20mm LIFE CYCLE TESTS

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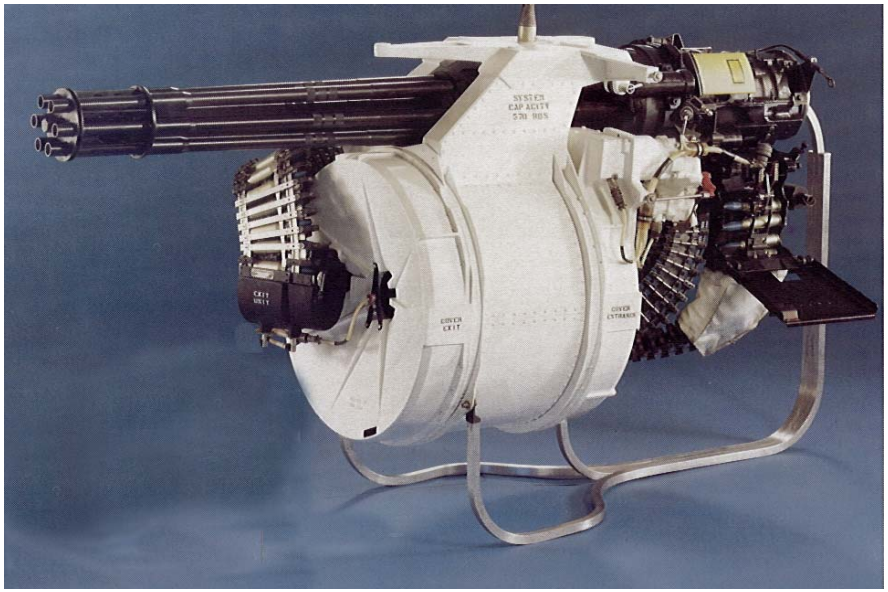


PURPOSE

- **Tests were undertaken to simulate the environment seen by ammunition during normal operations in the field**
  - **Routine ammunition cycling through the LALS-II and M61A2 including upload/download and firing operations**
  - **Simulate mission sorties to 30,000 feet altitude**
  - **Ammunition aging**
- **Observe handling conditions that could potentially result in damaged ammunition and/or compromised seals**

PURPOSE (cont'd)

- **Investigate the impact of compromised seals on 20mm ammunition performance**
- **Determine if performance impacts could potentially cause gun system mishaps**
- **To establish accept/reject criteria for the use of 20mm ammunition under typical life cycle conditions**

SCOPE

- **External damage described in inspection criteria were addressed with primary interest in:**
  - **Leaking seals between case neck/projectile**
  - **Leaking seals between primer and case**
  - **Scratches and dents to case and/or projectile**
  - **Excessive wear to Lot identification markings**
- **Internal damage/deterioration of energetics were address by:**
  - **Ballistic testing for chamber pressure, action time and velocity**
  - **Chemical analysis of propellant and primer mix**

SCOPE (cont'd)

- **Simulate up to 10 upload/download cycles through the LALS-II loading system**
- **Simulate up to 4 upload/download cycles through the M61A2 gun system**
- **Simulate the firing cycle through the M61A2 gun system**
- **Simulate up to 15 mission sortie flights (Temperature, Humidity, Altitude)**
- **Simulate aging by artificial (accelerated) aging up to 3 months**

TEST CONDUCT

- **PGU-27A/B ammunition was the primary test ammunition, with M55A2 included for comparison/control purposes**
  - **1500 rounds of pristine PGU-27A/B (Condition Code A)**
  - **500 rounds of M55A2 (Condition Code C)**
- **All rounds received were inspected for**
  - **Dirt or corrosion**
  - **AUR lot number**
  - **Gap between nose cap and projectile body**
  - **Severe gouges, scratches, dents in case**
  - **Primer Seating**
  - **Loose projectile or case neck gaps**

