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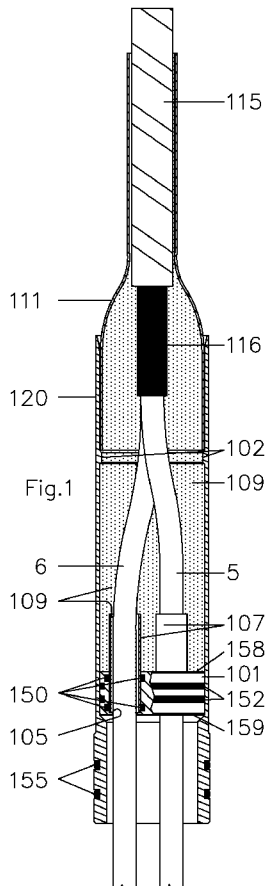
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(54) Title: SYSTEM FOR CONTINUOUS ELECTRICAL WELL CABLE FEED-THROUGH FOR A WELLHEAD AND METHOD OF INSTALLATION

(57) Abstract: An epoxy sealant combined with a transition seal body system for a down hole electric cable transition from a protected cable to separate conductors of three-phase electrical service provides an effective vapor and pressure seal preventing premature failure from temperature and pressure changes in the well bore. The use of epoxy completely surrounding the transition seal body within the penetrator mandrel permits safe and effective field installation of continuous electrical conductors from a wellbore through a pressure sealing wellhead to the surface that is easier to install and more protective than previous mechanical connections.



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SYSTEM FOR CONTINUOUS ELECTRICAL WELL CABLE FEED- THROUGH FOR A WELLHEAD AND METHOD OF INSTALLATION

This application claims priority to United States Provisional
Application No. 61/495,625 filed 10 June 2011, which is incorporated
5 herein by reference.

BACKGROUND OF INVENTION

Field of Invention

The present application relates to a new and improved method of
sealing a continuous electrical cable through a wellhead for providing
10 electrical power to an underground use of such power, such as an electrical
submersible pump or a heating system. Specifically, applicants claim a
wellhead penetrator system that seals against excessive pressure and high
temperatures and thereby maintains electrical integrity on a electrical
cable system, specifically on an ESP cable, which runs continuous through a
15 surface wellhead or other device using a combination of elastomeric seals
and epoxy seals as the primary sealing agents.

Description of Related Art

Electrical cable transitions and seals have for many years been
installed in well bores to provide power to electrical submersible pumps or
20 other down-hole equipment. This equipment utilizes three-phase electrical

conductors that penetrate a surface wellhead, which is intended to seal the well to prevent the release of dangerous or explosive vapors into the wellhead area on the surface.

Penetrator systems as above are described in U.S. Patent Nos. 5,762,135, and 5,289,882. Various arrangements have improved the reliability of these penetrator systems and very often they would use epoxy to seal the end of the electrical conductors in order to protect the insulation on each conductor from encroachment from hydrocarbon vapors which cause the conductor's protective elastomeric coverings to swell or crack and thereby cause the high voltage, high amperage wires to short out with catastrophic results. The physical integrity of the connections heretofore principally relied upon the mechanical cooperation of sleeves, compression fittings, and non-ferromagnetic covers to prevent the ingress of hydrocarbon vapors into the connection for the preservation of the connection. After many years of experimentation and use of existing technology, applicants have discovered that the use of field-mixed epoxy can provide both a seal for the conductors which are protected on the interior of the penetrator system and also a bonded surface which prevents further movement of the conductors within the penetrator, thereby assuring long lasting serviceability of the penetrator.

The present application seeks to claim a novel and improved means for a continuous electrical cable feed-through which permits electrical conductors to be sealed sufficiently to protect the conductors from ingress of damaging vapors within the well bore and thereby preventing premature failure by short-circuiting and the like, while also preventing pressure loss through the wellhead.

Summary of Invention

The present application is a system for a continuous electrical well cable feed-through for a wellhead which has a non-ferromagnetic transition seal body with at least three openings, or foramen, for the passage of electrical conductors through the body. Each of the foramen has an interior shoulder where steel tubes for supporting the three electrical conductors inserted into the non-ferromagnetic transition seal body is seated. A transition collar is inserted in a non-ferromagnetic mandrel to enclose the electrical conductors emerging from an armored pump cable in the interior of the mandrel. Finally, epoxy is packed between the non-ferromagnetic transition collar and the transition seal body covering the three steel tubes into which the electrical conductors are inserted and filling the interior of the mandrel.

The non-ferromagnetic transition seal body may have a chamfered edge around a proximal and distal edge of the body to facilitate entry into the mandrel. Further, the opening on the transition seal body may be chamfered to permit insertion of the tubes into the body for seating against the interior shoulder.

