STAVATTI™

A Submission of the

TIS-1
(Tactical Infantry System-1)
Gasdynamic Laser Weapon System

By Stavatti Corporation in Response to the

LFLAN

Light Fighter Lethality After Next-Statement of Objectives

TITLE: TIS-1 Gasdynamic Laser Weapon System
DATE OF SUBMISSION: 7/2/1999
SYSTEM DESCRIPTION: The TIS-1 (Tactical Infantry System1) is a gasdynamic laser weapon system conceived by Stavatti Corporation in direct response to the Statement of Objectives corresponding to the LFLAN (Light Fighter Lethality After Next). The TIS-1 is a revolutionary tactical weapon system for the individual combatant that will deliver a first round probability of hit using directed laser light as the lethal mechanism in selectable bursts from 1 to 170 shots per minute in excess of 60% at a range of 500 meters and 80% at 1500 meters.

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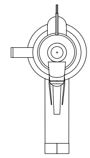
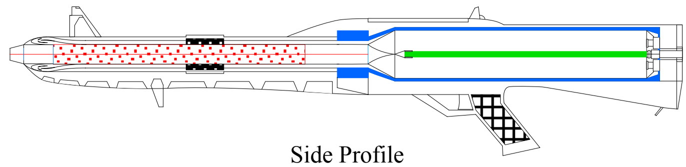
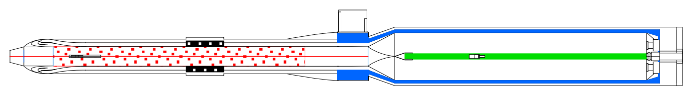
TIS-1 System General Arrangement



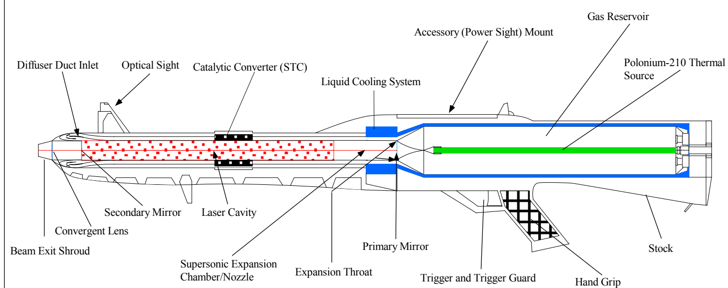
Forward Elevation



Side Profile



Top View



Side Profile with Component Recognition

Functioning of the System

The TIS-1 Gasdynamic Laser Weapon System will function as a result of gasdynamic thermal pumping of a 10%, 89% and 1% mixture of Carbon Dioxide, Nitrogen and Helium gas respectively. Initially contained at a state of thermal equilibrium at a high temperature (2173K) and pressure (272 atm) within a gas reservoir heated by a Polonium-210 power cell offering a high energy density of 141 W/g, the gas mixture is permitted, upon release of the weapon trigger, to enter a restrictive nozzle throat annulus whereby the gas will achieve local sonic velocity (Mach 1.0). Exiting the annulus, the gas is permitted to enter a supersonic expansion nozzle, consisting of an inverted aerospike configuration. Within the expansion nozzle, the gas temperature and pressure will be significantly reduced (to 288.1 K and O.1122 atm respectively) resulting in the onset of a hypersonic gas velocity of 1998 m/s (Mach 5.98). This rapid expansion process, occurring within the relaxation time of the upper and lower vibrational energy states of the gas mixture, results in the vibrational freezing of the gas molecules, thereby inducing a sequence of laser pumping cascading through a laser cavity of 40 cm length. Incorporating a resonance chamber consisting of both primary and secondary mirrors separated by a chamber length of 50 cm, the TIS-1 will provide a beam of 10.6 micrometer wavelength laser light for a duration of 0.35 seconds with a net energy output to target of approximately 1.9 kW. The TIS-1 is capable of delivering up to 170 bursts per minute on fully automatic mode, or one burst per trigger release for precision sniping. Effective range of the TIS-1 is dependent upon dispersion of the 1.3mm diameter laser beam over distance and is estimated at excess of 1500 meters. Powered by a Po-210 thermal energy source, the TIS-1 concept provides a practical, fieldable directed energy weapon.

