FINAL REPORT

of the

ARMY SCIENCE BOARD ISSUE GROUP STUDY

on the

LIQUID PROPELLANT ADVANCED FIELD ARTILLERY SYSTEM

13 September 1991

This is the final report of the Army Science Board Issue Group Study on Liquid Propellant Advanced Field Artillery Systems. It was presented to Major General Richard D. Beltson, Deputy for Systems Management, on 10 July 1991.

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The purpose of the study was to evaluate the anticipated technical maturity of the Army's liquid propellant Advanced Field Artillery System (AFAS) as of September 1991, at which time the Army must make a decision between liquid propellant and unicharge for AFAS.

PURPOSE OF THE STUDY

- Evaluate the Anticipated Technical Maturity,
  as of September 1991,
  of the Army's Liquid Propellant
  Advanced Field Artillery System

The Army plans to decide between unicharge and liquid propellant for AFAS by September 1991. The decision will be based on analyses and data both currently extant and obtainable over the next two months. While the Army has very long and broad experience with unicharge-like (solid propellant) systems, it has only short and narrow experience with liquid propellant systems. While many of the features of the liquid propellant system look attractive, the Army feared its maturity would be difficult to evaluate. The Army was also concerned that the consequences of choosing an immature liquid propellant system would be severe. Therefore, the Army Science Board was tasked to provide an objective, independent, broad-based evaluation of the liquid propellant AFAS.

BACKGROUND

- Army Plans to Decide Between the Unicharge and the Liquid Propellant Advanced Field Artillery System in September 1991
- Decision Will be Based Upon Analyses and Data Both Currently Extant and Obtainable Over the Next Seven Months
- Army has Long and Broad Experience with Unicharge-like Systems
- While Many Features of the Liquid Propellant System Appear Attractive, Its Maturity will be Difficult to Evaluate
- Consequences of Choosing an Immature Liquid Propellant System Would be Severe
- Army Would Like the Army Science Board to Provide an Objective, Independent, Broad-based Evaluation of the Liquid Propellant Advanced Field Artillery System

The primary focus of the study was to review and assess the maturity and technological risk associated with liquid propellant for selection for the Army's next generation field artillery system. Is it ready for adoption as the next generation propulsion system?

The Issue Group was also to determine what critical issues must be resolved and the analyses and data required to resolve those critical issues. The group was to review the Army's propulsion evaluation plan to determine if it addressed the critical issues inherent with selection of such a revolutionary propulsion system.

The secondary focus was to determine the critical logistical and operational issues inherent with selecting liquid propellant.

Finally, the group was to recommend changes, if required, in the scope and timing of the Army's downselect plan.

TERMS OF REFERENCE

A. Primary focus will be to review and assess the maturity and technological risk associated with liquid propellant for selection as the Army's next generation field artillery system. Is liquid propellant ready for adoption as the next generation propulsion system?

B. Determine what critical issues must be resolved and the analyses and data required to resolve those critical issues. Review the Army's propulsion evaluation plan to determine if it addresses the critical issues inherent with selection of a revolutionary propulsion system.

C. Secondary focus will be to determine the critical logistical operational issues inherent with selecting liquid propellant.

D. Recommend changes, if required, in the scope and timing of the Army's current downselect plan.

Major General Richard D. Beltson, Deputy for Systems Management (SARD-ZS) sponsored the study. The Staff Assistant was LTC Lloyd S. Takeshita, Close Combat Division (SARD-SC). This Army Science Board Issue Group originally consisted of the following four Army Science Board technology systems experts: Dr. William H. Evers, Jr. (Chair), Dr. Meredith C. Gourdine, Mr. Frederick E. Hartman, and Dr. Tito T. Serafini. When Dr. Serafini had to withdraw from the from the Issue Group, Dr. William S. Watt was brought on in an advisory capacity.

ORGANIZATION

- o Sponsor - Major General Richard D. Beltson
  Deputy for Systems Management (SARD-ZS)

- o Staff Assistant - LTC Lloyd S. Takeshita
  Close Combat Division (SARD-SC)

- o Army Science Board Issue Group Study Staff
  (Systems Technology Experts)

  - Dr. William H. Evers, Jr., Chair
  - Dr. Meredith C. Gourdine
  - Mr. Frederick E. Hartman
  - ~~Dr. Tito T. Serafini~~ Dr. William S. Watt (Advisor)

The Issue Group Chairman initially met with Major General Beltson in January 1991 to refine the study plan.

