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Produced by the NASA Center for Aerospace Information (CASI)
RESEARCH PRESSURE INSTRUMENTATION
FOR
NASA SPACE SHUTTLE MAIN ENGINE
NASA CONTRACT NO. NAS8-34769
MODIFICATION NO. 5

MONTHLY REPORT

GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

MAY 1984

Prepared By:

P.J. ANDERSON, PROGRAM MANAGER
P. NUSSBAUM, TECHNICAL DIRECTOR
G. GUSTAFSON, DEPUTY TECHNICAL DIRECTOR

HONEYWELL INC.
SOLID STATE ELECTRONICS DIVISION
12001 STATE HIGHWAY 55
PLYMOUTH, MN 55441
HONEYWELL INC.
SOLID STATE ELECTRONICS DIVISION
CONTRACT NO. NAS8-34769
MODIFICATION NO. 5

RESEARCH OF PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE
Monthly R & D Progress Report May 1984 - Report No. 8

A. Technical Progress and Plans
   - See attachment 'A'

B. Schedule
   - See attachment 'B'

C. Status of Funds

<table>
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<th>Description</th>
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<td>Total Baseline Plan</td>
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<td>Inception to Date Plan</td>
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<td>Estimate at Completion</td>
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D. Estimated percent of physical completion: 59%

E. At the present time the comparison of the cumulative costs to the percent of physical completion does not reveal any significant variance requiring explanation.
1.0 Introduction and Objective

The first phase of this contract (Tasks A and B) resulted in a highly successful demonstration in April 1983 at the MSFC of Honeywell's breadboard feasibility model of a silicon Piezoresistive Pressure Transducer suitable for SSME applications.

The purpose of Modification No. 5 of this contract is to expand the scope of work (Task C) of this research study effort to develop pressure instrumentation for the SSME. The objective of this contract (Task C) is to direct Honeywell's Solid State Electronics Division's (SSED) extensive experience and expertise in solid state sensor technology to develop prototype pressure transducers which are targeted to meet the SSME performance design goals and to fabricate, test and deliver a total of 10 prototype units.

SSED's basic approach is to effectively utilize the many advantages of silicon piezoresistive strain sensing technology to achieve the objectives of advanced state-of-the-art pressure sensors in terms of reliability, accuracy and ease of manufacture. More specifically, integration of multiple functions on a single chip is the key attribute of this technology which will be exploited during this research study.

The objectives of this research study will be accomplished by completing the following major tasks:

1. Transducer Package Concept and Materials Study
   Three transducer design concepts will be generated and analyzed for the SSME application and materials/processes will be defined for the research prototype transducer design.

2. Silicon Resistor Characterization at Cryogenic Temperatures
   The temperature and stress properties of a matrix of ion implanted piezoresistors will be characterized over the temperature range of -320°F to +250°F.

3. Experimental Chip Mounting Characterization
   The mechanical integrity of chip mounting concepts will be evaluated over temperature, pressure and vibration.

4. Frequency Response Optimization
   This task is a paper study which will specify and analyze an acoustic environment for which transducer frequency response can be determined and optimized.
5. Prototype Transducer Design, Fabrication, and Test

This major task will use the results generated in Tasks 1 through 4 above to design and develop a research prototype pressure transducer for the SSME application and will culminate in the delivery of 10 transducers, 5 each for the ranges of 0 to 600 psia and 0 to 3500 psia. This task is subdivided into the following five areas:

- Feasibility Evaluation of Transducer Concept
- Prototype Transducer Design
- Prototype Transducer Fabrication and Test
- Prototype Qualification
- Prototype Delivery.

6. Reports

Honeywell will submit monthly progress reports during the period of the contract; a final report will be provided at the completion of the contract.

The format of this report will be to discuss the work performed for this reporting period and the plans for the next reporting period for each of the major tasks outlined above.

2.0 Work Performed and Plans

2.1 Transducer Package Concept and Materials Study.

This task was completed per plan during January 1984.

