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Project Summary

Design of a Remotely Controlled Hovercraft Vehicle for Spill Reconnaissance

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This program was undertaken to design a prototype of a remotely controlled vehicle for reconnaissance use in hazardous material spill and release environments and to assemble and test a much simplified prototype.

The characteristics of past hazardous material spills were evaluated to determine the type of vehicle best suited for the reconnaissance duty and to develop the vechicle's performance standards. Based on the conditions present at a "typical spill," the desired vehicle capabilities, and the level of operator skill reasonably expected, the vehicle selected was a ground-effect machine (GEM) or hovercraft.

A skirted-hovercraft design was chosen over a peripheral-jet design because of power requirements. The proposed 8-ft diameter, 300-lb hovercraft is designed to clear obstacles approaching 18 in. in height using only 4 HP versus the 15 HP required by a peripheral-jet craft. The body of the vehicle has a sandwich-panel construction, using Nomex™ honeycomb filler between Kevlar™ face-sheets to yield a corrosion-resistant structure of high strength and an acceptable stiffness-to-weight ratio. High technology but state-of-the-art batteries and electric DC motors can drive a propulsion system that gives the vehicle an estimated 1.5-hr in-flight endurance at maximum power output and an effective operating range of 1/2 mile. Greater heights could be attained by some design changes and by operating at higher power levels for shorter times (acceptance of shorter reconnaissance periods at greater cost per period). The design also includes a television camera (high or low level lighting; visible, IR, UV) and a variety of gas sensors for remote reconnaissance of a spill or waste release area. In the half-scale prototype (4-ft OD), a small gasoline IC engine provided sufficient lift to clear 3-in. barriers; yaw was controlled with two battery-powered thrusters. An 8-mm cine camera was mounted on the unit, which was maneuvered by an RF (radio frequency) link.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This report describes the conceptual design of a prototype remotely controlled reconnaissance vehicle for use in a hazardous environment. The work was performed for EPA's Oil and Hazardous Materials Spills Branch, Edison, New Jersey.

In recent years, hazardous materials spills and releases have increased in frequency, severity, and distribution with a concomitant increase in loss of life, injuries, and property damage. This problem is expected to be exacerbated in the coming years.

Determination of the nature and source of a spill is the critical first step in controlling the situation. Further, in some spill or release situations, the nature and/or origin of the spill cannot be determined because of conditions caused by the spilled material (chemical haze, fire, etc.) or obstructions at the spill site. Reconnaissance of a spill site involves considerable risk when personnel must enter a potentially lethal environment.

The U.S. Environmental Protection Agency's Municipal Environmental Research Laboratory recognized the need for a remotely operated device that could be sent into a spill area to provide information on the nature of the spill and to provide a means of stopping or neutralizing the spill or release. In response to this need, the Department of Fire, City of Oxnard, Oxnard, California, was awarded a grant to design a device that could achieve such a goal without endangering workers. The Department of Fire chose Developmental Sciences, Inc. (DSI), as its prime contractor to perform the technical work on this program. DSI has been involved extensively in the manufacture of remotely piloted vehicles and has acted as a prime contractor to the Army, Air Force, Navy, and NASA on various unmanned vehicle programs.

The ultimate goal of the complete program was the construction, testing, and actual use of a full-scale system. The intermediate goals were the description and design of a full-scale device and the production and testing of a stripped-down, half-scale prototype. Funding limitations permitted achievement of only the intermediate goals. Thus, only the design and specification of the full-scale system and the configuration and operation of a half-scale model are discussed in the project report.

Discussion

Vehicle Selection

Existing data on hazardous substance spill and release situations, as well as the input from discussions with fire departments and other agencies that have experienced large spills, were analyzed to isolate certain spill characteristics that would determine the design of the vehicle and the performance standards. Based on the results of this review, the following conclusions were reached:

1. The vehicle must, in no way, accentuate the existing hazard, especially by introducing a source of sparks into a flammable environment.
2. The vehicle should have a range of approximately 1/2 mile, an endurance of 1/2 hr, and should be able to traverse a 20° slope and 18-in. high obstacles.
3. The vehicle should be compact and easily maneuvered.
4. Operator skill levels should be relatively low.
5. Maintenance and repair requirements should be minimal.
6. The vehicle should provide some form of remote chemical analysis (e.g., gas meters, explosion meters).