TEST CONDUCT (cont'd)
Cycle Test

- **Rounds were divided into test lots (PGU-27A/B/M55 mix) to include**
  - **Control lot (Lot A)**
  - **Temp/Humidity/cycling only (Lot B)**
  - **LALS-II cycling only (Lot C)**
  - **LALS-II/gun cycling at 400 spm rate (Lots D-H)**
    - **Cycle included loading of the LALS-II using hand crank (up to 4X), upload from the LALS-II to the M61A2 at 400 spm, download from the M61A2 into the LALS-II at 400 spm and unloading the LALS-II using the hand crank.**
  - **LALS-II/gun cycling at 6000 spm rate (Lots I & J)**

PLANNED TEST MATRIX

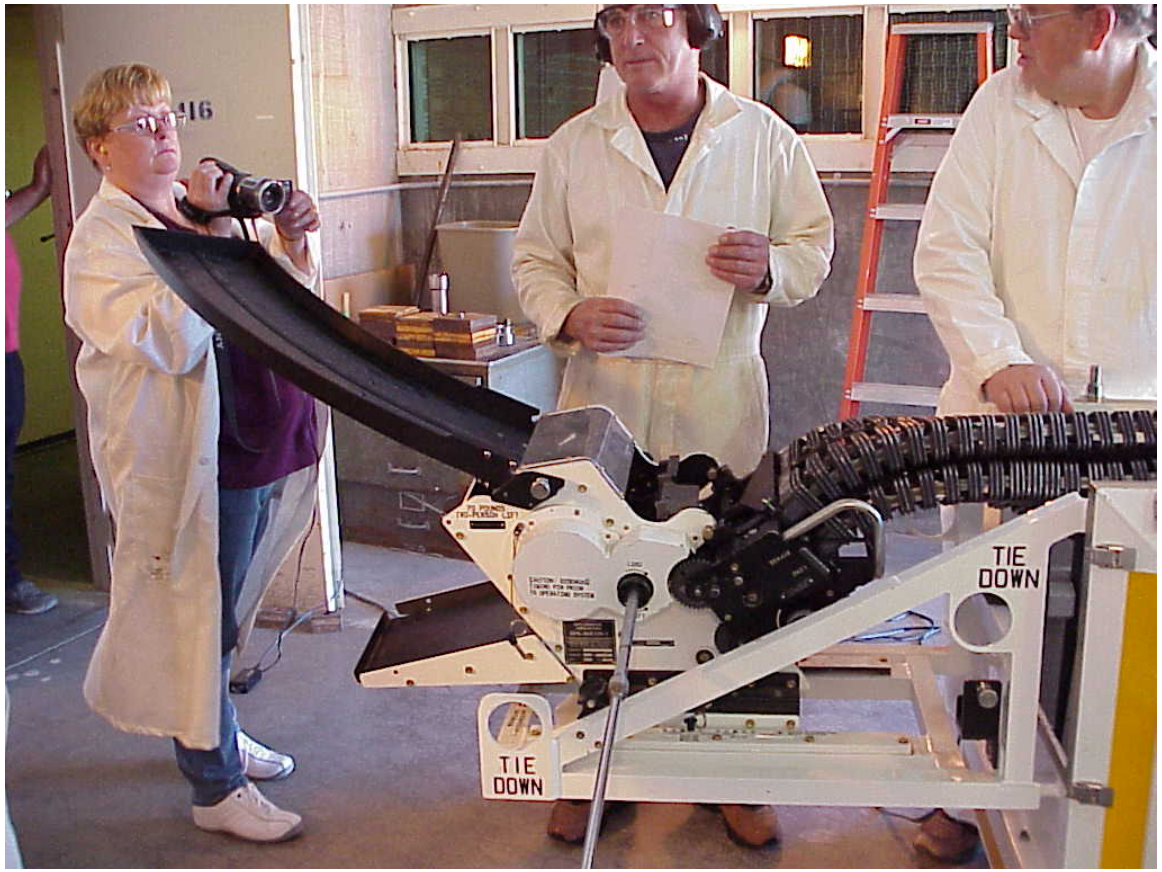
Test Lot	PGU-27A/B	M55A2	Total	Cycled	No. of Cycles	THA Cycled	Label
A	75	25	100	No	0	No	Control
B	75	25	100	No	0	Yes	Control
C	1200	400	1600	Yes	-	Yes	LALS-II only
D	1125	375	1500	Yes	1	Yes	One Cycle
E	900	300	1200	Yes	2	Yes	Two Cycle
F	675	225	900	Yes	3	Yes	Three Cycle
G	450	150	600	Yes	4	Yes	Four Cycles
H	225	75	300	Yes	4	No	Control
I	75	25	100	Yes	1	Yes	6000spm clearing cycle
J	75	25	100	Yes	1	Yes	6000spm drum only

