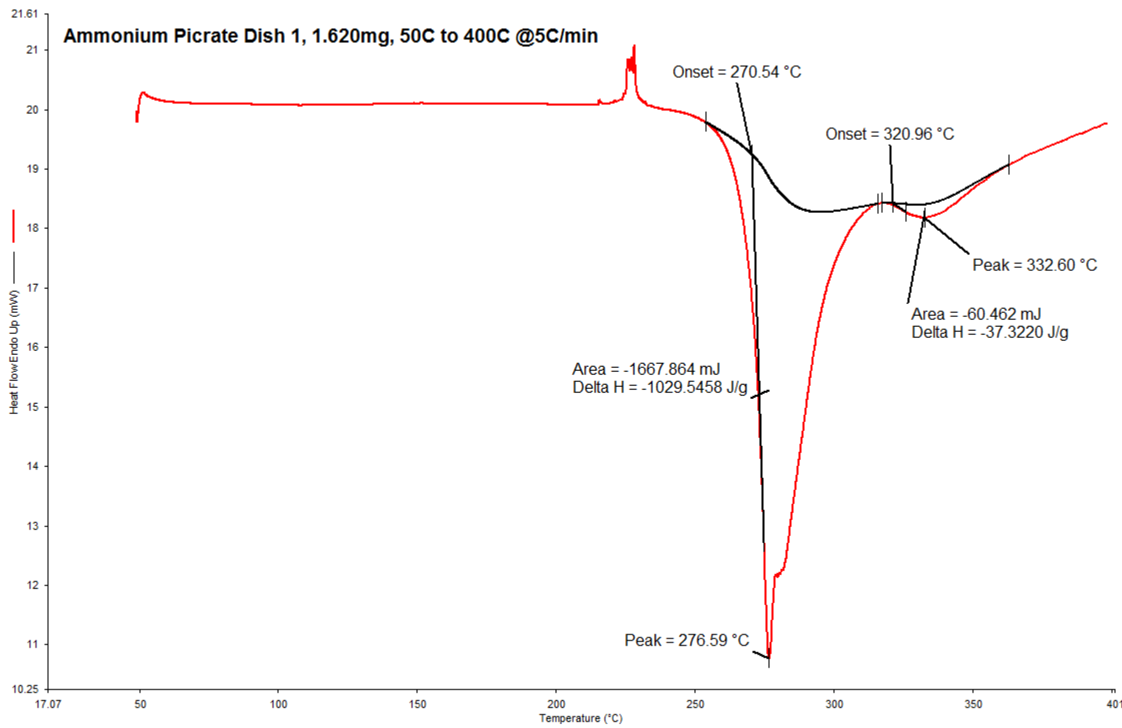
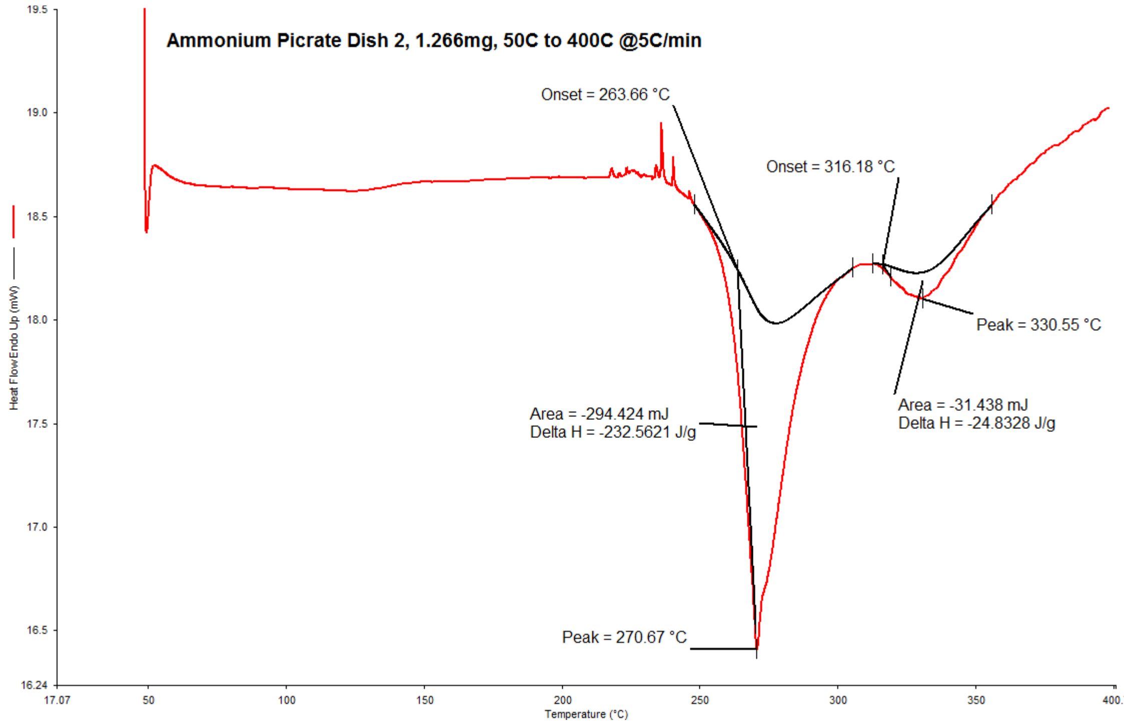
# APPENDIX
# DIFFERENTIAL SCANNING CALORIMETRY (DSC) RESULTS

