U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

400 Seventh Street, S.W.
Washington, D.C. 20590

AUG 31 2005

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Mr. Steven P. Reynolds
Senior Council, Sensors & Controls
Texas Instruments Incorporated
34 Forest Street, MS 20-21
Attleboro, MA 02703

NVS-214bby
EA05-005

Dear Mr. Reynolds:

The Office of Defects Investigation (ODI) of the National Highway Traffic Safety Administration (NHTSA) is investigating allegations that failures of Speed Control Deactivation Switches manufactured by Texas Instruments have caused engine compartment fires in model year (MY) 1995 through 2002 Ford F150, Ford Expedition, and Lincoln Navigator vehicles. Ford has determined that some speed control deactivation switches on the 2000 MY vehicles can develop a resistive short in the electrical circuit that could potentially result in an engine compartment fire. By its letter dated January 27, 2005, Ford limited the scope of the recall (05V-017) to 2000 MY Ford F150, Expedition, and Lincoln Navigator vehicles equipped with speed control and certain 2001 MY F150 Supercrew vehicles built through August 7, 2000.

At the time this investigation was opened ODI had received 218 complaints reporting engine compartment fires in certain (MY) 1995-2002 Ford F150, Ford Expedition, and Lincoln Navigator vehicles. All of the 218 complaints identified were confirmed as not being included in the scope of Ford's recall 05V-017.

To assist us with our investigation, ODI is requesting certain information from Texas Instruments.

Unless otherwise stated in the text, the following definitions apply to these information requests:

- **Subject vehicles:** All MY 1995 through 2002 Ford F150, Ford Expedition, and Lincoln Navigator vehicles.
- **Subject recall:** NHTSA Recall No. 05V-017 (Ford Recall No. 05S28).
- **Subject switches:** All Speed Control Deactivation Switches manufactured by Texas Instruments for use in the subject vehicles or vehicles included in the subject recall.

- **Texas Instruments:** Texas Instruments Incorporated, all of its past and present officers and employees, whether assigned to its principal offices or any of its field or other locations, including all of its divisions, subsidiaries (whether or not incorporated) and affiliated enterprises and all of their headquarters, regional, zone and other offices and their employees, and all agents, contractors, consultants, attorneys and law firms and other persons engaged directly or indirectly (e.g., employee of a consultant) by or under the control of Texas Instruments (including all business units and persons previously referred to), who are or, in or after 1991, were involved in any way with any of the following related to the alleged defect in the subject vehicles:

  a. Design, engineering, analysis, modification or production (e.g. quality control) of speed control deactivation switches;
  b. Testing, assessment or evaluation of such switches;
  c. Consideration, or recognition of potential or actual defects, reporting, record-keeping and information management, (e.g., complaints, field reports, warranty information, part sales), analysis, claims, or lawsuits.

- **Alleged defect:** Any malfunction (including brake fluid leaks) of the subject switches that may result in the loss of the speed control function, melting of switch materials, smoke, fire, or ignition of engine compartment materials or components.

- **Document:** "Document(s)" is used in the broadest sense of the word and shall mean all original written, printed, typed, recorded, or graphic matter whatsoever, however produced or reproduced, of every kind, nature, and description, and all non-identical copies of both sides thereof, including, but not limited to, papers, letters, memoranda, correspondence, communications, electronic mail (e-mail) messages (existing in hard copy and/or in electronic storage), faxes, mailgrams, telegrams, cables, telex messages, notes, annotations, working papers, drafts, minutes, records, audio and video recordings, data, databases, other information bases, summaries, charts, tables, graphics, other visual displays, photographs, statements, interviews, opinions, reports, newspaper articles, studies, analyses, evaluations, interpretations, contracts, agreements, jottings, agendas, bulletins, notices, announcements, instructions, blueprints, drawings, as-builts, changes, manuals, publications, work schedules, journals, statistical data, desk, portable and computer calendars, appointment books, diaries, travel reports, lists, tabulations, computer printouts, data processing program libraries, data processing inputs and outputs, microfilms, microfiches, statements for services, resolutions, financial statements, governmental records, business records, personnel records, work orders, pleadings, discovery in any form, affidavits, motions, responses to discovery, all transcripts, administrative filings and all mechanical, magnetic, photographic and electronic records or recordings of any kind, including any storage media associated with computers, including, but not limited to, information on hard drives, floppy disks, backup tapes, and zip drives, electronic communications, including but not limited to, the Internet and shall include any drafts or revisions pertaining to any of the foregoing, all other things similar to any of the foregoing, however denominated by Texas Instruments, any other data compilations from which information can be obtained, translated if necessary, into a usable form and any other documents. For purposes of this request, any document, which

contains any note, comment, addition, deletion, insertion, annotation, or otherwise comprises a non-identical copy of another document shall be treated as a separate document subject to production. In all cases where original and any non-identical copies are not available, "document(s)"also means any identical copies of the original and all non-identical copies thereof. Any document, record, graph, chart, film or photograph originally produced in color must be provided in color. Furnish all documents whether verified by the manufacturer or not. If a document is not in the English language, provide both the original document and an English translation of the document.