The present application also has a sub-system for a continuous electrical well cable feed-through for a wellhead with a non-ferromagnetic transition seal body seated on an interior shoulder of a protective mandrel and sealed inside that protective mandrel by a plurality of O-rings and a covering of epoxy extending from the well cable to the transition seal body. The transition seal body has three foramen for the passage of electrical conductors and an interior shoulder in each of the three foramen with at least three non-ferromagnetic tubes supporting the three electrical conductors inserted into the non-ferromagnetic transition body seated on the interior shoulder in the transition seal body.

The present application also depicts a method for the installation of a continuous electrical three-phase cable through a wellhead with a first step of stripping the protective outer sheath down to the insulation on an electrical conductor of a down-hole three-phase electrical cable; a second step of inserting each of the insulated electrical conductors into a non-ferromagnetic tubing; third, inserting each non-ferromagnetic tubing into a

non-ferromagnetic transition body seating the end of each tubing against an interior shoulder in the transition body; forth, distributing epoxy around the insulated electrical conductors covering the exposed end of the protective outer sheath of the electrical three-phase cable and covering
5 each of the tubes extending from the non-ferromagnetic transition body; fifth, enclosing the non-ferromagnetic transition body, seal and epoxy covered electrical conductors within a protective mandrel; and finally, inserting the mandrel into the wellhead hanger.

10 **Brief Description of the Drawings**

Fig. 1 is a partial cross-sectional view of an embodiment showing a transition seal of the electrical cables from a pump cable through the seal.

Fig. 2 is a more detailed view of the transition seal of Fig. 1 showing the seal fixed in the interior of the mandrel for enclosing the epoxy sealant.

15 Fig. 3 is cross-sectional view of the transition seal body.

Detailed Description of the Embodiment

As previously noted, users have long sought secure seals for down-hole electrical conductors experiencing high pressures and temperature. Applicants have discovered that secure, safe, vapor resistant, and field-

installable seals providing high temperature and high-pressure protection for electrical conductors in transition from the well bore to the surface through the well head can be established using epoxy in conjunction with a transition seal body seated within the penetrator mandrel. Fig. 1 is the proposed transition seal showing a non-ferromagnetic seal body **101** made from a nickel coated brass or stainless steel, which is intended to seat in a wellhead or tubing hanger (not shown), all in a manner previously well known to those skilled in this art. The seal body **101** provides an interior shoulder **105** against which is seated a non-ferromagnetic tubing **107** in each hole, which tubing, in this case, is fabricated from stainless steel.

Armored pump cable **115** is inserted in a non-ferromagnetic transition collar **111** and the electrical cables are separated from their twisted relationship. In this view, a lead jacket **116** often found around the individual conductors is also stripped from the insulated covering of the individual conductors **5, 6** upon insertion into the non-ferromagnetic penetrator mandrel **120** and into the stainless steel tubes **107** as previously discussed, leaving only the elastomeric covering on each conductor **5, 6**. This covering is normally made from ethylene propylene diene monomer rubber (EPDM). The transition collar **111** seats in a shoulder **102** on the interior surface of the mandrel **120**.

As is well known, these non-ferromagnetic materials do not conduct the eddy currents associated with the electrical current found in each of the separated three-phase electrical conductors. A quantity of epoxy **109** is installed between the transition seal body **101** and a penetrator mandrel **120** enclosing each of the separated conductors **5, 6**. The tubes **107** seating within the transition seal body **101** segregate and hold each leg of the electrical conductors in a fixed, but separate, position allowing the epoxy **109** to set and harden around the conductors **5, 6**, the tubes **107** and the interior wall of the penetrator mandrel **120**. A flat-to-round transition collar could be substituted for the transition collar **111**, permitting either the flat or round form of power cable to be used with this transition. The transition collar **111** is typically formed from stainless steel, provides the means for starting the separation of the electrical conductors **5,6** and covers a large portion of epoxy **109** as it is inserted into the penetrator mandrel where it seats on a mandrel shoulder **102**. While only two electrical conductors **5, 6** are shown in Fig. 1, a person having ordinary skill in this art will understand that most power cables are triple cables and the third conductor is not shown in this view.

As shown in Fig. 1, epoxy **109** fills the interior of the penetrator mandrel **120** and transition collar **111**. The epoxy also enters each of the tubes **107** creating a seal around each electrical conductor **5, 6**. The

penetrator mandrel **120** is inserted in a well head where it seals with O-rings **155**, all in a manner well known in this art. Fig. 2 shows in more detail the transition seal body **101** of Fig. 1.

