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**A SOURCE MANUAL FOR INFORMATION
ON NITINOL AND NiTi
FIRST REVISION**

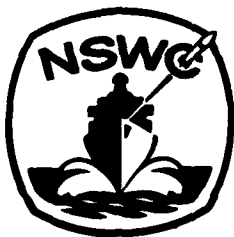
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RESEARCH AND TECHNOLOGY DEPARTMENT

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FOREWORD

This manual is a current listing of most of the published literature on NITINOL and NiTi alloys. It includes a bibliography, titles of a group of NSWC unpublished internal reports, and patents issued. Guidelines for obtaining licenses for Navy owned patents and for technical assistance by the Navy are presented.

The manual is intended to aid scientists and designers in locating specific kinds of information on NITINOL shape memory effect alloys.

Numerous additions have been made to both the Bibliography and Patent Listing in this first revision of the Source Manual, NSWC/WOL TR 78-26.

J. R. Dixon

J. R. DIXON
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PREFACE

The broad applications for NITINOL and the diversity of publications in which the literature appears presents difficulty to those researching shape memory effect alloys. This manual is intended to alleviate the difficulty.

Literature titles on NITINOL are indexed by year of publication. This indexing system permits adding titles from the current year and from prior years.

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1. INTRODUCTION

NITINOL is the generic name which has been given to the family of alloys which are near NiTi in composition. They were developed in 1961 during an examination of ten different intermetallic compounds considered potentially useful as missile nose tip materials. The NiTi alloy exhibited what is now identified as a "shape memory effect" (SME).

The inventors of record, (Patent 3 174 851) W. J. Buehler and R. Wiley named the alloy family "NITINOL". This is derived from the chemical symbol "NiTi" followed by "NOL", the acronym for Naval Ordnance Laboratory, the prior designation of the Naval Surface Weapons Center.

As knowledge of the existence of this shape memory effect alloy broadens, so does the demand for knowledge of its properties. To assist those now entering the NITINOL technology community this source manual has been prepared.

The early years of research in this alloy concentrated on an understanding of the mechanism of the transformation and a comprehension of the overt SME behavior of the alloy. This was followed by commercial production of the alloy and the appearance of a narrow line of commercial products using the alloy. Simultaneously a large number of patents and ingenious new ways to utilize the alloy surfaced, but only a few were commercialized.

Among the difficulties would-be entrepreneurs encountered were a lack of adequate NITINOL supplies in the shape and sizes desired, of selected transition-temperature and transition band widths at reasonable costs, and with prompt delivery. It has become clear that it is now in the Navy's interest to assist in the development of commercial applications for NITINOL. These will ultimately provide a self sustaining production base for alloy, as well as provide commercial sources of metal for low volume DOD applications.

It is against this background that the NITINOL Technology Center was activated in 1977 to explore low cost manufacturing technology for NITINOL and to assist in the development of NITINOL-using devices. The Center has a complete melting and fabricating facility for NITINOL.

For the development of NITINOL-using devices, the Technology Center offers guidance and/or prototype development programs. These

are usually joint efforts with other government agencies or commercial organizations. (Funding by the private sector for materials and/or services is permitted on a non-profit basis. Advance payment to the Commander, Naval Surface Weapons Center is required.) The facilities of NSWC are available to the NITINOL Technology Center, enabling complete design and fabrication of prototypes. This service is offered only if equivalent capability is not available from industry and is subordinate to Navy projects.

Current program emphasis is on manufacturing technology for NITINOL. Objectives are high quality wire and strip using existing commercial facilities. The output of this effort will be made available to designers and users for prototype devices and limited production runs.

2. LITERATURE SURVEY

Most of the publications listed here are available in open literature. Those with asterisks* following an identifier number may be ordered from the

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

NTIS also offers "Published Searches" of technical literature for \$25 and "On Line" search for \$100.

The NITINOL Technology Center maintains as complete a file of publications as possible. Duplication of specific articles can be arranged. Requests for assistance should be directed to:

Naval Surface Weapons Center
NITINOL Technology Center
Code CR-32
White Oak, Maryland 20910

Articles in the following bibliography are coded by the last two digits of the publication year, followed by the first letter of the principal author's name and a sequential number.

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3. INTERNAL REPORTS

The following reports are for internal distribution only. They are presented only to make known that some technical information has been developed on titled subject.