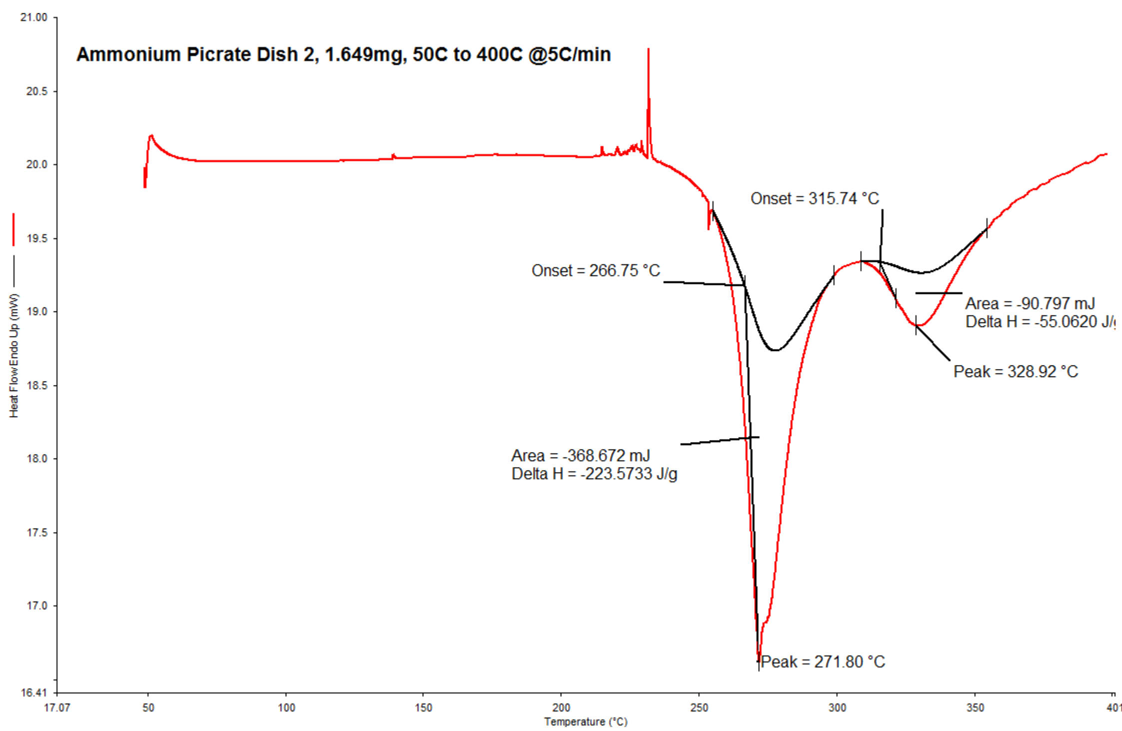


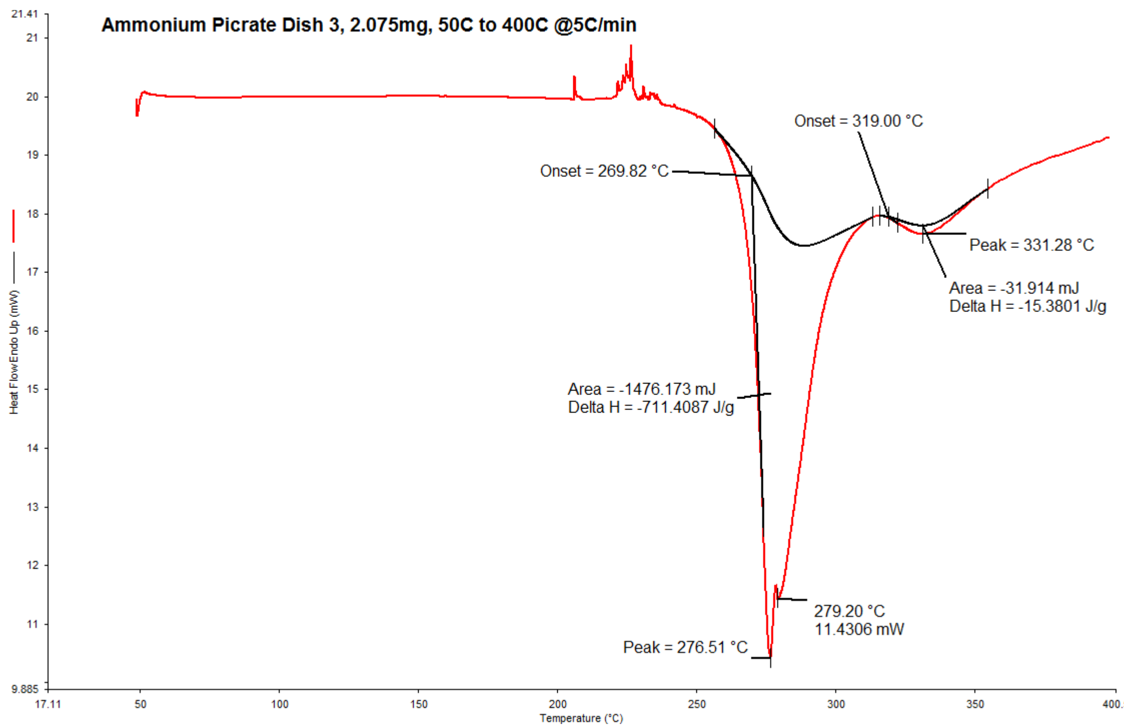
Ammonium Picrate Dish 1, 1.259mg, 50C to 400C @5C/min
Onset = 274.75 °C
Onset = 321.31 °C
Area = -69.840 mJ
Delta H = -55.4727 J/
Peak = 335.25 °C
Area = -1434.667 mJ
Delta H = -1139.5287 J/g
273.94 °C
12.7395 mW
280.49 °C
13.0625 mW
274.72 °C
12.6877 mW
Peak = 276.73 °C
Heat Flow Endo Up (mW)
Temperature (°C)

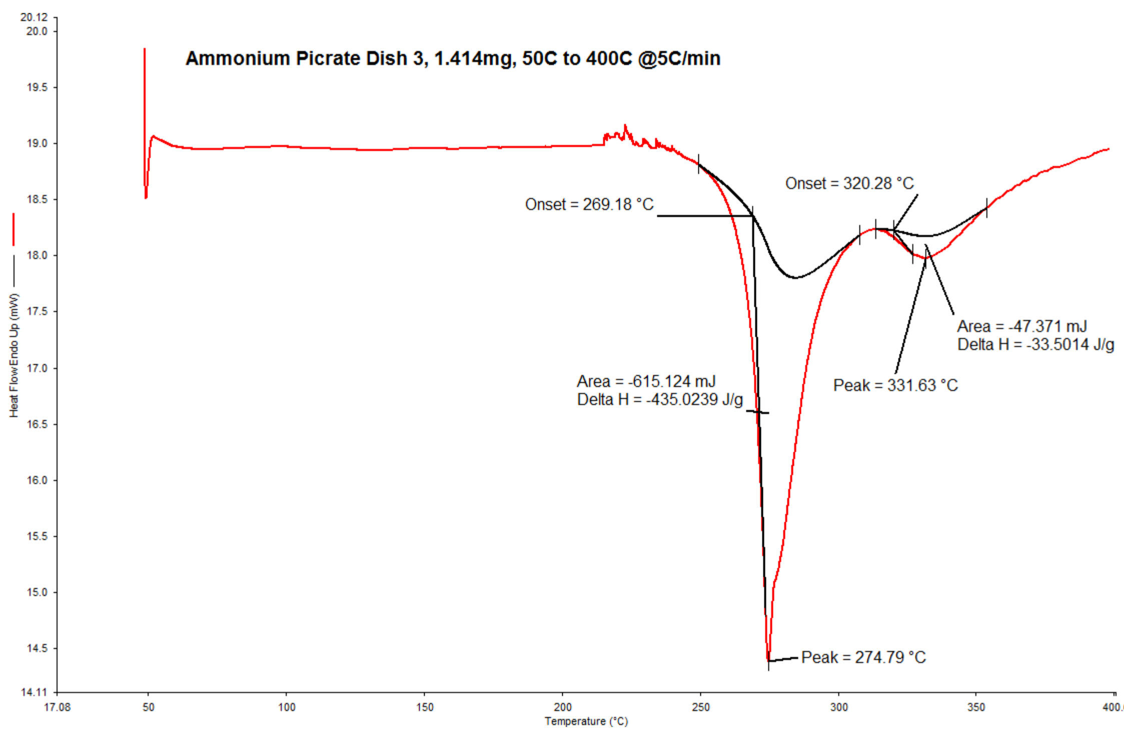



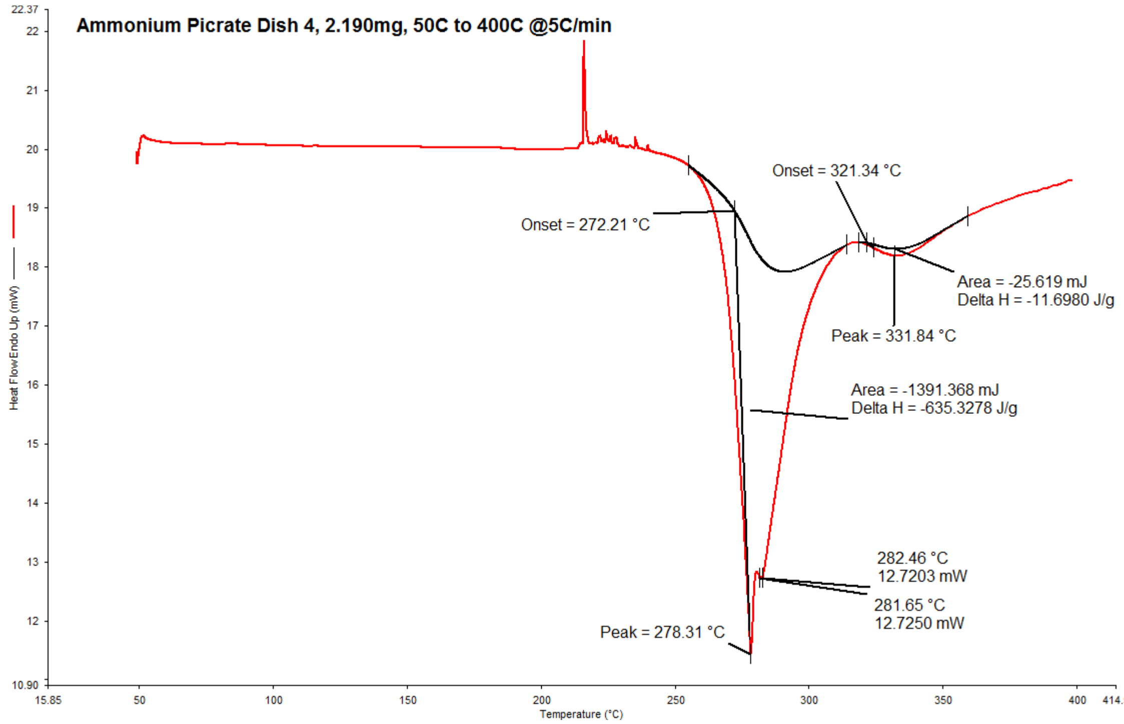
Ammonium Picrate Dish 1, 1.620mg, 50C to 400C @5C/min
Onset = 270.54 °C
Onset = 320.96 °C
Peak = 332.60 °C
Area = -60.462 mJ
Delta H = -37.3220 J/g
Area = -1667.864 mJ
Delta H = -1029.5458 J/g
Peak = 276.59 °C
Heat Flow Endo Up (mW)
Temperature (°C)

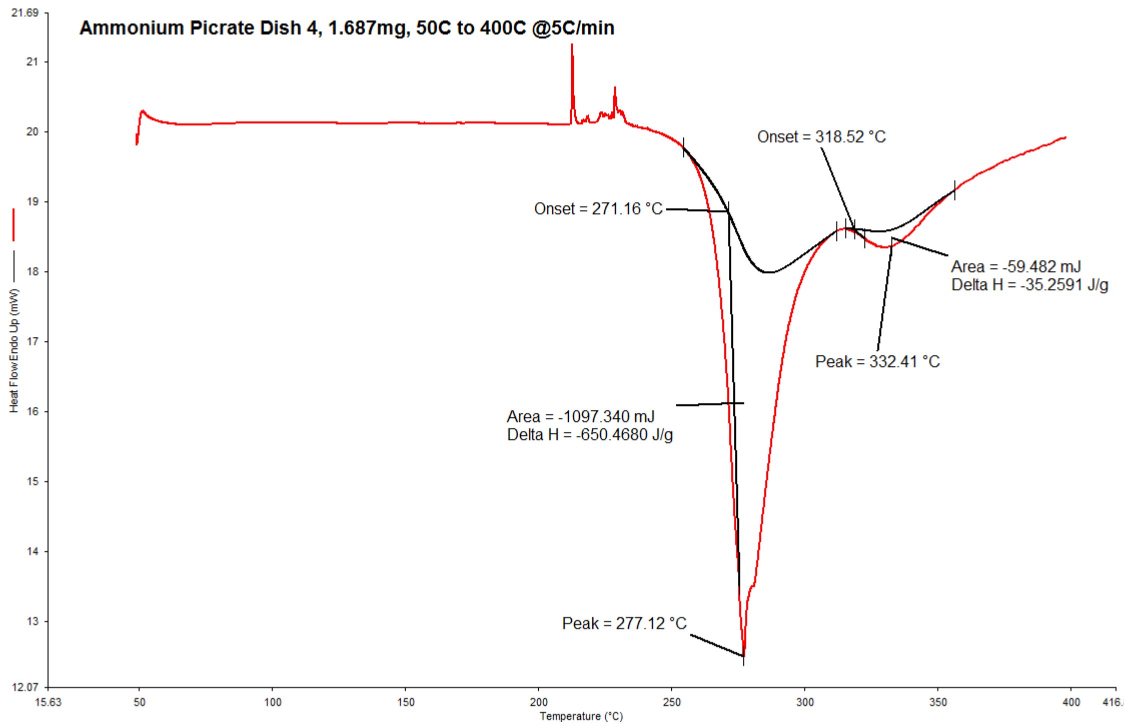

Ammonium Picrate Dish 2, 1.266mg, 50C to 400C @5C/min
Onset = 263.66 °C
Onset = 316.18 °C
Peak = 330.55 °C
Area = -31.438 mJ
Delta H = -24.8328 J/g
Area = -294.424 mJ
Delta H = -232.5621 J/g
Peak = 270.67 °C
Heat Flow Endo Up (mW)
Temperature (°C)

