APPENDIX H

PRESSURE TRANSDUCER AGING REPORT

GENERAL ELECTRIC
SPACE DIVISION
PHILADELPHIA

PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	1B50	CAMS	235	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FM Jerry D. Fuller, Project Engineer
Analyzer Programs
Room U-3035 - Ext. 2518

TO E.J. Savitsky, Manager
Analyzer Programs
Room U-3035 - Ext. 2956

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
10/2/80		2F3	

SUBJECT

ACCELERATED LIFE TEST REPORT - CEC-1000 PRESSURE TRANSDUCER

INFORMATION REQUESTED/RELEASED

The aging procedure defined in PIR 1B90-CAMS-205 was completed on CEC Pressure Transducer Part Number 1000-173, S/N 4240.

RESULTS

- Overall worse case change in performance occurred at 350°F and was a zero shift of -.413% of Full Scale.
- Unit aging is unnecessary since pressure transducer contains no age sensitive materials.
- Aging test served to increase confidence in component reliability.

SPECIMEN

The specimen included CEC Transducer S/N 4240, (see Attachment 1) mating connector P/N 17020 and ~50 feet of cable fabricated from Raychem Spec. 44 twisted shielded pair.

DISCUSSION

Log of key test activity is summarized in Table 1 and followed by a brief description of each.

TABLE 1

TEST LOG

ACTIVITY	LOCATION	DATE
Acceptance Test Procedure Dated 7/7/77	CEC	4/9/79
Accelerated Life Environment	GE-SD	8/ 2/79 to 8/17/79
Radiation Exposure	Isomedix, Inc.	9/79
Seismic Event	Acton, Acton, Mass.	10/79
Acceptance Test Procedure Dated 7/7/77	CEC	3/2/80

SO# 50-17-18-0

L. Heverly
F. DiSanto
E. Savitsky
J. Murphy
J. Fuller
E. Wong (CEC)
J. Ashly (CEC)

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Pre and Post Performance Tests

Both tests were performed at CEC to the 1000-04 (173) Acceptance Test Procedure dated 7/7/77 modified to include the linearity and hysteresis run at 250°F. Results were excellent with maximum deviation occurring at 350°F as a zero shift of -.413% of full range relative to the 4/9/79 test. The CEC calibration data summary is included with this report as Attachment 2.

Accelerated Life Environment, PIR 1B90-CAMS-205

To verify the long term operation requirements, the pressure transducer was subjected to the procedure presented in Attachment 3. The aging of the pressure transducer was performed by using present state-of-the-art aging technology. This technology allows acceleration of the time/temperature aging effects artificially by increasing the temperature. The pressure transducer contains both metallic and non-metallic components. The deterioration due to aging effects on the metallic components is judged to be insignificant. The aging of the pressure transducer was therefore based on its non-metallic materials only.

It is known for many non-metallic materials, that the degradation process can be defined by a single temperature-dependent reaction that follows the Arrhenius equation:

$$k = A\, e^{-\frac{Ea}{k_B T}} \qquad (1)$$

where,

k = reaction rate

A = frequency factor

Ea = activation energy

k_B = Boltzmann's Constant (8.617×10^{-5} eV/°K)

T = absolute temperature

It is further noted that, for many reactions, the activation energy can be considered to be constant over the applicable temperature range. Equation (1) can be transformed into a form which yields an acceleration factor to define a given amount of thermal degradation. The form is:

$$t_1/t_2 = e^{\frac{Ea}{k_B}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)} \qquad (2)$$

where,

t_1 = accelerated aging time at temperature T_1

t_2 = normal service time at temperature T_2

T_1 = accelerated temperature T_1 (°K)

T_2 = normal service temperature T_2 (°K)

Equation (2) can be used to derive the accelerated aging times for materials with known activation energies.

Normal operating temperature for the transducer is 120°F. The transducer was operated for 14 days at 300°F as presented in Table 2. From equation (2), this would age to greater than 40 years any material with an activation energy less than .81 eV. This would include most organic materials.