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4. PATENTS

Copies of patents may be obtained from the

U.S. Patent Office
U.S. Dept. of Commerce
Box 9
Washington D.C. 20231

The cost of patents is 50 cents each. Patents which are Navy owned (including the basic patent on NITINOL) may be licensed. The

following statement from the Navy Office of Patent Counsel details licensing procedures.

LICENSES UNDER NAVY PATENTS AND PATENT APPLICATIONS

The Department of the Navy has instituted a program to license for commercial purposes patents and patent applications owned by the United States Government and in the custody of the Navy. This program is necessary because making, using or selling an invention covered by a Navy patent without express permission by the Government constitutes an unauthorized use. The Department of the Navy is presently implementing the Presidential Statement of Government Patent Policy of August 23, 1971.

A major premise of the Presidential Statement of Government Patent Policy, August 23, 1971 (36 FR 16887, August 26, 1971), is that Government inventions normally will best serve the public interest when they are developed to the point of practical application and made available to the public in the shortest possible time. The granting of express nonexclusive or exclusive licenses for the practice of these inventions may assist in the accomplishment of the national objective to achieve a dynamic and efficient economy.

The granting of nonexclusive licenses generally is preferable since the invention is thereby laid open to all interested parties and serves to promote competition in industry, if the invention is in fact promoted commercially. However, to obtain commercial utilization of the invention, it may be necessary to grant an exclusive license for a limited period of time as an incentive for the investment of risk capital to achieve practical application of an invention.

Whenever the grant of an exclusive license is deemed appropriate, it shall be negotiated on terms and conditions most favorable to the public interest. In selecting an exclusive licensee, consideration shall be given to the capabilities of the prospective licensee to further the technical and market development of the invention, his plan to undertake the development, the projected impact on competition, and the benefit to the Government and the public. Consideration shall be given also to assisting small business and minority business enterprises, as well as economically depressed, low income, and labor surplus areas, and whether each or any applicant is a U.S. citizen or corporation. Where there is more than one applicant for an exclusive license, that applicant shall be selected who is determined to be most capable of satisfying the criteria and achieving these goals.

The Chief of Naval Research (Code 302), Arlington, Virginia 22217, is now accepting applications for nonexclusive and exclusive

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All licenses will be individually negotiated with responsible applicants. The usual nonexclusive license will be revocable, non-transferable and royalty-free. The time period or term, the geographical area and/or field of use of the invention and other terms and conditions of the license are matters which will be considered in each case.

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An applicant for an exclusive license should, in addition to the information set forth in the above paragraph, indicate whether or not he is a United States citizen, identify any other exclusive licenses he has ever had under patents or patent applications belonging to the U. S. Government, state to the best of his knowledge the extent to which the Government invention is being practiced by private industry, provide a statement of his capability to undertake the development and marketing required to achieve the practical application of the invention in a specified geographical area and field of use, provide a statement describing the time expenditure and other acts which he considers necessary to achieve practical application of the invention and include his offer to invest that sum to perform such acts if the license is granted. It would be beneficial for him to state why it will be in the public interest for him to have an exclusive license rather than a nonexclusive license.

An exclusive license may be granted after publication of the invention for nonexclusive licensing and after publication of the name of the selected applicant for a particular exclusive license if there is no responsible applicant for a nonexclusive license.

Exclusive licenses shall be subjected to several reservations of rights, as for example, an irrevocable royalty-free reservation throughout the world of rights in the invention to the United States Government. Exclusive licenses will contain a provision for royalty payments and/or other consideration flowing to the U. S. Government and in certain instances the granting of sublicenses to responsible applicants may be required of the exclusive licensee. Exclusive licenses will contain all terms and conditions which are required by law and by U. S. Government regulations and some additional provisions.

The information for applicants to submit in connection with requesting a license and the license provisions set forth in this paper are only intended to be illustrative and suggestive of the type of information needed and the possible kinds of provisions which may appear in a license. They are not intended to be limiting in content, meaning or words.

