Non-Lethal Applicants of Slippery Substances

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U.S. Forces are being tasked to conduct peacekeeping operations that may involve potential combatants, riotous crowds, or demonstrators protesting an event or situation. These operations may occur in an urban or rural area, municipality, or a third world country. Regardless of the location, terrain or environment, the soldier must be prepared and equipped to respond as necessary, to the level of intensity. A segment of that operation requires Marine Air-Ground Task Force and subordinate units to conduct various missions in Military Operations Other Than War (MOOTW). The Mission Need Statement (MNS) for an operational capability of U.S. Forces requires the tactical flexibility of employing a non-lethal weapon capability to conduct these operations. Furthermore, the MNS has identified a slippery or anti-traction material as a mobility denial system for personnel, vehicles, or aircraft. The requirements for a mobility denial system relate to all Department of Defense (DOD) components, and may have applicability to other Federal Government and local law enforcement agencies.

Background

The use of very low friction surface coatings has been suggested as useful as a method for disabling vehicles or controlling crowd movement. Despite popular perception, this concept is not new to military operational consideration - a significant history of experimentation dating back to the Korean War has been compiled previously (S. Scott, T. Goolsby, K. Collins and G. Goldsmith. "Dispensed Materials for Non-Lethal Operations". Third NDIA Conference on Non-Lethal Warfare, 1998).

The most recent experience with the military use of this concept began as a U.S. Army effort at Edgewood Chemical Biological Command (ECBC) in 1996. This project intentionally limited material screening to binary, water-activated polymers as low friction coatings. The chemical composition of materials considered at that time was further limited to polyacrylimide and polyacrylic acid-based substances, due to the very low risk of health or environmental hazard. Over two dozen commercially available polymer materials were qualitatively compared during this project, resulting in the selection of water mixtures with either Agefloc WT 603 (CPS Chemical) or various Percol powders (Allied Colliods) for further consideration. Subsequent field demonstrations performed in 1997 with these materials were successful in restricting vehicle and personnel mobility.

Despite the successful demonstration of the technology, problems remained with the logistic implications of the application. By 1998, advice from USMC personnel suggested that material improvements with the required quantities and dissemination methods were necessary.

Furthermore, the binary nature of the proposed coating implied that the water component was to be foraged from indigenous sources - a conditional dependence that may not always be met under all operational scenarios. An expansion of the classes of materials to be considered was therefore necessary, initiating the inclusion of Southwest Research Institute (SwRI) to this project in early 1999. At this point, the USMC MARCORSYSCOM formally adapted the program management of this development effort, acting as the lead agency for the JNLWD.

Currently, SwRI is under contract with the DOD to provide the support services in regards to the technical assessment of the capabilities and technologies currently available for an anti-traction material to meet the military's requirements. The work being performed consists of a sequence of tasks to systematically identify the military's requirements, review past efforts, perform a market survey of candidate materials, and perform a limited laboratory assessment of potential anti-traction materials to assess their operational characteristics. The contents of this presentation will summarize the activities to date and present the proposed approach for assessing candidate anti-traction materials.

Military Applications and Material Requirements

The application requirements define those scenarios of where, when, and how an anti-traction material would be employed. The material requirements represent the military's envisioned physical characteristics, properties, and performance criteria inherent for an anti-traction material. Identifying both the application and material requirements then provides the criterion for assessing candidate anti-traction material. Southwest Research Institute technical personnel met with military and civilian representatives cognizant of DOD's past and current anti-traction material programs and knowledgeable of the objectives when implementing an anti-traction material. The results of the meeting identified those requirements and application scenarios that could be used to select and evaluate candidate anti-traction materials.

To categorize the applicability of candidate materials, a classification criterion of *mandatory*, *preferred*, and *preferred plus* were established and applied to each of the military's requirements. That is, a defined minimum level of acceptability, an expected capability and an idealized performance level for an anti-traction material became necessary to differentiate candidate materials. In most cases, a material will be bound on the low end by the mandatory criteria, and a rough estimate of performance will be made on the high end. The preferred criteria will be expressed as a *performance objective* that describes the tactical environment and rationale for the performance measurement.

Tables 1 and 2 summarize the applications and material requirements generated by DOD personnel and the anti-traction material's classification for the various elements. The considerations presented in Tables 1 and 2 represent guidelines for defining the physical requirements and selection of anti-traction materials. The different elements associated with application requirements such as target, surface, dispensing method, etc., are considered to be broad based and encompassing. Foot traffic for example, would include pedestrians having no footwear, wearing civilian shoes, or personnel wearing military boots.