Aging Analysis

Table 3 describes the non-metallics in the pressure transducer. Both materials are included in the following list of materials that are considered to not have significant aging characteristics:

> Silicon semi-conductors, resistors; tantalum dry electrolytic capacitors; ceramic capacitors; dry paper and plastic film capacitors; mica capacitors; glass capacitors; integrated micro-electronic devices; hybrid micro-circuits; steel, aluminum, copper, epoxy fiberglass G10, G11, or equivalent; brass, ceramic, and glass-filled diallylphthalate.

Since there are no age sensitive materials in the transducer, no aging prior to seismic is required. The temperature aging test serves as a confidence test in the pressure transducer reliability. A detailed "aging" test log is presented in Table 2.

No detectable change observed in unit performance or visual appearance.

TABLE 2

AGING TEST LOG

DATE	ACTIVITY	COMMENTS	Temperature (°F)	Pressure (PSIA)	V_o (mv)
7/19/79	Chamber Installation	Chamber atmosphere was humidified with 15 ml H_2O.			
7/19→8/2/79	Low Temperature Operation	145°F with chamber total pressure variation of 15.8 to 17.6 PSIA.			
8/2/79	Initiate Aging Environment	Chamber was cooled to ambient and opened to allow transducer inspection. Atmosphere preparation included 1/2 atmosphere of 2% H_2/N_2 and water vapor (15 ml of water). Chamber was sealed and temperature set for 300°F.			
8-3	Aging Environment		302	53.5	18.739
8-6	"		302	55.3	19.241
8-7	"		302	53.5	18.804
8-8	"		302	49.4	17.464
8-9	"		302	49.3	17.364
8-10	"		302	49.4	17.282
8-13	"		302	47.2	16.79
8-14	"		308	49.7	17.574
8-15	"		305	49.5	17.525
8-17 (8:30)	"		305	48.6	17.259
8-17 (15:00)	"		305	48.4	17.151
8-17 (15:10)	Terminate Aging Environment	Set heat for 125°F.			
8-20 (11:45)			129	26.2	7.839
(11:50)	Terminate Test	Shut off heat, open the chamber and remove the specimen			

TABLE 3

PRESSURE TRANSDUCER - NON-METALLICS

COMPONENT	MATERIAL	COMMENTS
Bridge Substrate	Silicon Oxide SiO_2	Thin coating to which resistors are mounted.
Resistors	"Ceramicite" (CEC) Ceramic	Resistors are wire wound, nickel coated with Ceramicite which contains Al, Pb. Glass.

Radiation Exposure

The Transducer,connector and cable assembly was delivered to Isomedix for a radiation exposure of 1.2×10^6 Rads/hr. for a total integrated dose of 3.2×10^7 Rads. Dose certification is included with this report as Attachment 4. No detectable change in unit performance or visual appearance was observed during post exposure evaluation.

Simulated Siesmic Event

The specimen was subjected to the environment described in GE-SD Procedure 250852 as part of H_2 Analyzer P/N 47E240609 System Seismic Test. Test details are presented in the '609 system Qual Test Report.

J D Fuller

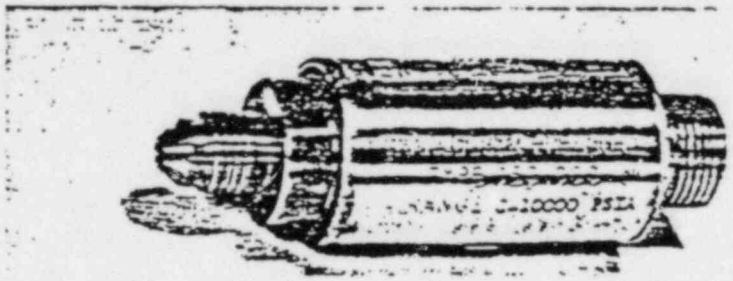
Jerry D. Fuller, Project Engineer
Analyzer Programs
Room U-3035 - Ext. 2518

Concurred: E J Savitsky

Edward J. Savitsky, Manager
Analyzer Programs
Room U-3035 - Ext. 2956

/mes

CEC® 1000-04 Sputtered Thin Film High Temperature Pressure Transducer



- Long-Term Stability
- Highly Reliable
- High Performance
- Advanced Sensor Design
- Rugged Dual Case Isolation

Providing long-term stability and reliability, CEC Sputtered Gage Pressure Transducers are the most accurate thin film transducers available. Performance stability is ±0.1% for extended operation at any combination of constant pressure and temperature within the operating range. The CEC 1000-04 has a compensated temperature range of 75°F to +400°F, and an operable temperature range of −65°F to +450°F. The thermal errorband performance is typically better than 0.5% within any 50°F temperature band.