Patents

Patent No. 3,174,851

"Nickel-Base Alloys"

W. Buehler and R. Wiley, Assignors to U.S.A.

Filed 1 Dec 1961

Issued 28 Mar 1965

3 Claims (Cl. 75-170)

Patent No. 3,285,470

"Thermally Actuated Devices"

E. H. Frei, S. Leibinzohn and Shtrikman

15 Nov 1966

Patent No. 3,351,463

"High Strength Nickel-Base Alloys"

A. G. Rozner and W. J. Buehler, Assignors to U.S.A.

Filed 28 Aug 1965

Issued 7 Nov 1967

10 Claims (Cl. 75-170)

Patent No. 3,352,650

"Metallic Composites"

D. M. Goldstein, W. J. Buehler and R. C. Wiley, Assignors to U.S.A.

Filed 19 Jul 1965

Issued 14 Nov 1967

12 Claims (Cl. 29-191)

Patent No. 3,352,722

"Method of Growing Single Crystals"

F. E. Wang, A. M. Syeles, W. L. Clark and W. J. Buehler,

Assignors to U.S.A.

Filed 27 Jul 1965

Issued 14 Nov 1967

8 Claims (Cl. 148-1.6)

Patent No. 3,391,882

"Erectable Structure for a Space Environment"

J. F. Johnson, D. Reiser and G. S. Ovrevik

9 Jul 1968

14 Claims (Cl. 244-1)

Patent No. 3,403,238

"Conversion of Heat Energy To Mechanical Energy"

W. J. Buehler and D. M. Goldstein, Assignors to U.S.A.

Filed 5 Apr 1966

Issued 24 Sep 1968

10 Claims (Cl. 337-393)

Patent No. 3,416,342

"Method for Treating Working and Bonding Refractory Metals and Alloys"

D. M. Goldstein, W. J. Buehler and R. C. Wiley, Assignors to U.S.A.

Filed 22 Nov 1965

Issued 17 Dec 1968

9 Claims (Cl. 72-47)

Patent No. 3,440,997

"Temperature Indicating Device"

N. E. Rogen and R. J. Hill, Assignors to Avco Corp.

Filed 11 Jul 1966

Issued 29 Apr 1969

12 Claims (Cl. 116-114.5)

Patent No. 3,450,372

"Self-Projectable Element for a Space Vehicle"

R. G. de Lange, C. A. Verbraak and J. A. Zijderveld, Assignors to
Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk
Onderzoek ten behoeve van Nijverheid, Corp. of the Netherlands

Filed 4 Feb 1966

Issued 17 Jun 1969

3 Claims (Cl. 244-1)

Patent No. 3,483,360

"Thermostatic Switching Device and Overheat Control System
Incorporating Same"

C. C. Perry, Assignor to W. M. Chase Co.

Filed 11 Jul 1967

Issued 9 Dec 1969

2 Claims (Cl. 219-512)

Patent No. 3,483,748

"Temperature Sensing"

N. E. Rogen and R. J. Hill, Assignors to Avco Corp.

Filed 5 May 1967

Issued 16 Dec 1969

20 Claims (Cl. 73-339)

Patent No. 3,483,752

"Temperature Monitor"

N. E. Rogen and R. J. Hill, Assignors to Avco Corp.

Filed 10 Feb 1967

Issued 16 Dec 1969

5 Claims (Cl. 73-362.8)

Patent No. 3,487,345

"Electronic Temperature Regulation System Using Solid State Devices
and Point Contact Sensors"

D. L. Watrous and J. D. Harnden, Assignors to General Electric Co.

Filed 2 May 1967

Issued 30 Dec 1969

3 Claims (Cl. 335-146)

Patent No. 3,508,914
"Methods of Forming and Purifying Nickel-Titanium Containing Alloys"
W. J. Buehler, Assignor to U.S.A.
Filed 7 Oct 1965
Issued 28 Apr 1970
8 Claims (Cl. 75-135)

Patent No. 3,513,429
"Heat Recoverable Actuator"
W. R. Helsop, Assignor to Raychem Corp.
Filed 30 Oct 1968
Issued 19 May 1970
22 Claims (Cl. 337-382)

Patent No. 3,516,082
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R. G. Cooper
Filed 9 Jun 1967
Issued 2 Jun 1970
6 Claims (Cl. 340-227.1)

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"Method for the Formation of an Alloy Composed of Metals Reactive in
Their Elemental Form with a Melting Container"
W. J. Buehler, Assignor to U.S.A.
Filed 4 Nov 1966
Issued 22 Sep 1970
19 Claims (Cl. 75-135)

Patent No. 3,558,369
"Method of Treating Variable Transition Temperature Alloys"
F. E. Wang and W. J. Buehler, Assignors to the U.S.A.
Filed 12 Jun 1969
Issued 26 Jan 1971
2 Claims (Cl. 148-11.5)

