

## **Previous Relevant Experience**

The AVT team has led and successfully completed on time and on budget 14 (fourteen) CFD and risk assessment projects within 2002 – 2008 as summarized below:

Project Name / Customer / Project Dates	Main Project Objectives	Reference
CFD Modeling Of Hydrogen Releases And Dispersion Of Hydrogen Clouds In A Repair Garage	To model transient 3-D dispersion patterns of hydrogen emissions inside a repair garage under conditions specified by the customer.	Experied 20 Experied 20 Experience of hydrogen CFD Modeling Of Hydrogen Releases And Dispersion Of Hydrogen Clouds In A Repair Garage Faul Report to Toyota Motor Sales, USA, Inc.
Toyota Motor Sales, USA October 2002 –	To assess the effectiveness of specified ventilation system designs.	Statt Energy Reference # 1001305-4 Job # 8017 Toysta Order # 38316 STUART ENERGY SYSTEMS CORPORATION Prepared by: Andrei V. Tchouvelev, Ph. D. Vladmir Agranat, Ph. D. January 2003
January 2003	To educate local regulatory authorities in regards to hydrogen releases and to facilitate obtaining necessary approvals.	© Stant Energy Systems, 2002 CONVEDENTIAL
CFD Modeling Of Hydrogen Releases And Dispersion Of Hydrogen Clouds In a Generator Room and During Emergency Venting	To model transient 3-D dispersion patterns of hydrogen emissions inside a generator room and during emergency venting under conditions specified by design requirements.	<image/>
Stuart Energy / CKI, Hong Kong February – April	To assess the effectiveness of selected ventilation design in the generator room.	Beta Hydrogen Energy Station In Hong Kong (Tap Shek Kok GIC Plant) Stuart Energy Project Number # H034 H3PB5-Beta C&S STUART ENERGY SYSTEMS CORPORATION Prepared by: Andrei V. Tchouveley, Ph.D. Vladmir Agranat, Ph.D.
2003	To assess the effectiveness of selected hydrogen venting options outdoors. To educate local regulatory	February – April 2003 © Smar Energy Systems, 2003 CONTIDENTIAL
	authorities in Hong Kong in regards to hydrogen releases and to facilitate obtaining necessary approvals.	



CFD Modeling of Hydrogen Releases and Dispersion of Hydrogen Clouds in Toyota Technical Center Hot Room Toyota Technical Centre, USA May – July 2003	To model steady-state and transient 3-D dispersion patterns of hydrogen emissions inside a Toyota Technical Center (TTC) Hot Room under conditions specified by the customer. To recommend appropriate locations for hydrogen sensors inside the Hot Room, based on the above modeling results and specified conditions by the customer.	
CFD Modeling of Hydrogen Releases and Dispersion of Hydrogen Clouds in Alpha Hydrogen Backup Power Station	To model transient 3-D dispersion patterns of hydrogen emissions inside a generator room under selected failure conditions. To assess the effectiveness of selected hydrogen sensor	CFD Modeling of Hydrogen Releases and Dispersion of Hydrogen Clouds in Alpha Hydrogen Backup Power Station   Internal Report   Status Entry Zefarese + 2014
Stuart Energy internal study July – September 2003	To facilitate obtaining necessary approvals for Alpha H2BPS. facility.	Prepare By: Zhong Cheng, Ph.D. Vladimir Agmansi, Ph.D. Andrei V. Tchouvelev, Ph.D. September 2003
CFD Modeling of Hydrogen Leak and Dispersion during Failures of Portable Sodium-Boron- Hydride Cartridges Powering Laptops in a Commercial Office Millennium Cell, USA May 2004	To model steady-state 3-D dispersion patterns of hydrogen emissions during potential failure scenarios of portable sodium-boron-hydride cartridges powering laptops in a commercial office under conditions specified by the customer. To facilitate obtaining necessary approvals from authorities having jurisdiction.	<image/> <image/> <text><text><text><text><text><text><text><text><text><text><text></text></text></text></text></text></text></text></text></text></text></text>