Advanced techniques of sputtered film deposition create sensing elements with a maximum combined error for non-linearity, hysteresis, and non-repeatability of ±0.25% of the full range output.

Available in many standard ranges from 15 to 10,000 psi, the CEC 1000 Series also feature an innovative double-case isolation. The basic sputtered sensor is electron beam welded to the pressure chamber/adapter which also provides a high degree of mechanical isolation from mounting torque effects. The sputtered sensor is well isolated from external case effects since the case is welded to the pressure chamber/adapter and not in contact with any portion of the sensor.

CEC Sputtered Gage Pressure Transducers are manufactured in accordance with the program quality requirements of MIL-Q-9858A.

For further information about this pressure transducer, or special application designs, contact the nearest Bell & Howell/CEC Division Sales Office or factory in Pasadena, California.

CEC DIVISION

BELL & HOWELL

ATTACHMENT 1

SCB-17-18-2

SPECIFICATIONS

CEC 1000-04 Sputtered Thin Film High Temperature Pressure Transducer

Pressure Rating

Standard Ranges:	0 to 15, 25, 50, 100, 250, 500, 1000, 1500, 2000, 2500, 5000 and 10,000 psi absolute.
	0 to 100 psi and above are available in psia.
Proof Pressure:	200% of rated pressure or 15,000 psi (whichever is less) will not cause changes in performance beyond specified tolerances.
Burst Pressure:	300% of rated pressure or 20,000 psi (whichever is less) will not cause rupture of the sensing element or case.

Electrical Characteristics

Excitation:	10 Vdc rated; 15 Vdc maximum.
Full Range Output:	30 mV nominal.
Residual Unbalance:	Within ±1%, FRO.
Bridge Resistance:	300 to 500 ohms.
Combined Linearity, Hysteresis and non-repeatability:	±0.25% FRO, BSL.
Insulation Resistance:	100 megohms or greater at 45 Vdc.
Connections:	6-pin Bendix PCIH-10-6P (101), or equivalent.
Shunt Calibration:	Provisions for single-arm, external shunt calibration.

Mechanical Characteristics

Pressure Chamber Materials:	17-4 PH Stainless Steel.
Pressure Fitting:	7/16-20 male per MS-33656-4, MS-6879 modified per CEC standards.
Weight:	5 oz. maximum excluding mating connector.
Mounting Isolation:	Double case isolation provides assurance that the sensing element will be unaffected by external stresses.
Sensing Element:	4 active-arm bridge using sputtered elements.