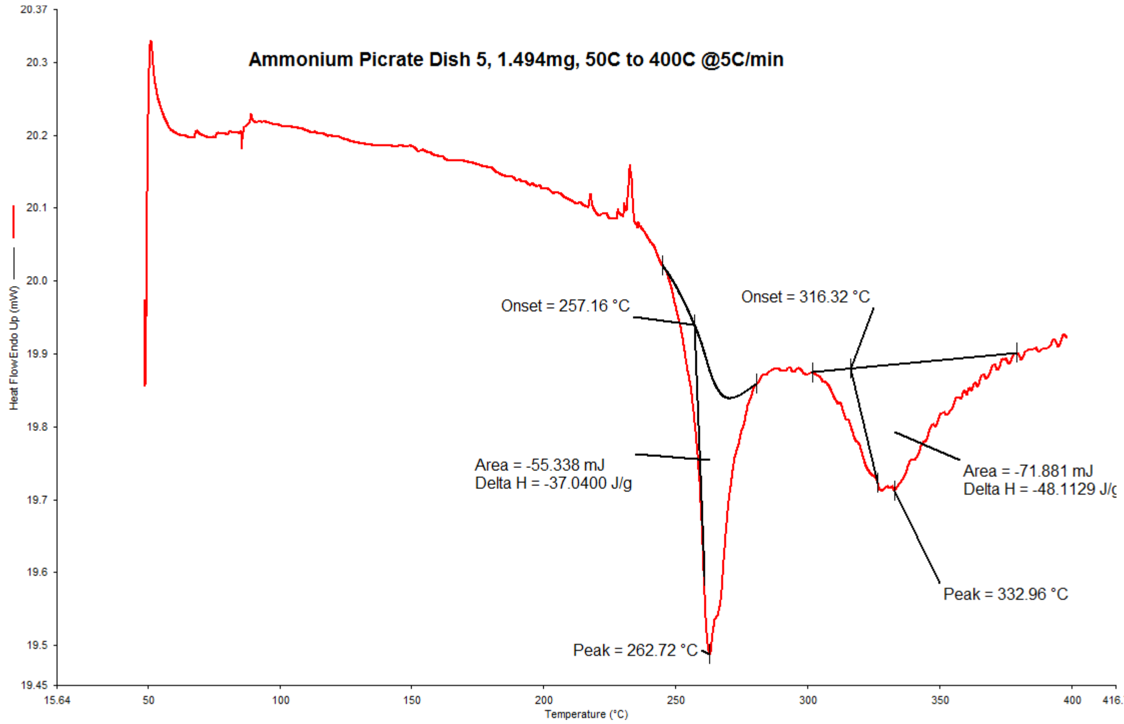

Ammonium Picrate Dish 2, 1.649mg, 50C to 400C @5C/min
Onset = 315.74 °C
Onset = 266.75 °C
Area = -90.797 mJ
Delta H = -55.0620 J/g
Peak = 328.92 °C
Area = -368.672 mJ
Delta H = -223.5733 J/g
Peak = 271.80 °C
Heat Flow Endo Up (mW)
Temperature (°C)

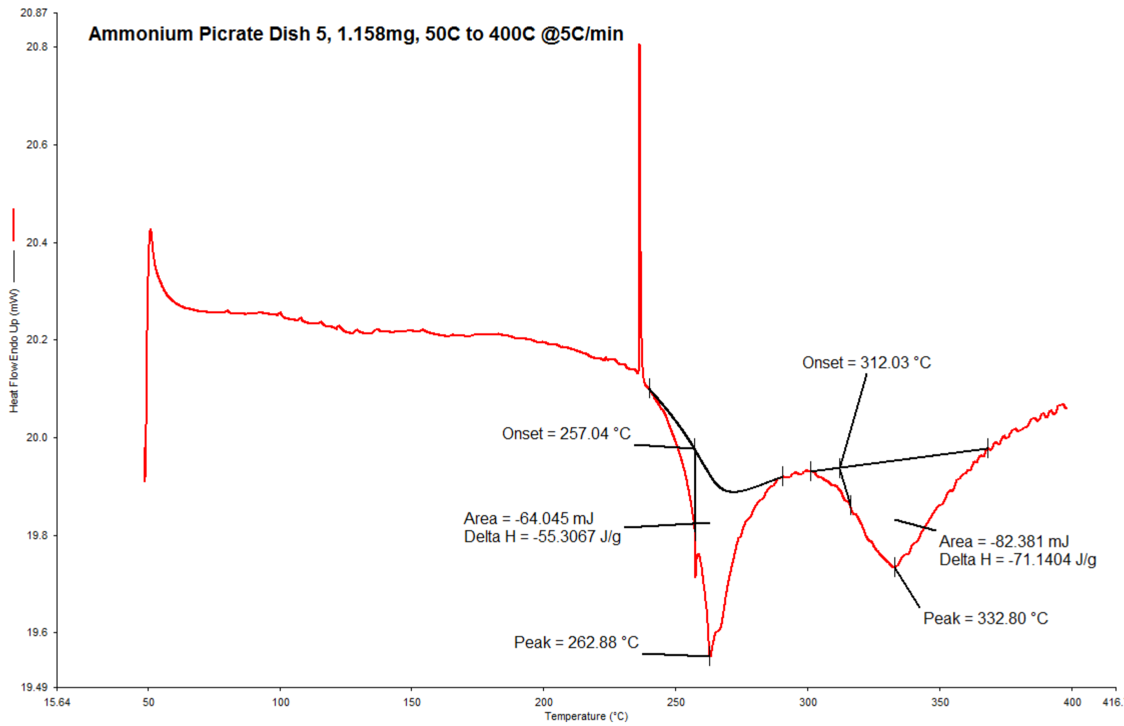

Ammonium Picrate Dish 3, 2.075mg, 50C to 400C @5C/min
Onset = 319.00 °C
Onset = 269.82 °C
Peak = 331.28 °C
Area = -31.914 mJ
Delta H = -15.3801 J/g
Area = -1476.173 mJ
Delta H = -711.4087 J/g
279.20 °C
11.4306 mW
Peak = 276.51 °C
Heat Flow Endo Up (mW)
Temperature (°C)

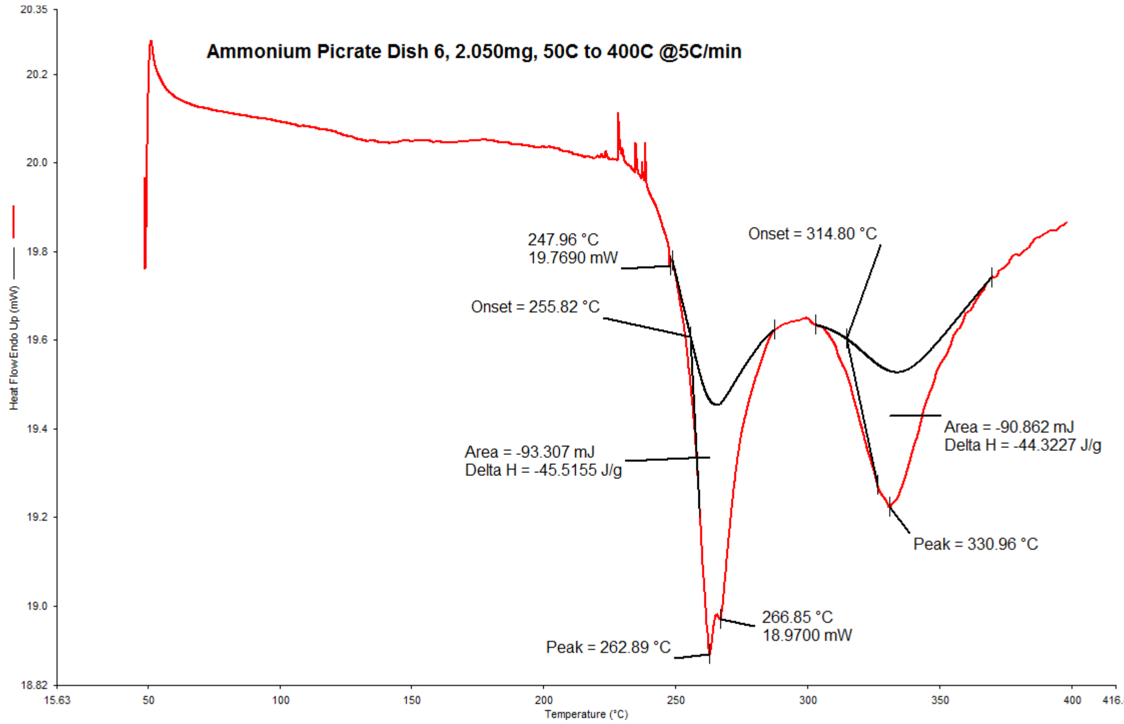

Ammonium Picrate Dish 3, 1.414mg, 50C to 400C @5C/min
Onset = 320.28 °C
Onset = 269.18 °C
Area = -47.371 mJ
Delta H = -33.5014 J/g
Peak = 331.63 °C
Area = -615.124 mJ
Delta H = -435.0239 J/g
Peak = 274.79 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 4, 2.190mg, 50C to 400C @5C/min
Onset = 321.34 °C
Onset = 272.21 °C
Area = -25.619 mJ
Delta H = -11.6980 J/g
Peak = 331.84 °C
Area = -1391.368 mJ
Delta H = -635.3278 J/g
282.46 °C
12.7203 mW
281.65 °C
12.7250 mW
Peak = 278.31 °C
Heat Flow Endo Up (mW)
Temperature (°C)

