GILLIG CORPORATION

BOX 3008
HAYWARD, CALIFORNIA
94540-3008
TELEPHONE 510/785-1500
FAX # 510/785-6819

June 23, 2004

Mr. Kenneth Weinstein
Associate Administration for Safety Assurance
National Highway Traffic Safety Administration
400 Seventh Street SW
Washington DC 20590

FAX 202-366-7882

04V-308
(29 pages)

Subject: 573 Defect Information Report
High Pressure Hydrogen Transducer Defect

Dear Mr. Weinstein:

Please find attached Gillig's 573 defect report on a potentially defective high pressure hydrogen transducer used on the fuel system of fuel cell powered buses. A single bus is involved.

Please contact me at 510-264-5031 if there are questions. Gillig intends to conduct the recall as soon as we have a recall number and an approved owner notification letter.

Sincerely,

GILLIG CORPORATION

Charles E. Kosko
Senior Vice President, Engineering

CEK/vo
Attachment

Cc: Mr. George Person, NHTSA
R. Birdwell

Form Approved: O.M.B. No. 2127-0004

Safety Defect and Noncompliance Report Guide for Vehicles
PART 573 Defect and Noncompliance Report[1]

On June 22nd, 2004, Gillig Corporation decided that a defect which relates to motor vehicle safety) exits in the motor vehicles listed below, and is furnishing notification to the National Highway Traffic Safety Administration in accordance with 49 CFR Part 573 Defect and Noncompliance Reports.

Date this report was prepared: June 23, 2004

Furnish the manufacturer's identification code for this recall (if applicable): N/A

1. Identify the full corporate name of the fabricating manufacturer of the vehicle being recalled. If the recalled vehicle is imported, provide the name and mailing address of the designated agent as prescribed by 49 U.S.C. §30164.

Gillig Corporation Hayward, California

Identify the corporate official, by name and title, whom the agency should contact with respect to this recall.

Charles E. Koske Sr. Vice President

Telephone Number: 510-264-5031 **Fax No.:** 510-264-3897

Name and Title of Person who prepared this report.

Charles E. Koske

Sr. Vice President

Signed: Charles E Koske

---

[1] Each manufacturer must furnish a report, to the Associate Administrator for Safety Assurance, for each defect or noncompliance condition which relates to motor vehicle safety.

This guide was developed from 49 CFR Part 573, "Defect and Noncompliance Reports" and also outlines information currently requested. Any questions, please consult the complete Part 573 or contact Mr. Jon White at (202) 366-5227 or by FAX at (202) 366-7882.

I. Identify the Vehicle Models Involved in the Recall

2. Identify the Vehicles Involved in the Recall, *for each make and model or applicable vehicle line (provide illustrations or photographs as necessary to describe the vehicle), provide:*

Make(s): Gillig Corp **Model Years Involved:** 2003-2004 **Model(s):** Low Floor

Production Dates: Beginning: 4/1/03 **Ending:** 6/10/04

VIN Range: Beginning: 15GGD281231073941, 15GGD281241073942, and 15GGD281441073943.

Vehicle Type: Bus **Bodystyle:** 40 foot Low Floor Transit

Note: Only 15GGD281231073941 has been delivered to a customer.

Descriptive information which characterizes/distinguishes the recalled vehicles from those model vehicles not included in the recall:

The three buses involved are powered by Ballard Fuel Cell Systems with gaseous hydrogen fuel systems.

Identify the approximate percentage of the production of all the recalled models manufactured by your company between the inclusive dates of manufacture provided above, that the recalled model population represents. For example, if the recall involved Widgets equipped with certain items of equipment from January 1, 1996 through April 1, 1997, then what was the percentage of the recalled Widgets of all Widgets manufactured during that time period.

100%

II. Identify the Recall Population

3. Furnish the total number of vehicles recalled potentially containing the defect or noncompliance.

Model	Year	Number of Vehicles Potentially Involved
Low Floor	2003	1
Low Floor	2004	2

Total Number Potentially Affected by the Recall: 3

4. Furnish the approximate percentage of the total number of vehicles estimated to actually contain the defect or noncompliance:

100%

Identify and describe how the recall population was determined--in particular how the recalled models were selected and the basis for the beginning and final dates of manufacture of the recalled vehicles:

All Ballard fuel cell equipped Gillig buses with gaseous hydrogen fuel system regardless of date of manufacture.

III. Describe the Defect or Noncompliance

5. Describe the defect or noncompliance. The description should address the nature and physical location of the defect or noncompliance. Illustrations should be provided as appropriate.

Gillig has no knowledge of the alleged defect. See the attached Texas Instruments 573 defect report for their explanation and expectation of a defect or failure characteristic. The transducers are located on the fuel cylinders which are roof mounted on the bus.

Gillig understands there has never been a failure of the transducer in testing or in the actual service. Gillig knows there have been no failures on any of the Gillig buses.

Describe the cause(s) of the defect or noncompliance condition.

Gillig has no knowledge of the cause of the alleged defect on the transducer. The alleged cause of defect is contained in the Texas Instruments form 573 report (attached) which claims a failure is possible due to hydrogen embrittlement characteristics of the base material used to in the manufacture of the part.

Describe the consequence(s) of the defect or noncompliance condition.

Texas Instruments claims in their 573 report (attached) that it could present a safety problem but they also claim to have no actual knowledge of the in-field potential consequences.