Hydrogen	To develop sound scientific and	Final Report - Hydrogen Clearence Distances Project
Clearance	engineering specifications that can	
Distances	be used to specify quantitative	stuart 💱
	values for:	the power of hydrogen
Natural Resources	- Clearance distances for hydrogen	HYDROGEN CLEARANCE DISTANCES
Canada / Canadian	storage, production and handling	
Transportation	components in hydrogen energy	Final Report
Fuel Cell Alliance	systems;	Submitted to Natural Resources Canada Artas: Ian MacIntyye
	- Hazardous zone classifications;	Research Officer - Rydrogen and Electric Vehicles 580 Booth Street, 13 <sup>th</sup> Floor, Room, B5 Ortawa Ontario Canada KLA 0E4
October 2003 –	- Declassifying hazardous zones	for the
September 2004	with ventilation.	Codes and Standards Working Group Canadian Transportation Fuel Cell Alliance
September 2001	with ventilation.	(IIII)
	To provide clear guidelines for the	adding a
	use of these new specifications in	September 12, 2004
	-	OLDICARDER EN. 2007
	commercial applications.	© Steart Energy Systems Corp. Commercially Confidential
	To use the project date to develop	
	To use the project data to develop	
	scientifically based guidelines for	
	the Canadian Hydrogen Installation	
	Code and the Canadian Electrical	
	Code.	
CFD Validation,	To improve understanding of	Indikgun
Calibration and	hydrogen gas properties and its	A
Enhancement	dispersion during various type of	
Project	intended and unintended releases in	
	enclosed, semi-enclosed and	"CFD VALIDATION, CALIBRATION AND
Natural Resources	unenclosed environments.	ENHANCEMENT PROJECT" Final Technical Report
Canada / Canadian		Submitted to
Transportation	To assist an on-going codes and	Natural Resources Canada Mutt. Ian Machityre Research Officer - Rytorogen and Electric Vehicles 590 Boeth Street, 13 <sup>th</sup> Hone, Rosen, B25
Fuel Cell Alliance	standards development work for	Ottawa Ontario Canada KLA-8E4 for the
	hydrogen systems including	Codes and Standards Working Group Canadian Transportation Fuel Cell Alluance
June 2004 (started	establishment of ventilation	June 2005
under Stuart	requirements, clearance distances	21400 BOD 2
Energy) – May	and hazardous locations.	
2005 (renewed in		© A.V.Teknereley & Associates and HBI Commercially Coefficients
April 2005 under	To improve consequence analysis of	
A.V.Tchouvelev &	potential failure scenarios of	
Associates after	hydrogen containing equipment for a	
Stuart's acquisition	quantitative risk assessment.	
by Hydrogenics)		



		Page 1 of 2
CFD Modeling Of	To model transient hydrogen and	
Flame Propagation	oxygen stoicheometric mixture	
Inside Hydrogen Storage Piping	flame propagation inside hydrogen storage piping to simulate worst case	CFD Modeling of Flame Propagation Inside Hydrogen Storage Piping System
System	oxygen ingress into the storage	Final Report to <sup>1</sup>
-	system with consecutive mixture	Green Island International
Green Island	ignition.	Green Island International Order of 6-Sep-05 A.V.Tchouvelev & Associates Reference # 1110
	ignition.	A. V. Tchouvelev & Associates Inc.
International,		Prepared by:
Hong Kong	To prove simultaneous explosions of	Sergei Zhubrin, Ph.D. and
8	1 1	Zhong Cheng, Ph.D.
	storage vessels is not feasible.	Reviewed by: Vladimir Agranat, Ph.D.
September –		Approved by:
October 2005	To support Quantitative Risk	Andrei V. Tchouvelev, Ph.D.
	Assessment findings.	October 2005
		<sup>1</sup> This report cannot be distributed or reproduced in any way without permission from Green Juland International
	To facilitate obtaining necessary	© A.V. Tekenvalev & Associates Inc., October, 2005. CONFIDENTIAL
	approvals.	



CFD Modeling of Hydrogen Leak and Dispersion during Failures of Portable Sodium- Boron-Hydride Cartridges Powering Laptops in a Modern Passenger Aircraft	To model steady-state 3-D dispersion patterns of hydrogen emissions during potential failure scenarios of portable sodium-boron- hydride cartridges powering laptops in a modern passenger aircraft cabin under conditions specified by the customer. To facilitate obtaining necessary	  CFD Descrittion Descrittion   CFD Modeling of Hydrogen Leak and Dispersion during Failures of Portable Sodium-Boron-Hydride Cartridges Powering Laptops in a Modern Passenger Aircraft Cabin   Bara Reporter   Builennium Cell Onter of Do-Spot   Altennium Cell Onter of Do-Spot
Cabin	approvals from authorities having jurisdiction.	Reviewed by: Vladimir Agranat, Ph.D. Approved by:
Millennium Cell, USA		Andrei V. Tehouvelev, Ph.D. October 2005
October 2005		© A.V. Tchonvdev & Associates Inc., October, 2005 CONFIDENTIAL
CFD Modeling Of Hydrogen Releases From a Fuel Cell Vehicle And Hydrogen Dispersion Inside Underground Public Caragos	To model transient 3-D release and dispersion patterns of hydrogen emissions from a tailpipe of a fuel cell vehicle inside underground public garages under conditions specified by the customer.	CFD Modeling of Hydrogen Releases from a Fuel Cell Vehicle a Hydrogen Dispersion inside Underground Public Garages CFD Generation Control of Control of Cell Vehicle a Fuel Report to <sup>1</sup>
Public Garages Fuel Cells Canada	To assess the effectiveness of existing ventilation system designs. To educate local regulatory	Fuel Cells Canada Order of # FCC-VP-05-020 A.V.Tchourvelev & Associates Int: Reference # 1114 A. V. Tchouvelev Associates Inc. Prepared by: Zhong Chrmg. Ph.D.
January – March 2006	authorities in regards to hydrogen releases and to facilitate obtaining necessary approvals.	Reviewed by: Vladimir Agamat, Ph.D. Approved by: Ambrei V. Tchowsriev, Ph.D. March 2006 <sup>1</sup> Tais report cannot be distributed or reproduced in any way without permission from Fuel Cells Canada. C.A.V.Echawirder & Associates Page 1 of 27 Commercially Condition