TEST CONDUCT (cont'd)
Cycle Test

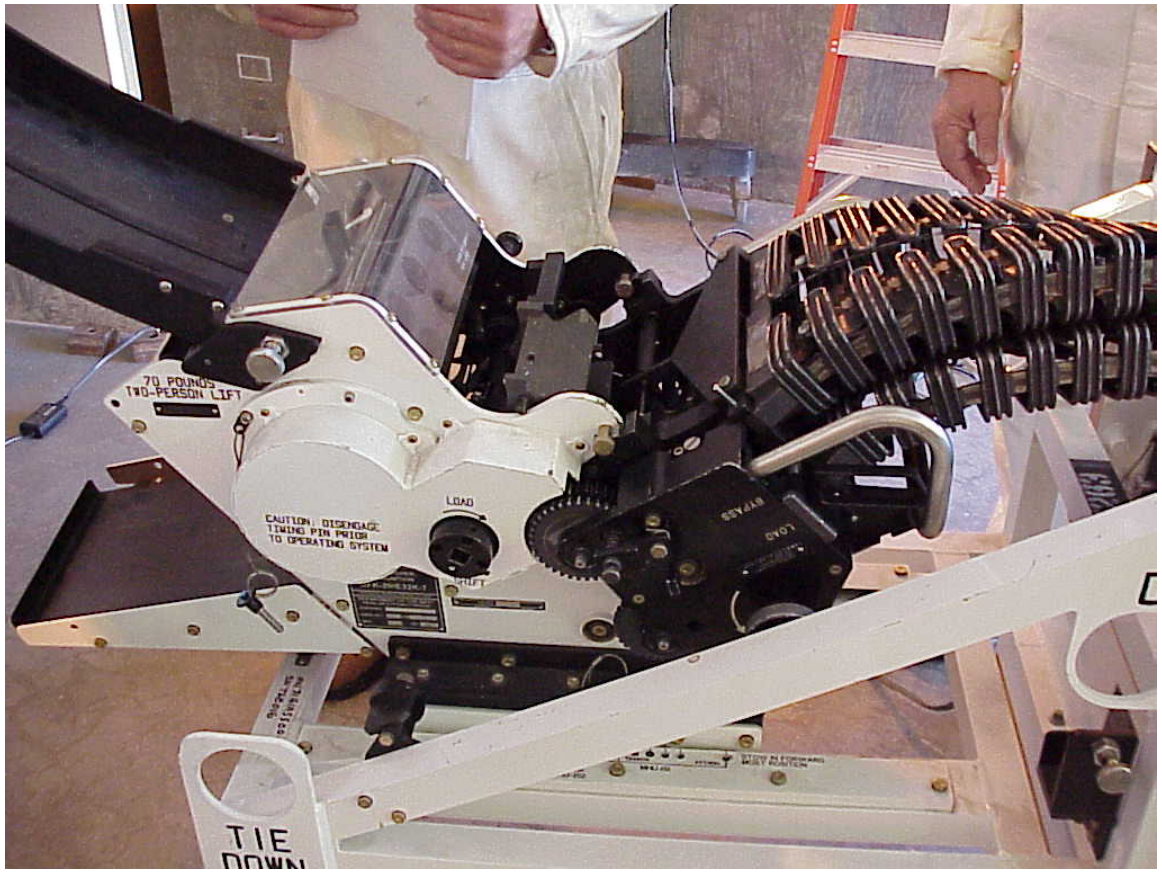
- **Goal was to cycle rounds in various handling scenarios until seals were compromised (75-80%), as determined through vacuum/water leak tests.**
- **Rounds completing each phase of cycling were inspected for physical damage, marked with indelible ink and a random sample of 10 rounds were checked for broken seals using the vacuum/water test chamber.**