2.2 Silicon Resistor Characterization at Cryogenic Temperatures.

2.2.1 Work performed in May.

This task was completed during this reporting period.

Two cryogenic test runs have now been completed down to -425°F. There were three sensors per run. Both TE bonded and "floating" sensor chips were evaluated. An implant dose of 1.28 E15 has the desired TCR and temperature-pressure sensitivity characteristics and was selected for use in the fabrication of the Feasibility Sensor Chip. Attachment 'C' contains some examples of the sensor characteristics from the second cryogenic run.
2.2.2 Plans for June

No activity is planned for the next reporting period since this task was completed in May.

2.3 Experimental Chip Mounting Characterization

2.3.1 Work performed in May

Detailed and interface drawings were received from Deutsch Connector during this reporting period. This allowed the design of the Experimental Sensor (electrically nonfunctional) piece-part hardware to be completed.

The design and fabrication of vibration fixturing to accommodate testing up to 150g's was completed. The design of vibration fixturing to accommodate 4,000g's was started.

The decision was made during this reporting period to pursue the Au/Ge solder approach for assembling the Experimental Sensor devices that are electrically nonfunctional. These sensors will be used to assess the mechanical integrity of our selected sensor design approach. (Re: Honeywell's April Monthly Report, Attachment 'D' (Alternate D)).

The solder creep experiment for the aforementioned approach was beyond the scope of the original plans for this task. This work was stopped based on cost considerations. The impact of solder creep, if it is significant, will be evaluated from the temperature/pressure testing of the Feasibility Sensor devices later on in this program.

The status of the piece-part build for the Experimental Sensor is as follows:

- Silicon Nitride Parts: Material on order (due early June)
- Stainless Steel Housing: Complete
- Stainless Steel Base: Complete
- Pyrex Cover Glass and Mounting Washer: Material Received and is being lapped and polished (estimate-to-complete is mid June)
- Au/Ge Performs: Complete
- INVAR mounting plate: Complete

An updated and more complete materials list was completed and forwarded to Mr. T. Marshal under separate cover. See Attachment 'D' for details.
2.3.2 Plans for June

The plans are as follows:

- Complete design and start the fabrication of these test fixtures:
  - Vibration testing (4,000g's).
  - High pressure testing.
  - High pressure leak checking.

- Receive these parts:
  - Silicon nitride subassemblies.
  - Lapped and polished pyrex washer.
  - Lapped and polished cover-window.

- Complete assembly of experimental sensors.

- Complete temperature, pressure and vibration testing.

2.4 Frequency Response Optimization

This task was completed per plan in February 1984.

2.5 Temperature Sensor Network Concept Study.

This task was deleted when the contract was negotiated.

2.6 Prototype Transducer Design, Fabrication and Test

2.6.1 Feasibility Evaluation of Transducer Concepts.

2.6.1.1 Define/Finalize Concept for Feasibility Transducer.

1 Work performed in May

The design of the Feasibility Sensor and an internal design review were completed. Also the layout of this sensor chip was started and completed, including incorporation of changes recommended from the design review. Attachment 'E' is a summary of the sensor design and the layouts as it will be submitted to the mask shop.

Two sources for silicon washer material were identified. These sources are:

- SSID Inventory
- Monsanto
The thickness of the wafers will be in the 22-24 mils range. The SSED material will be used at the primary source and Monsanto as a back-up source of supply.

2. Plans for June

The plans are as follows:
- Complete mask fabrication for Feasibility Sensor.
- Start wafer processing.

2.6.1.2 "Prototype" Transducer Design

1 Work performed in May

This task was closed per plan as reported in our April Monthly Report. Recall, the activity being addressed recently was Frequency Response design considerations. The work performed was a logical extension of the "Frequency Response Optimization" task, (Re: Section 2.4). Rather than stop and restart this activity as part of the "Prototype Transducer Design", we elected to keep the momentum going and complete it as reported last month.