It is possible if the transducer failed it would lead to a high pressure hydrogen leak which potentially could lead to a vehicle fire.

Identify any warning which can (a) precede or (b) occur.

Gillig has no knowledge of any warning. Texas Instruments 573 report also claims no specific knowledge of a warning.

If the defect or noncompliance is in a component or assembly purchased from a supplier, identify the supplier by corporate name and address.

The transducer is manufactured in Japan and imported by Texas Instruments. It was sold to Dynetek of Canada who sells it as part of the hydrogen fuel storage system to Ballard Power Systems who sold the complete fuel cell system to Gillig Corp.

Ballard Power Systems

9000 Glenlyon Parkway

Burnaby BC

Canada V5J5G1

Identify the name and title of the chief executive officer or knowledgeable representative of the supplier:

_____Byron Somerville Bus Program Manager_____

IV. Provide the Chronology in Determining the Defect/Noncompliance

If the recall is for a defect, complete item 6, otherwise item 7.

6. With respect to a defect, furnish a chronological summary (including dates) of all the principle events that were the basis for the determination of the defect. The summary should include, but not be limited to, the number of reports, accidents, injuries, fatalities, and warranty claims.

7. With respect to a noncompliance, identify and provide the test results or other data (in chronological order and including dates) on which the noncompliance was determined.

On June 1, 2004 Gillig became aware of a number of e-mails sent late Friday May 29, 2004 and over the Memorial day weekend by Ballard Power Systems concerning the high pressure hydrogen pressure transducer. The initial e-mail dated May 28, 2004 requested buses not be operated until Ballard reviews the situation. On June 1, 2004 Gillig reviewed Ballard's assessment which was at odds with Texas Instruments conclusion and based on specific tests of the subject transducer and several years of successful usage. Via the press Gillig learned that Toyota and GM grounded their vehicles with the suspect pressure transducer while Ford and DaimlerChrysler continued to operate their fuel cell vehicles.

Gillig became aware on June 1, 2004 that the Texas Instruments Recall 04E-037 was posted on NHTSA's website and then removed. Gillig obtained a copy of the Texas Instruments recall from Ballard. In discussions with NHTSA Gillig was told NHTSA preferred the vehicle manufacturer conduct the recall.

Gillig knows of no warranty claims, part failures outside of warranty, accidents, injuries or fatalities related to this pressure transducer.

On June 22, 2004 Gillig reviewed the situation with Ballard. Texas Instruments has never notified their direct customers of the recall. However, they will be making a replacement part available. In the interest of public safety and consumer confidence in fuel cell vehicle technology Gillig decided to recall the questionable part.

V. Identify the Remedy

8. Furnish a description of the manufacturer's remedy for the defect or noncompliance. Clearly describe the differences between the recall condition and the remedy.

Replace the potentially defective transducer (TI part number100HP8-4) with a replacement part manufactured from a different material per Texas Instruments form 573 (TI part number 3PP8-10).

Clearly describe the distinguishing characteristics of the remedy component/assembly versus the recalled component/assembly.

The old transducer (TI part number 100HP8-4) was a multi-piece welded unit with broad wrench flats below the body of the transducer – it appears to be made from bright metal. The new part has the wrench flats on the body of the transducer and the base material has a dull finish.

Identify and describe how and when the recall condition was corrected in production. If the production remedy was identical to the recall remedy in the field, so state. If the product was discontinued, so state.

Production remedy is the same as the field recall.

VI. Identify the Recall Schedule

Furnish a schedule or agenda (with specific dates) for notification to other manufacturers, dealers/retailers, and purchasers. Please, identify any foreseeable problems with implementing the recall.

Gillig plans to issue a recall letter within one week from the time we receive NHTSA's response to this 573 report and they assign a recall number. We will fax a draft copy of recall communication for NHTSA's review during that one week. A limited number of replacement parts are available and the recall on the single bus will be completed as soon as the customer makes the bus available for repair. The bus has not been operated since May 29th.

VII. Furnish Recall Communications

9. Furnish a final copy of all notices, bulletins, and other communications that relate directly to the defect or noncompliance and which are sent to more than one manufacturer, distributor, or purchaser. This includes all communications (including both original and follow-up) concerning this recall from the time your company

determines the defect or noncompliance condition on, not just the initial notification. ***A DRAFT copy of the notification documents should be submitted to this office by Fax (202-366-7882) for review prior to mailing.***

Note that these documents are to be submitted separately from those provided in accordance with Part 573.6 requirements.

The Privacy Act of 1974 - Public Law 93-579, As Amended: This information is requested pursuant to the authority vested in the National Highway Traffic Safety Act and subsequent amendments. You are under no obligation to respond to this questionnaire. Your response maybe used to assist the NHTSA in determining whether a manufacturer should take appropriate action to correct a safety defect. If the NHTSA proceeds with administration enforcement or litigation against a manufacturer, your response, or statistical summary thereof, may be used in support of the agency's action

STEPTOE & JOHNSON LLP

ATTORNEYS AT LAW

096-037

David H. Coburn
202.429.8065
dcoburn@steptoe.com

1330 Connecticut Avenue, NW
Washington, DC 20036-1795
Tel 202.429.3000
Fax 202.429.3902
steptoe.com

May 17, 2004

Mr. Kenneth Weinstein
Associate Administrator for Safety Assurance
National Highway Traffic Safety Administration
400 Seventh Street, SW
Washington, DC 20590

Re: Part 573 Filing of Texas Instruments, Inc.