VACUUM LEAK TEST CHAMBER

LALS-II LOADING TRANSFER UNIT

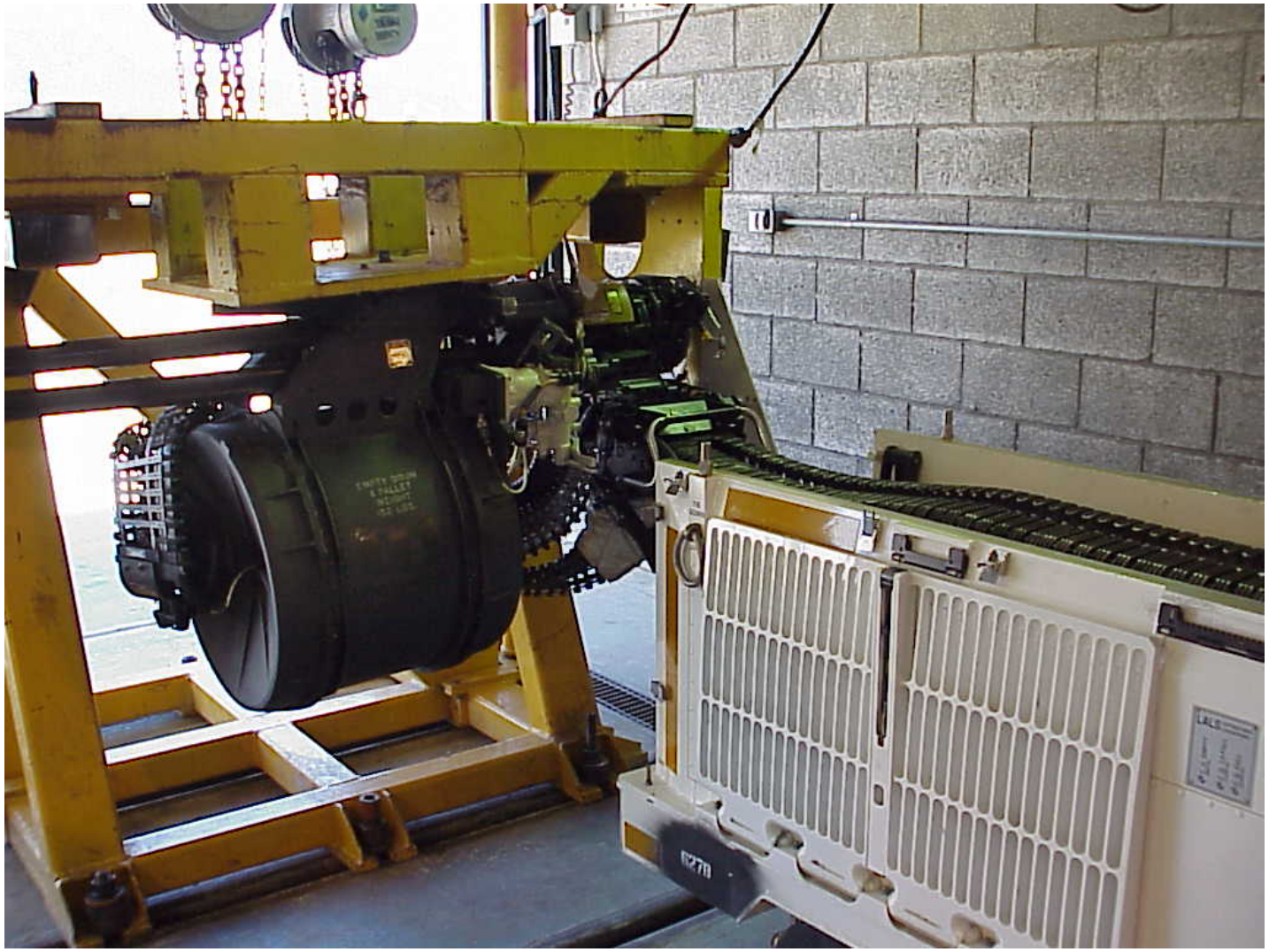


LALS-II LOADING TRAY



LALS-II

M61A2 WITH LALS-II ATTACHED



M61A2/LALS-II CYCLING

RESULTS OF CYCLE TESTS

- **After cycling through the LALS-II and the M61A2 gun at 400 spm rate up to 4 cycles (Lots C-H)**
  - **0 to 20% Leakers only**
  - **No Loose Projectiles were detected by hand twisting**
  - **Minor scratches and dents were present**
  - **Many AUR Lot Numbers were illegible after only 3 cycles**