Table 1. Application Requirements

Material Classification	Target Sets / Surface Type		Dispensing System	Environment	Area Coverage
Mandatory	Foot Traffic	Level Surface Sloping Surface Concrete Walkways & Roads Asphalt Compact Soil	Manual (man portable)	40° to 100°F	800 sq. ft.
Preferred	Wheel Vehicles	Vegetated and Loose Soil Non-Porous	Mechanical (vehicle mount)	32° to 120°F	1,200 sq. ft.
Preferred Plus	Track Vehicles Aircraft	Concrete, Asphalt Compact Soil	Aircraft	<32° to 120°F	1,500 sq. ft.

Table 2. Material Requirements

Material Classification	Form	Activation	Deactivation	Application Time	Availability	Durability
Mandatory	As Available	As Required	Removable	1-hour	COTS	2 hours
Preferred	Single Component	Ready-to-Use	Biodegradable	10 – 30 minutes	COTS / MOTS	24 hours
Preferred Plus	Multiple Component or Single Sheet	Water Humidity Chemically	Reversible	5–minutes or less	Formulation	Several days

Identification of Anti-Traction Technologies

Southwest Research Institute was tasked to identify and investigate all appropriate anti-traction technologies and to determine the specific qualitative and quantitative measurements for each material or solution identified to meet the applications and requirements of Tables 1 and 2. The starting point for identification of anti-traction materials was DOD's and SwRI's *a priori* knowledge and experience in this area with materials typically used to reduce friction.

To minimize the selection of anti-traction materials to a workable choice of candidates, SwRI integrated the military's objectives with the technical requirements for anti-traction materials. The combination of these two elements defines the physical properties and characteristics for a material to be considered as a candidate anti-traction material with the military's requirement to accomplish a specific objective.

Anti-traction materials are dependent upon meeting both the military's applications and material requirements plus certain physical parameters that will enable the material to function as an anti-traction media. SwRI combined the required material parameters with the military's

requirements to produce a list of parameters for evaluating candidate material. These parameters, as indicated in Table 3, when combined with the military's requirements presented in Tables 1 and 2, produced a list of 16 criteria for assessing candidate anti-traction material. The material assessment parameters represent a combination of material requirements, application considerations, environmental concerns, physical characteristics, and cost considerations.

Table 3. Material Assessment Parameters

Material Properties	Performance Characteristics	Economic Factors
Ecology	Activation	Availability
Temperature Range	Coverage	Cost
Toxicity	Deactivation	Composition
Viscosity	Dispensability	Storage
	Durability	
	Effectiveness	
	Surface	
	Target	

The criteria for the material assessment parameters, as defined for this study, are:

1. **Ecology:** The effect or lack of effect the material produces when exposed to the surrounding environment. An optimum material would be biodegradable, leaving no permanent or residual effects on any areas of contact.

2. **Temperature Range:** Refers to the temperature range associated with the climatic and surface conditions where the anti-traction material may be applied and remain capable of meeting performance requirements.

3. **Toxicity:** The relative personal protection required when handling and dispensing of the candidate material. Ideally, dispensing of the material would require minimum protective clothing or training with its use. An acceptable material, if ingested or within contact of the eyes, would not produce a life threatening or permanent injury.

4. **Viscosity:** The property of a fluid that defines its internal resistance to flow. The metric unit of measure for viscosity is poise, named in honor of Poiseuille. Water at 68°F has a viscosity of 0.01 poise, or one centipoise (cps). Bee's honey has a viscosity of 1500 cps, while 10-weight automotive motor oil has a viscosity of 70 cps.

5. **Activation:** The requirements imposed on an individual prior to dispensing the material.

6. **Coverage:** The effective area that can be covered with an anti-traction material by an individual using a man-portable dispensing system.

7. **Deactivation:** Time period required to intentionally remove or render the material ineffective as an anti-traction material.

8. **Dispensability:** The physical and mechanical hardware requirements to prepare and apply the material to a surface.

9. **Durability:** An anti-traction material is expected to remain in place for a finite time period. The material should have a cohesive ability to adhere to surface, be resistant to easy removal and require unique or specialized equipment for removal.

10. **Effectiveness:** A measure of the materials ability to be fully functional and capable of meeting performance requirements within a specified time period.