Dear Mr. Weinstein:

Please find enclosed a Part 573 Defect and Noncompliance Report on behalf of Texas Instruments, Inc. ("TI") concerning pressure transducers installed on hydrogen fuel cell vehicles. The filing contains the Part 573 Report, a spreadsheet showing the specific equipment at issue (including part numbers specific to each customer/purchaser), a summary of a test report prepared for TI concerning these transducers, TI's draft Part 577 notification letter to its customers and a sample of a letter TI previously sent out to its customers concerning this matter. As discussed recently with Ms. Kelly Schuler of your office, these transducers were sold to entities that have used them in experimental hydrogen fuel cell vehicles. Some of these vehicles, we understand, are registered for use on public highways. None of these transducers were sold by TI directly to consumers for such vehicles and the vehicles on which they were installed are not generally available for purchase by consumers.

We look forward to speaking with you or your colleagues about this matter. Please contact me at the above number to discuss any questions or concerns you might have.

Sincerely,

David H. Coburn
Attorney for Texas Instruments, Inc.

cc: Ms. Kelly Schuler, NHTSA
Steven P. Reynolds, Esq.

Enclosures

Safety Defect and Noncompliance Report Guide for Equipment
PART 573 Defect and Noncompliance Responsibility and Reports[1]

On May 4, 2004, Texas Instruments Incorporated, Sensors and Controls business decided that a defect which relates to motor vehicle safety exists in items of motor vehicle equipment listed below, and is furnishing notification to the National Highway Traffic Safety Administration in accordance with 49 CFR Part 573 Defect and Noncompliance Responsibility and Reports.

Date this report was prepared: May 14, 2004

Furnish the manufacturer's identification code for this recall (if applicable): N/A

1. Identify the full corporate name of the fabricating manufacturer/brand name/trademark owner of the recalled item of equipment. If the recalled item of equipment is imported, provide the name and mailing address of the designated agent as prescribed by 49 U.S.C. §30164.

Texas Instruments Incorporated - Importer

NKS (Nanmoo Keiki Co. Ltd.) - Fabricating Manufacturer - See Answer to Question #5

Identify the corporate official, by name and title, whom the agency should contact with respect to this recall.

Steven P. Reynolds, Senior Counsel, Law Department

Telephone Number: 508 236 3245 Fax No.: 508 236 1960

Email - s-reynolds1@ti.com

Name and Title of Person who prepared this report.

Steven P. Reynolds, Senior Counsel, Law Department

Signed: Steven P. Reynolds

[1] Each manufacturer must furnish a report, to the Associate Administrator for Enforcement, for each defect or noncompliance condition which relates to motor vehicle safety.

This guide was developed from 49 CFR Part 573, "Defect and Noncompliance Responsibility and Reports" and also outlines information currently requested. Any questions, please consult the complete Part 573 or contact Mr. George Person at (202) 366-5210 or by FAX at (202) 366-7882.

I. Identify the Recalled Items of Equipment

2. Identify the Items of Equipment involved in this Recall, *for each make and model or applicable item of equipment product line (provide illustrations or photographs as necessary to describe the item of equipment), provide:*
Pressure transducer. See attached document listing various information, including part numbers, quantities and customers.

Generic name of the item:

Make: _____ **Model:**

Part Number: _____ **Size:**

Function:

Other information which characterizes/distinguishes the items of equipment to be recalled:
The communication involves only the parts identified above that are used in high pressure hydrogen radiation environments.

Identify the approximate percentage of the production of all the recalled models manufactured by your company between the inclusive dates of manufacture provided above, that the recalled model population represents. For example, if the recall involved Widgets equipped with certain items of equipment from January 1, 1996, through April 1, 1997, then what was the percentage of the recalled Widgets of all Widgets manufactured during that time period. N/A

II. Identifying the Recall Population

3. Furnish the total number of items of equipment recalled potentially containing the defect or noncompliance.

Model	Year	Number of Items Potentially Involved

TI sold 2,766 units of the transducer to eleven (11) customers that we believe use the transducer in a high pressure hydrogen application environment. It is our belief that two (2) of these customers, who are responsible for 97% of the purchases, are working with

customers such as Honda, Hyundai and Daimler Chrysler on fuel cell cars in California, Japan, Korea and Germany and fuel cell buses in California, with the other nine (9) using the product in demonstration vehicles located at their company premises in US and Canada. We do not have information on the number or type of vehicles.

Total Number Potentially Affected by the Recall: 2765 units

4. Furnish the approximate percentage of the total number of items of equipment estimated to actually contain the defect or noncompliance: 100% of transducers in high-pressure hydrogen applications.

Identify and describe how the recall population was determined--in particular how the recalled models were selected and the basis for the beginning and final dates of manufacture of the recalled items of equipment:

Communication involves only those transducers used by customers in high pressure hydrogen application environments. Transducers of the same type used by customers in non high-pressure hydrogen applications are not impacted.

III. Describe the Defect or Noncompliance

5. Describe the defect or noncompliance. The description should address the nature and physical location of the defect or noncompliance. Illustrations should be provided as appropriate.

Third party testing contracted by TI indicates that the diaphragm component of the transducer, which is made of 17-4 PH Stainless Steel material, may be susceptible to embrittlement in a high pressure hydrogen sulfide environment. See attached report which has been provided to customers. The defect in question is one of application and not one inherent in the nature of the material or caused by production issues. The testing conducted may or may not be representative of actual performance of the transducer in specific applications.

