

***TRANSIT-BASED LPG MICROTURBINE  
RAPID-INTERVENTION PROJECT***

Prepared For:

**PROPANE EDUCATION & RESEARCH COUNCIL  
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## TRANSIT-BASED LPG MICROTURBINE RAPID-INTERVENTION PROJECT

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### I. EXECUTIVE SUMMARY

The shuttles at Los Angeles Department of Transportation (LADoT) are currently out of service due to non-attainment of minimum performance criteria set by LADoT for ISE Research (ISE), the shuttle integrator, to meet. Major issues preventing bus operation include: inadequate range capabilities (150 mile minimum), high fuel consumption, and low in-service availability. Due to ADEPT's work in Phase I, LPG is not blamable in the event these shuttles do not return to service. ADEPT continues to monitor the situation.

The shuttles at Island Transit in Galveston, TX have experienced mechanical difficulties. They have been running intermittently since August. On the propane side, the shuttles experienced occasional failures due to an oily residue build up in the vaporized fuel lines. Oily residue accumulation is reported to deteriorate the regulators' ability to maintain steady pressure to the turbine. At ADEPT's suggestion, vaporizers were installed on all Advanced Vehicle Systems' (AVS) hybrid shuttles. This diminished but did not fully solve the problem. Currently, residue is known to form after the regulator. It has been reported that it clogs the manifold, the smart proportioning valve (SPV), and the turbine injectors. To deal with this matter, a drip leg and coalescent filter were added in the vaporized fuel line. At ADEPT's request, this residue is to be collected on a regular basis when the shuttles are in service. This temporary measure has kept propane fuel issues out of the line of fire, but a more elegant means to keep the vaporized fuel path clear to the turbine injectors is advisable.

Much of the work from August through present focused on the oily residue issue. The fuel was checked and determined to be within HD-5 standards. Extensive tests were run at a well qualified laboratory, to determine the composition of the oily residue.

Several possible solutions are currently under evaluation to more elegantly alleviate the residue problem, including the use of appropriate filters and/or additives. Trials are planned to test the efficiency and viability of these resolution options.

**II. PROJECT SITES**

Table 1 below lists the locations and parties involved in this project.

**Table 1: Microturbine Location Details**

<b>Location</b>	Los Angeles, CA	Galveston, TX
<b>Owner</b>	LADoT	Island Transit <sup>1</sup>
<b>Operator</b>	First Transit	Island Transit
<b>Hybrid Shuttle Integrator</b>	ISE	AVS
<b>Microturbine Manufacturer</b>	Capstone	Capstone
<b>Fuel Provider</b>	Mutual Propane	AmeriGas

**III. WORK PERFORMED**

**A. LADoT, Los Angeles, CA**

ADEPT held extensive exchanges with ISE, LADoT and Mutual Propane (Mutual). ADEPT visited First Transit’s facility on four (4) occasions, Mutual on three (3) occasions, and LADoT on two (2) occasions. ADEPT had the fuel, supplied by Mutual, tested at Dixie Services (Dixie) on October 15, 2001. The fuel was found to fully meet HD-5 specifications. Similar tests with similar results were conducted by Cummins Engine Company in February of 2001.

ADEPT also addressed on-board component safety issues. A safety inspection directed at LPG components was conducted on September 19, 2001 by Energy Control Equipment, Inc. ADEPT technical staff witnessed this inspection. The ensuing report identified several possible safety issues, including:

1. Field welding on a propane storage tank.
2. A disconnected vapor service valve that may need to be capped.
3. A tank that may have been installed off of the appropriate axis.
4. An outage valve not piped to a fill port.
5. Lack of hydrostatic relief valves to stop fuel from moving between on-board storage tanks (in lines that connect together to the vaporizer).

These issues were communicated to Mutual Propane. They will be discussed with ISE once Mutual Propane has fully reviewed them in mid-November. These safety issues are to be fully resolved as part of the proposed follow-on project.

<sup>1</sup> Island Transit has not yet paid anything to AVS for the three (3) shuttle vehicles. This issue may become the source of a major dispute between AVS and Island Transit.

ADEPT provided ISE with a prescreened list of vaporizer manufacturers. ISE will review this list to select the most suitable unit.

In late September, LADoT and ISE set new minimum on-road and in-service performance criteria to be met by ISE. At this date, ISE has not yet met those requirements. Future operation of the LADoT shuttles is uncertain until ISE can meet these requirements.

## **B. Island Transit, Galveston, TX**

The shuttles at Island Transit have seen sporadic on-road service since August due to several mechanical failures. Similar mechanical problems were reported on the same shuttle model at another AVS site (in Coconut Creek, FL) where propane also powers the shuttle's Capstone microturbine (also the 30 kw model).

ADEPT worked jointly with AVS to formulate a fuel system related problem statement and to suggest suitable action items to resolve various issues. Some mechanical problems were attributed to the regulator's inability to maintain steady pressure to the turbine at below 55 psi. One helpful move was to replace the regulator internal steel seats with Viton seats. The Viton seats delayed the onset of the pressure leakage condition, but after some use, the problem reoccurred. The problem statement identified the oily residue as the main cause in the pressure loss ahead of the regulator. The sequence and location of various components in the vaporized fuel system were also reviewed and rearranged to minimize the possibility to form residue in the regulators as well as to increase safety.