11. **Surface:** The intended composition, structure, surface condition, and topography where the anti-traction material would be applied.

12. **Target:** The specific person, place, or thing designated to become immobile as a result of interaction with the anti-traction material.

13. **Availability:** The commercial availability and accessibility of the base materials required producing the end item.

14. **Cost:** The estimated cost associated with the end product.

15. **Composition:** The physical make-up of the material or materials required for producing an anti-traction material.

16. **Storage:** The ability of the material to withstand periods of exposure to temperature and humidity extremes as commonly experienced in a storage location, without detriment to its effectiveness.

The sources for the candidate materials include materials identified after review of technical literature, professional publications, commercial product reports, prior government studies on anti-traction materials, review of patents delineating reduced traction or friction reducing materials, in-house experience with lubricants, friction reducers, material compositions, and, *a priori* knowledge and experience. Tables 4 and 5 identify categories that meet the proposed criteria for the material assessment parameters.

Tables 4 and 5 list the common chemical name or formulation and typical usage or application for the materials provided. Also indicated are those materials commonly thought of as being slippery or conducive to generating an anti-traction surface, e.g., artificial snow, oils, and greases. While these materials serve their intended purpose in specific applications when subjected to the assessment criteria in Table 3, they may have limited advantages and applicability. The tables are not intended nor designed to indicate a preferred selection or ranking of the individual materials but rather indicate the potential capability to meet the military's requirements.

Table 4. Non-Aqueous Anti-Traction Materials

Classification	*Representative Products*
Fats and Fatty Acids	
Animal	Lard
Vegetable	Tall Oil/Lecithin
Greases	
Animal	Lard
Fuels	Jet/Diesel
Metal Soaps	Magnesium Stearate
Mineral	Auto Crankcase
Polyaliphatics	Hexadecyl-myristate
Polyalphaolefins	Synthetic motor Oil
Polyaromatics	Tetralin
Polyglycols	Carbowax 2000
Polysilicones	DC 2000
Polysiloxanes	GE SR32
Oils	
Mineral	Motor oil
Vegetable	Corn oil, etc.
Surfactants	
Anionnic	Sodium oleate
Fatty Alcohols	Tetradecanol
Glycolesters	Butyl Carbipol
Glycolethers	Dimethylcellusolve
Glycols	Glycerin
Nonionic	Triton X100

Table 5. Aqueous Anti-Traction Materials

Classification	*Representative Products*
Polysacchrides	
Cellulosics	Alginates
Guar Gums	Jaguar
Starches	Corn, Rice
Sugars	Corn Syrup
Polyols	
Cellulose Esters	Carboxymethyl – Cellulose
Cellulose Ethers	Methylcellulose
Glycols	Glycerin, Propyleneglycol
Polyacrylamides	Agrofloc
Polyacrylates	Cydril
Polyethylene – Oxides	Polyox
Polyglycols	Carbowax 2000
Vinyl Alcohols	Elvanols
Surfactants	
Soaps, Detergents	Dishwashing and Laundry Detergents

The candidate materials listed in Tables 4 and 5, while capable of producing a reduction in the coefficient of friction thereby producing a “slippery surface” are, in their current composition, not considered acceptable for meeting the military's requirements. During prior studies by SwRI, it became apparent that a low coefficient of friction (COF) is only partially essential to assure denial. Rheology, mass, and film thickness are also critical values for resistance to displacement by foot or vehicle traffic. A thin film of slippery material of any viscosity (low or high) is only effective against rapid motion or high speeds where hydroplaning or low displacement of lubricant films occurs. To effectively address all speeds, masses, and profiles interfacing with the lubricant and the substrate, the film thickness and resistance to displacement by foot or vehicle movement must be considered together with COF. Initial screening studies suggest a film thickness of approximately 100-150 mils (0.010 to 0.015 inches) with sufficient stiffness to resist vertical displacement, is necessary and applicable to all target areas. Such a film has little or no slump, is adherent to flat and sloping surfaces, and should prove to be equally effective against all types of terrain and surfaces identified in the military's requirements.

Laboratory testing of candidate materials will define the physical characteristics of selected materials and their ability to meet the military's requirements. During the laboratory evaluation effort, the feasibility of chemically enhancing and/or physically altering the composition of the material to meet specific objectives will be assessed. The candidate anti-traction materials will be initially assessed in a laboratory environment and then verified during a simulated field environment to replicate the military's scenarios for anti-traction material.