SKU JOURNAL OF ENGINEERING RESEARCH Vol-3 Issue-1
(NATIONAL PEER REVIEWED E-RESEARCH JOURNAL)
(January – March 2026)
E-ISSN 3048-930X

Improvement of a Remotely Controlled Robotic Vehicle System

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ABSTRACT

This study presents a new method for applying liquid nitrogen (LN2) onto fires for the purpose of fire extinction. LN2 is being studied as a fire extinguishing medium due to the rise of new challenges that traditional water-based methods cannot tackle. Global warming's impact has increased the frequency and ferocity of forest fires, stretching firefighters' abilities utilizing water. Additionally, the rise of the electric car industry has created new obstacles in putting out road fires compared to more common internal combustion engine vehicles. This study aims to develop and test an LN2 dispensing robot capable of traversing tough terrain, transporting a tank of LN2 to a fire, and, utilizing a hose carried by an articulated arm, to spray the cryogen onto fires. This fully remote-controlled robot will help to remove firefighters from dangerous areas and assist them in situations where water-based methods are insufficient. The results of this study, tested on an array of pine needle fires and alcohol pool fires, prove that the robot is not only sufficient at extinguishing flames, but is more effective than its water-based counterparts. The most evident test proving its superiority over water was shown in applications involving liquid fuel fires, where a water spray was incapable of extinguishing the flames, whereas an LN2 spray was exceedingly effective at completely extinguishing the fire. This study shows that a remote-controlled robotic LN2 dispensing robot is a viable solution to assist firefighters in tackling challenging situations.

KEYWORD

Firefighting robots, robotic system, unmanned ground vehicle (UGV), and remotely operated.

INTRODUCTION

Global warming's impact has made the planet susceptible to ever-increasing forest fires. With the fires growing in frequency and fury, new approaches are needed to prevent the spread and devastation that the fires exact. As seen by the recent fires in Los Angeles, California, traditional water-based methods are no longer sufficient for fighting fires. A diminishing supply of water and the effect on the water quality call for additional methods of extinguishment. Traditional forest firefighting methods create several detrimental effects on the environment. The brackish water that is dispersed onto the burning area creates highly salinated soil and prevents the local flora and fauna from flourishing in the region after the fires have been quenched. Additionally, the carbonated water runoff has the capability of entering watersheds and negatively affecting the drinking water for the local population. The greatest effect on the local ecosystem comes from the fire-extinguishing compositions mixed into the water used to fight forest fires. The rise in the popularity of electric cars poses a new challenge for firefighters. While electric car fires are less frequent with respect to those with

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internal combustion engines, traditional methods cannot properly extinguish the flames. The high electrical conductivity of water renders water-based fire extinguishment ineffective.

While a remote-controlled vehicle capable of dispensing LN2 does not yet exist, many real world examples of this idea do. There are several firefighting vehicles created to aid firefighters in remotely controlling fires. Among these are the DOK-ing Emergency Response Robotic System, Howe X Howe's fleet of Thermite robots, and Shark Robotic's array of fire-fighting robotic vehicles. As displayed these robots all feature the design points listed prior but utilize water dispensing systems instead of the LN2 system that are tested in this study.

Figure- DOK-ing Fire Extinguishing Robot

Figure- Howe X Howe's Fleet of The mite Robots

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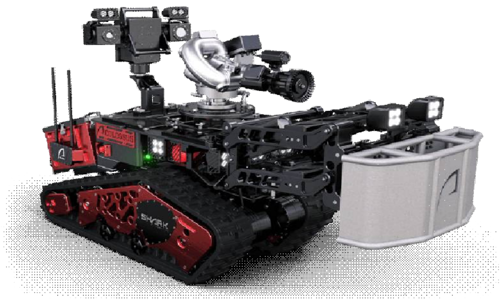

Figure-Shark Robotics Fire Extinguishing Robot

Drive Train and Body

The robotic vehicle's drive train has two main requirements: robustness, to allow the vehicle to survive harsh terrain and environments, and power, to ensure that the vehicle is able to make it to the scene, as well as potentially use its body to displace debris. As the purpose of this study is to develop a working model for this vehicle, the power and robustness of the drive train and body will also be scaled. To account for these requirements, a vehicle with an aluminum frame that utilizes tank treads was selected. The vehicle allows for a large amount of modification, customization, and user control that will be essential in the rapid design and redesign of the subsequent sub components.