It was further concluded that remote reconnaissance was the single most desirable capability of the device. The ability to perform certain spill mitigating tasks, while very useful, was determined to be an impractical goal in light of the large variance in corrective measures necessary for specific spills. Specifically, mechanical actions by the device can only be accomplished when the vehicle can provide the required reaction (Newton's third law), which means that there must be the extra power capacity to provide high, instantaneous torque and/or thrust, a requirement that severely complicates design and adds excessive weight.

Three classes of vehicles were considered for use as a remote reconnaissance device.

The first class considered was ground-based vehicles including wheeled, tracked, and even "walking" vehicles or robots. The tracked vehicles were rejected primarily because of their inability to traverse large "muddy" areas that may be caused by large volume spills. A highly modified version of a commercially available "all terrain vehicle" (ATV) was also considered. Although ATV's can travel over large areas and with heavy payloads, they were rejected because the ATV must travel *through* the spill, which would be undesirable or impractical under certain conditions. It was also judged that an ATV would be more valuable as a cleanup tool rather than as a reconnaissance vehicle, and that ATV manufacturers could meet any demand for modified vehicles that the cleanup industry might be willing to pay for. Walking devices (and robots) were (1978) emerging as state-of-the-art systems and could be expected to become available for spill reconnaissance and cleanup by the private sector.

The second class of vehicle considered was ground-effect machines (GEM) or, as they are commonly referred to, hovercraft. This type of vehicle offers a major advantage in that it can traverse a wide range of terrains with minimal ground contact. These features not only minimize the degree of corrosion resistance necessary but also reduce the risk of spark generation caused by the striking of hard objects by the vehicular components of the other classes.

The third class of vehicle considered was free-flying craft, such as remotely controlled helicopters of ducted-rotor design, "model" airplanes, and lighter-than-air crafts (blimps). While this class offered reconnaissance capability, the complexity and cost of the devices, coupled with the level of operator skill required to operate such vehicles, eliminated them from consideration. In particular, small radio-guided aircraft cannot hover or move at the low speeds necessary for detailed reconnaissance at short distances. Blimps present serious problems in maneuverability and in stability in crosswinds and up-and-down-drafts.

As a result of the analysis, it was concluded that the GEM or hovercraft would be best suited for this particular application.