To quantitatively compare risk from	Tinal Report
stand-out features of hydrogen and	
CNG refuelling technologies using	
e e	
To assist an on-going codes and	"QUANTITATIVE RISK COMPARISON OF HYDROGEN AND CNG REFUELLING
0 0	OPTIONS"
÷	NRCan Reference # CO414-CETC 502
nydrogen systems.	Final Technical Report
	Submitted to
1 11	Natural Resources Canada Attn: Ian MacIntyre
	Atta: la MaCahyre Hydrogen, Fuel Cells and Transportation Energy Bydrogen, Fuel Cells and Transportation Energy 589 Booth Strevet, 13 <sup>th</sup> Floor Ottawa, Ontario, Canada KLA 9E4
hydrogen systems.	for the Codes and Standards Working Group
	Codes and Standards working Group Canadian Transportation Fuel Cell Alliance
	March 2006
	CAV-Eduarder & Associates Commercially Confidential
To model transient 3-D dispersion	
	CFD Modeling of Hydrogen Release and
1 2 2	Dispersion from Ground Storage of the
••••	NextEnergy Center Refuelling Station Final Report to <sup>1</sup>
с с.	DMA Technical Services Inc
6	DMA Order of # 02-Jan-07
building within a State University.	A.V.Tchouvelev & Associates Inc. Refetence # 1121
To perform numerical simulations of	A. V. Tchouvelev Associates Inc.
1	Prepared by: Zhong Cheng, Pit D.
1	Reviewed by:
	Vladimir Agranat, Ph.D. Approved by:
jet.	Andrei V. Tchouvelev, Ph.D.
	February 2007
-	DRAFT
outcomes of a catastrophic loss of	DMA NEXTÉNERGY
containment at the ground storage	<sup>3</sup> This report cannot be distributed or reproduced in any way without permission from DMA.
piping manifold in order to develop	
solutions.	
	CNG refuelling technologies using CFD modeling tools. To assist an on-going codes and standards development work for hydrogen systems. To improve approach and methodology of risk analysis of hydrogen systems. To model transient 3-D dispersion patterns of the hydrogen emissions during release of hydrogen from the ground storage inside NextEnergy Refueling Station located close to a building within a State University. To perform numerical simulations of thermal effects from potential immediate ignition of the hydrogen jet. To demonstrate the potential outcomes of a catastrophic loss of containment at the ground storage piping manifold in order to develop risk mitigation engineering



CFD Modeling of	To model transient 3-D dispersion	A/T
Venting of	patterns of the hydrogen emissions,	
Hydrogen Ground	represented by a flammable (4 to	CFD Modeling of Venting of Hydrogen Ground Storage at NextEnergy Center
Storage at	75% vol.) $H_2$ cloud during release of	Final Report to <sup>1</sup>
NextEnergy Center	hydrogen from the vent stack in the	DMA Technical Services Inc
	event of venting of the ground	DMA Order of # 31-Jan-07
DMA Technical	storage at the NextEnergy Center	A.V.Tchouvelev & Associates Inc. Reference # 1121-2
Services /	located close to a building within a	A. V. Tchouvelev Associates Inc.
NextEnergy	State University.	Prepared by:
		Zhong Cheng, Ph.D., P.Eng, Reviewed by:
January – March	To perform numerical simulations of	Vladimir Agranat, Ph.D.
2007	thermal effects from potential	Approved by: Andrei V. Tchouvelev, Ph.D.
2007	immediate ignition of the hydrogen	March 2007
	jet.	DRAFT
	jet.	DMA NEXTÉNERGY
	To demonstrate the potential	<sup>1</sup> This report cannot be distributed or repreduced in any way without permission from DMA.
	outcome of the ground storage	
	venting.	
IEA HIA Task 19	To provide leadership in IEA HIA	Final Report (Journey - March 2008)
Hydrogen Safety	Task 19 Subtask A Risk	
and EU Network	Management as well as participate in	
of Excellence	other subtasks and manage Canadian	Powertech m
HySafe	contribution.	
		"SUPPORT OF IEA AND HYSAFE ACTIVITIES ON HYDROGEN SAFETY"
CTFCA / Natural	To participate in selected work	NRCan Reference # CO414-CETC 628
Resources Canada	packages on risk management and	Final Report <sup>1</sup>
Lesources Cunudu	CFD modeling of HySafe.	For the Period Between
July 2006 – March	or 2 modeling of Hybure.	January 1 and March 31, 2008
2008		
2000		
		<sup>1</sup> This report is prepared by A.V.Tohav-shee & Associates is consolitations with TDEC. HIS and Prevaresh Labo
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A.V.Tchouvelev & Associates has proven skills and experience to meet your needs.