LN2 System

To design the LN2 dispersion system, inspiration was drawn from dermatological spray cans. These devices are insulated bottles, capable of storing LN2 for long periods of time, that use the GN2 evaporation to generate pressure. This pressure is then released via a dip tube that isolates the LN2 from the GN2 and sprays out of a forward facing nozzle. This concept was validated by attaching a cryogenic tube to the end of the nozzle and spraying LN2 . The test analyzed LN2 exit flow based on differing endpoint tube heights, internal pressure, and amount of time the flow valve was open. The results of this test showed that pressure generation via evaporation did not yield a long or consistent stream and showed that pressure generation took too long to be reliable. To accommodate this, a pressure tank and compressor were added to the design to increase the volume of pressurized gas and to generate required pressures at a faster rate.

The designed REV A system is displayed consisting of a compressor, pressurized air tank, pressure relief valve, electronic solenoid valve, insulated LN2 tank, dip tube, and cryogenic tubing, among various hardware and pipe fittings. The assembled system, was initially validated with water. Consistent flow was achieved at variable heights over longer spans of time. The pressure relief valve was then successfully calibrated to ensure low velocity flow exited the tube. Upon filling the system with LN2 , the lack of thermal insulation of the tank resulted in rapid generation of GN2 . This created numerous problems. The rapid generation of GN2 coupled with the small neck of the tank caused a vapor lock to form making it extremely difficult to fill the container. Additionally, the rapid generation resulted in an excess expulsion of LN2 out of the tubing. This depleted the tank of all LN2 before the solenoid valve was opened. The solution to the discovered problem was to utilize a more insulated container for the LN2 .

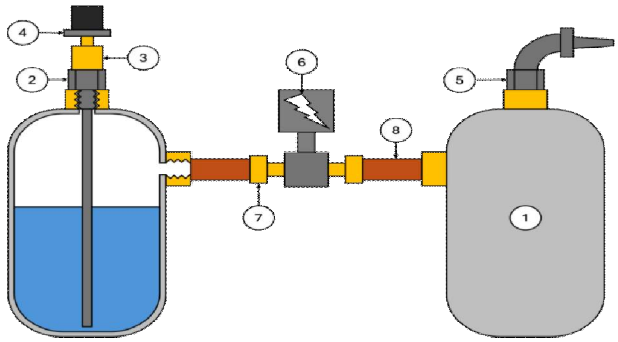

Figure-REVALN_2 System

Table: REVA Bill of Materials

	Bill of Materials
1	0.5L Air Tank
2	Dip Tube
3	Pipe Fitting
4	Cryogenic Tubing
5	Hose Connection
6	Solenoid Valve
7	¼”NPTtoYorLokFitting
8	Steel Tubing

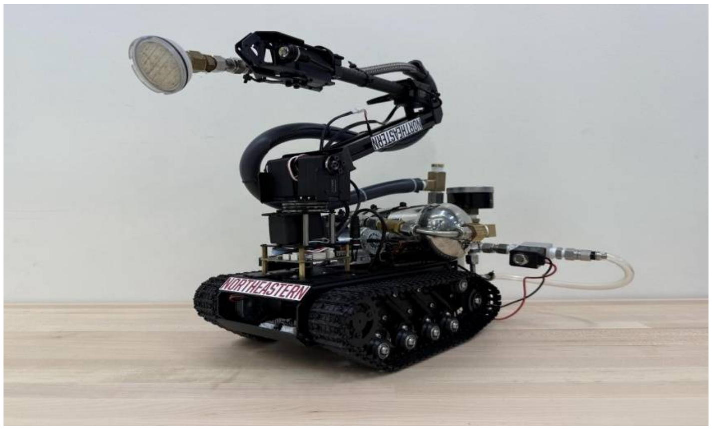

Figure- REV A System Set Upon The Robotic System

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RC - Drive control

To complete the design of this remote control vehicle, remote control capabilities needed to be integrated. To accomplish this, a reputable RC controller and receiver were selected: Flysky fs-i6 controller and receiver. This system utilizes pulse width modulation (PWM), a control system that transmits square waves of variable length from the controller to the receiver for each of the controller's channels. The driver code then takes these pulses, measures their length, and translates that into usable values that can be sent to the motor controller. With just this functionality, the robot is completely remotely controlled. However, additional components are needed to improve the control and functionality of the remote system. Due to the controller and receiver's high sensitivity to changes in channel value and small variabilities in the signal, the vehicle's drive system keeps it in constant and slow motion. An adjustable dead zone was implemented to allow the vehicle to remain at rest despite small changes in the channel signal.