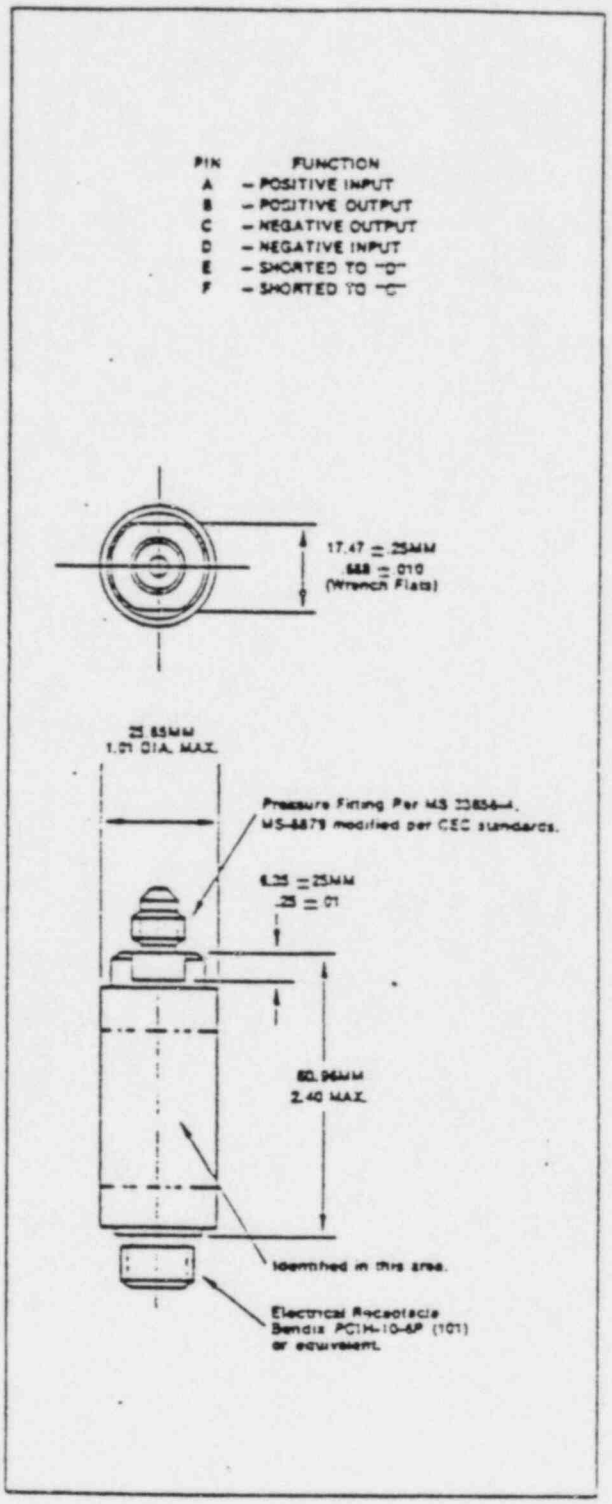
Environmental Performance

Temperature:	
Operating Range:	−65 to +400°F.
Compensated Range:	+75 to +400°F.
Thermal Zero Shift:	±0.01% FRO/°F over the compensated temp. range.
Thermal Sens. Shift:	±0.01% FRO/°F over the compensated temp. range.
Thermal Zero Stability:	0.25% FRO over the compensated temp. range.
Thermal Sens. Stability:	0.15% FRO over the compensated temp. range.
Vibration:	At 35g peak from 10 to 2000 Hz (.1" D.A. max.) the output shall not exceed 0.04% FRO/g for 15 psi units decreasing logarithmically to .003% FRO/g for 1000 psi units and above.
Natural Frequency:	50 kHz at 5000 psi, decreasing logarithmically to 5kHz at 15 psi.
Shock:	100g, 11 msec, half sine wave without damage.
Humidity:	Per MIL-E-5272C, Procedure 1.

Accessories

Included:	Calibration record and dust caps (2).
Optional:	Mating electrical connector Physical Sciences T106-10-6S-C-F1 or equivalent. Specify Bell & Howell PN 170200.

In keeping with Bell & Howell's policy of continuing product improvement, specifications may be changed without notice. If the performance and configuration provided herein for our standard product do not fit your exact needs please check with us regarding customized transducers. Contact us directly at the factory or through your nearest CEC Sales Office.



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360 Sierra Madre Villa, Pasadena, California 91109

BELL & HOWELL

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ATTACHMENT 1

308-17-18-2

BELL & HOWELL
CEC DIVISION
360 SIERRA MADRE VILLA, PASADENA, CA 91109 TELEPHONE (213) 796-9381 TELEX: 67-5415

CALIBRATION DATA SUMMARY

CEC 1000-0173
S/N 4240
0-100 PSIA

Temperature	77°F *B	77°F *A	+250°F *B	+250°F *A	350°F *B	350°F *A	77°F *B	77°F *A
Full Scale (MV)	33.389	33.504	34.100	34.260	34.149	34.188	33.368	33.486
Zero (MV)	0.262	0.353	0.855	0.924	0.732	0.594	0.253	0.350
Sens. (MV)	33.127	33.151	33.245	33.336	33.417	33.594	33.115	33.136
Insulation Resistance	10KMΩ	10MΩ	10KMΩ	10KMΩ	5KMΩ	5KMΩ	5KMΩ	10MΩ
ΔZero (MV)		+0.091		+0.069		-0.138		+0.097
ΔSens. (MV)		+0.024		+0.091		+0.177		+0.021
ΔZero (%FR)		+0.275		+0.208		-0.413		+0.293
ΔSens. (%FR)		+0.072		+0.274		+0.530		+0.063

LINEARITY AND HYSTERESIS RUN AT +250°F

%FS	0	20	40	60	80	100	80	60	40	20	
*B	0.855	7.473	14.115	20.769	27.430	34.099	27.438	20.776	14.122	7.482	0.
*A	0.924	7.558	14.223	20.896	27.579	34.268	27.586	20.903	14.229	7.568	0.