RESULT OF CYCLE TESTS (cont'd)

- **Test Plan was modified to increase the number of test rounds used for 6000 spm cycle tests. Increased the total rounds for Lots "I" & "J" to 200 PGU-27A/U and 70 M55A2 each.**

  -Lot "I" - added 125 PGU-27A/U from Lots "D" & "E"

  - added 45 M55A2 from Lots "D" & "E"

  -Lot "J" - added 125 PGU-27A/U from Lot "D"

  - added 45 M55A2 from Lot "D"

RESULT OF CYCLE TESTS (cont'd)

- **Lot "I" (cycled through gun clearing cycle) at 6000 spm-**

  - 60% loose projectiles (hand twist) plus scratches and dents

- **Lot "J" (cycled through magazine drum and chuting only) at 6000 spm–**

  - No loose projectiles with minor scratches and dents

HAND TWIST NOT A RELIABLE TEST FOR FINDING LEAKING PROJECTILE SEAL

- **Lot "I" – Random sample of 10 PGU-27A/B = 100% leakers by vacuum/water test method also indicated 100% loose projectiles by hand twist method.**
- **Lot "J" – Random sample of 10 PGU27A/B = 20-50% leakers by vacuum/water test method but checked O.K. by hand twist method.**

RESULT OF CYCLE TESTS (cont'd)

- **Very few leakers (<20%) observed (at 400 SPM rate) after:**

  -11+ cycles through LALS-II

  -4 cycles through M61A2 gun

- **540 rounds cycled through gun and/or drum at 6100 SPM rate**

  -<u>All</u> rounds that went through the gun had broken seals

  -Some (20 to 50%) that went through the drum only, had broken seals.

1.5 METER DROP TEST (PGU-27A/B)

- **Dropped nose down**
  - **7 out of 10 had projectile/case neck leaks as indicated by vacuum/water test method.**
- **Dropped 45° nose down**
  - **10 out of 10 had projectile/case neck leaks as indicated by vacuum/water test method.**

AGGRESSIVE LALS-II DOWNLOADING

- 100 rounds of PGU-27A/B with intact projectile seals (vacuum/water leak checked) were subjected to aggressive downloading by rapid hand cranking of the LALS-II and letting the ammunition fall into ammunition cans on the floor.
- After one cycle – 7% were leakers by vacuum/water test
- After two cycles – 25% were leakers by vacuum/water test

AGGRESSIVE LALS-II DOWNLOADING

CONCLUSIONS (Cycling Tests)

- **Loading and downloading using a properly functioning LALS-II does not break case neck seals**
- **Cycling through the drum magazine at rate <u>may</u> break seals**
- **Cycling through the gun at rate <u>does</u> break seals**
- **Dropping ammunition <u>does</u> breaks seals**
- **Aggressive downloading can break seals**

TEST CONDUCT (cont'd)
THA Testing

- **After all cycling through the LALS-II/M61A2 gun were complete, the test ammunition was shipped to the test contractor for temperature, humidity, altitude cycling.**
- **THA cycling was conducted at National Technical Systems, Camden, Arkansas**

AMMUNITION IN ALTITUDE CHAMBER

TEST CONDUCT (cont'd)
THA Testing

- **THA conditioning of three test groups**
  - **Test Group #1 – 5 altitude cycles**
  - **Test Group #2 – 10 altitude cycles**
  - **Test Group #3 – 15 altitude cycles**
- **Temperature cycled from 90º F and 85% Humidity at ambient pressure to-**
- **-37º F at simulated 30,000 feet altitude**
- **Two hour ramp up time**
- **Two hour dwell at set conditions**