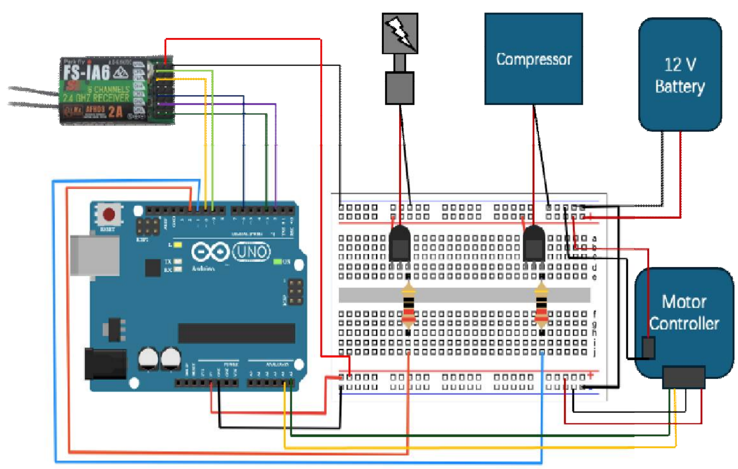

Figure- Circuitry Diagram

Design Verification and Validation Testing

The next VnV test was designed to simulate burning of a forest floor and assess the robots ability to extinguish the fire without spreading the burning fuel. The design consisted of placing 20 g of loose pine needles into a metal dish and placing it in the corner of a fume hood. The pile was then lit and the robot was directed toward the flame. Once in position, the compressor was toggled and the arm controlled over the fire until the flames were fully extinguished or the water was completely purged from the system. The third of the VnV tests was to demonstrate the mobility of the arm in a fire situation. This test featured a "tree-like" structure made out of a wooden dowel and secured pine needles. The tree was then be set ablaze, and the robot would drive up to the fire, extend its arm, and begin spraying water until the fire is extinguished, moving the arm through the entirety of the spray to reach ignited areas. The fourth of the VnV tests was designed to test the functionality of a water-based extinguishment system on a chemical fire. To do so, a pool of isopropyl alcohol was used and ignited. The robot would then drive up to the fire and spray water onto the ignited medium until the fire was extinguished or the system was depleted of water.

Results/Analysis

The VnV tests proved sufficient and effective functionality of all the robotic systems. The first of the tests showed that the robot was effective at navigating a path. The robot was capable of driving the length of the hallway and was able to effectively motion its arm into a position where it could access the inside of the bucket. Remote toggling of the spray system was also proven to be working as water was sprayed from the diffuser

LN2 Testing

To test the LN2 system, REV C was utilized. This system, due to the tank's large size, cannot be secured to the body of the vehicle and does not support the capability to drive. As a result, the Dewar was initially secured to a test stand and the cryogenic tubing was secured to the arm of the robot, as seen in the set-up displayed. For following tests, a trailer was constructed, utilizing plywood and caster wheels and attached to the rear of the robot. This allowed the dewar to be mobile and strongly secured to the system. An array of fire scenarios were then tested. These include: pine needle pyres, loose pine needle piles, pseudo pine needle "trees", and alcohol fires.

CONCLUSIONS

This study focused on testing the viability of utilizing a remote-controlled LN2 dispensing robot for fire extinction. This was tested through traditional water-based VnV testing then repeating the same experiment with a dewar of LN2 . The remote controlled LN2 robot proved to be an effective delivery device for extinguishing fires. The VnV tests showed that the robot is capable of driving to a fire and maneuvering its arm around the flames. The LN2 tests showed that the vehicle is capable of dispensing cryogen in a controlled manner. Due to LN2's nature, challenges were overcome concerning vapor locks, hose stiffening due to the cooling, and two phase flow. These respective challenges were overcome by utilizing and modifying a cryogenic dewar to be used as the LN2 containment vessel, by utilizing a strong robotic arm and rigidly attaching the dewar to the robot, and by pre-cooling the system before any tests were run.

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