- Other terms: To the extent that they are used in these information requests, the terms "claim," "consumer complaint," "dealer field report," "field report," "fire," "fleet," "good will," "make," "model," "model year," "notice," "property damage," "property damage claim," "rollover," "type," "warranty," "warranty adjustment," and "warranty claim," whether used in singular or in plural form, have the same meaning as found in 49 CFR 579.4.

In order for my staff to evaluate the alleged defect, certain information is required. Please provide numbered responses to the following information requests. When documents are produced, the documents shall be produced in an identified, organized manner that corresponds with the organization of this information request letter (including all individual requests and subparts). When documents are produced and the documents would not, standing alone, be self-explanatory, the production of documents shall be supplemented and accompanied by explanation.

Please repeat the applicable request verbatim above each response. After Texas Instrument's response to each request, identify the source of the information and indicate the last date the information was gathered. If requested information is unavailable, so state and provide a brief explanation. Along with your written response, please provide this information in Microsoft Word 2000, or a compatible format, entitled "IR Response."

1. Provide copies of all engineering standards, specifications, quality control documents, and detail drawings related to the subject switches or their sub-components.

2. Describe, and provide copies of all documents relating to, all design verification and validation tests that relate in any way to the durability of the subject switch or its sub-components.

3. Provide a chronology of all events relating to the initial testing and supply of the subject switches for MY 1993 through 2002 Ford F150, Expedition, and Lincoln Navigator vehicles (including all prototype and pre-test designs) and of the subsequent investigation that led to the subject recall.

4. Describe, and provide copies of all documents relating to, all inspections, tests, and other analyses of subject switches. Provide a listing of all such switches that were inspected, tested, evaluated, or assessed by stating the vehicle's VIN, recall repair date, mileage at the

recall repair date, switch part number, part serial number (identifying marking), part date of build, anomalies detected, and reason for specific switch analysis.

5. Describe all assessments, analyses, tests, test results, studies, surveys, simulations, investigations, inquiries, assessments and/or evaluations (collectively, "actions"), that relate to, or may relate to, the alleged defect in any of the subject switches, that have been conducted, are being conducted, are planned, or are being planned by, or for, Texas Instruments. For each such action, provide the following information:

   a. Vehicle make, model, and model year for which the subject switch was or may be used;
   b. Action title or identifier;
   c. The actual or planned start date;
   d. The actual or expected end date;
   e. Brief summary of the subject and objective of the action;
   f. Engineering group(s)/supplier(s) responsible for designing and for conducting the action; and,
   g. A brief summary of the findings and/or conclusions resulting from the action.
   h. For each action identified, provide copies of all documents related to the action, regardless of whether the documents are in interim, draft, or final form. Organize the documents chronologically by action.

6. Describe any situation, design, manufacturing process, or other issue that might have resulted in physical differences between any two subject switches. As part of this description please include the physical difference being described, the cause of the difference, and when the cause for the difference began and ended in production.

7. Describe all modifications or changes made by, or on behalf of, Texas Instruments in the design, material composition, manufacture, quality control, supply, or installation of the subject switches or subject switch sub-components, from the start of production to date. For each such modification or change, provide the following information:

   a. The date or approximate date on which the modification or change was incorporated into production;
   b. A detailed description of the modification or change;
   c. The reason(s) for the modification or change;
   d. The part numbers (service and engineering) of the original component;
   e. The part number (service and engineering) of the modified component;
   f. Whether the original unmodified component was withdrawn from production and/or sale, and if so, when;
   g. When the modified component was made available as a service component; and
   h. Whether the modified component can be interchanged with earlier production components.

8. Provide a detailed explanation of the extended cycle life switch design discussed in US Patent Number 5,932,857, dated August 3, 1999 (copy attached). As part of your response, please include:

   a. A detailed chronology of all events, meetings, communications, both internal to Texas Instruments and external, in which Texas Instruments was involved and which lead or contributed to the Patent application of May 6, 1997 which resulted in the Patent award on August 3, 1999;
   b. Any discussions or communications with Ford regarding the extended cycle life switch design described in Patent Number 5,932,857 and if no communications took place related to this topic, explain why not.
   c. In chronological order describe all assessments, analyses, tests, test results, studies, surveys, simulations, investigations, inquiries and/or evaluations (collectively, "actions") that relate to, or may relate to the preparation or application for, or awarding of Patent Number 5,932,857; For each such action, provide the following information:

      i. Action title or identifier;
      ii. The actual or planned start date;
      iii. The actual or expected end date;
      iv. Brief summary of the subject and objective of the action;
      v. Engineering group(s)/supplier(s) responsible for designing and for conducting the action; and
      vi. A summary of the action activities, findings and/or conclusions

9. Following the May 6, 1997 filing application which lead to the award of Patent Number 5,932,857, describe all modifications or changes made by, or on behalf of, Texas Instruments in the design, material composition, manufacture and/or fabrication, quality control, supply, or installation of the subject switches, which relate to, or may relate to the alleged defect. For each such modification or change, provide the following information:

   a. The date or approximate date on which the modification or change was incorporated into switch production;
   b. A detailed description of the modification or change;
   c. The reason(s) for the modification or change;
   d. The part numbers (service and engineering) of the original component;
   e. The part number (service and engineering) of the modified component;
   f. Whether the original unmodified component was withdrawn from production and/or sale, and if so, when;
   g. When the modified component was made available as a service component; and
   h. Whether the modified component can be interchanged with earlier production components.