The first full meeting of the group was held at Picatinny Arsenal, New Jersey, at which ARDEC, BRL, and GE personnel all presented information on the liquid propellant AFAS. This was followed by meetings in June at the Pentagon where BRL, Thiokol, and Olin presented information on both the gun and the liquid propellant itself. All participants were extremely well prepared knowledgeable, and forthcoming.

SCHEDULE

Date	Topic	Location
30 January	MGen Richard D. Beltson, Deputy for Systems Management Charge to Subpanel	Pentagon
5-6 June	Project Manager, Advanced Field Artillery System Program Overview Unicharge Status Liquid Propellant Status	Picatinny
5-6 June	Propulsion Evaluation Board Chairman and Subpanel Chairmen CAPEP Review	Picatinny
5-6 June	BRL Detailed Liquid Propellant Status Liquid Propellant Logistics Liquid Propellant Gun Modelling	Picatinny
	GE Defense Systems Liquid Propellant Gun Status	Picatinny
17 June	BRL Gun Modelling Results GE Gun Incident Liquid Propellant Production Thiokol Liquid Propellant Production Olin Liquid Propellant Production	Pentagon
18 June	Briefing Preparation	Pentagon
9 July	Briefing Preparation	Pentagon
10 July	Briefing Presentation to MGen Beltson	Pentagon
13 September	Final Report	

The emphasis of the study was to focus on the technical (as opposed to political, logistical, or historical) discriminators between the liquid propellant and the conventional solid propellant/ unicharge-based AFAS. These discriminators were to be evaluated using full-scale data, sub-scale data, analyses, and plausibility arguments. Many of the conclusions and observations were based on data while some were based only on plausibility arguments. Each are noted in this report.

EMPHASIS

- o Focus on Technical Discriminators
  - Full-Scale Data
  - Sub-Scale Data
  - Analyses
  - Plausibility Arguments

The Issue Group concluded that regenerative liquid propellant guns have MAJOR, INTRINSIC advantages over solid propellant guns. Those advantages are; greater range with lower projectile and gun stress, and the ability to put more rounds on target simultaneously.

The second major conclusion was that the concepts and technology appeared to be mature enough to enter into an Advanced Technology Transfer Demonstration (ATTD) program.

REGENERATIVE LIQUID PROPELLANT GUN CONCLUSIONS

- Regenerative Liquid Propellant Guns Have MAJOR INTRINSIC Advantages Over Solid Propellant Guns
  - Greater Range with Lower Projectile and Gun Stress
  - More Rounds on Target Simultaneously
- Concepts and Technology are Mature Enough to Enter ATTD

In looking at the regenerative liquid gun itself, several advantageous features are apparent. First, the regenerative liquid propellant gun has programmable, controlled propellant injection that is fundamentally different from the solid propellant gun. In the solid propellant gun the gas generation rate is determined by the burning rate of the solid propellant. In the regenerative liquid propellant gun, the gas generation rate is controlled primarily by the injection rate of the propellant.

The second substantial feature is that there is a continuously variable propellant volume control. It is not constrained to a number of discrete increments as it is in either a unicharge gun or conventional solid propellant gun. Therefore, there is a continuously variable control on the amount of propellant volume, and, therefore, on the muzzle velocity of the projectile.

The third major feature is that the propellant itself is pumpable. It does not have to be handled mechanically when it gets to the gun and this leads to several advantageous features when it comes to firing rate.

The fourth substantial feature is that the combustion products are non-reactive. They are water, nitrogen, and carbon dioxide.

The fifth major feature is a cooler combustion temperature than seen in solid propellant guns, about 2450K as opposed to 2700-2800K.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- o Programmable Controlled Propellant Injection
- o Continuously Variable Propellant Volume Control
- o Pumpable Propellant
- o Non-Reactive Combustion Products (H_2O, N_2, CO_2)
- o Cooler Combustion Temperature (2450K)

Programmable Controlled Propellant Injection - The regenerative liquid propellant gun allows decoupling of the gas generation rate from the propellant burn rate. The gas generation rate is controlled by the propellant injection rate which in turn is controlled by the gun mechanical characteristics. Thus the pressure profile can be programmed thereby controlling the impulse on and acceleration of the projectile. A higher muzzle velocity can be generated with lower projectile and gun stress.