Advantages of the System

The TIS-1 Gasdynamic Laser Weapon System Offers Numerous Significant Advantages Over Competing Systems Including:

• A Totally Integrated, Stand-Alone Personal Tactical Weapon System For the Individual Light Fighter

• A Concise, Directed Lethal Mechanism Without Dispersion or Course Deviation For Over 1500 Meters

• A System that Contains An Integrated High Energy Density Power Source (Po-210) That Provides Continuous Energy, And Resultant Weapons Use, For Over 60 Days

• A Weapon That Delivers a Lethal Beam In The Millisecond Time-Frame Capable of Penetrating Medium Material Targets In All Atmospheres and Operational Environments

• A System That Is Fully Compatible With Existing Training Techniques and M16/M4 Accessories (Including M203 Grenade Launchers, etc.) As Well As Next Generation Target Distinguish/Designation Systems.

• A System That is Tactically Superior To All Future Weapon Systems Potential US/NATO Adversaries Will Ever Consider Developing, Derived Solely From US Research/Technology.

I. Introduction

Stavatti Corporation has developed a novel tactical directed energy weapon for submission as a direct response to the LFLAN(Light Fighter Lethality After Next) requirement. Based upon ground-breaking research performed at the Avco Everett Research Laboratory in conjunction with ARPA and the USAF by Gerry, et. al, Stavatti proposes a compact GASDYNAMIC LASER MODULAR WEAPON SYSTEM to attain, and/or exceed all LFLAN requirements.

The Stavatti concept, designated the TIS-1 (Tactical Infantry System-1) by Stavatti Corporation, consists of a modular light rifle weapon system that delivers a coherent, directed Laser beam over a range in excess of 1500 meters to achieve lethality against visible and defilade targets. The TIS-1 differs from competing directed energy weapon concepts in providing a total integrated weapon system, including high energy density power source, laser medium, resonator and focusing system, in a unit length of approximately 107cm (42.1 in), a unit height of approximately 26 cm (10.25 in) and a total system weight of approximately 4.17 kg (9.2 lbs).

The Stavatti LFLAN candidate will provide a rugged, fieldable weapon system suitable for large force infantry and precision targeting operations alike through a previously unconsidered means. Although slightly heavier than the present M16/M4 system weight, the TIS-1 will offer the ability to engage targets at greater ranges, increase the probability of first round hit from a 'cold' article, increase the total duration and volume of available firepower associated with the individual light fighter on the battlefield, and, with the incorporation of an integrated targeting designation/identification system, provide the capability to distinguish and designate a particular target from a class of targets.

II. System Concept

The TIS-1 has been developed to satisfy the requirements as stipulated in the LFLAN Statement of Objectives as issued 5/21/99. Primary objectives of the LFLAN system as declared in the Statement of Work include the delivery of a weapon system to serve as a Follow-On-To the existing M16/M4 Modular Weapon System with attachments in the 2020 to 2025 time frame. The goal of the LFLAN is to deliver a high probability of hit for the first round fired, minimal collateral damage, extended effective range and the ability to hit visible and defilade targets alike under all tactical battlefield conditions. Specifically, it is stated that the LFLAN system must maintain a 90% probability of hit at 500 meters (547 yrds) and 75% at 1000 meters (1094 yrds).

Additional goals of the LFLAN include the ability to ensure a high probability of hit at extended ranges despite the potential motion of the target or launch platform/atmospheric conditions that may alter the path of the lethal mechanism. To achieve these additional goals, it is suggested that the lethal mechanism will maintain the ability to alter its course while on-route to the designated target. In summary, the ultimate LFLAN system must ensure that the lethal mechanism as released by the LFLAN will engage the designated target, despite adverse launch or environment conditions or evasive target motion over a range in excess of 1000 meters.

To address the LFLAN Statement of Objectives, Stavatti Corporation, an aerospace defense prime contractor, has focused upon providing a modular tactical weapon system that offers the greatest degree of effective accuracy and lethality over a range of 1000 meters. Rather than concentrate upon a lethal mechanism that can alter course in mid-flight to ensure target engagement, the Stavatti LFLAN concept relies upon delivery of a lethal mechanism that will engage the designated target in a near instantaneous time frame upon release. Coupled with a suitable target designation system to permit the designation of a particular target from a class of targets, the near instantaneous delivery of the lethal mechanism will result in the engagement of the target prior to evasive measures and other motion as undertaken by the target.

Upon an analysis of potentially suitable tactical lethal mechanisms, the mechanism determined to deliver the highest probability of kill over extended range in a near-instantaneous time frame was a LASER. Specifically, Stavatti selected to propose a tactical weapon system that employed a coherent beam of directed laser energy as the lethal mechanism.