2. Plans for June

No activity is planned for this reporting period. This task is scheduled to be reopened in 11/84.

3.0 Schedule -- See Attachment 'B'.

The "Experimental chip Mounting" task was not completed in May as planned. The major elements leading to this delay were the re-evaluation of the assembly approach and longer than planned delivery of the pyrex and silicon nitride materials. The plan is to complete this task in June; however, that is contingent upon the timely delivery of the polished pyrex glass and silicon nitride materials. It is possible that completion of this task will slip to July, 1984. This delay is not expected to have an adverse impact on the completion of the Feasibility Sensor task. (Re: Section 2.6.1)
RESEARCH PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE SCHEDULE

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<th>TASKS</th>
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<td>2.1 Transducer Package Concept and Materials Study</td>
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<td>2.2 Silicon Resistor Characterization at Cryogenic Temperatures</td>
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</tr>
<tr>
<td>2.3 Experimental Chip Mounting Characterization</td>
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<tr>
<td>2.4 Frequency Response Optimization</td>
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<td>2.6 Prototype Transducer Design, Fabrication and Test*</td>
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<tr>
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<td>2.6.2 Prototype Transducer Design</td>
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</tr>
<tr>
<td>2.6.3 Prototype Transducer Fabrication and Test</td>
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<td></td>
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<td>2.6.4 Prototype Qualification</td>
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<td>2.6.5 Prototype Delivery</td>
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<td>2.7 Reports</td>
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<tr>
<td>2.7.1 Monthly Program Reports</td>
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<tr>
<td>2.7.2 Final Report</td>
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PRELIMINARY DESIGN REVIEW
CRITICAL DESIGN REVIEW
FINAL DESIGN REVIEW

* 12/83: Numbering changed to retain numbering in original proposal. Task 2.5 was deleted during contract negotiations.
ORIGINAL PAGE IS
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ATTACHMENT "C"

NASA CRYOGENIC TESTING

[Graph showing normalized span shift against resistance, normalized to 25°C.]

- By 5-0-0, FLOATING
- DATE
- 1.85 x 10^15 Long/4in^2
- 50A/F

[Graph showing a curve labeled "Resistance Curve."
ATTACHMENT "C"
NASA CRYOGENIC TESTING

[Graph showing normalized resistance curve with annotation: 2.80x10^5 Tons/cm^2, 35 Ω/Ω]
Mr. Thomas Marshall  
NASA  
Marshall Space Flight Center  
Marshall Space Flight Center, AL 35812  

RE: 1. NASA Contract No. NAS8-34769  
2. Six Month Review At NASA/MSPC, 4/12/84  

Dear Tom:  

Enclosed is a more comprehensive materials list which we are planning to use in the fabrication of our deliverable pressure transducers. (Reference 1) This list was prepared in response to your 12, April 1984 request for same. (Reference 2) Please review this list and provide us with your comments and questions as soon as possible. This list is an updated version of the one presented at our Six Month Review (Reference 2) and which was also included in our January Monthly Report. (Reference 3)  

At our Six Month Review, you indicated that you were expecting, in the following week, to receive a reply from your Materials Lab regarding the support you can provide in the area of materials testing and evaluation of some materials for which we are either lacking data and/or are not on the approved list of NASA materials. (Reference 4) My records indicate we have not yet received a response from you on this subject.*  

I am requesting that you review the review materials list and respond as soon as possible with your comments. Also, please include your response to our request for materials testing and evaluation support. (Reference 4)*  

We look forward to hearing from you soon.  