Describe the cause(s) of the defect or noncompliance condition.

See the attached report.

Describe the consequence(s) of the defect or noncompliance condition.

TI has no actual knowledge of the in-application, in-field potential consequences which may differ depending on the specific customer application. Embrittlement could potentially lead to transducer diaphragm failure, which could present a safety problem.

Identify any warning which can (a) precede or (b) occur.

TI has no specific knowledge as to in-application conditions.

If the defect or noncompliance is in a component or assembly purchased from a supplier, identify the supplier by corporate name and address.

The transducer sensing element is designed and manufactured by NKS (Nagano Keiki Co. Ltd.), 1-30-4, Higashimagome, Ohta-Ku, Tokyo, Japan. TI purchases the transducer in a private label arrangement from ADZ Nagano GmbH, Gewerbestraße 28/Gewerbegebiet, 01109 Dresden, Germany.

Identify the name and title of the chief executive officer or knowledgeable representative of the supplier:
Reinhard Hegewald, Leiter Hochvakuumentwicklung, ADZ Nagano GmbH

IV. Provide the Chronology in Determining the Defect/Noncompliance

If the recall is for a defect, complete item 6, otherwise item 7.

6. With respect to a defect, furnish a chronological summary (including dates) of all the principle events that were the basis for the determination of the defect. The summary should include, but not be limited to, the number of reports, accidents, injuries, fatalities, and warranty claims.

7. With respect to a noncompliance, identify and provide the test results or other data (in chronological order and including dates) on which the noncompliance was determined.

6. To TI's knowledge, there have been no reports, accidents, injuries, fatalities or warranty claims related to the transducer in a high pressure hydrogen application environment. Beginning in 2002, TI became aware of industry data which raised potential concerns about various materials in high pressure hydrogen application environments. TI shared these concerns with customers and decided to contract with NASA Huntsville to have the diaphragm material, and some alternative materials, tested to determine suitability to a high pressure hydrogen environment. See attached report. Based on that report, TI is proactively engaging with customers to inform them of the results and recommend that the transducers be replaced in the applications. The testing conducted may or may not be representative of actual performance of the transducer in specific applications.

V. Identify the Remedy

8. A description of the manufacturer's program for remedying the defect or noncompliance. This program shall include a plan for reimbursing an owner or purchaser who incurred costs to obtain a remedy for the problem addressed by the recall within a reasonable time in advance of the manufacturer's notification of owners, purchasers and dealers, in accordance with §573.13 of this part. A manufacturer's plan may incorporate by reference a general reimbursement plan it previously submitted to NHTSA, together with information specific to the individual

recall. Information required by §573.13 that is not in a general reimbursement plan shall be submitted in the manufacturer's report to NHTSA under this section. If a manufacturer submits one or more general reimbursement plans, the manufacturer shall update each plan every two years, in accordance with §573.13. The manufacturer's remedy program and reimbursement plans will be available for inspection by the public at NHTSA headquarters.

TI has and will continue to notify customers and then work with each of the customers to determine a proper corrective action, which may differ according to their specific application. We have offered a replacement transducer made with a diaphragm material that the third party testing has recommended as better suited to the environment. We will provide the replacement transducer free of charge to all customers who want it.

9. Furnish a description of the manufacturer's remedy for the defect or noncompliance. Clearly describe the differences between the recall condition and the remedy.

Remedy may be application-specific and, as noted, we will work with each of our customers to replace the transducer free of charge.

Clearly describe the distinguishing characteristics of the remedy component/assembly versus the recalled component/assembly.

The replacement transducer contains different diaphragm material.

Identify and describe how and when the recall condition was corrected in production. If the production remedy was identical to the recall remedy in the field, so state. If the product was discontinued, so state.

TI will no longer sell the transducer with 17-4PH stainless steel diaphragm material to customers using the transducer in high pressure hydrocarbon environments unless those customers reasonably believe that there is no safety risk in their specific application. TI will offer an alternative transducer using a different diaphragm material.

VI. Identify the Recall Schedule

10. Furnish a schedule or agenda (with specific dates) for notification to other manufacturers, dealers/retailers, and purchasers. Please, identify any foreseeable problems with implementing the recall.

TI first informed its customers on May 7, 2004. See attached communications. Additional communications are also attached. TI plans to follow-up and work with each of these customers.

VII. Furnish Recall Communications

11. Furnish a final copy of all notices, bulletins, and other communications that relate directly to the defect or noncompliance and which are sent to more than one manufacturer, distributor, or purchaser. This includes all communications (including both original and follow-up) concerning this recall from the time your company determines the defect or noncompliance condition on, not just the initial notification. *A DRAFT copy of the notification documents should be submitted to this office by Fax (202-366-7882) for review prior to mailing.*