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"Temperature Sensing Relay"
D. L. Watrous and J. D. Harnden, Assignors to General Electric Co.
Filed 18 Jun 1969
Issued 1 Jun 1971
2 Claims (Cl. 337-382)

Patent No. 3,594,239
"Method of Treating Unique Martensitic Alloys"
F. E. Wang, Assignor to U.S.A.
Filed 26 Feb 1968
Issued 20 Jul 1971
6 Claims (Cl. 148-13)

Patent No. 3,594,674
"Temperature-Responsive Control Devices Adjustably Responsive to
Various Operating Temperatures"
J. R. Willson, Assignor to Robertshaw Controls Co.
Filed 13 Aug 1969
Issued 20 Jul 1971
25 Claims (Cl. 337-139)

Patent No. 3,594,675
"Temperature-Sensing Probe"
J. R. Willson, Assignor to the Robertshaw Controls Co.
Filed 28 May 1969
Issued 20 Jul 1971
9 Claims (Cl. 337-140)

Patent No. 3,613,732
"Temperature-Responsive Valve Operators"
J. R. Willson, K. T. Krueger, H. J. Tyler and W. F. Jackson,
Assignors to Robertshaw Controls Co.
Filed 17 Jul 1969
Issued 19 Oct 1971
62 Claims (Cl. 137-625.44)

Patent No. 3,620,212
"Intrauterine Contraceptive Device"
R. D. Fannon, B. R. Lower and L. E. Laufe, Assignors to L. E. Laufe
File 15 Jun 1970
Issued 16 Nov 1971
8 Claims (Cl. 128-130)

Patent No. 3,634,803
"Temperature-Responsive Switch Assemblies"
J. R. Willson, K. T. Kreuger, H. J. Taylor and W. F. Jackson,
Assignors to Robertshaw Controls Co.
Filed 22 Jul 1969
Issued 11 Jan 1972
28 Claims (Cl. 337-123)

Patent No. 3,645,443
"Automobile Thermostat"
J. R. Willson and K. T. Krueger, Assignors to Robertshaw Controls Co.
Filed 19 Dec 1969
Issued 29 Feb 1972
9 Claims (Cl. 236-34)

Patent No. 3,652,969
"Method and Apparatus for Stabilizing and Employing Temperature
Sensitive Materials Exhibiting Martensitic Transitions"
J. R. Willson and D. W. Carey, Assignors to Robertshaw Controls Co.
Filed 27 May 1969
Issued 28 Mar 1972
10 Claims (Cl. 337-140)

Patent No. 3,660,082

"Corrosion and Wear Resistant Nickel Alloy"

A. Negishi, K. Takayanagi and M. Ikeda, Assignors to the Furukawa Electric Co., Ltd, Tokyo, Japan

Filed 27 Dec 1968

Issued 2 May 1972

16 Claims (Cl. 75-134)

Patent No. 3,664,582

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W. F. Jackson and J. R. Willson, Assignors to Robertshaw Controls Co.

Filed 29 Oct 1969

Issued 23 May 1972

20 Claims (Cl. 236-93)

Patent No. 3,672,879

"TiNi Cast Product"

W. J. Buehler

Filed 4 Nov 1966

Issued 27 Jun 1972

1 Claim (Cl. 75-170)

Patent No. 3,676,815

"Thermally Sensitive Controls for Electric Circuits"

G. A. DuRocher, Assignor to Essex International, Inc.

Filed 28 Jul 1969

Issued 11 Jul 1972

17 Claims (Cl. 337-140)

Patent No. 3,679,394

"Method for Casting High Titanium Content Alloys"

W. J. Buehler, Assignor to the U.S.A.

Filed 24 Nov 1969

Issued 25 Jul 1972

8 Claims (Cl. 75-10)

Patent No. 3,684,994

"Hot Wire Relay Type Devices and Methods of Maintaining or Producing Such Devices"

H. J. Tyler, Assignor to Robertshaw Controls Co.

Filed 2 Jul 1969

Issued 15 Aug 1972

10 Claims (Cl. 337-140)

Patent No. 3,691,499

"Actuating Device Employing A Heat Expansible Wire"