Sincerely,  

[Signature]  

P. Anderson  
Program Manager  

c: P. Nussbaum MN14-3B35  
D. Wamstad MN14-3B35  
J. Offroy MN14-3B35  
M. McChesney MN14-3B35  
D. Street MN14-4C37  
D. Wamstad MN14-3B35  
J. Shea MN14-3B20  

* Response Received 6/4/84
Honeywell Interoffice Correspondence

Date: May 22, 1984

Subject: PROPOSED MATERIAL LIST FOR THE NASA PRESSURE TRANSDUCER

To: P. Anderson  MN14-3B25
    J. Onffroy  MN14-3B35
    J. Shea    MN14-3B20

From: D. Wamstad
      Organization: SSED
      HED: MN14
      MS: 3B35
      Telephone: 541-2091

The attached list of materials are proposed for the construction of the NASA Pressure Transducer. The list of material shows the location of materials as referenced by item number in Figures 1 and 2, and also provides the material interface temperature, pressure and pressure media which the material will be exposed to.

Would you submit this to NASA for their recommendations as to the suitability of the material.

DH/in

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OF POOR QUALITY
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<td>Silicon</td>
<td>-423°F</td>
<td>20K psi</td>
<td>He, H, N₂O</td>
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<td>Silicon Sensor Chip</td>
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<td>He, H, N₂O</td>
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<td>Sensor Mount.</td>
<td>2</td>
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<td>Silicon Nitride - Hot Press.</td>
<td>&gt;-423°F</td>
<td>&lt;20K psi</td>
<td>He(2.0 psi)</td>
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<td>Elect. Terminal Board</td>
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<td>Gold (88%)/Germanium (12%)</td>
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<td>Solder</td>
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<td>&gt;-423°F</td>
<td>&lt;20K psi</td>
<td>No Specific Media</td>
<td></td>
<td>Metalization</td>
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<td>Available</td>
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<td>&gt;-423°F</td>
<td>&lt;13 psi</td>
<td>He (2.0 psi)</td>
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<td>Cover Glass</td>
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<tr>
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<td>He (2.0 psi)</td>
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<td>Solder</td>
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<td>&lt;13 psi</td>
<td>He (2.0 psi)</td>
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<td>Metalization</td>
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<td>Not Available</td>
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<td>He, H, N₂O</td>
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<td>Pyrex Hasher</td>
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<td>20K psi</td>
<td>He, H, N₂O</td>
<td></td>
<td>Solder</td>
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<td>10354</td>
<td>Copper Wire</td>
<td>&gt;423°F</td>
<td>&lt;15 psi</td>
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<td>Electrical Connectors</td>
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<td>Gold Wire .002&quot; Dia.</td>
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*NOTE: For Item No. Designation See Figure 1
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<td>He, H, N&amp;O</td>
<td>Res 1231-E-1005N'</td>
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*NOTE: For Item No. Designation See Figure 2*
FIGURE 1: SSME PRESSURE SENSOR MOUNTING - SILICON TO SILICON
NITRIDE MATCHED COMPRESSION SEALS

1 SIlICON SENSOR CHIP - MOUNTING AREA ON CIRCUIT SIDE.
2 SILICON NITRIDE - TO PROVIDE HERMETICALLY SEALED ELECTRICAL
CONDUCTOR PADS FROM SILICON SENSOR CHIP TO LEAD W...S.
3 SILICON NITRIDE - TO PROVIDE HERMETICALLY SEALED ELECTRICAL
CONDUCTOR PADS WITH ELECTRICAL ISOLATION AREA.
4 SOLDER BOND - TO PROVIDE HERMETIC SEAL BETWEEN THE TWO (2) SILICON
NITRIDE PARTS.
5 COVER GLASS - TO ALLOW LASER TRIMMING OF THE SILICON SENSOR CHIP
COMPLETING NETWORK AND PROVIDE A HERMETIC SEAL BETWEEN THE COVER.
6 SOLDER BOND - TO PROVIDE HERMETIC SEAL AND VACUUM REFERENCE.
7 PYREX WASHER - TO PROVIDE SENSOR MOUNT AND SENSOR DIAPHRAGM.
8 SOLDER BOND - TO PROVIDE ELECTRICAL CONNECTION BETWEEN SENSOR
AND EXTERNAL CONNECTION.
9 COPPER WIRE - TO PROVIDE ELECTRICAL CONNECTION BETWEEN SENSOR.
10 GOLD WIRE LEADS
NASA PRESSURE TRANSDUCER PROGRAM