When the group first started considering the overall comparison between liquid propellant, solid propellant, and unicharge we found that the ROC for the AFAS required a 40 km range (assisted). While the liquid propellant design was projecting a range of 40 km, the unicharge gun could only achieve 37.5 km.

Our first question was: Is the requirement really so stringent that the 2.5 km difference matters? Then we discovered that was not the right question since it was not a fair comparison. The liquid propellant gun was designed with a new breach that could be any size, whereas the unicharge gun was restricted to a 1400 cc breach dictated by MOU. Thus, the number of increments of unicharge propellant that could be put into the gun was limited.

Our next question was: Why are we comparing a liquid propellant gun with no constraints to a unicharge gun constrained to a 1400 cc breach? Why don't we allow the unicharge gun a larger breach, use more increments, and achieve more range capability? That, too, was the wrong question since there were other limitations on the number of unicharge increments that could be used.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- o Programmable Controlled Propellant Injection
  - \- Programmable Pressure (Impulse and Acceleration) Profile
    - -- Higher Muzzle Velocity with Lower Projectile and Gun Stress

      Longer Range
      and/or
      More Sensitive Projectiles
      and/or
      Lighter/Smaller System

    - -- Better Precision
    - -- Temperature Independent Performance (to -45°C)
    - -- Less Acceleration-Driven Tube Degradation (Coppering)
    - -- No Greater Velocity-Driven Tube Degradation (End Runout)
    - -- Lower Blast Overpressure

Looking into it further, we found the right question was: What stress can existing projectiles (i.e., those that are in the inventory) withstand? For a solid propellant gun, the gun and projectile must be designed to withstand the maximum pressure loading (i.e., maximum number of increments fired at the maximum temperature). That situation creates the largest stress on both the projectile and the gun, and therefore, limits the number of unicharge increments that can be used. In fact, with the five increment unicharge baseline, not all of the existing projectiles can be fired due to base pressure limitations.

An even better question becomes: How much flexibility exists for liquid propellant versus solid propellant or unicharge? It is the programmable pressure profile that allows limitation of the maximum pressure. This allows the firing of existing projectiles using existing gun tubes. It also reduces design constraints on new projectiles and new gun tubes.

The Army can take advantage of this liquid propellant unique feature to obtain longer range and/or to use more sensitive projectiles (with more sensitive fuses or more sensitive cargos) and/or to achieve the same muzzle velocity in a lighter and smaller system. The fundamental point is that the programmable pressure profile allows much more design flexibility.

The second benefit of decoupling gas generation rate from propellant burn rate is better precision. Mechanical injection results in much tighter control of gas generation. The gas generation rate in a solid propellant gun is dependent upon temperature, ignition characteristics, and configuration, and as a result, there is much more variability in muzzle velocity than in a liquid propellant gun with its controlled gas generation rate.

The performance of the liquid propellant gun is temperature independent. Thus the firing tables are simplified and there is design and software flexibility in computing firing solutions.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- o Programmable Controlled Propellant Injection
  - Programmable Pressure (Impulse and Acceleration) Profile
    - -- Higher Muzzle Velocity with Lower Projectile and Gun Stress

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We also believe it is reasonable to expect less acceleration-driven tube degradation. Experience with existing guns indicates that coppering occurs at the point of peak acceleration. Since the peak acceleration in the liquid propellant gun is lower than in the equivalent solid propellant gun, it is reasonable to expect that coppering will not be as serious a problem.

We expect no greater velocity-driven degradation for the same muzzle velocity. Existing systems show tube wear at the end of the tube apparently due to projectile wobble upon exit from the tube. Thus, there should be no difference in wear for the same muzzle velocity.