Traditionally, lasers and similar directed energy weapons maintain significant size and power requirements. Although the lethality and functionality of lasers as lethal mechanisms has been proven through previous DoD efforts, leading to the current development of the Air Borne Laser (ABL) for ballistic missile defense, tactical laser weapons suitable for widespread use by individual infantry men were previously unavailable due to size, weight and power requirements.

In response to LFLAN requirements, however, Stavatti Corporation has developed a means by which a tactical laser weapon system can be incorporated into the US DoD/NATO infantry corps as a primary system. The Stavatti TIS-1, is a gasdynamic laser that delivers a beam of coherent laser energy over a distance in excess of 1500 meters (1640 yrds) in a near instantaneous time-frame, estimated at approximately 0.905 milliseconds

Employing a gasdynamic laser concept, whereby a mixture of Carbon Dioxide and Nitrogen gas is thermally pumped to the population-energy inversion necessary to sustain the lasing process via the rapid expansion of the gas mixture through a supersonic nozzle, permits the development of a weapon system that provides an output intensity sufficient to serve as a lethal mechanism while significantly reducing the overall physical dimensions of the weapon chassis. To facilitate the gasdynamic process and provide the output energy necessary to deliver a lethal mechanism, a high density power cell fueled by Polonium-210 (Po-210) is employed. Use of Po-210, a radioisotope that provides approximately 141 watts/gram of thermal energy through continuous emission of alpha particles, permits the delivery of the heat energy ultimately necessary to facilitate the gas lasing process. This combination of employing a laser beam produced by a gasdynamic laser process as fueled by the heat energy supplied by a Po-210 power source results in a directed energy weapon concept that, upon further development, will lend to the widespread deployment of a tactical laser weapon for infantry men, offering greater lethality and effective range than the present M16/M4 system.

III. System Application and Use

The Stavatti TIS-1 will serve as a direct Follow-On-To the M16/M4 Modular Weapon System fulfilling the requirement for an individual rifle article for individual infantry personnel. Differing from the M16/M4 systems through the application of a laser beam of 10.6μm wavelength as the lethal mechanism, the TIS-1 concept will maintain largely similar dimensions to the M16 system although a weight increase of approximately 1.0 lb will be incurred due to the requirements specific to a laser weapon system including power supply and liquid/air coolant.

The TIS-1 is a totally integrated article, containing everything necessary for system operation within the individual weapon chassis, thereby differing from alternate directed energy weapon concepts that may require elaborate power supply systems, targeting systems, etc. in addition to the beam delivery device. The TIS-1 will be capable of delivering a maximum rate of fire of approximately 170 lethal laser bursts per minute with each individual burst lasting a maximum of 0.35 seconds delivering approximately 1900 thermal watts in the 10.6μm wavelength to the designated target over the duration of the burst. Differing from the individual small arms currently employed by the US DoD, the TIS-1 does not employ ammunition in the conventional sense, relying upon the thermal energy provided by a Po-210 power source which offers a half-life of approximately 138 days. Thus, the TIS-1 may be fielded for continuous tactical use for a period of over 60 days at which time the Po-210 power cell must be replaced or experience a significant reduction in energy delivery per burst.

The TIS-1 will be produced in largely conventional rifle frame consisting of a barrel, stock, handle, trigger, etc. and will be fully capable of accepting current inventory accessories including spotting/targeting scopes, bayonets, M203 grenade launcher, along with future advanced targeting systems that would permit target distinguish/designate capabilities. The TIS-1 will include provisions for a radioisotopic thermoelectric generator (RTG) power cell such that residual Po-210 thermal energy can produce useful power to drive said target designators/accessories. The TIS-1 will require only slightly additional training per infantry personnel than conventional weapon systems and will greatly enhance the lethality of the individual soldier as the lack of vibration and projectile in-flight deviation as associated with traditional firearms will be significantly diminished.

IV. System Technical Overview and Functional Characteristics

The TIS-1 consists of a gasdynamic laser integrated into a modular light rifle configuration measuring approximately 107cm (42.1 in) long, approximately 26 cm (10.25 in) high and with a total system weight of approximately 4.17 kg (9.2 lbs) including a dry weapon weight of 3.02 kg (6.65 lbs) and a consumable laser medium/Po-210 and coolant weight of 1.16 kg (2.55 lbs.) The TIS-1 functions as a conventional rifle system with the depression of a trigger located immediately forward of the weapon handle used to initiate the lasing process and discharge the lethal laser beam.