   If modifications or changes as described in the Patent Number 5,932,857 were not made to the SCDS, state so and explain why they were not.

10. Provide copies of all documents or communications between Texas Instruments and Ford regarding the alleged defect in the subject switches. Organize the document copies in chronological order.

11. Provide copies of all documents or communications between Texas Instruments and DuPont regarding the alleged defect in the subject switches. Organize the document copies in chronological order.

12. Provide copies of all documents transmitted internally within Texas Instruments that relate to the alleged defect in the subject switches.

13. Describe and decode all identifying markings used by Texas Instruments on the subject switches.

14. Provide copies of all failure mode and effects analyses related to the subject switches.

15. State the number of each of the following that Texas Instruments has sold either as original equipment or replacement parts that may be used in the subject vehicles by component name, part number (both service and engineering/production), model and model year of the vehicle in which it is used, month/year of sale *(including the cut-off date for sales, if applicable)*, and the location to where the component was shipped:

    a. Subject components; and
    b. Any kits that have been released, or developed, by Ford for use in service repairs to the subject component/assembly.

    Provide this information in Microsoft Access 2000, or a compatible format, entitled "REQUEST NUMBER FIFTEEN DATA." See Enclosure 1, Data Collection Disc, for a pre-formatted table designed for this submission.

16. For each sub-component of the subject switch, provide the supplier's name, address, and appropriate point of contact (name, title, and telephone number).

17. Provide copies of any and all documents and/or communications prepared at any time by Texas Instruments and/or any contractor or representative working on behalf of Texas Instruments, which relates or may relate to Texas Instruments opinion, including the approval, or disapproval, of the application and utilization of the Texas Instruments pressure switch as used in any and all Ford vehicles. Include any and all background material used as a basis for these opinions. These documents may include but are not limited to any and all assessments, analyses, tests, test results, studies, surveys, simulations, investigations, inquiries and/or evaluations that were performed by or for Texas instruments.

18. Furnish Texas Instruments' assessment of the alleged defect in the subject switches, including:

    a. An assessment of the failure mechanism;
    b. An assessment of the design factors of the subject switches that may influence the durability of the subject switches;
    c. An assessment of the manufacturing factors that may influence the durability of the subject switches;
    d. An assessment of the vehicle assembly factors that may influence the durability of the subject switches; and
    e. An assessment of the use factors of the subject switches that may influence the durability of the subject switches.

    Please be as specific as possible in your answers and provide engineering explanations for how various factors affect the switch durability.

If Texas Instruments cannot respond to any specific request or subpart(s) thereof, please state the reason why it is unable to do so. If on the basis of attorney-client, attorney work product, or other privilege, Texas Instruments does not submit one or more requested documents or items of information in response to this information request, Texas Instruments must provide a privilege log identifying each document or item withheld, and stating the date, subject or title, the name and position of the person(s) from, and the person(s) to whom it was sent, and the name and position of any other recipient (to include all carbon copies or blind carbon copies), the nature of that information or material, and the basis for the claim of privilege and why that privilege applies.

Texas Instrument's response to this letter, in duplicate, together with a copy of any confidentiality request, must be submitted to this office by **September 21, 2005**. Please refer to EA05-005 in Texas Instrument's response to this letter. If Texas Instruments finds that it is unable to provide all of the information requested within the time allotted, Texas Instruments must request an extension from Mr. Richard Boyd at (202) 366-4933 no later than five business days before the response due date. If Texas Instruments is unable to provide all of the information requested by the original deadline, it must submit a partial response by the original deadline with whatever information Texas Instruments then has available, even if an extension has been granted.

If Texas Instruments claims that any of the information or documents provided in response to this information request constitute confidential commercial material within the meaning of 5 U.S.C. § 552(b)(4), or are protected from disclosure pursuant to 18 U.S.C. § 1905, Texas Instruments must submit supporting information together with the materials that are the subject of the confidentiality request, in accordance with 49 CFR Part 512, to the Office of Chief Counsel (NCC-113), National Highway Traffic Safety Administration, Room 5219, 400 Seventh Street, S.W., Washington, D.C. 20590. Texas Instruments is required to submit two copies of the documents containing allegedly confidential information (except only one copy of blueprints) and one copy of the documents from which information claimed to be confidential has been deleted.

If you have any technical questions concerning this matter, please call Bruce York of my staff at (202) 366-6938.

Sincerely,

Kathleen C. DeMeter, Director
Office of Defects Investigation
Office of Enforcement

Enclosure 1, one CD ROM titled Data Collection Disc containing one files
Enclosure 2, copy of US Patent #5,932,857

US005932857A

United States Patent [19]

Stander et al.

[11] Patent Number: 5,932,857

[45] Date of Patent: Aug. 3, 1999

[54] **PRESSURE SWITCH WITH BIAXIALLY ORIENTED THERMOPLASTIC DIAPHRAGM**

[75] Inventors: Richard A. Stander, Chelmsford; John E. Brennan, North Attleboro; Bryan J. Dague, Norton, all of Mass.