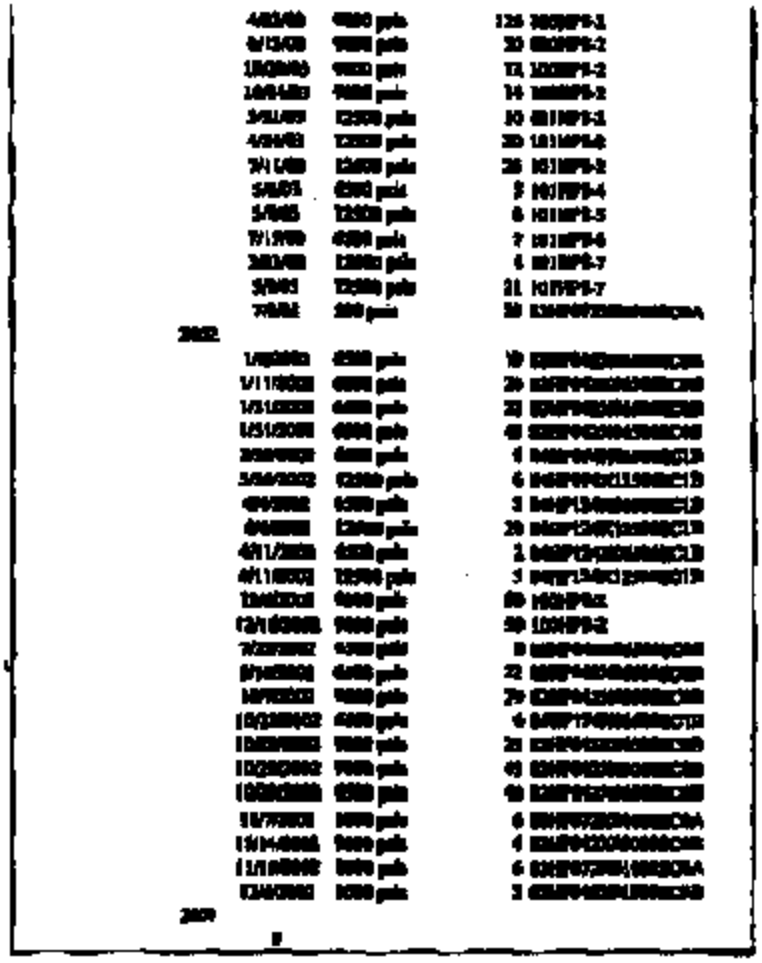
Note: These documents are to be submitted separately from those provided in accordance with Part 573.6 requirements.

See attached May 7, 2004 communication, including third party test report, and all subsequent communications.

LIST OF ENTITIES THAT PURCHASED THE PRESSURE TRANSDUCER AND PART NUMBERS

Customer	Ship date	Percent range	Qty	Pin
[redacted]				
BALLARD				
	2004			
		4/28/04	200 psig	5 [redacted]
		[redacted]		
	2003			
		1/10/03	200 psig	23 [redacted]
		4/28/03	200 psig	5 [redacted]
		7/14/03	200 psig	3 [redacted]
		9/5/03	200 psig	3 [redacted]
		10/17/03	200 psig	4 [redacted]
	2002			
		3/13/2002	200 psig	2 [redacted]
	2001			
		D		
CELLEX POWER				
	2004			
		[redacted]		
	2003			
		D		
	2000			
		5/5/2000	200 psig	1 [redacted]
		10/4/2000	2000 psig	2 [redacted]
		10/4/2000	4500 psig	4 [redacted]
	2001			
		D		
GM				
	2004			
		3/2/04	12000 psig	3 [redacted]
		4/28/04	12000 psig	1 [redacted]
	2003			
		12/3/03	4500 psig	2 [redacted]
		5/2003	4500 psig	5 [redacted]
		1/2003	4500 psig	1 [redacted]
		6/03	10000 psig	1 [redacted]
		12/5/03	10000 psig	1 [redacted]
	2002			
		10/1/2002	10000psig	3 [redacted]
	2001			
		D		
HONDA				
	2004			
		1/2/04	4500psig	16 [redacted]
		3/10/04	4500 psig	49 [redacted]
		[redacted]		
	2003			
		1/2/03	4500 psig	169 [redacted]
		7/24/03	4500 psig	35 [redacted]
		11/4/03	4500 psig	39 [redacted]
		11/7/03	4500 psig	84 [redacted]
		9/3/03	20 bar	20 [redacted]
		4/9/03	4500 psig	178 [redacted]
		6/9/03	4500 psig	5 [redacted]
		4/8/03	4500 psig	169 [redacted]
		2/14/03	20 bar	168 [redacted]
		3/27/03	20 bar	20 [redacted]
		3/27/03	20 bar	60 [redacted]
		9/9/03	4500 psig	14 [redacted]
	2002			
		1/9/2002	20 bar	18 [redacted]
		7/8/2002	20 bar	20 [redacted]

[redacted]



Device: GEN	Title: High Pressure Hydrogen Compatibility Summary Test Report	Rev: C	1002606
Proj: 3514			

1.0. OBJECTIVE:

The objective of this testing was to evaluate the behavior of four metal types when exposed to a high pressure hydrogen environment in order to judge their suitability for use as pressure port materials in hydrogen applications. The metals investigated were:

1.1. 17-4 PH stainless steel: A precipitation hardenable stainless steel that is a material commonly used in high pressure, hermetic pressure transducers

1.2. UNS G43400: A low alloy steel that has a low resistance to high pressure hydrogen exposure. This material was used as a control during the test.

1.3. AISI S31603 (316L): A low carbon, austenitic stainless steel reported to provide good resistance to hydrogen embrittlement. It also is commonly used in the fabrication of pressure transducers serving the hydrogen market.

1.4. Alternate Material (Alt): This metal has been targeted as the replacement material for 17-4 PH hermetic pressure transducers produced by Texas Instruments to serve the high pressure hydrogen market.