Considering the mechanism by which the TIS-1 will provide a lethal laser beam in the configuration as proposed, the following description has been provided to concisely summarize how the TIS-1 functions. The TIS-1 is a gas laser whereby 75.23 grams (2.5612 moles) CO_2N_2He gas in a 10%, 89% and 1% proportioned mixture respectively is initially contained in a Titanium/Boron Nitride cylindrical gas reservoir measuring 40cm long and 7.62cm in diameter (roughly equivalent to 1824 cc) at ambient temperature (288.1K) and a pressure of 36.14 atm (531 psi). To increase the energy level of the CO_2N_2He gas mixture, a Zirconium-Nickel fuel rod approximately 40cm long and 1.8 cm in diameter containing approximately 740 grams (78cc) of Polonium-210 (Po-210) is contained within, and located down the centerline of, the cylindrical gas reservoir.

The Po-210 provides a thermal energy source of approximately 141 watts/gram through the emission of alpha particles via the process of nuclear decay. This energy source provides a significant power density while alleviating the shielding requirements and apparent health risks associated with gamma ray emitting radionuclides. The presence of the Po-210 in the reservoir chamber will result in the delivery of approximately 104.34 kW to the CO_2N_2He gas mixture, thereby raising the gas to a state of thermal equilibrium corresponding to an internal reservoir pressure of approximately 272.1 atm, temperature of 2173.16 K and gas density of 44 kg/m^3.

Similar in design to a supersonic wind tunnel or rocket motor, upon release of the TIS-1 trigger, the CO_2N_2He gas mixture is released via a reservoir relief valve into an annular constricting throat consisting of an annulus of 3.05cm internal diameter and an overall throat height of 0.0093 cm, corresponding to the effective relaxation time of the upper and lower energy states of the Carbon Dioxide and Nitrogen gas. Total annular throat area is approximately 0.0934 cm^2. At the center of the annulus is a 3.05cm diameter primary mirror, marking the beginning of the laser resonator tube. The passage of the CO_2N_2He gas through the throat results in the acceleration of the gas mixture to supersonic speed, or approximately 843.6 m/s (Mach 1.0) at a throat temperature of 1837 K, a throat pressure of 142.3 atm and a gas density of 27.26 kg/m^3. Total distance from gas reservoir to throat is approximately 4.25 cm.

From the throat, the gas mixture expands into a distinct expansion nozzle consisting of an inverted aerospike (or aerojet) design with an expansion area of 7.85 cm^2 over a distance of approximately 10.0 cm. This expansion zone, serving the purpose of a laval type nozzle on a rocket motor, accelerates the gas mixture to supersonic velocities while significantly reducing the temperature, pressure and density of the gas mixture. Specifically, over the 10.0 cm long inverted aerospike expansion region, the CO_2N_2He gas attains a mean velocity of 1998 m/s (corresponding to a local Mach number of 5.98) with a temperature of 288.1K, a pressure of 0.1122 atm and a density of 0.137 kg/m^3.

The expansion to supersonic velocities is the key to the gasdynamic laser as through this expansion process, the gas mixture which was at thermal equilibrium without any population-energy inversion is subjected to a rapid decrease in gas mixture temperature and pressure in a time span that is relatively short in comparison to the vibrational relaxation time of the upper energy levels of the CO_2N_2 gas. Concurrently, the He in the mixture serves as a catalyst to reduce the relaxation time of the lower energy levels in the CO_2N_2 gas to a duration shorter than that of the expansion process, thus resulting in a significant disparity in upper and lower energy levels in the CO_2N_2 gas mixture and the occurrence of vibrational freezing where the vibrational energy of CO_2N_2 molecules is 'hung up' at a population level characteristic of that realized in the reservoir, or stagnation, region. It is ultimately an inversion of energy level populations caused by the rapid expansion to supersonic velocities of a hot gas mixture originally at thermal equilibrium that provides the lasing, or pumping action and corresponding high energy density of the TIS-1 weapon system.