[73] Assignee: Texas Instruments Incorporated, Dallas, Tex.

[21] Appl. No.: 08/851,819

[22] Filed: May 6, 1997

[51] Int. Cl.[6] H01H 35/40

[52] U.S. Cl. ..... 200/83 B; 200/83 P; 200/83 J

[58] Field of Search ..... 200/83 R, 83 A, 200/83 B, 83 J, 83 P, 83 N, 83 WM, 81.4

[56] References Cited

U.S. PATENT DOCUMENTS

3,874,052	4/1975	Schantz	200/83 WM X
4,219,394	8/1980	Babinsky et al.	205/517
4,267,413	5/1981	Reis	200/81.4
4,419,443	10/1983	Tyree et al.	200/83 N
4,447,852	5/1984	Clement	361/306.1
4,469,923	9/1994	Chamberlain	200/83 P
4,746,536	5/1988	Ishikawa et al.	427/98
5,259,664	12/1993	Bane	417/360
5,508,483	4/1996	Czarn et al.	200/83 J

OTHER PUBLICATIONS

'Toray' PPS Film Torelina Technical Information (1994).

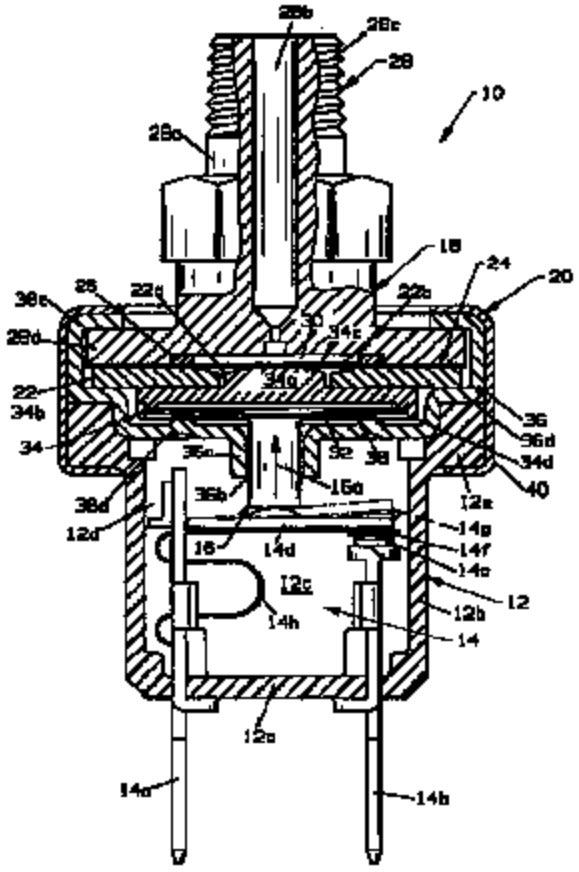
Primary Examiner—J. R. Scott

Attorney, Agent, or Firm—Russell E. Baumann; Richard L. Donaldson; Rene' E. Grossman

[57] ABSTRACT

A pressure responsive electric switch (10) is shown having an improved flexible diaphragm (28) to extend the useful life of the switch particularly when used with fluid media of a corrosive nature. The flexible diaphragm (28) comprises a base layer (28a) of resin having excellent mechanical properties over a wide range of temperature and a first level of fold endurance capability covered on one or both face surfaces with a protective layer (28b) of resin having excellent corrosion resistance capability and a second level of fold endurance capability at least as great as the first level. In a second embodiment, the flexible diaphragm is composed of biaxially oriented polyphenylene sulfide which can be used without additional protective layers.