H. J. Taylor, Assignor to Robertshaw Controls Co.

Filed 10 Sep 1971

Issued 12 Sep 1972

3 Claims (Cl. 337-123)

Patent No. 3,700,434
"Titanium-Nickel Alloy Manufacturing Methods"
S. Abkowitz, J. M. Siergiej and R. R. Regan, Assignors to S. Abkowitz
Filed 21 Apr 1969
Issued 24 Oct 1972
7 Claims (Cl. 75-170)

Patent No. 3,703,693
"Liquid Level Sensing System"
R. N. Levinn, Assignor to American Thermostat Corp.
Filed 1 Apr 1971
Issued 21 Nov 1972
3 Claims (Cl. 337-140)

Patent No. 3,707,694
"Thermally Sensitive Circuit Control Apparatus"
G. A. DuRocher, Assignor to Essex International Inc.
Filed 9 Mar 1970
Issued 26 Dec 1972
17 Claims (Cl. 337-139)

Patent No. 3,725,835
"Memory Material Actuator Devices"
J. B. Hopkins and W. Rindner
Filed 20 Jul 1970
Issued 3 Apr 1973
13 Claims (Cl. 337-140)

Patent No. 3,731,247
"High Temperature Sensing Apparatus Effective Over Extensive Lengths"
R. N. Levinn, Assignor to American Thermostat Corp.
Filed 8 Jan 1971
Issued 1 May 1973
9 Claims (Cl. 337-140)

Patent No. 3,734,348
"Method of Expelling Liquid Propellant from a Storage Tank in a
Liquid Rocket"
H. M. White, Assignor to the U.S.A.
Filed 23 Sep 1971
Issued 22 May 1973
2 Claim (Cl. 222-1)

Patent No. 3,740,839
"Cryogenic Connection Method and Means"
R. F. Otte and C. L. Fischer, Assignors to Raychem Corp.
Filed 29 Jun 1971
Issued 26 Jun 1973
16 Claims (Cl. 29-628)

Patent No. 3,748,197
"Method for Stabilizing and Employing Temperature Sensitive
Material Exhibiting Martensitic Transitions"
J. R. Willson and D. W. Carey, Assignors to Robertshaw Controls Co.
Filed 14 Sep 1971
Issued 24 Jul 1973
7 Claims (Cl. 148-131)

Patent No. 3,753,700
"Heat Recoverable Alloy"
J. D. Harrison, J. Y. Choi and P. R. Marchant, Assignors to
Raychem Corp.
Filed 2 Jul 1970
Issued 21 Aug 1973
2 Claims (Cl. 75-134)

Patent No. 3,753,792
"Method of Achieving Thermally Balanced Hot Wire Relay Type Devices"
H. J. Tyler, Assignor to Robertshaw Controls Company
Filed 9 Dec 1971
Issued 21 Aug 1973
10 Claims (Cl. 148-13)

Patent No. 3,759,552
"Hydraulic Coupling with Metallic Sealing Member"
R. Levinsohn and J. E. Jervis, Assignors to Raychem Corp.
Filed 8 Sep 1970
Issued 18 Sep 1973
13 Claims (Cl. 285-175)

Patent No. 3,783,429
"Temperature Actuated Connector"
R. F. Otte, Assignor to Raychem Corp.
Filed 21 Jun 1972
Issued 1 Jan 1974
12 claims (Cl. 337-393)

Patent No. 3,802,930
"Alloy"
G. B. Brook and R. F. Iles, Assignors to Fulmer Research Institute
Limited
Filed 30 Apr 1970
Issued 9 Apr 1974
9 Claims (Cl. 148-11.5)

Patent No. 3,827,426
"Prosthetic Pump"
Mark Page and Phillip N. Sawyer
Filed 16 Jul 1971
Issued 6 Aug 1974
11 Claims (Cl. 128-1D)

Patent No. 3,839,903

"Method for Determining the Matrix Composition of a TiNi Base Alloy"

W. J. Buehler

Filed 1 May 1972

Issued 8 Oct 1974

8 Claims (Cl. 73-67.1)

Patent No. 3,849,756

"Nitinol Activated Switch Usable as a Slow Acting Relay"

C. D. Hickling, Assignor to American Thermostat Corp.

Filed 14 Jun 1973

Issued 19 Nov 1973

10 Claims (Cl. 337-382)

Patent No. 3,861,030

"Article and Method for Locating Contacts"

R. F. Otte, Assignor to Raychem Corp.

Filed 4 Apr 1975

Issued 21 Jan 1975

13 Claims (Cl. 29-626)

Patent No. 3,872,415

"Relay"