Once through the expansion nozzle, the gas mixture flows through a laser cavity with an overall length of 40 cm and constant diameter of 3.05 cm. Throughout the laser cavity, the gas remains in a state of 'population inversion' for a distance of 40cm, providing a medium by which lasing is stimulated. Directly at the end of the laser cavity is a secondary mirror of 3.05 cm diameter, which is spaced a distance of approximately 50 cm from the primary mirror located at the center of the throat annulus, upstream of the expansion flow. This mirror is located immediate at the end of the laser cavity and is accompanied by a diffuser duct to divert the supersonic CO_2N_2He gas flow around the mirror via an inverted aerospike effect, similar to that applied in the case of the primary mirror as a fore mentioned. The entire process of transfer of the CO_2N_2He gas mixture from the gas reservoir to the throat, through the expansion nozzle and downstream through the laser cavity to produce the coherent energy beam, is estimated to require approximately 40 milliseconds. The laser beam produced will have a wavelength of 10.6μm with a corresponding output beam diameter of approximately 1.3mm. Total net output power is estimated at 1.9 kW over a burst time of 0.35 seconds corresponding to a lethal net beam intensity in excess of 760 watts/ cm^2 dependent ultimately upon the configuration of the laser resonator, the radius of curvature of the secondary and primary mirrors, etc. Total losses due to expansion throat inefficiency, boundary layer effects, collisional deactivation, laser cavity inefficiency, mirror absorption and unliberated laser energy is estimated at 16.4 kW

Once flow has been achieved through the laser cavity, the CO_2N_2He gas mixture is diverted into an annulus that reverses gas flow through a gas diverter duct, where the flow remains supersonic (at 1990 m/s) and a temperature of approximately 300K. The diverter duct spans the length of the gun 'barrel,' thereby retaining a reasonable temperature throughout the weapon's barrel length. Midway through the barrel, the gas is circulated through a catalytic converter (as developed by STC Corporation) such that the gas may remain in a closed environment indefinitely. The gas flow is then returned, via diffusion and a pressure differential provided by an integrated electrical pump into the gas reservoir for a reinitiation of the gasdynamic laser cycle.

Due to the significant temperatures associated with the gas reservoir, a liquid cooling system must be incorporated into the weapon system such that the gas reservoir and compression zone immediately prior to the expansion nozzle throat is encased in a jacket of cyclic coolant, exposed to ambient conditions via a radiator located on the right side of weapon system, directly perpendicular to the gun frame. Furthermore, to reduce the weight of the weapon system that incorporates pressure vessels requiring significant strength, the TIS-1 will be composed largely of Titanium and Stainless Steel alloys for all pressure vessels with use of Carborundum AX05 Grade Boron Nitride materials in high temperature regions. The weapon frame will be composed largely of injection molded components and autoclave cured IM9/AFR 700B graphite/BMI composites.

V. Contractor Previous and Related Work

Stavatti Corporation is an aerospace defense prime contractor established in 1994. Stavatti is responsible for the conception, design, development, prototyping, evaluation, qualification, production, sales, service and support of tactical and strategic air warfare systems, general aviation systems and related defense articles. Stavatti is presently undertaking the DEM/VAL program of the F-26 Stalma multi-role fighter as a commercial, company initiated follow-on-to F-16 for US/NATO allies.

Stavatti has not previously, nor is currently involved in an effort to develop a qualified small arm weapon system similar to the weapon system concept as so stated in the LFLAN Statement of Objectives. Stavatti Corporation has, however, pursued the conception and development of a high power, gas dynamic laser weapon system for use on tactical aircraft as a Follow-On-To M61A2 Vulcan 20mm cannon as a corporate initiative.

VI. System Technical Challenges and Risk

The Stavatti TIS-1 gasdynamic laser weapon system maintains a high degree of technical risk, mainly consisting of the development of a system architecture for the Po-210 power source. Currently, Po-210 is produced only in microgram quantities for research purposes at facilities such as Oak Ridge National Laboratory. Po-210 production must be significantly increased as the Stavatti LFLAN concept is heavily dependent upon securing gram quantities of this material which, although poses no threat via radioactivity (it is an alpha emitter), is chemically toxic. Furthermore, the TIS-1 design results in significant heat energy transfer which must be insulated from the user while the weapon is in use.

Additionally, residual Po-210 thermal energy must dissipated while the weapon is in a storage mode-in essence the system produces 104 kW of heat energy which if harnessed through a RTG generator, could be used to provide significant electrical energy. Although a compact weapon due to the use of the gasdynamic laser process, Stavatti estimates significant weapon weight increases as the system is developed for field use. A significant development and per unit cost is also envisioned for the TIS-1 as the weapon system is composed of significant quantities of exotic materials uncommon for a small arm, in addition to the cost of Po-210, the cost of which in pound quantities is yet to be explored due to its current absence of commercial applications. Finally, it is estimated that the weapon will deliver a recoil force of approximately 90lbs in the forward direction upon discharge, thereby requiring the employment of a recoil alleviation/mitigation system.