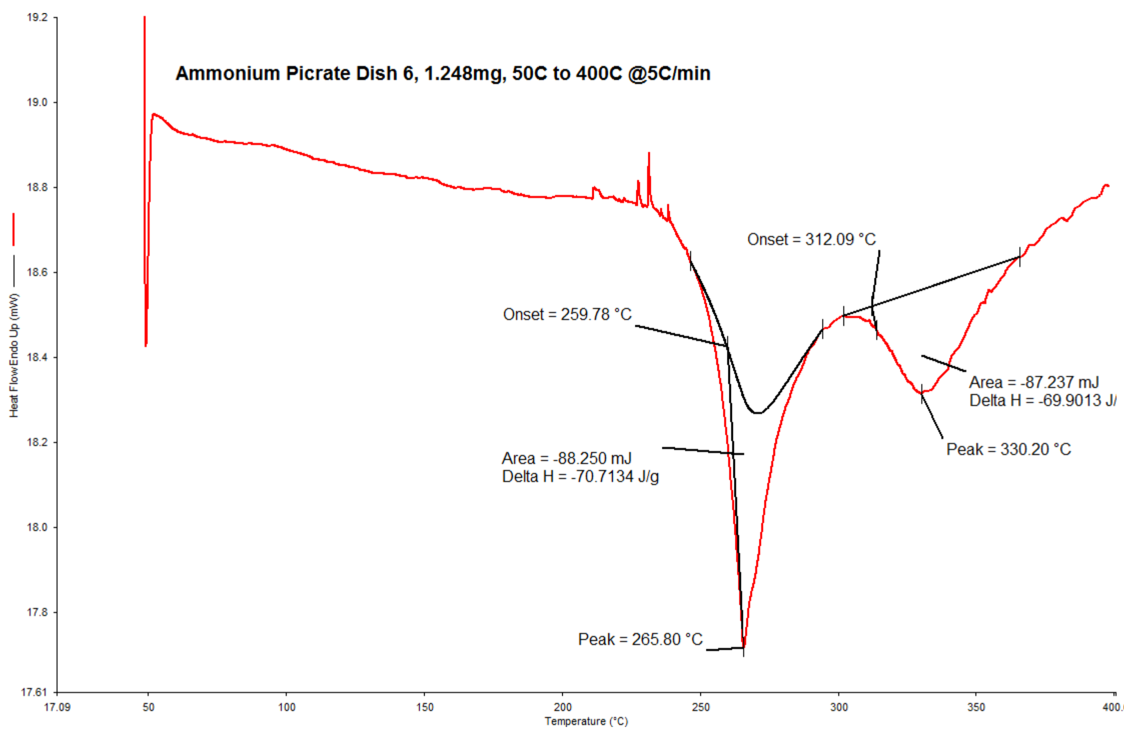

Ammonium Picrate Dish 4, 1.687mg, 50C to 400C @5C/min
Onset = 318.52 °C
Onset = 271.16 °C
Area = -59.482 mJ
Delta H = -35.2591 J/g
Peak = 332.41 °C
Area = -1097.340 mJ
Delta H = -650.4680 J/g
Peak = 277.12 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 5, 1.494mg, 50C to 400C @5C/min
Onset = 257.16 °C
Onset = 316.32 °C
Area = -55.338 mJ
Delta H = -37.0400 J/g
Area = -71.881 mJ
Delta H = -48.1129 J/g
Peak = 332.96 °C
Peak = 262.72 °C
Heat Flow Endo Up (mW)
Temperature (°C)

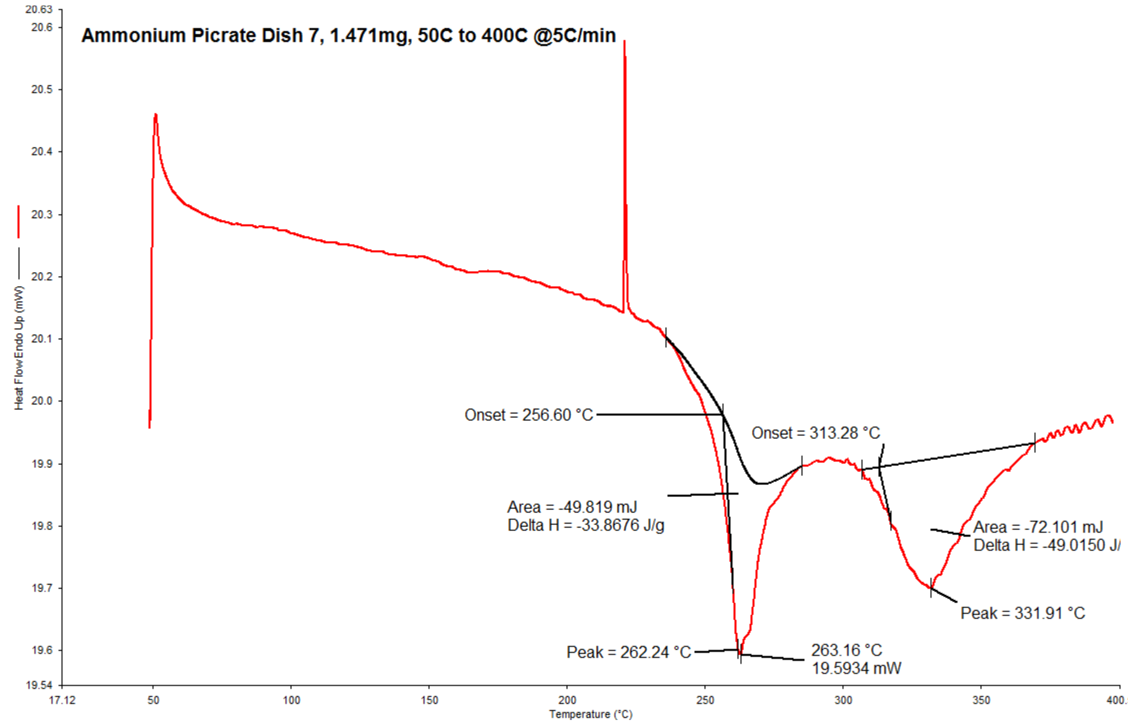

Ammonium Picrate Dish 5, 1.158mg, 50C to 400C @5C/min
Onset = 312.03 °C
Onset = 257.04 °C
Area = -64.045 mJ
Delta H = -55.3067 J/g
Area = -82.381 mJ
Delta H = -71.1404 J/g
Peak = 332.80 °C
Peak = 262.88 °C
Heat Flow Endo Up (mW)
Temperature (°C)