3 Claims, 1 Drawing Sheet



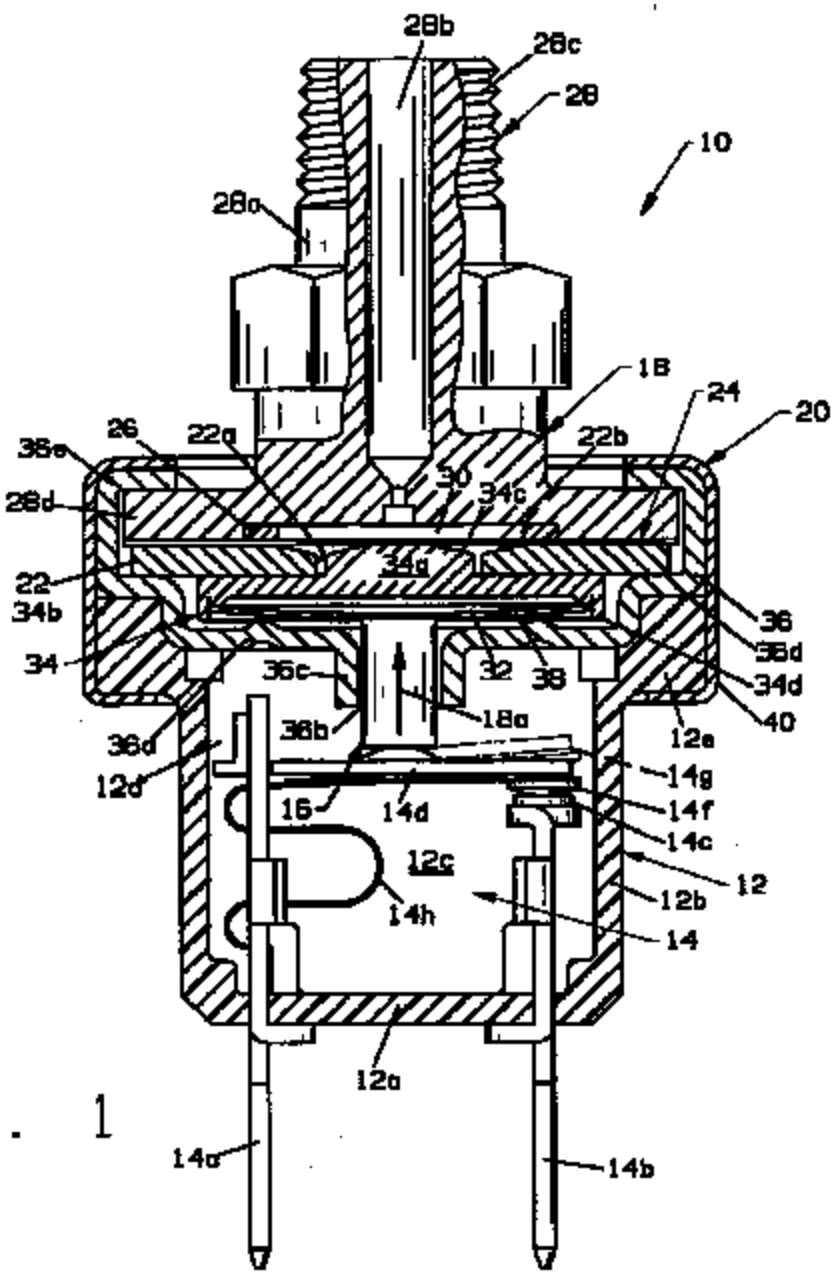

28b
28c
28
10
28a
18
24
20
26
22a
22b
38e
30
34c
28d
34a
22
34b
36
38d
34
36c
32
38
34d
18a
40
36b
12e
36d
14g
12d
14f
16
14d
14c
12c
12
12b
14h
14
12a
14a
14b

FIG. 1

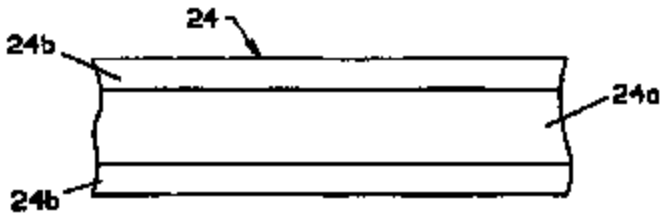

24
24b
24a
24b

FIG. 2

PRESSURE SWITCH WITH BIAXIALLY ORIENTED THERMOPLASTIC DIAPHRAGM

BACKGROUND OF THE INVENTION

This invention relates generally to pressure responsive electrical switches and more particularly to such switches used to monitor pressure levels of a fluid medium having adverse chemical and/or moisture characteristics.

Polyimide films are commonly used as diaphragm materials in pressure responsive electrical switches as a flexible interface between the pressure medium and the mechanical switch mechanism due to their excellent mechanical properties and outstanding resistance to change over a wide range of temperatures. However, these mechanical properties can degrade substantially when exposed to certain chemicals and/or moisture. Polyimide films exposed to water or water vapor undergo hydrolysis, which can adversely affect the film's ductility.

One supplier's literature describes a test where polyimide film (Kapton type H) is subjected to boiling water for 166 days prior to tensile testing. The film was said to retain 65% of its original tensile strength and 20% of its original elongation. This sharp decrease in elongation renders the film less ductile, i.e., embrittled. Similar tensile test results were found when immersing polyimide in moisture laden brake fluid at elevated temperature. For pressure switch diaphragm applications, this loss in ductility is highly undesirable and can lead to premature diaphragm failure due to film fracturing.

To alleviate this problem, the industry uses polyimide films which have been laminated with a protective overcoat, such as fluorinated ethylene propylene (FEP) resin. This composite film combines the high chemical inertness and water phobicity of the FEP fluorinated resin with the generally superior mechanical properties of polyimide. This overcoat effectively shields the polyimide from direct exposure to these adverse conditions, enhancing its overall performance.

However, pressure switches using diaphragms comprising FEP coated polyimide films, when used with certain fluid media, such as automotive brake fluids, are nevertheless subject to a primary mode of failure in which the pressure switch diaphragm ruptures resulting in brake fluid leakage. Initial film damage typically comprise cracks in the FEP protective layer followed by delamination of the FEP from the polyimide propagating from the cracked areas. Examination of test devices shows that fracturing of the FEP film precedes fracturing of the polyimide base film. Once this FEP overcoat fractures, the polyimide is exposed directly to the system fluid. This can cause the unprotected polyimide film to fail prematurely if the system fluid is detrimental to the base polyimide film, especially in dynamic applications requiring a high degree of film flexation, such as a pressure switch diaphragm.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide pressure responsive electrical switches having extended cycle life. Another object of the invention is to provide a pressure switch having a flexible diaphragm disposed between the pressure fluid being monitored and the mechanical components of the switch which has improved life expectancy, particularly when used with fluids having adverse chemical, corrosive and/or moisture characteristics.