We also expect lower blast overpressure because a lower maximum pressure profile is used to get the same muzzle velocity.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- o Programmable Controlled Propellant Injection
  - Programmable Pressure (Impulse and Acceleration) Profile
    - -- Higher Muzzle Velocity with Lower Projectile and Gun Stress

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      and/or
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    - -- Better Precision
    - -- Temperature Independent Performance (to -45°C)
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Continuously Variable Propellant Volume Control - This feature allows continuously variable trajectories which in turn gives the capability to put more rounds on target simultaneously. Such capability is limited only by the maximum differential time of flight between the longest and shortest flyout times and the rate of fire of the gun. Solid propellant guns allow only two firing solutions (for maximum zone) for putting a round on target: the high (long) firing solution and the low (short) firing solution. Liquid propellant guns allow a large number of firing solutions; giving the capability to fire rounds at the rate of fire limit with all landing simultaneously (by proper adjustment of the propellant volume and the tube elevation). The continuously variable trajectories also allow better range coverage from the shortest to the longest ranges.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- o Continuously Variable Propellant Volume Control
    - Continuously Variable Trajectories
        - -- More Rounds on Target Simultaneously

          Limited Only by:

            Maximum Differential Time of Flight
            Rate of Fire
        - -- Better Range Coverage

Pumpable Propellant - This feature allows more rapid and less complex propellant loading into the gun. Thus there is the potential for a higher rate of fire and better reliability than might be achieved with a mechanical autoloader. With a unicharge system, any damage to the mechanical autoloader would put the system out of operation. With the liquid propellant system, redundant hoses and systems with smaller cross-sections for damage could lead to a much more reliable loading system.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- Pumpable Propellant
  - More Rapid, Less Complex Propellant Loading
    - Higher Rate of Fire
    - Better Reliability than Mechanical Autoloader

Non-Reactive Combustion Products (H_2O, N_2, CO_2) - Another area of gun wear is at the entrance to the tube (apparently caused by hot gas erosion). Non-reactive combustion products should result in less hot-gas driven tube degradation. The lower reactivity of the combustion products may also result in less natural decoppering. Existing data are insufficient to come to any conclusion in this regard. This needs to be addressed in the ATTD program.

The non-reactive combustion products produce no secondary flash. Thus there is a substantially reduced visible signature and a much reduced blast overpressure. Only a steam puff is visible.

Finally, the exhaust is non-toxic.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- o Non-Reactive Combustion Products (H_2O, N_2, CO_2)
  - Less Hot-Gas-Driven Tube Degradation (Entrance Erosion)
  - Different Decoppering Characteristics
  - No Secondary Flash
    - -- Reduced Visible Signature
    - -- Lower Blast Overpressure
  - Non-Toxic Exhaust

Cooler Combustion Temperature (2450K) - This cooler combustion temperature should result in less hot-gas driven tube degradation, different decoppering characteristics, and a lower thermal loading and a potentially higher rate of fire than the solid propellant gun.

REGENERATIVE LIQUID PROPELLANT GUN FEATURES

- Cooler Combustion Temperature (2450K)
  - Less Hot-Gas-Driven Tube Degradation (Entrance Erosion)
  - Different Decoppering Characteristics
  - Lower Thermal Loading
    - Higher Rate of Fire

One of the issues for liquid propellant gun systems has been combustion pressure oscillations. All of the recent regenerative liquid propellant gun firings have shown the energy in the combustion pressure oscillations to be extremely low and the frequency to be very broadband. Less than a quarter of one percent of the total energy of combustion appears in the oscillations, and less than ten percent of that occurs in chamber acoustic modes. Thus our expectation is that the impact of the oscillations on the gun and projectile will be small. However, the impact of the oscillations on the projectile is unknown and this issue needs to be addressed in the ATTD program.

The ATTD program should continue to address these issues by: 1) determination of the mechanism for the combustion pressure oscillations and development of solutions thereto; 2) determination of the transmission of those oscillations from the chamber where they have been measured in the past to the base of the projectile (i.e., how much of the oscillations actually get to the projectile); and 3) determination of the gun and projectile response to the oscillations both from a thermal and stress standpoint. Do the oscillations enhance the thermal load in the gun and on the projectile? Do they enhance the stress load? We expect these issues to be resolved in a straightforward way during the ATTD program because of the low energy in the oscillations and because of the fact that they are not confined to a particular acoustic mode. Thus the driving energy at any particular frequency (e.g., resonant mode of the projectile) is extremely small.