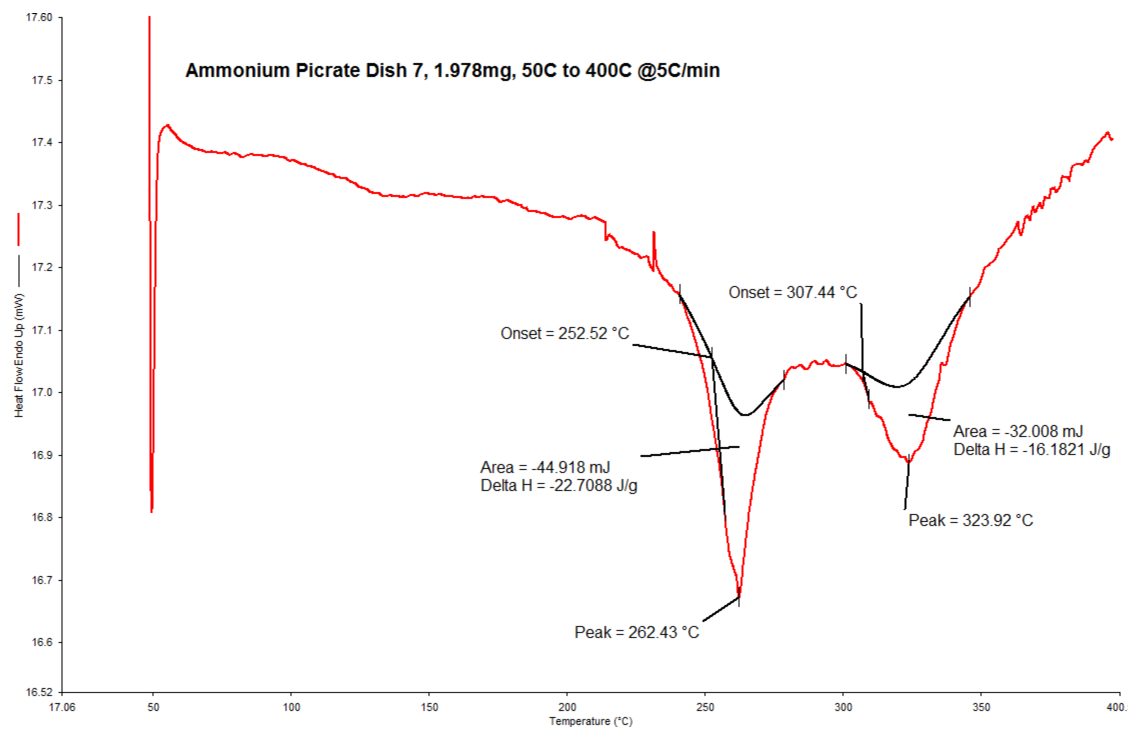


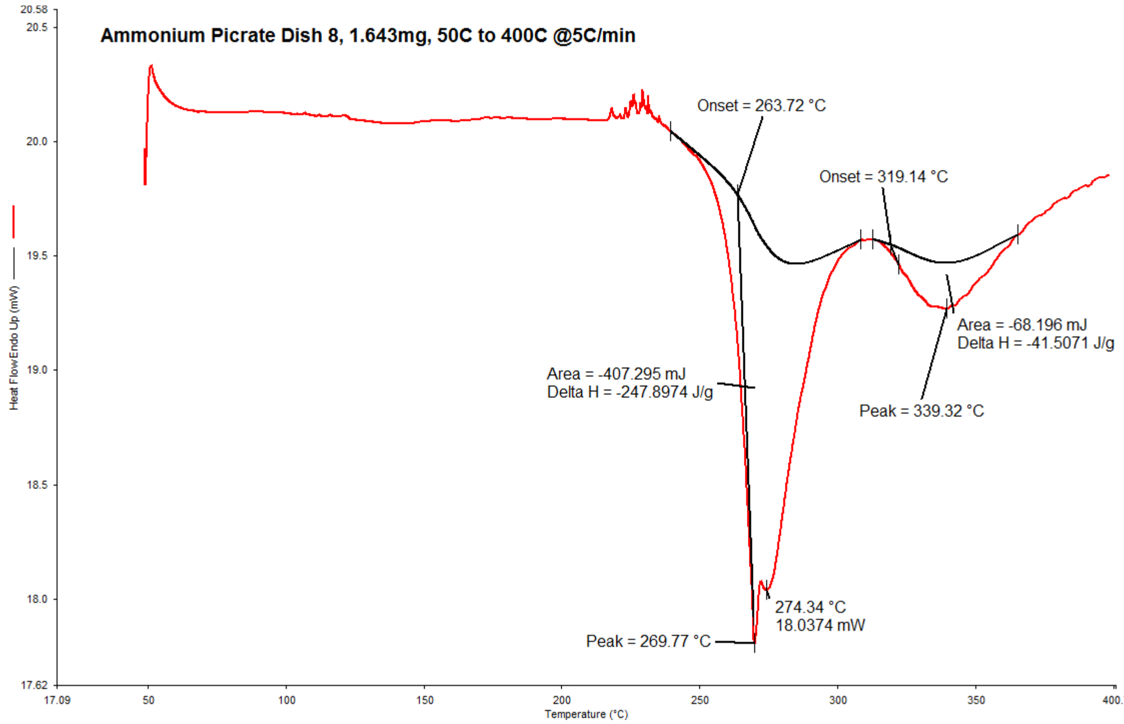
Ammonium Picrate Dish 6, 2.050mg, 50C to 400C @5C/min
247.96 °C
19.7690 mW
Onset = 255.82 °C
Onset = 314.80 °C
Area = -93.307 mJ
Delta H = -45.5155 J/g
Area = -90.862 mJ
Delta H = -44.3227 J/g
Peak = 330.96 °C
266.85 °C
18.9700 mW
Peak = 262.89 °C
Heat Flow Endo Up (mW)
Temperature (°C)

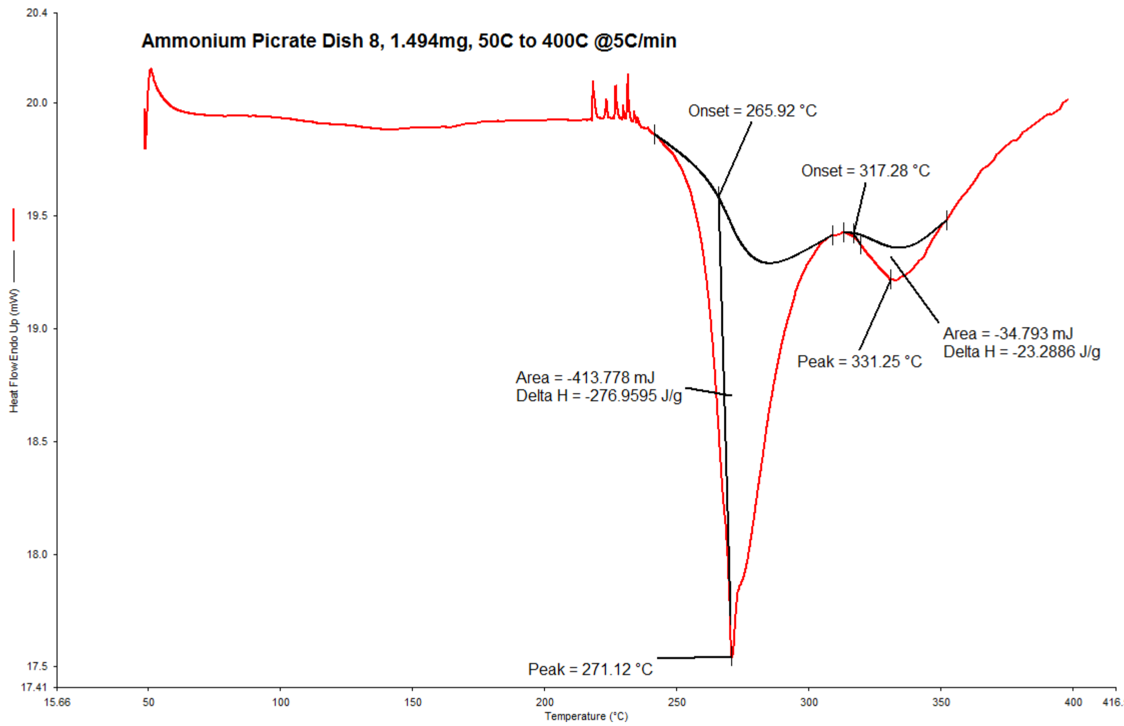



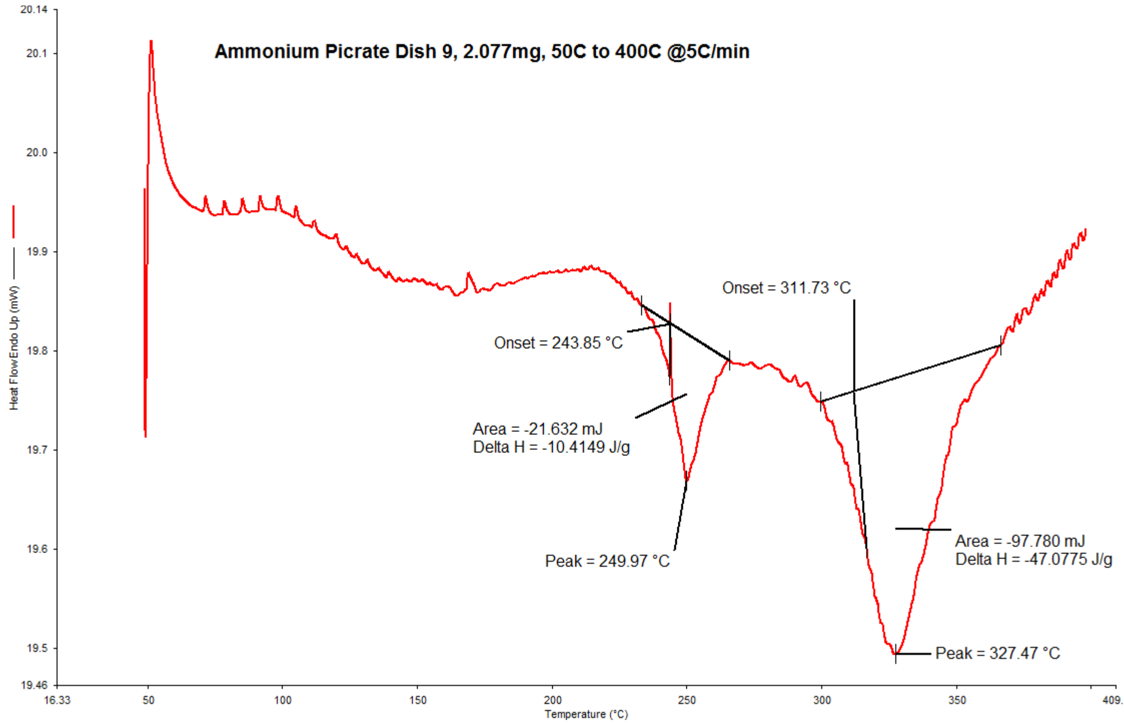
Ammonium Picrate Dish 6, 1.248mg, 50C to 400C @5C/min
Onset = 312.09 °C
Onset = 259.78 °C
Area = -87.237 mJ
Delta H = -69.9013 J/
Peak = 330.20 °C
Area = -88.250 mJ
Delta H = -70.7134 J/g
Peak = 265.80 °C
Heat Flow Endo Up (mW)
Temperature (°C)