Briefly, in accordance with the invention, a flexible diaphragm is shown for use with a pressure responsive electric switch to separate the fluid medium from the mechanical components of the switch comprising a base layer of polyimide, such as Kapton HN, having fold endurance level of capability of approximately 30,000 cycles, coated on one or both face surfaces with a protective layer having excellent chemical resistance as well as fold endurance level of capability at least as great, and preferably greater than that of the polyimide. Suitable materials included Teflon PFA having a fold endurance level of capability of approximately 100,000 cycles and Teflon PTFE having a fold endurance level of capability of approximately 1,000,000 cycles. According to a second embodiment, the diaphragm is composed of a polyphenylene sulfide film which has exceptional resistance to hydrolysis as well as excellent chemical resistance and therefore requires no protective layers.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, advantages and details of the invention appear in the following detailed description of preferred embodiments of the invention, the detailed description referring to the drawings in which:

FIG. 1 is a cross sectional view of the pressure responsive electric switch in which a diaphragm made in accordance with the invention is used; and

FIG. 2 is a broken away front view of a portion of a diaphragm made in accordance with the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to the drawings, numeral 10 in FIG. 1 indicates a fluid pressure responsive electric switch which is shown to include a base 12, control switch means 14 or the like mounted on the base to be movable between selected control positions, motion transmitting means 16, a discrete pressure responsive unit 18 and means 20 for mounting the discrete pressure responsive unit on the base to move the motion transmitting means for moving the control means between selected control positions in response to the application of selected fluid pressure to the pressure sensing unit 18.

The base 12 comprises a generally cup-shaped and generally cylindrical housing having a bottom wall 12*a*, a sidewall 12*b* defining a chamber 12*c*, having an open end 12*d* and having a mounting flange 12*e* extending around the open end of the housing. The housing is preferably formed of a strong and rigid electrically insulating material such as a phenolic resin or the like.

Control means 14 are preferably mounted on the housing within the housing chamber and is of any conventional type. As shown the control means comprises an electric switch means having a pair of terminals 14*a*, 14*b* mounted in the bottom wall 12*a* to extend out of the housing from within the housing chamber, has a stationary contact 14*c* mounted on terminal 14*b*, has a movable contact arm 14*d* pivotable on the other terminal 14*a*, has a movable contact 14*f* carried by the arm to be movable between a first, closed circuit switch position as indicated in solid lines in FIG. 1 and a second, open circuit position as indicated by broken lines 14*g* and has spring means 14*h* electrically connected between the terminal means 14*a* and movable arm 14*d* for normally biasing the movable contact 14*f* to disengage the stationary contact 14*c* as will be understood.

Motion transmitting means 16 comprises a motion transfer pin of a ceramic material or the like and normally holds the switch arm 14*d* in closed circuit position against the bias of spring 14*h* as shown in FIG. 1 but is axially movable as

indicated by the arrow 16a for permitting the switch arm 14d to move to the described open circuit position indicated at 14g in response to the spring 14h as described below.

Pressure responsive unit 18 comprises a support 22 having an opening 22a therethrough. The support comprises a flat round plate of cold rolled steel or the like having a round central opening 22a and having tapered or radiused portions 22b formed around the margin of the support opening. A diaphragm 24 formed of flexible material, to be discussed below, is disposed on the support plate to extend over the support opening. The diaphragm is adapted to flex over the support opening 22a in response to the application of fluid pressure to the diaphragm but which is also adapted to withstand substantial fluid pressure forces without rupture and to be capable of retaining its strength properties at elevated temperatures and under corrosive conditions.

A gasket means such as an annular, elastomeric, O-ring type gasket 26 or the like is mounted on one side of the diaphragm opposite support 22 to be concentric with the support opening 22a. A metal port body 28 is mounted to bear against the gasket for forming a sealed pressure chamber 30 in the switch at the said one side of the diaphragm. The port body includes integral connector means 28a defining a passage 28b which communicates with the pressure chamber 30 and has thread means 28c for use in connecting the chamber 30 through passage 28b to a pressure zone to be monitored in a conventional manner.

The pressure responsive unit 18 further comprises a conventional dished or domed metal disc spring element 32 formed of stainless steel or the like adapted to move with snap action from an original dished configuration as shown in FIG. 1 to an inverted or oppositely dished configuration in response to the application of selected force to the element. The element 32 is adapted to return to its original configuration when the applied force is reduced to a reset level or is removed. A force converter 34 is disposed between the dished element 32 and support 22. The converter has a force receiving portion 34a of a selected diameter which is movable in the support opening 22a to be responsive to movement of the diaphragm 24 and has an annular force applying portion 34b of relatively larger diameter which bears against a corresponding diameter portion on one side of the disc element 32 for transmitting the diaphragm movement to the disc as a force tending to move the disc to its inverted dished configuration. The force receiving portion 34a of the force converter has a diameter only slightly smaller than the diameter of the support opening 22a and is adapted to slide closely within the opening. Preferably, the margins of the force receiving portion are tapered at 34c. In that arrangement, the force receiving portion of the converter provides support for diaphragm 24 over substantially the entire expanse of the support opening 22a and the margins of the opening and of the force receiving portion are tapered to avoid injury to the diaphragm when very high fluid pressures are applied to the diaphragm in chamber 30.