FIGURE 2: SSME PRESSURE SENSOR PACKAGE - SILICON TO SILICON NITRIDE MATCHED COMPRESSION SEALS - INVAR INSERT WITH V-RING

ORIGINAL PAGE IS OF POOR QUALITY

SEE FIGURE 1
ITEMS 1 THRU 10

15 ELECTRICAL CONNECTOR RES 1231-E-1005N
14 METAL V-RING
13 STAINLESS STEEL BASE
12 STAINLESS STEEL HOUSING
11 INVAR INTERFACE PLATE
ATTACHMENT "D" CONT.D.

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<td></td>
<td>J. O'Neill</td>
<td>Call Me</td>
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<tr>
<td></td>
<td>P. Wissmann</td>
<td>Note and Forward</td>
</tr>
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<td></td>
<td>D. Weisbad</td>
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<td></td>
<td>J. Shea</td>
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<td>R. McMullen</td>
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<td>J. Stahr</td>
<td>Recommendation</td>
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ATTACHED IS RESPONSE RECEIVED FROM MATERIALS LABORATORY. Re: Date

For materials used
in pressure sensor. It appears we will have to announce for O2 testing.

Re'd 6/4/84

NAME: T. M. Marshall
CODE (or other designation): EB 22
TEL. NO. (or code) & EXT.: 453-4624
DATE: 6-17-84
```

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ROUTING SLIP
May 8, 1984

TO:      EB21/Mr. Garrett
FROM:   EH01/Mr. Schwinghamer

SUBJECT: Materials Testing SSME Technology Program Pressure Transducer

Reference is made to your memorandum EB22(84-62). Honeywell requested the following information:

a. 304-CRES: Reaction data in hydrogen, oxygen, nitrogen and helium area range of -423°F to +200°F. Pressure limit of 20,000 psi, operating pressure of 9500 psi.

b. Silicon Nitride and INVAR: Above data plus thermal expansion, thermal conductivity, tensile strength and yield strength for temperature range of -423°F to +200°F.

Enclosure 1 contains data currently available in this Laboratory. There is no reacting problem with hydrogen, nitrogen and helium for the above materials. High pressure oxygen tests currently are limited to 10,000 psi. Please feel free to contact Mr. Riehl, EH31, directly regarding testing in oxygen.

R. J. Schwinghamer
Director
Materials & Processes Laboratory

CC:
EH02/Mr. Key
EH31/Mr. Riehl
**Relative Resistance to Hydrogen @ Room Temperature**

**DATA DERIVED FROM TEST ON NOTCHED ROUND BARS**

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<th>NOTCH CONC. FROM KE</th>
<th>GAS PRESSURE (ATM)</th>
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<td>.87</td>
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<tr>
<td>347</td>
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<td>.91</td>
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316 CRES IS BETTER PERFORMANCE THAN 304.

"L" WILL PROVIDE RELATIVELY NO CHANGE FROM THE STANDARD CARBON VERSIONS OF 304 & 316.

ALTHOUGH NOT IN CONFORM WITH HYDROGEN IN THE ATTACHMENT

THE FOLLOWING IS PROVIDED FOR INFORMATION.

DATA ON INVAR WAS NOT AVAILABLE HOWEVER THE RANGE OF PERFORMANCE CAN BE ESTIMATED FROM FOLLOWING DATA SINCE INVAR IS ESSENTIALLY 36% NICKEL WITH THE REMAINDER IRON.

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</tr>
