COMPACT THERMOELECTRIC CONVERTER PROGRAM
INTERNAL TECHNICAL MEMORANDUM

Subject: Thermoelectric Material Properties Data Requirements

Shop Order No.:

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MASTER

Summary: This document lists the:

- 1) Data required
- 2) Data existing, source, and reliability
- 3) Testing required
- 4) Testing in progress
- 5) Testing Proposed

on Lead Telluride, Bismuth Nitride, and Manganese.

The tests required are divided into high, medium,
and low priority material and component tests.

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DATA REQUIRED

The following mechanical properties of Lead Telluride (PbTe), Boron Nitride (BN), and Magnesium Silicate (AlsiMag) are required to efficiently use computer stress codes.

- (1) PbTe - "P" type and "N" type
 - a) Stress-strain curves as a function of temperature
 - b) Bulk modulus as a function of pressure and temperature
 - c) Poisson's ratio as a function of stress and temperature
 - d) Coefficient of thermal expansion as a function of temperature
 - e) Stress relaxation as a function of temperature and initial stress
 - f) Anisotropic properties. Relationships a) to e) above, in direction of pressing and normal to pressing direction
- (2) BN
 - a) Stress-strain curves as a function of temperature
 - b) Bulk modulus as a function of temperature
 - c) Coefficient of thermal expansion as a function of temperature
 - d) Thermal conductivity as a function of temperature
- (3) AlsiMag
 - a) Compactability or densification as a function of time and temperature
 - b) Stress-strain curves as a function of temperature
 - c) Coefficient of thermal expansion as a function of temperature
 - d) Bulk modulus as a function of temperature

DATA EXISTING, SOURCE, AND RELIABILITY

- (1) PbTe "P" type and "N" type
 - a) Data on compression or tension stress-strain curves as a function of temperature is unavailable for PbTe
 - b) Data on bulk modulus as a function of temperature and pressure is unavailable for PbTe
 - c) Data on Poisson's ratio as a function of stress and temperature is unavailable for PbTe
 - d) Data on the coefficient of thermal expansion of PbTe as a function of temperature is available on Page 52 of Report WACP-1938-WAPD. However, this data requires corroboration; anisotropy of thermal expansion coefficient and the effect of percent doping on expansion coefficient are unknown.
- (2) BN
 - a) Stress-strain curves of Boron Nitride are available for ambient temperature, 250°C, 500°C, 700°C in tension. Compression stress-strain curves are available for ambient temperature, 500°C, 700°C. (Source is TEM Stress Analysis Report; data appears reliable.)
 - b) Data on bulk modulus as a function of temperature for Boron Nitride is not available. However, data on Young's modulus and Poisson's ratio as a function of temperature is reported in the TEM Stress Analysis Report. Bulk modulus can be computed from these two quantities.

DATA EXISTING, SOURCE, AND RELIABILITY, (2) BN (continued)

- c) Data on the coefficient of thermal expansion of Boron Nitride as a function of temperature is available on Page 52 of Report WCAP-1938-WAPD, "SNAP 10A Thermoelectric Module Design and Stress Analysis." However, this report also indicates the inconclusiveness of the data.
- d) Data on thermal conductivity of Boron Nitride normal to the pressing direction for temperatures from 300° to 1150°K is available from Carborundum Corporation and is presented in a WANL Materials Development letter of January 29, 1965. Data appears to be reliable.

(3) AlsiMag - 222

- a) Data on compactability or densification of AlsiMag-222 as a function of time and temperature is unavailable.
- b) Data on compression stress-strain curves of AlsiMag as a function of temperature is unavailable.
- c) Data on the coefficient of thermal expansion of AlsiMag as a function of temperature is available on Page 52 of Report WACP-1938-WAPD. Data appears reliable.
- d) Data on bulk modulus of AlsiMag as a function of temperature is unavailable.