Unit 30 further comprises a reaction means 36a in the form of an annular portion of a different diameter than the force applying portion 34a of the force converter. The reaction means bears against a corresponding diameter on the opposite side of the dished disc element 32 and forms a part of mounting means in the form of sleeve 36 which mounts the support plate, the port body, gasket and diaphragm, as well as the force converter and disc together in fixed relation to each other to form the discrete unit 18. A central opening 36b and guide flange 36c slidably received motion transfer pin 16 therein. A shoulder 36d is formed on the sleeve intermediate its ends for receiving and positioning support plate 22. A second integral inturned flange 36e at the opposite end of the sleeve bears against the clamping ring portion 28d of the port body for compressing the gasket and for securing the components of the pressure sensing unit together. The pliable film 38 of a polyimide material or the like is shown disposed between the disc 32 and sleeve 36 to serve as a lubricant and prevent galling of the disc during relative movement of the disc and sleeve.

Motion transfer pin 16 is slidably disposed in opening 36b in the pressure unit mounting sleeve, the pressure responsive unit 18 is mounted on the housing flange 12e and a second metal sleeve 40 or the like is swaged over the unit 18 and flange 12e for securing the housing, switch means and pressure unit together to form the pressure responsive electric switch 10.

Fluid pressure is adapted to be introduced into chamber 30 through port passage 28b to be applied to the diaphragm 24 so that the diaphragm flexes over support opening 22a and transmits its flexing movement to the disc element 32 through force converter 34. When that applied fluid pressure is below a selected level, the disc element remains in the position shown in FIG. 1 and a disc spring holds the pin 16 and contact arm 14d in the position shown against the bias of spring 14h so that the switch means 14 remains in closed circuit position. However, the relative diameters of the force receiving and applying portions 34a and 34b of the force converter and the diameter of the annular reaction means 36a cooperate in a known manner to apply a force to the disc element and that force cooperates with the selected snap acting characteristics of the element so that the disc moves with snap action to its inverted dished configuration when applied fluid pressure reaches a selected level. When that occurs, the motion transfer pin 16 moves in the direction of the arrow 16a in response to the bias of switch spring 14h and permits switch arm 14d to move to the open circuit position. Force converter 34 has an annular stop 34d which fits around the disc and which is adapted to engage sleeve 36 after the disc element has moved to its inverted configuration, thereby to protect the disc element against any excessive over-pressures which may be applied to the diaphragm 24 as well as preventing diaphragm rupture.

When the fluid pressure in chamber 30 is subsequently reduced to a reset level or is removed, the disc element 32 moves back with snap action to its original dished configuration and restores switch arm 14d to is closed circuit position.

Further details of the above described switch can be had in U.S. Pat. No. 4,469,923, assigned to the assignee of the present invention, the subject matter of which is incorporated herein by this reference.

Switch 10 is particularly suitable for use in monitoring high fluid pressure levels such as those employed in automotive power steering, brake systems and the like. Diaphragm 24 comprises one or more sheets of material each comprising a base layer 24a, preferably of a polyimide, such as Kapton HN available from DuPont de Nemours, which has excellent mechanical properties over a wide range of temperatures, coated with a protective layer 24b on each face side of base layer 24a. By way of example, each base layer 24a may be approximately 0.003 inches in thickness and each protective layer 24b may be approximately 0.001 inches in thickness.

When used in applications requiring high cycle life and involving significant flexing under stress which occurs, for example, in snap acting switches, particularly in high fluid

pressure applications, the diaphragm must be capable of such extended performance without fracturing. Fold endurance capability is a measure of the flexural property required to provide this performance. Polyimide has a fold endurance capability of approximately 30,000 cycles. The prior art fluorinated ethylene propylene (FEP) layer, on the other hand, while providing outstanding chemical resistance, has a fold endurance capability of approximately 10,000 cycles. As noted above, the primary mode of failure of prior art switches used with certain fluid media, such as automotive brake fluids, involved the cracking of the FEP layer thereby exposing the polyimide layer to the corrosive affects of the fluid. It should also be noted that the outer protective layer is subjected to even greater stresses than the base layer because it is further removed from the thickness centerline of the diaphragm sheet.