</tbody>
</table>

INVAR EXPECTED TO BE BETWEEN THE GIVEN VALUES AND NO WORSE THAN .70 OR BETTER THAN .86.
2. Reheat to 600°F (315°C), hold 1 hour per inch (25 mm) of thickness, air cool.
3. Reheat to 205°F (96°C), hold 48 hours, air cool.

Mechanical Properties

Tensile Properties and Hardness

Typical room temperature mechanical properties of annealed and cold worked 36 per cent nickel-iron alloy are shown in Table II. The effect of temperature on the tensile properties of plate and forged bars in the annealed condition are shown in Figures 1 and 2.

36 per cent nickel-iron alloy is not notch-sensitive; the ratio of notched tensile strength to unnotched tensile strength is on the order of 1.10 at room temperature as well as at -320°F (-196°C).

![Figure 1. Effect of temperature on the typical tensile properties of annealed 36% Ni-Fe alloy.](image)

![Figure 2. Effect of temperature on the tensile properties of forged 36% Ni-Fe alloy in the annealed condition.](image)

**TABLE II**

Typical Mechanical Properties of 36 Per Cent Nickel-Iron Alloy

<table>
<thead>
<tr>
<th>Property</th>
<th>Annealed</th>
<th>Cold Worked 15%</th>
<th>Cold Worked 25%</th>
<th>Cold Worked 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, psi</td>
<td>71,400</td>
<td>93,000</td>
<td>100,000</td>
<td>106,000</td>
</tr>
<tr>
<td>Yield Strength (0.2% Offset), psi</td>
<td>40,000</td>
<td>65,000</td>
<td>69,500</td>
<td>95,000</td>
</tr>
<tr>
<td>Elongation (2 in. or 50 mm, %)</td>
<td>41</td>
<td>14</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Reduction of Area, %</td>
<td>72</td>
<td>64</td>
<td>62</td>
<td>59</td>
</tr>
<tr>
<td>Brinell Hardness</td>
<td>131</td>
<td>187</td>
<td>207</td>
<td>217</td>
</tr>
</tbody>
</table>
Figure 6. Effect of temperature on the Modulus of Elasticity of 36% Ni-Fe alloy.

Figure 7. Effect of temperature on the Modulus of Rigidity of 36% Ni-Fe alloy.

Figure 8. The effect of temperature on the Thermal Conductivity of 36% Ni-Fe alloy.

**TABLE VI**

<table>
<thead>
<tr>
<th>Temperature Range</th>
<th>Mean Coefficient of Linear Expansion per°F</th>
<th>per°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>per°C</td>
<td></td>
</tr>
<tr>
<td>-400 to 0</td>
<td>1.20 x 10^-4</td>
<td>2.16 x 10^-4</td>
</tr>
<tr>
<td>-200 to 0</td>
<td>1.10 x 10^-4</td>
<td>1.98 x 10^-4</td>
</tr>
<tr>
<td>0 to 200</td>
<td>0.70 x 10^-4</td>
<td>1.26 x 10^-4</td>
</tr>
<tr>
<td>200 to 400</td>
<td>1.50 x 10^-4</td>
<td>2.70 x 10^-4</td>
</tr>
<tr>
<td>400 to 600</td>
<td>6.40 x 10^-4</td>
<td>11.52 x 10^-4</td>
</tr>
</tbody>
</table>

**Thermal Expansion Data on 36 Per Cent Nickel-Iron Alloy**
EXPERIMENTAL SENSOR DESIGN

OBJECTIVE: Design and fabricate an experimental pressure sensor for use in the evaluation of the influence of the packaging concept on silicon piezoresistive pressure sensors over temperature, pressure, and vibration.

SCOPE: - Design and layout of an experimental sensor chip.
- Mask fabrication.
- Wafer processing.

APPROACH: - Minimize deviations from Honeywell's established silicon piezoresistive pressure sensor technology.
- Ion implanted, buried piezoresistors. Implant dose modified to enhance temperature compensation over extended temperature range (-320°F (77K) to 250°F (394K))