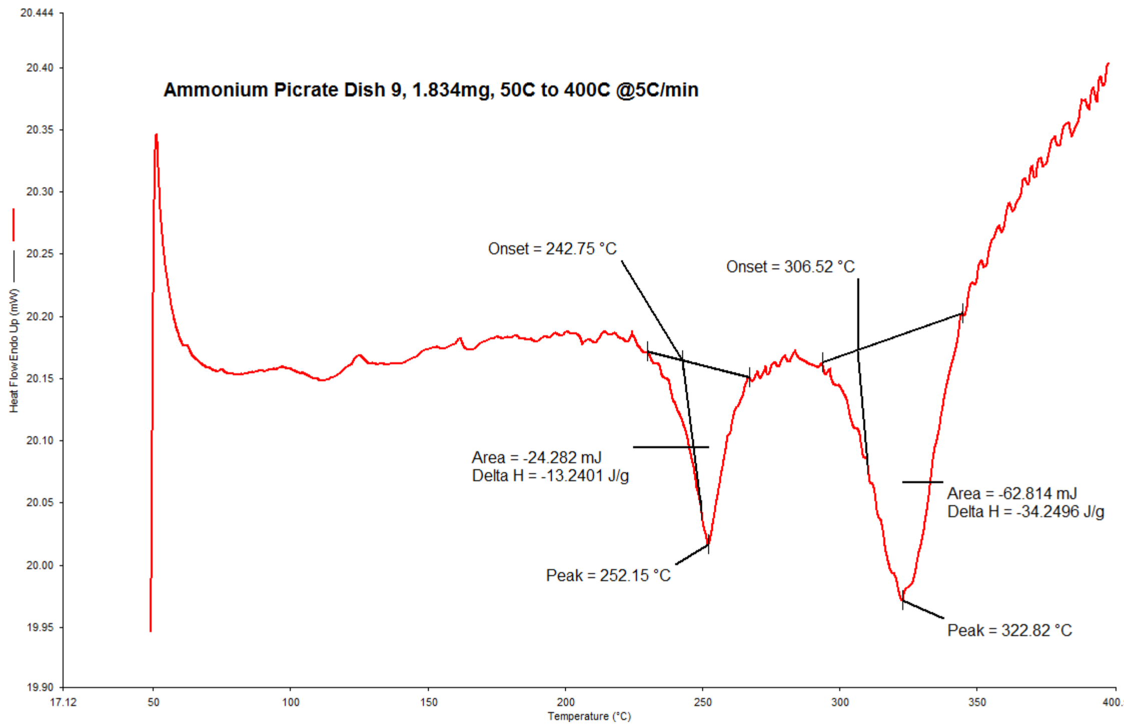

Ammonium Picrate Dish 7, 1.471mg, 50C to 400C @5C/min
Onset = 256.60 °C
Onset = 313.28 °C
Area = -49.819 mJ
Delta H = -33.8676 J/g
Area = -72.101 mJ
Delta H = -49.0150 J/
Peak = 331.91 °C
Peak = 262.24 °C
263.16 °C
19.5934 mW
Heat Flow Endo Up (mW)
Temperature (°C)