D. E. Clarke, Assignor to Texas Instruments Inc.

Filed 16 Apr 1973

Issued 18 Mar 1975

7 Claims (Cl. 337-140)

Patent No. 3,872,573

"Process and Apparatus for Making Heat Recoverable Composite Couplings"

P. E. Nichols and C. L. Martin, Assignors to Raychem Corp.

Filed 19 Dec 1973

Issued 25 Mar 1975

17 Claims (Cl. 29-447)

Patent No. 3,883,885

"High-speed Shutter"

C. Orlando

Filed 4 Dec 1973

Issued 13 May 1975

5 Claims (Cl. 354-258)

Patent No. 3,893,055

"High Gain Relays and Systems"

E. M. Jost, L. E. McBride, and T. J. Santala, Assignors to Texas Instruments Inc.

Filed 16 Apr 1973

Issued 1 Jul 1975

15 Claims (Cl. 337-140)

NSWC TR 80-59

Patent No. 3,900,939

"Method of Plugging Steam Generator Tubes"

J. S. Greacen, Assignor to Combustion Engineering, Inc.

Filed 31 Oct 1973

Issued 26 Aug 1975

5 Claims (Cl. 29-401)

Patent No. 3,905,228

"Mechanical Heat Flux Recorder"

W. K. Smith

16 Sep 1975

Patent No. 3,906,422

"Resettable Fuse"

R. M. Healy

Filed 16 Sep 1974

Issued 16 Sep 1975

15 Claims (Cl. 337-141)

Patent No. 3,913,326

"Energy Conversion System"

R. M. Banks, Assignor to the U.S.A.

Filed 11 Apr 1974

Issued 21 Oct 1975

9 Claims (Cl. 60-527)

Patent No. 3,913,444

"Thermally Deformable Fastening"

R. F. Otte, Assignor to Raychem Corp.

Filed 8 Nov 1972

Issued 21 Oct 1975

10 Claims (Cl. 85-8.3)

Patent No. 3,922,591

"Heated Wire Servo Motor Control System"

E. O. Olsen, Assignor to Foxboro Co.

Filed 4 Dec 1973

Issued 25 Nov 1975

43 Claims (Cl. 318-676)

Patent No. 3,930,629 (N. C. No. 56,253)

"Overheated Journal Bearing Derailment Prevention System"

21 Claims (Cl. 246-169A)

Patent No. 3,937,019

"Thermal Engine"

E. Renner, Assignor to Vereinigte Flugtechnische Werke-Fokker GmbH

Filed 25 Oct 1974

Issued 10 Feb 1976

15 Claims (Cl. 60-527)

Patent No. 3,940,935
"Positioning Device using Negative Spring-Rate Tensioning Means"
D. A. Richardson and R. J. Robinson, Assignors to Foxboro Co.
Filed 22 Feb 1974
Issued 2 Mar 1976
17 Claims (Cl. 60-528)

Patent No. 3,948,688
"Martensitic Alloy Conditioning"
J. P. Clark, Assignor to Texas Instruments Inc.
Filed 28 Feb 1975
Issued 6 Apr 1976
10 Claims (Cl. 148-11.5 R)

Patent No. 3,953,253
"Annealing of NiTi Martensitic Memory Alloys and Product
Produced Thereby"
J. P. Clark, Assignor Texas Instruments Inc.
Filed 21 Dec 1973
Issued 27 Apr 1976
6 Claims (Cl. 148-131)

Patent No. 3,957,206
"Extendable Rocket Motor Exhaust Nozzle"
J. N. Mason
18 May 1976

Patent No. 3,967,227
"Actuator System with Ambient Temperature Compensation"
D. E. Clarke, R. P. Lackey and J. P. Clark, Assignors to Texas
Instruments Inc.
Filed 10 Jan 1975
Issued 29 Jun 1976
21 Claims (Cl. 337-124)

Patent No. 3,999,790
"Heat Releasable Lock"
N. E. Rogen, Assignor to Niccoa Corp.
Filed 6 Oct 1975
Issued 28 Dec 1976
8 Claims (Cl. 292-201)

Patent No. 4,001,928
"Method for Plugging an Aperture with a Heat Recoverable Plug"
R. J. Schweiso, Assignor Raychem Corp.
Filed 3 Jun 1975
Issued 11 Jan 1977
4 Claims (Cl. 29-447)