2.0. SUMMARY:

Eight standard notched tensile specimens were manufactured from each material as called out in ASTM G 142 – 98. Half of each group was pulled to failure at room temperature and in an air atmosphere and the ultimate tensile strength was determined. The second group of four parts for each material was soaked at room temperature for a period of 1 hour in hydrogen at 9000 psig while experiencing a static tensile stress, after which they were pulled at a constant rate until failure. The application of the failure load was applied while the samples were in a 9000 psig hydrogen atmosphere. The ratio of the notched tensile strength in hydrogen over the notched tensile strength in air reflects the material sensitivity to environmental assisted cracking per ASTM Practice G 129, section 11.1.4. Notch tensile strength ratios whose values are less than unity indicate susceptibility to environmentally assisted cracking; the lower the value, the greater the degree of susceptibility.

Testing was performed at the Marshall Space Flight Center (MSFC), Huntsville, Al in March of 2004.

REV	C	08/06/2004	Revised section 8.0 and section 3.0.	CR
Distribution				

By:	M. McGrevin	TEXAS INSTRUMENTS Sensor and Controls Div. Attleboro MA 02703	Size: A	Dwg. No.: 1002606
Eng.:	M. McGrevin			Page 1 of 7
Appr:				
Appr:				Code Ident No.82547

3.0. BACKGROUND:

The intent of the testing selected was to gather data on material behavior divorced from specific design parameters unique to various configurations of pressure transducers. As the applications of interest involve measurement of pressure in a variety of high pressure hydrogen storage containers, the most reasonable test condition was determined to be performing tensile pull tests after some degree of pretest saturation had occurred and while the samples were still exposed to a high pressure hydrogen environment. The selection of notched specimens reflects the fact that machined ports generally have some level of micro-fracturing introduced during the manufacturing process, leading one to conclude that the behavior of a notched specimen would reasonably reflect the behavior of a machined part.

4.0. PROCEDURES:

4.1. Applicable Documents:

4.1.1. ASTM G 142-98: Standard Test Method for Determination of Susceptibility of Metals to Embrittlement in Hydrogen Containing Environments at High Pressure, High Temperature or Both.

4.1.2. ASTM E 8-01: Test Methods for Tension Testing Metallic Materials.

4.1.3. ASTM G 129-00: Standard Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking

4.1.4. Texas Instruments, Inc drawing, EX3514-303, Hydrogen Embrittlement Notched Tensile Test specimen

4.1. Summary of Test Method:

A total of 32 tensile specimens were exposed to the pressure / tensile pull schedule shown in Appendix 1. For each type of material, eight notched standard test specimens were fabricated per the requirements shown in Appendix 2. The heat treat schedule for the elements material has been intentionally omitted. Four specimens of each material were subjected to a static axial force creating a tensile stress at the notched region equivalent to approximately 10% of the material's nominal unnotched ultimate tensile strength and subjected to one hour of constant exposure to 9000 psig hydrogen gas at room temperature. The hydrogen gas was sampled to be >99.995% pure both before and

after testing. At the conclusion of one hour of constant exposure, each specimen was subjected to a constant extension rate of 0.02mm/s +/-10% until the samples fractured while remaining in 9000 psig hydrogen gas. Ultimate tensile strength at break was determined by dividing the force applied at break by the associated normal area of the specimen notch. The diameter of the notch was independently measured on each sample to accurately determine the area.

A second set of four samples of each material was exposed to standard tensile pull test in air at room temperature and pressure. The test method was the same as that used when testing was performed in hydrogen, except that no pre-test static force was applied.

5.0. RESULTS:

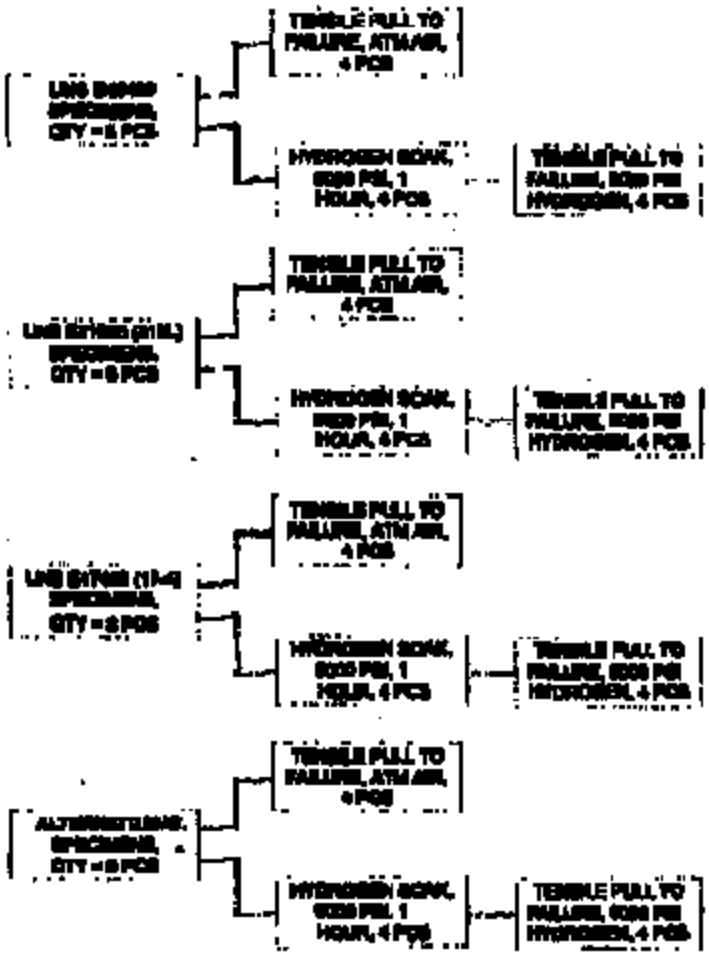
The test results are shown in Appendix 3. The minimum notched tensile strength ratios were computed by dividing the minimum ultimate tensile strength value of the four samples tested in hydrogen by the maximum ultimate tensile strength value found for the corresponding four samples tested in air. MSFC considers a ratio swing up to +/-0.12 away from unity to indicate no significant change in strength.