NAVAIR

NAWC
TEMPERATURE HUMIDITY ALTITUDE

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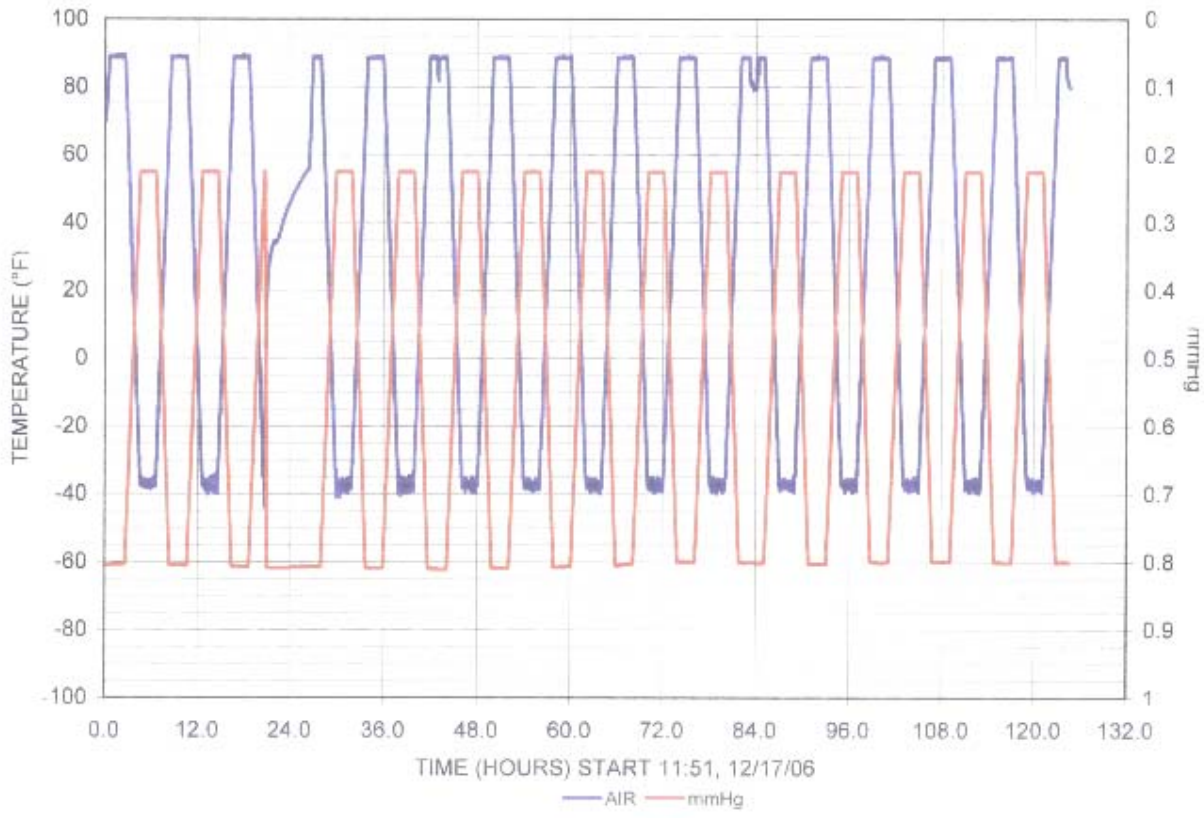