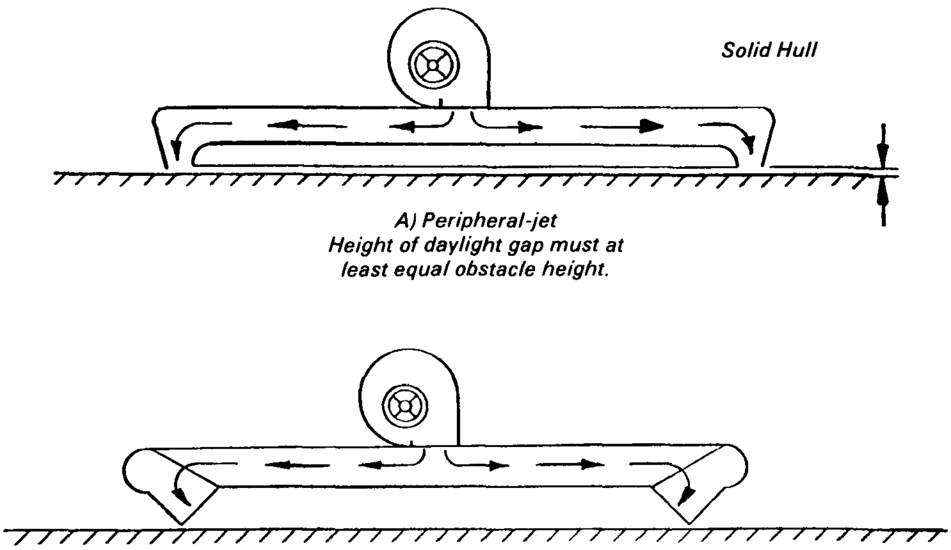
Vehicle Conceptual Design

The two basic hovercraft designs are the peripheral-jet hovercraft and the skirted hovercraft (Figure 1). The peripheral-jet design was eliminated because of the high power requirements for obtaining sufficient ground clearance to move above sizeable objects. The skirted design, on the other hand, allows the craft to pass over substantial obstacles without the need for the larger, power-consuming "daylight" clearance necessary in a peripheral-jet machine. The skirted hovercraft provides comparable performance with a smaller power unit. Note that operation only in the ground-effect mode is being considered. The lifting and traversing thrust is obtained by action against the ground plane. Operation beyond the ground-effect mode requires action against the atmosphere (including the expelled thrusting gas itself), i.e., operation in a rocket mode, where much greater power is required for flight and for hovering at high altitudes.

Vehicle Components

Power

An electrical source power was chosen to drive the propulsion system. Consideration was given to other systems, including pneumatic and liquid nitrogen engines. Applying recent advances in battery and DC electric motor technologies, a lightweight system consisting of graphite composite batteries (450 watt-hr/lb) and brushless, selenium-cobalt DC



A) Peripheral-jet
Height of daylight gap must at
least equal obstacle height.

B) Skirted
Skirt deforms to absorb obstacles
under craft without large daylight clearance.

Figure 1. *Basic peripheral-jet and skirted hovercraft concepts.*

electric motors was designed. The system requires only 4 lb of total weight for each horsepower produced. Thrust, braking, and yaw movements are provided by two 20-in. diameter, variable/reversible pitch, ducted rotors.

Control

An on-board autopilot is included in the design because of the complexity and frequency of the commands necessary to keep the hovercraft on course. The autopilot's function is to make changes in the direction and magnitude of thrust to compensate for varying terrain and wind conditions. This feature frees the operator to concentrate on controlling the craft's forward speed and lift and operating ancillary equipment such as TV camera and samplers. Depending chiefly on the type of TV imaging desired, the GEM will be controlled and transmit data by RF or microwave links as determined by the bandwidth needed. Operations will be essentially line-of-sight.

Camera and Sensors

The remote reconnaissance capability is provided by an on-board TV camera (mounted on pan/tilt gimbals) and meter-type gas/vapor sensors or detector tubes. The use of these sensors will allow the operator to "man" gas/vapor concentrations, thus aiding in locating the spill or leak.

Performance objectives for the proposed prototype are given in Table 1.

Table 1. *Prototype Vehicle Performance Characteristics*

Characteristic	*Requirement*
Maximum velocity	*10 fps*
Maximum grade capability	*20 degrees*
Maximum crosswind (at forward velocity of 4 fps)	*25 knots*
Maximum obstacle height	*18 in.*
Range (from command post)	*0.5 mile*
Endurance (new batteries, maximum power consumption)	*1.5 hr*
Turning circle diameter	*0 in.**

**The vehicle can rotate, in place, about its own axis.*

Construction/Test of a Half-Scale GEM Hovercraft

Concomitant with the design study for a full-scale GEM, a simplified, half-scale, skirted model was constructed and tested. The unit was powered by a low HP gasoline IC engine (with explosion-initiation protection equipment on the exhaust) to drive the lift fan and two, small, battery-powered DC electric motors to power opposed thruster rotors. The unit was controlled by an RF link adapted from those used with model airplanes. There was no auto-pilot. A super 8-mm cine camera was mounted on the system, which resembled a large "Frisbee" (ca. 30 cm [12 in.] high) with a top hat in the center. The unit was maneuvered about a warehouse at about 7.5 cm (3 in.) above the floor. Subsequently, a portable B/W TV camera was installed (fixed mount) and signal was returned to the operating console with a thin, lightweight, trailing co-axial cable. The model operated in such a manner as to reinforce the design and operational expectations for the full-scale system.

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Henry Gustafson and Roy Furr were with the City of Oxnard, Oxnard, CA 90303; Keith Souter and Gerald Seemann were with Development Sciences, Inc., City of Industry, CA 91744, when the project was performed.
***John E. Brugger** is the EPA Project Officer (see below).*
The complete report, entitled "Design of a Remotely Controlled Hovercraft Vehicle for Spill Reconnaissance," (Order No. PB 84-124 904; Cost: $8.50, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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