- Silicon slab or etched silicon cavity diaphragm
- TE chip bonding techniques
- Design to provide data for prototype sensor design
  - On chip metal interconnects.
  - Wire bond interface to sensor chip.
  - Bridge resistance ~ 500 Ω

EXPECTED RESULTS: Experimental data base for use in determining the feasibility of the sensor packaging concept and for directing the prototype sensor design.
ATTACHMENT "E" CONT'D.

REQUIREMENTS: Transducer Input and Output Resistance is 1350Ω to 2500Ω. Honeywell temperature compensation concept requires bridge resistance of ~500Ω.

Sensitivity: 3 mV per volt of transducer bias.

\[ S_B = (3) \times \left( \frac{\text{TRANSDUCER INPUT RESISTANCE}}{\text{BRIDGE RESISTANCE}} \right) \]

Zero Pressure Output: <0.03 mV per volt of transducer bias @ 75°F

\[ V_o(0) = S_B / 100 \]

\[ |R_n - R_f| \times V_o(0) \times (R_n + R_f) \]

Burst Pressure: 3 times full scale or 20,000 psi, whichever is smaller.

PACKAGE IMPOSED REQUIREMENTS:

- Unique packaging configuration
- Wire bond pads must be within R2 = 0.5(D2) = 30 mils
- Tolerance on D1
  
  ± 3 mils on pyrex washer ID
  
  ± 3 mils on packaging alignment
  
  Maximum radial location of implant ≤ 60 mil

![Diagram of packaging requirements]
POSSIBLE SENSOR CONFIGURATIONS

- **Slab**
  - 35 mil thick for 10,000 psi sensor
  - Diaphragm defined by ID of pyrex ring
  - Piezoresistors near inner edge of pyrex ring for maximum sensitivity
- **Etched Diaphragm**
  - 100 mil thick for 10,000 psi sensor
    - 40 mil diameter diaphragm
    - 15 mil thick diaphragm
  - Two piezoresistor locations for maximum sensitivity
    - Near edge of etched diaphragm
    - Near inner edge of pyrex ring

SELECTED SENSOR CONFIGURATION

- Slab Configuration
  - Sensors available sooner
  - Costs less
  - **Contract Does Not Require 20,000 PSI Burst Pressure Demonstration**
- Silicon Wafers: Use maximum thickness that is
  - compatible with standard processing and fixturing at SSPC (t < 25 mils)
  - considered standard by silicon wafer suppliers (t > 15 mil is not standard and a special order)
- Available Starting Material: 15 mil silicon with a 7 to 9 mil thick epi
DESIGN DETAILS
- Piezoresistors
  - Width = 13 microns
  - Length adjusted to yield a bridge resistance of 6.47 Ω.
  - (L/W)(35) = 430.8 Ω/piezoresistor
- Leadouts
  - Tangential Resistor Leadout
    - R = (3.098)(35) = 108.4 Ω
    - 2R = 216.8 Ω
  - Radial Resistor Leadouts
    - R1 = (3.383)(35) = 118.4 Ω
    - R2 = (2.814)(35) = 98.5 Ω
    - (R1 + R2) = 216.9 Ω
- Bridge Resistance: 6.47.4 Ω
- Zero Pressure Output
  - |R_R - R_T| = 0.00012 (R_R + R_T)
  - R_R = 647.7 Ω
  - R_T = 647.6 Ω
  - |R_R - R_T| = 0.12 × 0.00012 (R_R + R_T) = 0.15 Ω
- Burst Pressure = 14,000 psi
- Maximum Operating Pressure ≤ 4670 psi
- Calculated Sensitivity = 17 MV/VOLT OF BRIDGE BIAS
  Required Sensitivity = 12 (=S_B) MV/VOLT OF BRIDGE BIAS
ATTACHMENT "E" CONT'D.

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JO I
Layer 42 - Piezoresistor and Leadout Implant
ATTACHMENT "E" CONT'D.

ORIGINAL PAGE 19
OF POOR QUALITY

LAYER 64 - CONTACT CUT AND TE BOND AREA