NAVAIR

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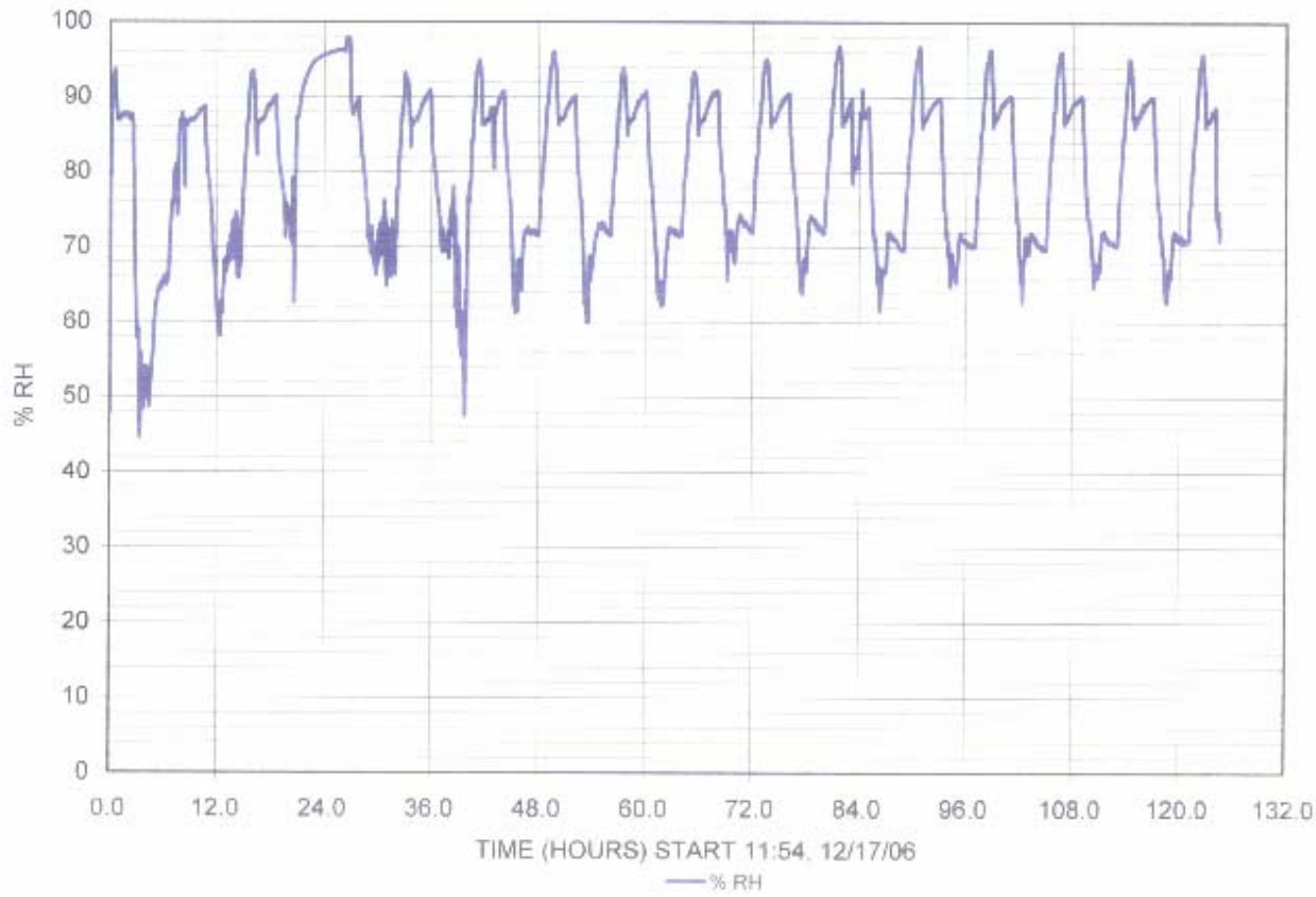