REGENERATIVE LIQUID PROPELLANT GUN ISSUES

- o Combustion Pressure Oscillations
  - Energy in Oscillations is Low, Frequency is Broadband
    - -- Less than 0.25% of Total Energy in Oscillations
    - -- Less than 10% of Oscillations in Chamber Acoustic Modes
  - Impact of Oscillations on Gun is Small
  - Impact of Oscillations on Projectiles is Unknown
- o ATTD Program Should (and Does) Continue to Address
  - Determination of Mechanism ... Development of Solutions
  - Determination of Transmission to Projectile Base
  - Determination of Gun and Projectile Response
    - -- Thermal and Stress

The second issue for liquid propellant gun systems is that of high pressure and temperature seal reliability. Internal to the gun are high pressure and high temperature sliding seals. The current seal solution seems to be progressing satisfactorily although there have been some difficulties as GE has gone to higher propellant loadings. The seals have to be tuned at these loadings. While we feel that this solution can be engineered, there is concern because it does have the potential for single point failure. The ATTD program needs to address this issue.

The third and final issue is that of thermal control at a high rate of fire. We have not seen a design for a thermal control system for liquid propellant or unicharge. The ATTD program must address this issue.

REGENERATIVE LIQUID PROPELLANT GUN ISSUES

- High Pressure/Temperature Gun Seal Reliability
  - Current Seal Solution Seems Satisfactory
  - Potential for Single Point Failure
  - ATTD Program Should (and Does) Continue to Address
- Thermal Control at High Rate of Fire
  - ATTD Program Should (and Does) Address

We have not seen a credible mechanism postulated for the observed combustion pressure oscillations. We suggest that such a mechanism might be chaotic liquid jet breakup. No oscillations are observed during the initial combustion, when the injection is primarily a fine spray. At later times, when the injection is an annular jet, the oscillations appear.

If the annulus were tailored to provide fine spray injection throughout, the oscillations should be further reduced. If the annular jet were not as subject to breakup the oscillations might disappear. In this latter case, there might be some "travelling charge" benefit in performance, but with a potential price in muzzle velocity variability.

REGENERATIVE LIQUID PROPELLANT GUN OBSERVATIONS

- Combustion Pressure Oscillations
  - Liquid Jet Breakup Could be Mechanism
  - Solution Could Involve Injection Annulus Tailoring
  - Solution Might Result in Greater Jet Penetration
    - "Travelling Charge" Could Result In

      Enhanced Efficiency
      and/or
      Greater Muzzle Velocity Variability

To this point we have addressed the regenerative liquid propellant gun. The liquid propellant itself has two primary operational and technical features of interest. First, the Army has postulated and conducted initial design on what appears to be a very acceptable supply concept. In the course of doing that, all indications are that the insensitive munition criteria will be satisfied.

The second feature is that the liquid propellant appears to be manufacturable in a straightforward manner from inexpensive chemicals. This should lead to low development, facilitization, and production costs.

LIQUID PROPELLANT FEATURES

- o Acceptable Supply Concept Postulated
  - Insensitive Munition Criteria are Satisfiable
- o Straightforward Manufacture from Inexpensive Chemicals
  - Low Development, Facilitization, and Production Costs

Acceptable Supply Concept Postulated - This concept packages the liquid propellant in a sealed container at the factory and then transports it to the ammunition supply point (ASP) on a pallet. This approach eliminates the long term storage contamination issue. BRL has conducted long term storage tests in the appropriate containers and found, without contamination, the long term storage characteristics are very good. Putting the sealed containers together on pallets minimizes the modification of handling equipment and techniques so that a straightforward introduction of liquid propellant into the supply train is achievable. This sealed package design configuration provides design space for hazard control. Pressure venting vessels can be used for deflagration control and using baffles and barriers internal and external to individual containers of liquid propellant can be used for detonation control. There is sufficient design space to end up with a pallet of liquid propellant that has very good survivability characteristics.

The final part of the concept is to pump the liquid propellant from the pallets at the supply point into the FARV-A and then into the AFAS and then to the gun. The result is short term storage in relatively small, conformal tanks within the FARV-A and AFAS. The liquid propellant packages very efficiently allowing weight limited loads of propellant and ammunition. Further, liquid propellant may not need any special protection and may even provide some protection for the internal ammunition storage in both the FARV-A and AFAS.