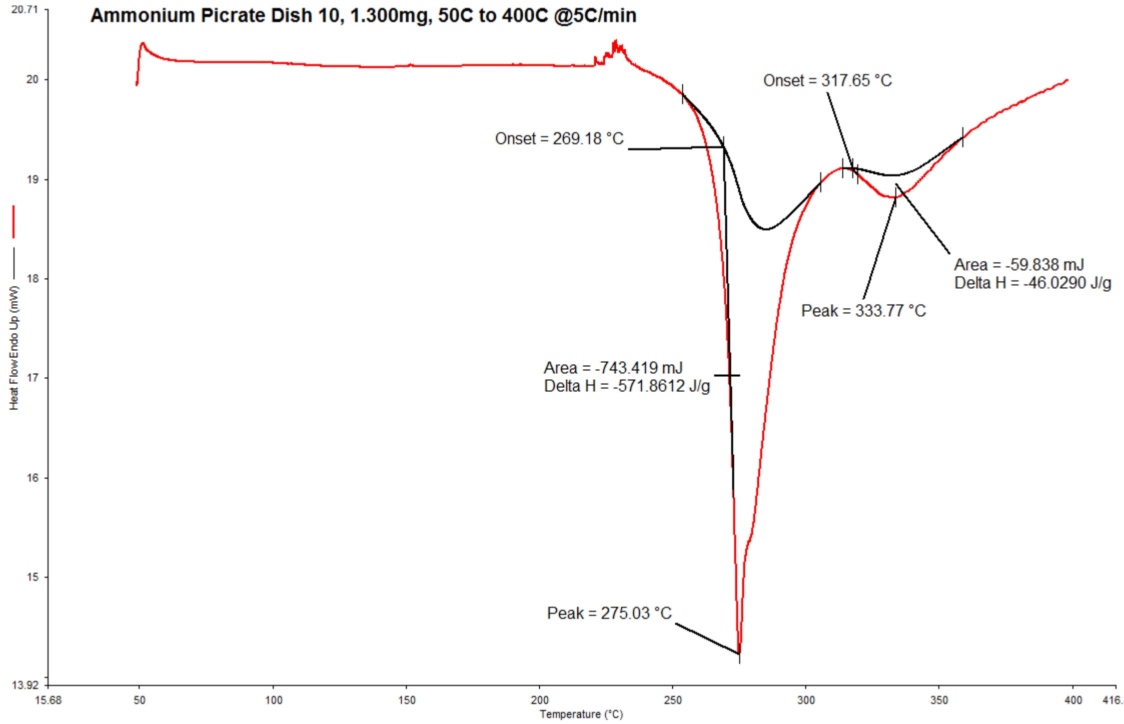

Ammonium Picrate Dish 7, 1.978mg, 50C to 400C @5C/min
Onset = 307.44 °C
Onset = 252.52 °C
Area = -32.008 mJ
Delta H = -16.1821 J/g
Area = -44.918 mJ
Delta H = -22.7088 J/g
Peak = 323.92 °C
Peak = 262.43 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 8, 1.643mg, 50C to 400C @5C/min
Onset = 263.72 °C
Onset = 319.14 °C
Area = -68.196 mJ
Delta H = -41.5071 J/g
Area = -407.295 mJ
Delta H = -247.8974 J/g
Peak = 339.32 °C
274.34 °C
18.0374 mW
Peak = 269.77 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 8, 1.494mg, 50C to 400C @5C/min
Onset = 265.92 °C
Onset = 317.28 °C
Area = -34.793 mJ
Delta H = -23.2886 J/g
Peak = 331.25 °C
Area = -413.778 mJ
Delta H = -276.9595 J/g
Peak = 271.12 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 9, 2.077mg, 50C to 400C @5C/min
Onset = 243.85 °C
Onset = 311.73 °C
Area = -21.632 mJ
Delta H = -10.4149 J/g
Peak = 249.97 °C
Area = -97.780 mJ
Delta H = -47.0775 J/g
Peak = 327.47 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 9, 1.834mg, 50C to 400C @5C/min
Onset = 242.75 °C
Onset = 306.52 °C
Area = -24.282 mJ
Delta H = -13.2401 J/g
Peak = 252.15 °C
Area = -62.814 mJ
Delta H = -34.2496 J/g
Peak = 322.82 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 10, 1.300mg, 50C to 400C @5C/min
Onset = 317.65 °C
Onset = 269.18 °C
Area = -59.838 mJ
Delta H = -46.0290 J/g
Peak = 333.77 °C
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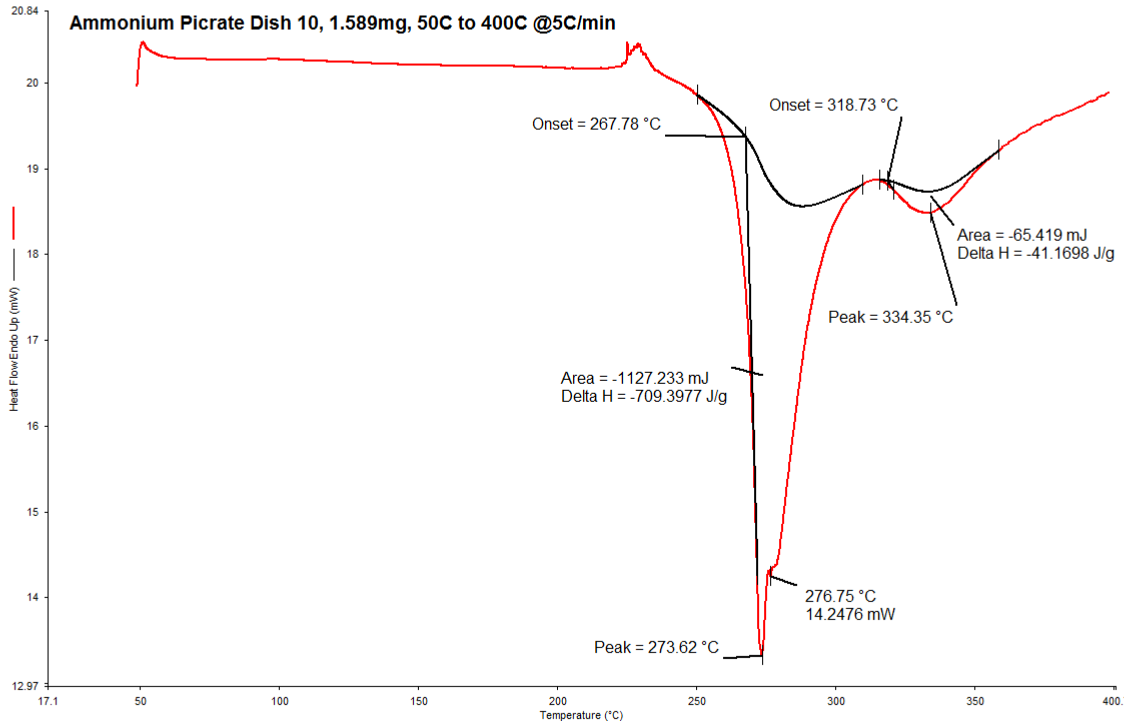
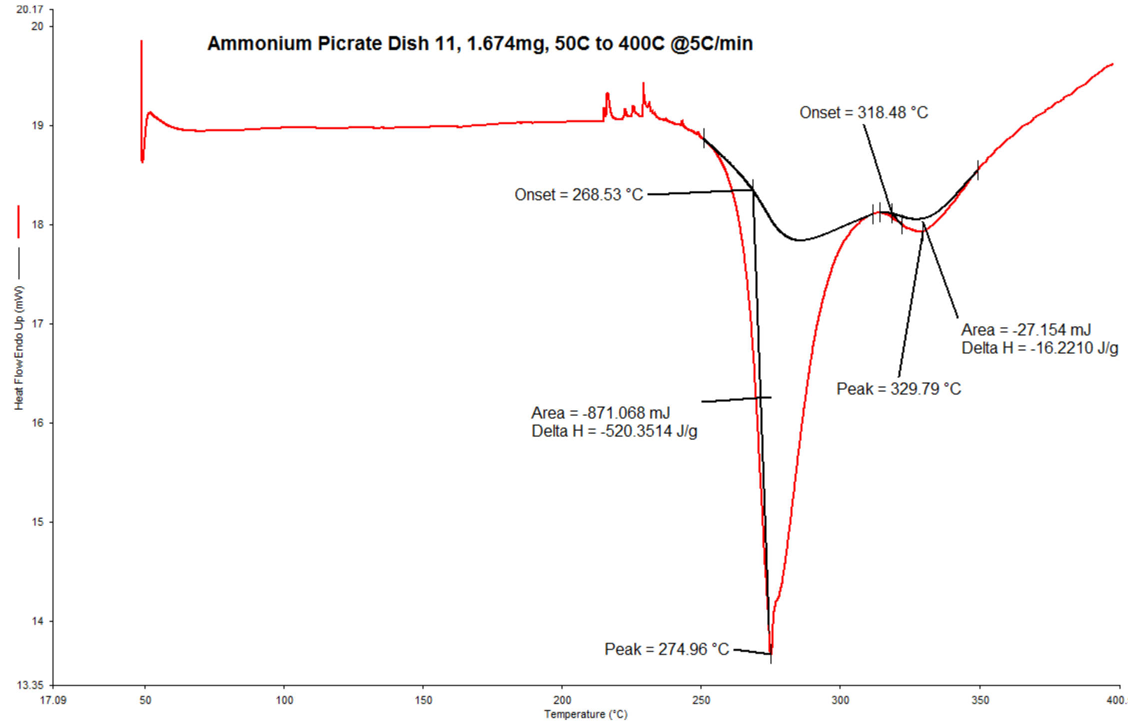
Delta H = -571.8612 J/g
Peak = 275.03 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 10, 1.589mg, 50C to 400C @5C/min
Onset = 318.73 °C
Onset = 267.78 °C
Area = -65.419 mJ
Delta H = -41.1698 J/g
Peak = 334.35 °C
Area = -1127.233 mJ
Delta H = -709.3977 J/g
276.75 °C
14.2476 mW
Peak = 273.62 °C
Heat Flow Endo Up (mW)
Temperature (°C)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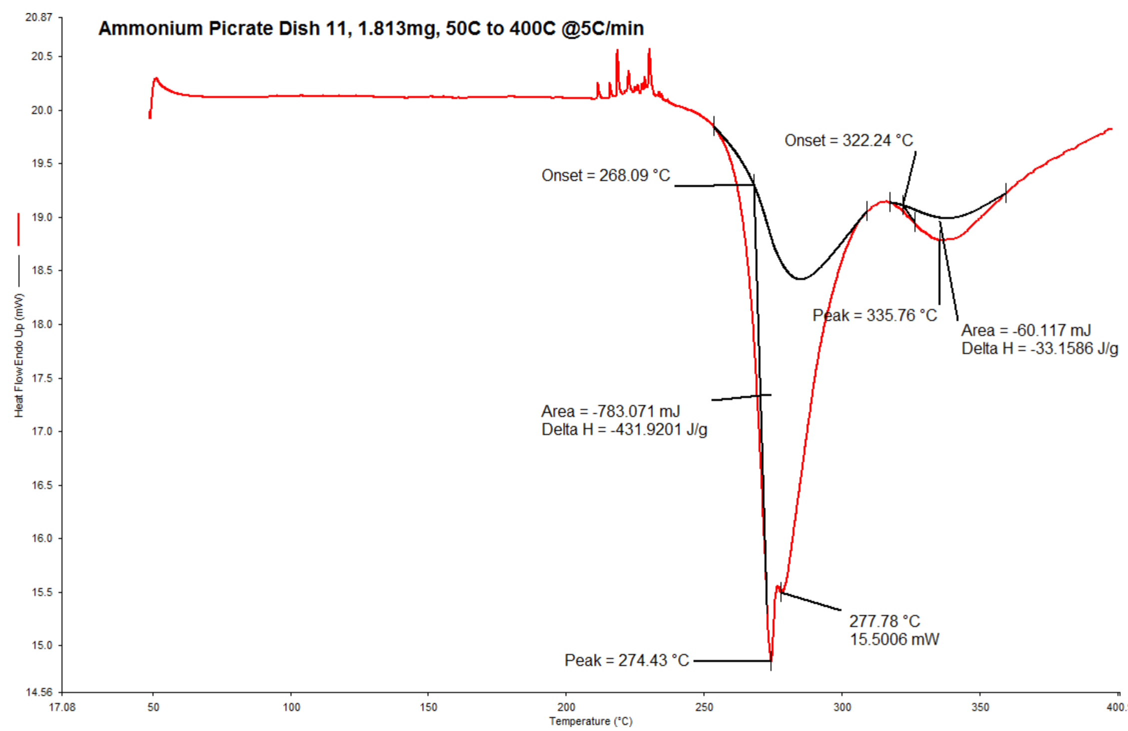
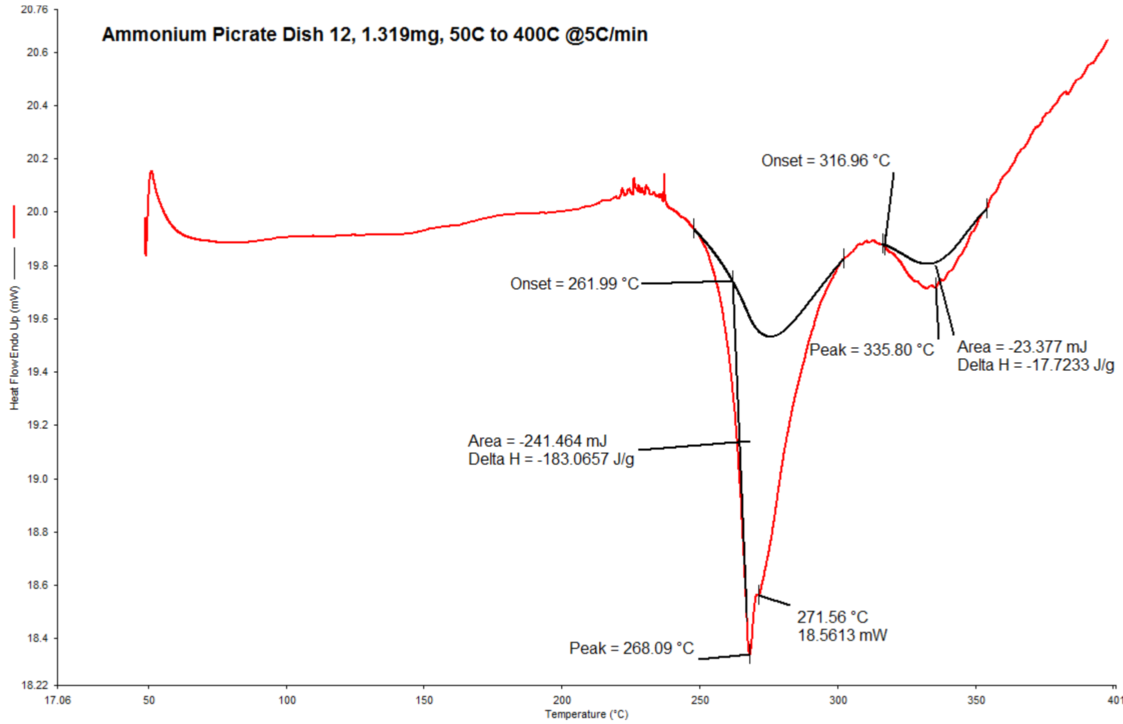