In accordance with the invention, layers **24***b* are formed of a corrosion resistant material which has a fold endurance capability at least equal to, and preferably greater than, that of base layer **24***a*. One such material is perfluoroalkoxy (PFA) which has a fold endurance capability of approximately 100,000 cycles. Another suitable material is polytetrafluoroethylene (PTFE) which has a fold endurance capability of approximately 1,000,000 cycles. While these materials do not have all the mechanical properties needed to serve as the base layer, e.g., they exhibit a tendency to creep with elevated temperature, they do provide corrosion protection and have superior fold endurance capability. It will be appreciated that other corrosive resistant materials, including modified PFA and PTFE resins, having a fold endurance capability at least equal to, and preferably greater than that of the base layer, can be used in practicing the invention. Although it is preferred to provide protective layer **24***b* on each face surface of base layer **24***a*, it will be understood that, if desired, the protective layer could be provided only on the face surface of the diaphragm to be exposed to the fluid medium. The following table can be used to compare the flexural properties of the reference materials. The table includes fold endurance test data (manufacturer's) to determine the performance of various resins of equal film thickness (0.002") under ideal conditions.

Polyimide (Kapton HN)	Approximately 30,000 cycles
Teflon FEP	10,000 cycles
Teflon PFA	100,000 cycles
Teflon PTFE	1,000,000 cycles

A polyimide film overcoated with PFA resin, such as Dupont's Kapton XP, will avoid premature fracturing of the protective overcoat. The PFA resin also has increased bond strength retention at elevated temperatures (up to 160 degrees C. or greater). Since both resins are mostly mechanically bonded (melt bonded) to the polyimide, the PFA resin encounters less softening at elevated temperatures than the FEP resin, because PFA's melting point is 80 degrees C. higher. At room temperature and below, the mechanical properties of both the FEP and PFA resins are nearly identical. Since both Kapton XP and FN use the same polyimide base film, the overall mechanical properties of both films are nearly identical, greatly enhancing product interchangeability.

EXAMPLES

Materials were tested including Kapton XP—a PFA coated polyimide film, Kapton FN—and FEP coated polyimide film (used as a control group). A direct comparison was made using pressure switches with 3 layers of each of these diaphragm materials. Samples were placed on a serpentine manifold with the Kapton XP switches mounted closest to the pressure source, followed by the Kapton FN group.

Test results showed a greater than 600% improvement in diaphragm life for switches utilizing PFA overcoated polyimide (Kapton XP) vs. Kapton FN (control group). These devices were cycled at pressures from 40 to 1450 psig at rates varying from 2 to 2.3 hz. Test temperatures were @ 135 degrees C. with some testing performed at −40 degrees C. and RT. System fluid consisted of new brake fluid, without any additional moisture content intentionally added.

According to a second embodiment of the invention, diaphragm **24** is composed of one or more layers of polyphenylene sulfide (PPS) film, a polymer composed of a series of alternating aromatic rings and sulphur atoms, such as Torelina PPS film. Torelina is a registered trademark of Toray Industries, Inc. for polyphenylene sulfide films. PPS films display virtually no hydrolysis as well as excellent resistance to chemicals. Torelina PPS film is biaxially oriented which provides mechanical resistance to the formation of stress cracks caused by bending and the like. As a result, biaxially oriented polyphenylene sulfide can be used for diaphragm **24** without any protective layers and provides an advantage of being a lower cost material than corresponding laminated materials.

By means of the invention, switches can be tailored for reduced cycle life requirements at lower cost, or extended cycle life requirements at slightly higher cost, or for applications using aggressive fluids such as brake switch applications. Further, unit cost can be reduced by the capability to reduce the number of layers required in certain pressure switch applications. The ability to use molded composite in accordance with the invention produce the following benefits:

- Reduced diaphragm material cost.
- Reduced production waste (no post-punching material discarded).
- Elimination of punching, shearing, or cutting operations.
- Ability to produce a pre-contoured film with:
  - Reduced form (wetted) film stress.
  - Enhanced cross sectional thickness control.
  - Ability to incorporated additional geometric features into the diaphragm film such as shape, ridges, variable cross sectional thickness, etc.

Although one particular switch is described herein, it will be realized that the improved diaphragm can be used with various fluid pressure responsive switches as an interface between the fluid medium and the switch mechanism. It should be understood that although particular embodiments of the invention have been described by way of illustration of the invention, the invention includes all modifications falling within the scope of the appended claims.

What is claimed:

1. A fluid pressure responsive electric switch comprising a housing defining a switch chamber and a fluid pressure receiving chamber, an electric switch mounted in the switch chamber having a stationary and a movable electrical contact, a pressure responsive mechanism disposed in the switch chamber of the housing movable between the first and second configurations, a motion transfer mechanism extending between the pressure responsive mechanism and the movable contact to transfer motion therebetween to move the movable

contact into one of engagement and disengagement with the stationary contact in one of the first and second configurations, a port formed in the housing to allow ingress of a fluid medium into the fluid pressure receiving chamber and a flexible diaphragm disposed in the housing between the fluid pressure receiving chamber and the switch chamber allowing flexible movement of the diaphragm while separating the fluid medium from the switch chamber, the diaphragm formed of at least one layer of "biaxially-oriented" polyphenylene sulfide polymer.

2. A fluid pressure responsive electric switch according to claim 1 in which the pressure responsive mechanism comprises a snap acting disc.

3. A fluid responsive electric switch according to claim 1 in which the pressure responsive mechanism comprises a pressure to force converter and a snap acting disc, the pressure to force converter disposed between the diaphragm and the disc.

* * * * *