LIQUID PROPELLANT FEATURES

- o Acceptable Supply Concept Postulated
  - Discrete Sealed Package from Factory to ASP
    - -- Eliminates Contamination Issue for Long Term Storage
    - -- Minimizes Modification of Handling Equipment/Techniques
    - -- Provides Design Space for Hazard Control
      Pressure Venting Vessels for Deflagration Control
      Baffles and Barriers for Detonation Control
  - Pumped to FARV-A and Then to AFAS and Then to Gun
  - Short Term Storage in Small Conformal Tanks on FARV-A and AFAS
    - -- Packages Very Efficiently
    - -- May Not Need Protection (May Even Provide It)

Liquid propellant is straightforwardly manufactured from inexpensive chemicals. The Hydroxyl Ammonium Nitrate (HAN) component is made by electrolysis of nitric acid. The Tri-Ethanol Ammonium Nitrate (TEAN) component is made from weak acid-base neutralization. Liquid propellant is a mixture of HAN, TEAN, and water, produced by a straightforward mixing process.

The current cost for research quantities of liquid propellant is about twice the solid propellant production cost. The projected cost for large quantities of liquid propellant is about one-fifth the solid propellant production cost. The cost advantage appears to be real and could well be significant. Even if the cost estimates for liquid propellant are not precise, liquid propellant should still be less expensive than solid propellants.

LIQUID PROPELLANT FEATURES

- o Straightforward Manufacture from Inexpensive Chemicals
  - Hydroxyl Ammonium Nitrate from Electrolysis of Nitric Acid
  - Tri-Ethanol Ammonium Nitrate from Weak Acid Base Neutralization
  - Liquid Propellant a Mixture of HAN, TEAN, and Water
    - -- Current Cost (for Research Quantities) is Twice the Solid Propellant Production Cost
    - -- Projected Cost (for Large Quantities) is One-Fifth the Solid Propellant Production Cost

Cost Advantage is Real and Could Well Be Significant

The first issue for the liquid propellant itself is that hazard classification is incomplete. At this time only small volumes have been tested. Small volumes lead to high surface to volume ratios that could disguise potential problems. Second, the sympathetic detonation packaging protection has not yet been designed. The ATTD program should address these issues as well as engineer the requisite solutions.

LIQUID PROPELLANT ISSUES

- Hazard Classification Incomplete
  - Only Small Volumes Have Been Tested
    - High Surface to Volume Ratio Could Disguise Problems
  - Sympathetic Detonation Packaging Protection Not Yet Designed
- ATTD Program Should (and Does) Address
  - Larger Volume Testing
  - Sympathetic Detonation Testing
  - Engineering of Requisite Solutions

In addition to the preceding issue, we would like to present the following observations of the liquid propellant gun system.

The HAN and TEAN should both be manufactured and mixed at the same place to form the liquid propellant in order to minimize contamination and transportability concerns.

The toxicity issues appear to be manageable. Color and odor need to be added to discriminate the liquid propellant from water. The system needs to be designed to avoid breathing droplets or mist. The ROC says the crew has to be protected during liquid propellant transfer which would automatically protect them from this. Skin contact appears to be readily treatable. The Health Hazards Analysis must be completed early in the ATTD program.

The environmental hazards appear to be manageable. On the production side are low risk, chemical processes. On the user side, in-the-field spill and waste disposal procedures have been defined and seem to be viable.

REGENERATIVE LIQUID PROPELLANT GUN OBSERVATIONS

- HAN, TEAN Should be Manufactured and Mixed to Form LP at One Location
  - Minimizes Contamination and Transportability Concerns
- Toxicity Issues are Manageable
  - Need to Add Color and Odor to Discriminate from Water
  - System Design to Avoid Breathing Droplets or Mist
  - Skin Contact Readily Treated
- Environmental Hazards are Manageable
  - Production Involves Low-Risk Chemical Processes
  - In-the-Field Spill and Waste Disposal Procedures are Viable

In conclusion, the Issue Group feels that regenerative liquid propellant guns have MAJOR, INTRINSIC advantages over solid propellant guns. Those advantages are greater range with lower projectile and gun stress, and the ability to put more rounds on target simultaneously.

We also feel that the concepts and technology appear to be mature enough to enter into an Advanced Technology Transfer Demonstration (ATTD) program.

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