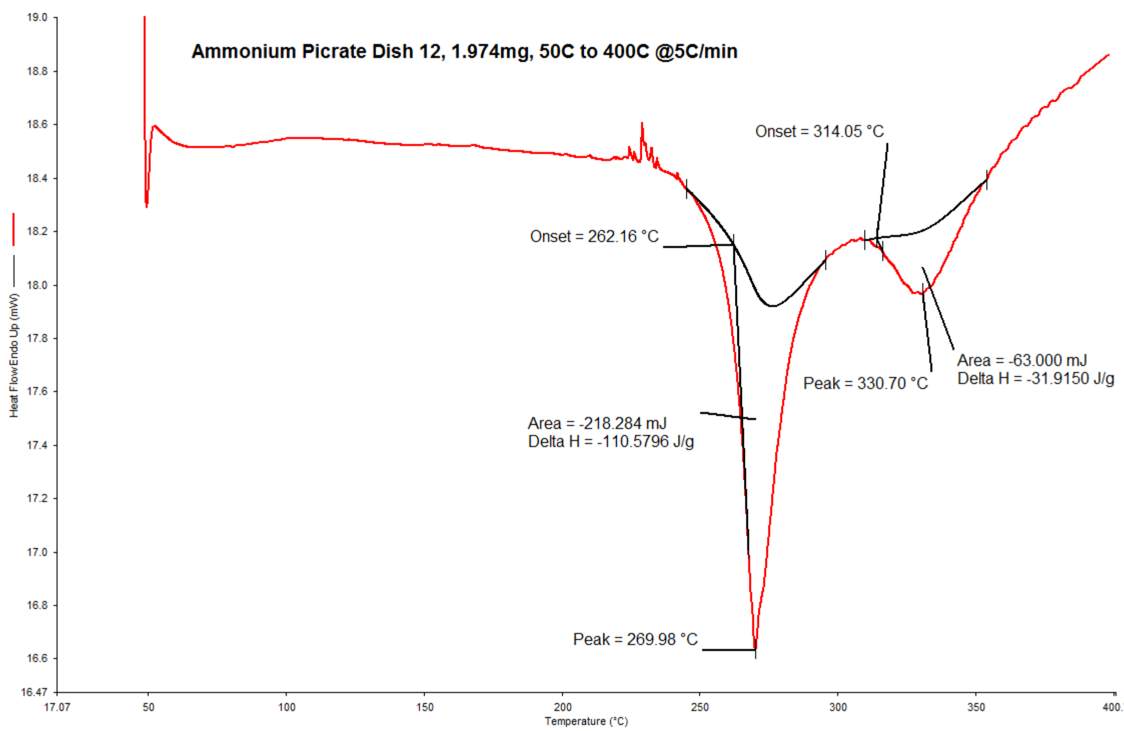
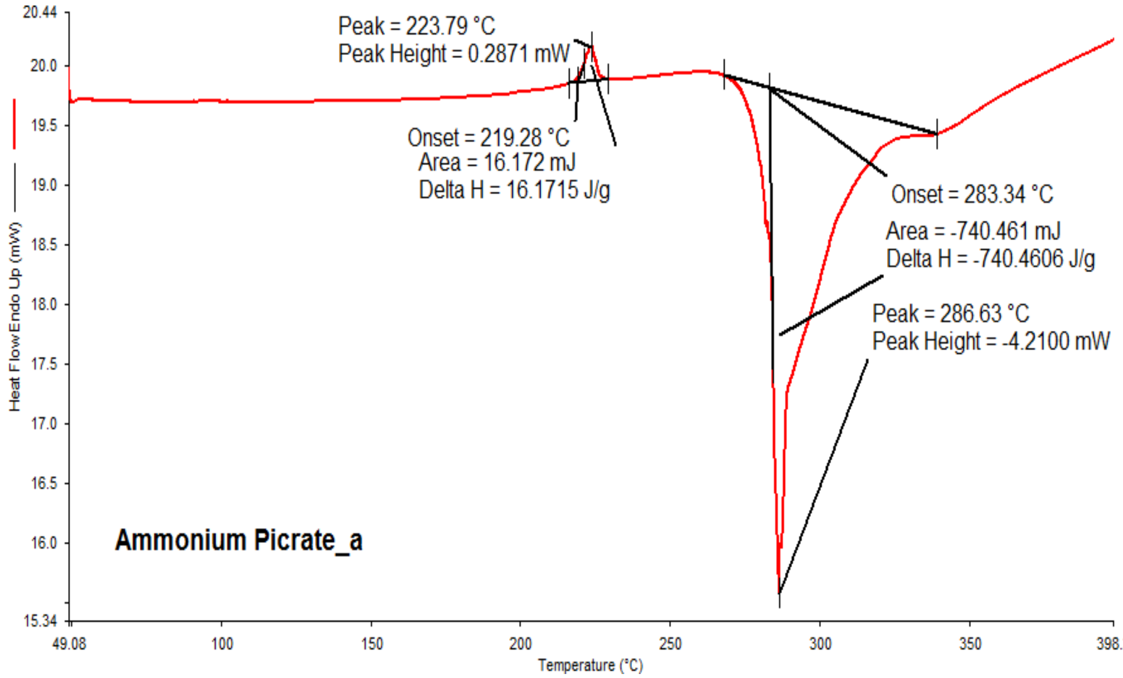
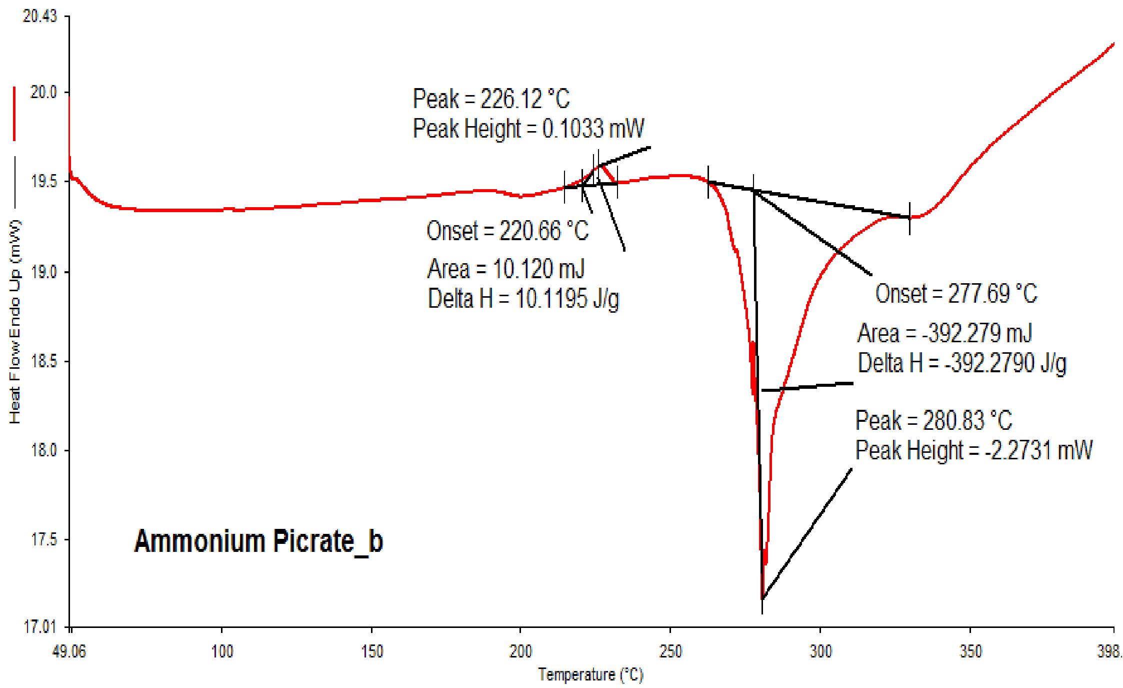
Onset = 318.48 °C
Onset = 268.53 °C
Area = -27.154 mJ
Delta H = -16.2210 J/g
Peak = 329.79 °C
Area = -871.068 mJ
Delta H = -520.3514 J/g
Peak = 274.96 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 11, 1.813mg, 50C to 400C @5C/min
Onset = 322.24 °C
Onset = 268.09 °C
Peak = 335.76 °C
Area = -60.117 mJ
Delta H = -33.1586 J/g
Area = -783.071 mJ
Delta H = -431.9201 J/g
277.78 °C
15.5006 mW
Peak = 274.43 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 12, 1.319mg, 50C to 400C @5C/min
Onset = 316.96 °C
Onset = 261.99 °C
Peak = 335.80 °C
Area = -23.377 mJ
Delta H = -17.7233 J/g
Area = -241.464 mJ
Delta H = -183.0657 J/g
271.56 °C
18.5613 mW
Peak = 268.09 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Ammonium Picrate Dish 12, 1.974mg, 50C to 400C @5C/min
Onset = 314.05 °C
Onset = 262.16 °C
Area = -63.000 mJ
Delta H = -31.9150 J/g
Peak = 330.70 °C
Area = -218.284 mJ
Delta H = -110.5796 J/g
Peak = 269.98 °C
Heat Flow Endo Up (mW)
Temperature (°C)


Peak = 223.79 °C
Peak Height = 0.2871 mW
Onset = 219.28 °C
Area = 16.172 mJ
Delta H = 16.1715 J/g
Onset = 283.34 °C
Area = -740.461 mJ
Delta H = -740.4606 J/g
Peak = 286.63 °C
Peak Height = -4.2100 mW
Ammonium Picrate_a
Heat Flow Endo Up (mW)
Temperature (°C)
20.44
20.0
19.5
19.0
18.5
18.0
17.5
17.0
16.5
16.0
15.34
49.08
100
150
200
250
300
350


Peak = 226.12 °C
Peak Height = 0.1033 mW
Onset = 220.66 °C
Area = 10.120 mJ
Delta H = 10.1195 J/g
Onset = 277.69 °C
Area = -392.279 mJ
Delta H = -392.2790 J/g
Peak = 280.83 °C
Peak Height = -2.2731 mW
Ammonium Picrate_b
Heat Flow Endo Up (mW)
Temperature (°C)
20.43
20.0
19.5
19.0
18.5
18.0
17.5
17.01
49.06
100
150
200
250
300
350

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| Title | Project |
| Brian E. Fuchs | |
| Author/Project Engineer | Report number/Date received (to be completed by LCSD) |
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