The control samples made from G4340 steel showed an expected susceptibility to high pressure hydrogen. 17-4PH also showed a significant degree of susceptibility. One sample out of four 316L specimens showed some level of sensitivity while the alternate material showed no significant change in strength between air and high pressure hydrogen.

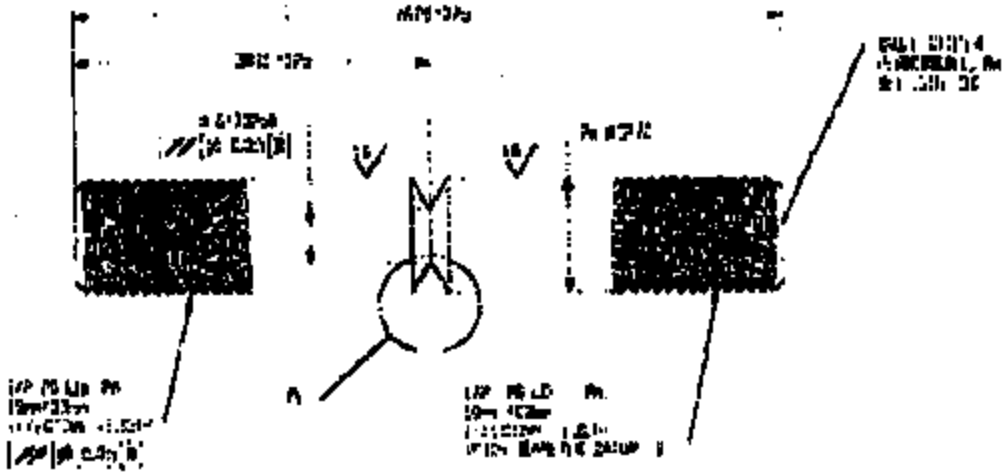
6.0. RECOMMENDATIONS / CONCLUSIONS:

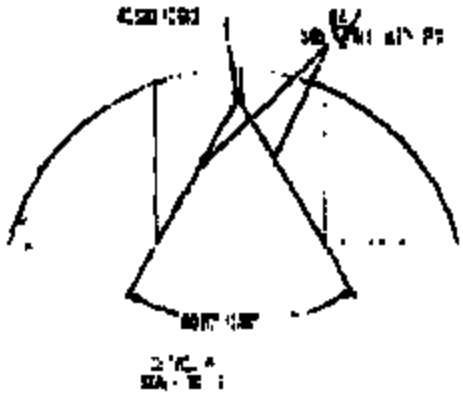
On the basis of these results, the alternate material is the best of the materials tested in a high pressure hydrogen environment. 316L showed a degree of sensitivity to high pressure hydrogen indicating that testing in specific hydrogen environments for suitability is warranted. The data strongly indicates that the strength of 17-4 PH and G4340 is substantially reduced in a high pressure hydrogen environment and that these materials should be replaced with an alternate material.

APPENDIX 1: TEST SEQUENCE



APPENDIX 2: NOTCHED TEST SPECIMENS





APPENDIX 2: NOTCHED TEST SPECIMENS, CONTINUED

NOTES:

1.0. MATERIAL AND POST MACHINING HEAT TREAT PER DASH TABLE.

2.0. SURFACE TO BE FINAL MACHINED USING GRINDING TO AVOID LOCALIZED GROOVES AND COLD WORK AREAS. TOTAL METAL REMOVEL IN THE LAST 2 PASSES SHALL BE LIMITED TO A TOTAL OF 0.05mm AND HAVE A SURFACE FINISH OF 0.4µm OR BETTER.

3.0. FINISHED PARTS SHALL BE BAGGED OR TAGGED WITH PART NUMBER. MATERIAL AND HEAT TREAT CERTIFICATIONS ARE REQUIRED. COLOR CODING ON FACES SHOWN ACCEPTABLE TO IDENTIFY MATERIAL.

4.0. SPECIMENS FABRICATED FROM UNS G43400 SHALL BE PACKAGED TO PREVENT RUST AND CORROSION. ALL MATERIALS TO BE PACKAGED TO PROTECT SURFACE FINISH.