TESTS REQUIREDA. Materials Tests

(1) High Priority Tests

a) PbTe

- i) Compression stress-strain curves as a function of temperature, including anisotropy
- ii) Stress relaxation curves as a function of initial stress and temperature, including anisotropy
- iii) Bulk modulus as a function of temperature and pressure
- iv) Coefficient of thermal expansion, including anisotropy and effect of percent doping

b) BN

- i) Coefficient of thermal expansion, including anisotropy

(2) Medium Priority Tests

a) AlsiMag

- i) Compression stress-strain curves as a function of temperature

(3) Low Priority Tests

a) PbFe

- i) Poisson's ratio as a function of stress and temperature

B. Component Tests

(1) High Priority Tests

a) PbTe

- i) Electrical contact resistance and thermal contact resistance of PbTe-Fe interface as a function of pressure
(Ref.: Drawing 946C346 for specimens)
- ii) Tests of new end cap and fabrication - closure designs to see how well they swage and withstand sintering

TESTS REQUIRED, Component Tests (continued)

- iii) Tests of one pair of PbTe elements enclosed in a stainless tube, then evacuated, sealed, swaged, and sintered. Determine contamination to PbTe in processes. (Ref.: Drawing 946C345 for specimens)

b) BN

- i) Thermal resistance of the 316-BN, Inco 750-BN, and Fe-BN interfaces as a function of pressure. (Ref.: Dwg. 946C346)
- ii) Determine if BN sleeves buckle during swaging (Ref.: Dwg. 946C347).
- iii) Compressibility of BN at 1400°F and at 10,000 psi pressure (Ref.: Dwg. 946C348)

c) AlsiMag

- i) Compactibility and densification of AlsiMag after swaging and after sintering at 1400°F and 10,000 psi pressure (Ref.: Dwg. 979D375)

(2) Medium Priority Tests

a) PbTe

- i) Density of PbTe after swaging as a function of density before swaging and as a function of percent area reduction
- ii) Density of PbTe after gas pressure sintering as a function of density before sintering

C. Assembly Tests - Later

(1) High Priority Tests

a) PbTe

- i) Test of purging operation with new end geometry to measure effluent chemistry vs. number of purge cycles

TESTS IN PROGRESS (As of September 8, 1965)A. Materials Tests

(1) PbTe

- a) Specimens $\frac{1}{2}$ " x $\frac{1}{2}$ " are being made. Compressive testing as a function of temperature has begun. (E. F. Vandergrift, Materials)

(2) AlSiMag

- a) Specimens $\frac{1}{2}$ " x $\frac{1}{2}$ " are being made. Compressive testing as a function of temperature has begun. Flexure specimens $1-\frac{1}{2}$ " x $\frac{1}{2}$ " x $\frac{1}{2}$ " are being made. Flexure tests as a function of temperature has begun. (H. Nicholson, Materials)

B. Components Tests

(1) PbTe

- a) Electrical and thermal contact resistances. Test program to Engineering Mechanics (letter of August 11, 1965, by J. Karbowski to D. F. Miller). Engineering Mechanics has prepared a test plan and cost estimate (N. Ettenson). Cost estimate is \$10,000. Decision has yet to be made whether to fund test program.
(Ref.: Drawing 946C346)

TESTS PROPOSEDA. Materials Tests

(1) PbTe

- a) Stress relaxation curves as a function of temperature and initial stress
- b) Coefficient of thermal expansion, including anisotropy and effect of percent doping
- c) Bulk modulus as a function of temperature and pressure

TESTS PROPOSED (continued)

B. Components Tests

(1) PbFe

- a) Determine contamination in processing (Ref.: Dwg. 946C345)

(2) BN

- a) Buckling of BN sleeves in swaging (Ref.: Dwg. 946C347)
- b) Compressibility of BN at 1400°F and at 10,000 psi pressure
(Ref.: Dwg. 946C348)

(3) AlsiMag

- a) Compactibility and density of AlsiMag after swaging and sintering
(Ref.: Dwg. 979D375)

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