*B is before radiation 4/09/79
*A is after radiation 3/20/80

E. Wong
E. Wong
Sr. Product Specialist

ATTACHMENT 2

GENERAL ELECTRIC
SPACE DIVISION
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PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	1B90	CAMS	205	

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FROM	TO
J. D. Fuller, Project Engineer	F. P. Rudek, Manager - Analyzer Systems

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
7-25-79			

SUBJECT

CEC-1000-04(173) Pressure Transducer Aging Procedure

INFORMATION REQUESTED/RELEASED

The purpose of this test is to subject the transducer proposed for current configuration H_2 Analyzers to a combination of environmental conditions simulating long term operation of the transducer.

1. Initial Conditions:

   a. Place 30 ml H_2O in the chamber prior to closing.

   b. Pressurize the chamber to 15 PSIG with 2% H_2/N_2 then vent to ambient pressure. Close inlet and outlet valves.

   c. Set the temperature for 135°F ± 5°F.

   d. Record the following data for stabilized sensor performance.

      - Temperature
      - Pressure
      - Transducer Output
      - Time (Date and Time of Day)

2. Accelerated Life Temperature, Pressure Conditions:

   a. Set temperature controller to achieve a chamber temperature of $300^{\circ}{}^{+10^{\circ}}_{-0^{\circ}}$F

   b. Upon achieving a chamber temperature of 300°F, record the time and date. Vent the chamber as required to maintain a chamber pressure < 65 PSIG.

   c. Maintain the conditions established in the preceding step for 14 days and record the following information daily:

      - Temperature
      - Pressure
      - Sensor Output
      - Time

cc: J. D. Fuller, L. R. Heverly, J. E. Murphy, F. P. Rudek

PAGE NO. 1 OF 2

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ATTACHMENT 3

I-9

508-17-18-2

d. Decrease the temperature setting to achieve a chamber temperature of 125 ± 5°F and maintain for 2 days. Daily record the data noted in step 2.c.

e. Shut off the heat, open the test chamber and remove the transducer for visual inspection.

3. Radiation Exposure:

a. Subject the transducer to a total integrated dose of 3.2×10^7 Rads at a rate of 1.2 megarads/hour.

b. Perform CEC ATP.

J. D. Fuller, Project Engineer
Analyzer Systems
Room #U-3035, VFSC
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ATTACHMENT 3

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ATTACHMENT 3

ISOMEDIX

Sept. 13, 1979

J. J. Collery
General Electric Company
Space Systems
P.O. Box 8555
Philadelphia, Pa. 19101

Dear Mr. Collery:

This will summarize parameters pertinent to the irradiation of CEC XDUCER, calibration cap and cylinder, as per your purchase order A28-A10311, dated August 28, 1979.

The specimens were exposed for 37 hours at an average dose rate of 1.0 Megarads per hour, yielding a dose of 37 Megarads. The specimens were over-irradiated to account for the ±3% accuracy of the the dosimetry system; the reported dose is 32 Megarads.

Halfway through the exposure, the specimens were rotated 180° to give a more uniform dose distribution.

Dosimetry was performed using Harwell Red 4034 Perspex dosimeters, utilizing a Bausch and Lomb Model 710 spectrophotometer as the readout instrument. This system is calibrated directly with NBS, with the last calibration being May 30, 1979. A copy of the dosimetry correlation report is available upon request.

Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 130°F, as indicated by previous measurements on an oil solution in the same relative position.

Irradiation was initiated on August 31, 1979, and was completed on September 2, 1979.

Sincerely yours,

ISOMEDIX, INC.

David P. Constantine

David P. Constantine
Production Manager

DPC:vt
cc: G. Deitz

I-11

ATTACHMENT 4

508-17-18-2