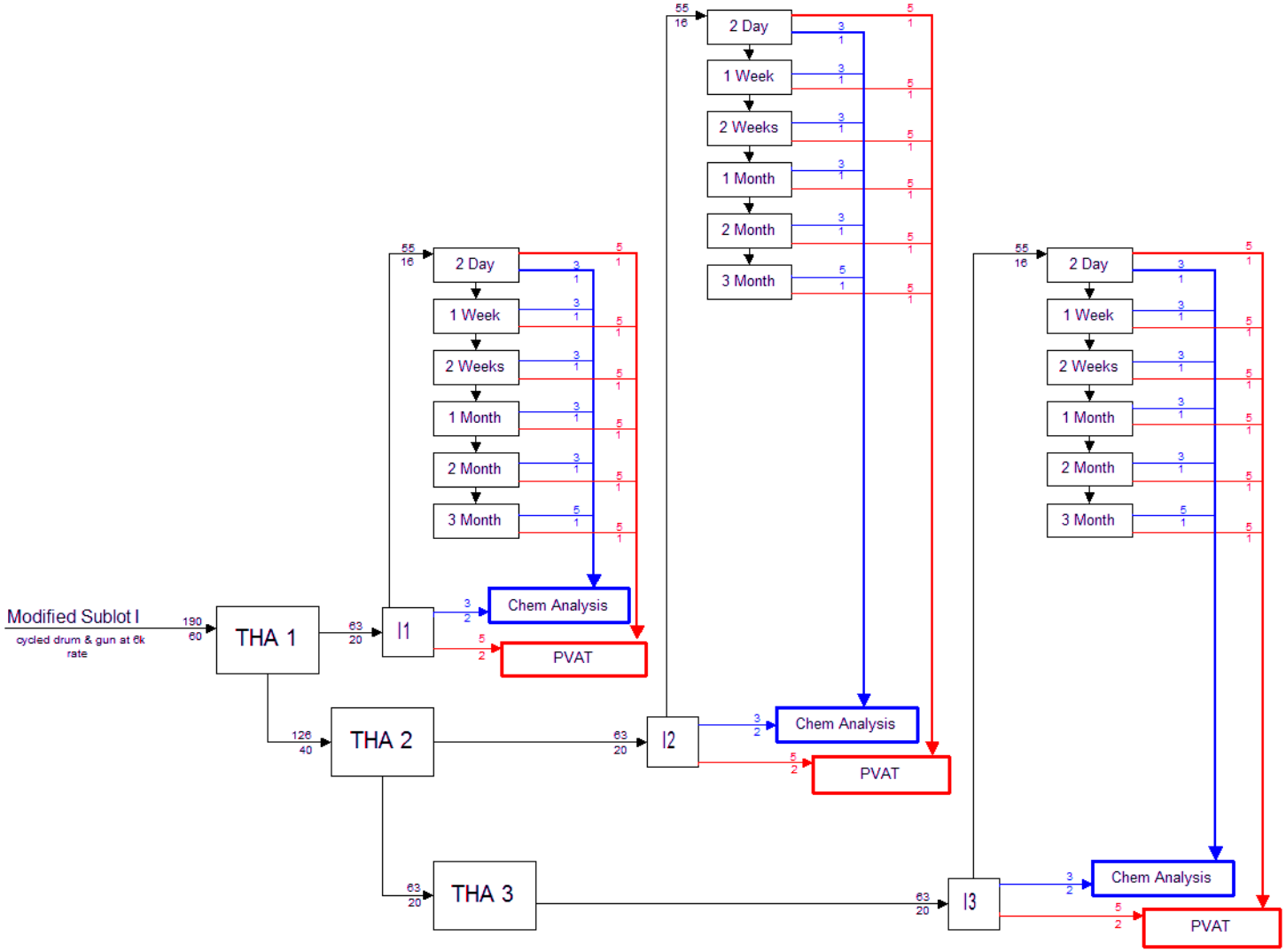
TEST CONDUCT (cont'd)
Artificial Aging

- **After completion of THA cycling, the test ammunition was shipped to NSWC, Crane, for artificial aging, chemical analysis and ballistic testing.**
- **The purpose was to investigate the impact of THA cycling combined with Artificial Aging on rounds with compromised seals for ammunition performance degradation**

ACCELERATED AGING

- **160º F Storage for the following periods:**
  -2 days, 1 week, 2 weeks, 1 month,
  2 months, 3 months
- **Sample rounds were inserted into aging chamber at appropriate staggered intervals in order to remove all rounds at once for chemical analysis and ballistic testing.**

TEST FLOW FOR ROUNDS WITH BROKEN SEALS



CHEMICAL ANALYSIS

- **Heat Flow Micro-Calorimetry**
  - Shelf life comparison between control lot and broken seal lot
- **High Performance Liquid Chromatography/Gel Permeation Chromatography**
  - Propellant condition/degradation
- **Karl Fischer**
  - Moisture content of propellant and primer mix
- **Differential Scanning Microscopy**
  - Degradation in primer output

BALLISTIC TESTING

- **Single shot Mann Barrel testing for:**

  -Peak case mouth pressure

  -Velocity

  -Action time