Patent No. 4,010,455
"Cyclical Bi-Directional Rotary Actuator"
W. C. Stange, Assignor to the U.S.A.
Filed 17 Jul 1975
Issued 1 Mar 1977
25 Claims (Cl. 340-224)

Patent No. 4,010,612
"Thermal Motor"
D. J. Sandoval
Filed 13 Dec 1974
Issued 8 Mar 1977
12 Claims (Cl. 60/527-529)

Patent No. 4,016,721
"Positioning Device Using Negative Spring-Rate Tensioning Means"
D. A. Richardson and R. J. Robinson, Assignors to Foxboro Comp
Filed 15 Sep 1975
Issued 12 Apr 1977
5 Claims (Cl. 60-528)

Patent No. 4,018,308
"Elevating by Shape Memory Induction"
N. E. Rogen
Filed 23 Oct 1975
Issued 19 Apr 1977
3 Claims (Cl. 187-17)

Patent No. 4,022,519
"Heat Recoverable Connection"
F. W. Hill, Assignor to Raychem Limited
Filed 14 May 1975
Issued 10 May 1977
10 Claims (Cl. 339-30)

Patent No. 4,027,479
"Variable Density Heat Engine"
J. S. Cory
Filed 6 May 1976
Issued 7 Jun 1977
38 Claims (Cl. 60-527)

Patent No. 4,030,298
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Dante J. Sandoval
Filed 19 Feb 1976
Issued 21 Jun 1977
9 Claims (Cl. 60/527-529)

Patent No. 4,035,007
"Heat Recoverable Metallic Coupling"
J. D. Harrison, and J. E. Jervis, Assignors Raychem Corp
Filed 29 Oct 1973
Issued 12 Jul 1977
25 Claims (Cl. 285-381)

Patent No. 4,037,324
"Method and System for Orthodontic Moving of Teeth"
G. F. Andreasen, Assignor to the University of Iowa Research
Foundation
Filed 21 May 1973
Issued 26 July 1977
19 Claims (Cl. 32-14)

Patent No. 4,037,411
"Thermal Energy Converting Assembly"
P. A. Hochstein
Filed 2 Feb 1976
Issued 26 Jul 1977
28 Claims (Cl. 60-527)

Patent No. 4,049,151
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R. J. Schweiso, Assignor to Raychem Corp.
Filed 4 Jan 1973
Issued 20 Sep 1977
7 Claims (Cl. 220-201)

Patent No. 4,055,955
"Memory Alloy Heat Engine and Method of Operation"
A. D. Johnson
Filed 16 Aug 1976
Issued 1 Nov 1977
25 Claims (Cl. 60-527)

Patent No. 4,075,846
"Thermal Engine with Entrapped Working Medium"
Y. T. Li, Assignor to Massachusetts Institute of Technology
Filed 4 May 1976
Issued 28 Feb 1978
9 Claims (Cl. 60-527)

Patent No. 4,086,769
"Compound Memory Engine"
W. K. Smith, Assignor to the U.S.A.
Filed 19 May 1975
Issued 2 May 1978
6 Claims (Cl. 60-527)

NSWC TR 80-59

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N. E. Rogen, Assignor Nicoa Corp.
Filed 28 Aug 1975
Issued 19 Sep 1978
11 Claims (Cl. 116-114.5)

Patent No. 4,117,680
"Continuous Loop Shape Memory Effect Heat Engine"
R. H. Smith, Assignor to Solergy, Inc.
Filed 7 Dec 1976
Issued 3 Oct 1978
4 Claims (Cl. 60-527)

Patent No. 4,126,758
"Method for Sealing Integrated Circuit Components with Heat
Recoverable Cap and Resulting Package"
J. F. Krumme, Assignor to Raychem Corp.
Filed 30 Apr 1974
Issued 21 Nov 1978
16 Claims (Cl. 174-52 FP)

Patent No. 4,144,057
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K. Melton and O. Mercier, Assignors to BBC Brown Boveri and Co.
Filed 25 Aug 1977
Issued 13 Mar 1979
24 Claims (Cl. 75-134)

Patent No. 4,149,911
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R. J. T. Clabburn, Assignor to Raychem Limited
Filed 17 Jan 1978
Issued 17 Apr 1979
26 Claims (Cl. 148-11.5 R)

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