5.0. UNLESS OTHERWISE SPECIFIED, ALL DIMENSIONS AND SURFACE FINISHES ARE METRIC.

	MATERIAL	POST MACHINE HEAT TREAT
[illegible]	LOW ALLOY STEEL, UNS G43400	AUSTENITIZE AT 830°C FOR 1 HR PLUS WATER QUENCH AND TEMPER AT 480°C FOR 2 HRS
[illegible]	STAINLESS STEEL UNS S31653 (316L)	HEAT TO 1040 -1120°C FOR 1 HR PLUS WATER QUENCH
[illegible]	STAINLESS STEEL UNS S17400, (17-4PH, TYPE [illegible]	HEAT AT 480°C FOR 1 HR AND AIR COOL
[illegible]	ALTERNATE MATERIAL	

APPENDIX 3: HIGH PRESSURE HYDROGEN TEST RESULTS

MATERIAL	MEDIA	PRESSURE psig	TEMP. F	ULTIMATE LOAD lbs	INITIAL AREA in²	MEASURED UTS ksi	NOTCH TENSILE STRENGTH RATIO
G 4340 steel	Air	Amb	RT	11580	0.053	218.7	0.14
G 4340 steel	Air	Amb	RT	11480	0.053	217.9	
G 4340 steel	Air	Amb	RT	11480	0.053	217.9	
G 4340 steel	Air	Amb	RT	11580	0.053	218.0	
G 4340 steel	GH2	5,000	RT	3618	0.039	68.5	
G 4340 steel	GH2	5,000	RT	1760	0.039	33.2	
G 4340 steel	GH2	5,000	RT	1795	0.039	33.3	
G 4340 steel	GH2	5,000	RT	1668	0.039	31.4	
316 SS	Air	Amb	RT	5380	0.053	101.3	0.02
316 SS	Air	Amb	RT	5370	0.053	100.0	
316 SS	Air	Amb	RT	5442	0.053	102.7	
316 SS	Air	Amb	RT	5468	0.053	102.8	
316 SS	GH2	5,000	RT	4725	0.053	91.1	
316 SS	GH2	5,000	RT	5400	0.053	94.8	
316 SS	GH2	5,000	RT	4700	0.044	105.7	
316 SS	GH2	5,000	RT	4610	0.044	95.7	
17-4	Air	Amb	RT	14601	0.053	275.0	0.18
17-4	Air	Amb	RT	14798	0.053	294.9	
17-4	Air	Amb	RT	14480	0.053	276.9	
17-4	Air	Amb	RT	14810	0.053	281.9	
17-4	GH2	5,000	RT	3488	0.045	77.5	
17-4	GH2	5,000	RT	3480	0.044	85.2	
17-4	GH2	5,000	RT	2776	0.045	61.1	
17-4	GH2	5,000	RT	3120	0.045	69.7	
ALTERNATE MATERIAL	Air	Amb	RT	11170	0.053	214.0	1.12
ALTERNATE MATERIAL	Air	Amb	RT	11480	0.053	218.1	
ALTERNATE MATERIAL	Air	Amb	RT	11500	0.053	218.3	
ALTERNATE MATERIAL	Air	Amb	RT	11380	0.053	218.8	
ALTERNATE MATERIAL	GH2	5,000	RT	11198	0.045	247.7	
ALTERNATE MATERIAL	GH2	5,000	RT	10800	0.042	255.0	
ALTERNATE MATERIAL	GH2	5,000	RT	10680	0.045	248.2	
ALTERNATE MATERIAL	GH2	5,000	RT	11580	0.044	257.4	

Texas Instruments Incorporated
Sensors & Controls

TEXAS INSTRUMENTS

34 Forest Street
P.O. Box 2909
Attleboro, MA 02703-0909

(508) 236-3800

May 6, 2004

Mr. Ajit Ala
Quantum Technologies, Inc.
17872 Cartwright Road
Irvine, CA 92614

Dear Ajit,

SUBJECT: TI PRESSURE TRANSDUCERS IN HYDROGEN ENVIRONMENT

This letter is a follow up to both written and verbal communications that we have had over the last two (2) years regarding the compatibility of 17-4PH Stainless Steel TI Pressure Transducers with a Hydrogen environment.

Recent TI testing performed at NASA - Marshall Space Flight Center (MSFC) shows that the strength of 17-4PH Stainless Steel is substantially reduced in a high pressure Hydrogen environment per the test criteria documented in our test report. The detailed test report is attached for your review. Please recognize that our data is based on specific test parameters that may or may not be representative of your own application. Based on this test data, as the diaphragm of the 'HP' family of pressure transducers you have procured from TI is made from 17-4PH Stainless Steel, we strongly recommend that you replace these with an alternate material transducer that demonstrates more robust strength characteristics in this type of environment.

Approximately two years ago TI identified and shared with you industry data indicating the susceptibility of 17-4PH Stainless Steel to Hydrogen embrittlement. At that time, we informed you that TI had little experience with Hydrogen pressure applications and that we had never (and to date have still never) observed a TI product failure related to this failure mode. We communicated to you that we were initiating our own evaluations to assess the performance of 17-4PH Stainless Steel in a Hydrogen environment in addition to investing in a search for a robust material suitable for pressure transducer construction and use in high pressure Hydrogen environments. We have now reached decision points on both of these items. As a result of the TI specific material testing that has recently been completed, it is our strong recommendation that devices using 17-4PH Stainless Steel be replaced. Further, we have identified an alternate material, per our test criteria, whose strength is not adversely affected by exposure to high pressure Hydrogen.

I will contact you shortly so that we can discuss an appropriate strategy to address the TI product that you have in service or inventory for these Hydrogen applications.

Sincerely,

Gregg W. Peterson
Marketing Program Manager
Texas Instruments Incorporated
Industrial Sensors

Cc: Roger Mountford, TI - Redmond, WA
Marty McGinnes, TI - Attleboro, MA
Matt Hickenbottom, Semmartek, Costa Mesa, CA

Enclosure