Algas Z10 vaporizers were installed on AVS shuttles at both locations. These vaporizers helped but did not fully alleviate the propane system problems.

ADEPT initiated multiple tasks to troubleshoot the build-up of the oily residue:

1. Contracted Dixie to conduct extensive fuel quality tests of the propane stored on site (sampled on September 25, 2001). Test results showed that the fuel was fully within HD-5 specifications.
2. Arranged for inspection of on-board components at Island Transit.
3. Engaged in exchanges with vaporizer manufacturers to discuss issues and troubleshoot the problem.
4. Reviewed microturbine issues with Capstone: vaporizer issues, reasons behind an August 28, 2001 service bulletin, SPV requirements.
5. Collected oily residue, shipped oily residue, ordered composition and extensive evaporative residue tests on fuel samples.

ADEPT visited Island Transit on September 21, 2001. ADEPT inspected and photographed the shuttles, the stationary and on-board LPG storage systems, the turbine assembly, the on-board regulator, the vaporizer, the coalescent filter, and

also collected an oily residue sample. The residue sample was taken to Dixie for suitable analysis. Dixie's analysis revealed that the residue is comprised mainly of heavy carbon chains (C20-C40) with a viscosity similar to motor oil.

ADEPT, with these tests results in hand, consulted a select group of industry experts who are known to have extensive prior experience with oily residues in automotive-grade LPG and/or in LPG automotive applications. These experts were requested to provide opinions on possible contamination sources that could be causing the residue problems. A list of the most likely contaminant sources was assembled and distributed to the appropriate parties for further review and comment.

Three (3) respective residue tests were performed on propane fuel samples from Island Transit. These three large samples were collected over a five month period. Test results showed that the amount of residue in the fuel varied over time. Between June 15, 2001 and September 25, 2001, the amount of particulate residue increased by a factor of 3 and the non-volatile residue increased by a factor of 7 (see Table 2 for quantified Residue measurements). The last two samples came from a different supplier than the first sample. It should be noted that both fuel providers sold fuel to Island Transit that was within HD-5 specifications.

**Table 2: Measured Residues of Propane Samples from Island Transit**

Test #	Date	Particulates (mg/kg)	Non-volatile residue (mg/kg)
1	6/15/01	0.05	16.4
2	9/25/01	0.14	116.0
3	11/01/01	0.23	114.0

ADEPT suggested to Island Transit a number of changes to help determine the conditions under which the oily residue accumulates. AVS agreed to further instrument the shuttles to better assess the condition under which the residue is formed in the vaporized fuel line. This work is to be conducted in the proposed Phase II of this project.

Several other options are currently under investigation. Additive manufacturers were approached to determine if any propane additives exist that may cost-effectively alleviate the residue problems. Oily residue samples and test results from Dixie were forwarded to the two additive manufacturers who have expressed interest to help resolve the residue problem at Island Transit. These additive manufacturers are to be contacted again as part of Phase II of this project.

Additional and/or different types of filters to trap these residues are also under investigation. Plans are underway to conduct an experiment to determine the most appropriate filters (and/or arrangement of filters) to trap the residue while on board. The focus is on on-board systems because the fuel must remain odorized

(for safety reasons) before it travels to the on-board carburization / vaporization / injection / reformatting system.

## IV. CONCLUSIONS

The outcome of microturbine shuttles at the LADoT site is presently out of PERC's control. In any event, appropriate actions have been taken to assure that the fuel cannot be blamed if the buses are not returned to service. The safety issues of the on-board LPG system must be appropriately resolved within the next three months to close out the few remaining propane-related points.

The Galveston, TX site remains a viable opportunity to prove the capabilities of propane-powered microturbines in mass-transit applications. The oily residue has been identified by AVS to be the cause of specific turbine and or fuel system component mechanical failures. These repeated failures lead to the garaging of the shuttles prior to the start of this project. Working with AVS and Island Transit, a mutually agreeable method was found and activated to keep the shuttles operating (i.e. periodic collection of oily residues at newly installed coalescent filter and/or at drip leg valve).

There is reason to believe that specific "off the shelf" and innovative approaches/technologies may be able resolve the identified oily residue issues. These applied research efforts may well lead to tangible means to resolve long standing propane quality issues, which may also help in other propane fuel quality-sensitive applications (e.g. fuel cells).

## V. RECOMMENDATIONS

The Rapid Intervention project should continue to monitor the LADoT situation, including the attainment of criteria imposed by LADoT for ISE, as well as to resolve the remaining identified safety issues.

The Rapid Intervention project should continue to monitor the Galveston situation. The transit authority, the fuel provider, and the shuttle integrator have expressed willingness to make certain changes to alleviate the oily residue difficulties. The proposed technical resolution approaches include filters and additives. These approaches require diligent further investigation before they can be widely implemented on on-road vehicles with a high degree of confidence.

Another site, Santa Clara, CA, should be added to Phase II of the Rapid Intervention project. This site is highly visible. Santa Clara recently acquired three (3) AVS-made 35 foot hybrid buses that are each powered by two (2) Capstone microturbines (2 x 30 kw). The fuel systems of these microturbines are reported to experience certain fuel quality problems. These problems should be promptly investigated and addressed.

**VI. ATTACHMENTS**

1. LADoT fuel quality test results.
2. Working document that includes the LADoT safety inspection report.
3. Island Transit fuel quality test results.
4. Island Transit oily residue composition test results.