Viewing Fig. 2, one can see the transition seal body **201** providing a chamfered edge **259** on the lower edge of the seal body **201** and a chamfered edge **258** on the upper outer edge of the seal body **201**. These chamfered edges allow the body **201** to be inserted easily into the interior of the penetrator mandrel **220**. O-rings **252** retained in grooves and extending from the outer circumferential surface of the seal body **201** seal within the penetrator body **220**. Each steel tube **207** is inserted in the seal body **201** where each seals in a second set of interior O-rings **250**, where each tube seats against the interior shoulder **205**. Epoxy **209** is inserted into the mandrel **220** where it surrounds each tube **207** and enters the space between the tubes **207** and the exterior surface of the electrical conductor inserted into the tube. This epoxy **209** seals each conductor **5, 6** within the transition seal body **201** and minimizes failures from high temperature and high pressure. Tests on this embodiment indicate this seal will maintain the seal up to 325° F (163° C) and about 4500 psi (31.02640 MPa). Other tests suggest that a similar embodiment can provide a seal 460° F (238° C) and about 6000 psi (41.36854 MPa).

Fig. 3 is a face view of the present transition seal body **301** showing the three holes or passages for the electrical conductors. Outer diameter **358** provides at least two grooves **352** into which are seated O-rings which sealingly engage the inner diameter of the penetrator mandrel (not shown in this view). Each tube passage ends on a lower shoulder **305** on the interior of each passage in tube body **301** permitting the tubes **207** shown in Fig. 2 to seat on said shoulder. Each passage provides a chamfered edge **357** allowing the insertion of each tube to seal against the O-ring installed inside the grooves **350**.

The combination of the transition seal body, the O-rings sealing the stainless steel tubes in the body and the epoxy packing prevent the migration of damaging vapors and liquids thereby prevents vapors from causing expansion and contraction damage to the electrical conductors and premature failure from arcing over to the companion conductor and short-circuiting the system at this vulnerable position in the electrical system in the well.

Other embodiments could be formed by installing more than one transition seal body by providing an epoxy packing between each redundant seal to back up the seal as required by internal pressures and temperatures that may be experienced in the well.

The particular embodiment and use disclosed above is illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

CLAIMS

1. A system for a continuous electrical well cable feed-through for a wellhead comprising:

a non-ferromagnetic transition seal body providing at least three foramen

5 for the passage of electrical conductors and having an interior shoulder within each of the three foramen;

at least three steel tubes for supporting the three electrical conductors

inserted into the non-ferromagnetic transition seal body and seated on the interior shoulder in said transition seal body;

10 a transition collar inserted in a non-ferromagnetic mandrel enclosing the electrical conductors emerging from an armored pump cable in an interior of said mandrel; and,

epoxy packed between the non-ferromagnetic transition collar and the

transition seal body covering the three steel tubes into which the

15 electrical conductors are inserted, said epoxy filling the interior of the mandrel.

2. The system for continuous electrical well cable feed-through for a wellhead of claim 1 wherein the non-ferromagnetic transition seal body

has a chamfered edge around a proximal edge of the body and around a distal edge of the body to facilitate entry into the mandrel.

3. The system for continuous electrical well cable feed-through for a wellhead of claim 1 wherein the opening on the transition seal body is

5 chamfered to permit insertion of the tubes into the body for seating against the interior shoulder.

4. A sub-system for a continuous electrical well cable feed-through for a wellhead comprising:

a non-ferromagnetic transition seal body seated on an interior shoulder of

10 a protective mandrel and sealed on an interior surface of said protective mandrel by a plurality of O-rings and a covering of epoxy extending from the well cable to the transition seal body; and providing three foramen for the passage of electrical conductors and having an interior shoulder in each of the three foramen; and,

15 at least three non-ferromagnetic tubes supporting the three electrical conductors inserted into the non-ferromagnetic transition body seated on the interior shoulder in said transition seal body.

5. A method for installation of a continuous electrical three-phase cable through a wellhead comprising:

stripping the protective outer sheath down to the insulation on an electrical conductor of a down-hole three-phase electrical cable;

inserting each of the insulated electrical conductors into a non-ferromagnetic tubing;

5 inserting each non-ferromagnetic tubing into a non-ferromagnetic transition body seating the end of each non-ferromagnetic tubing against an interior shoulder in said transition body;

distributing epoxy around the insulated electrical conductors covering the exposed end of the protective outer sheath of the electrical
10 three-phase cable and covering each of the tubes extending from the non-ferromagnetic transition body;

enclosing the non-ferromagnetic transition body, seal and epoxy covered electrical conductors within a protective mandrel; and,

inserting the mandrel into the wellhead hanger.

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AMENDED CLAIMS

received by the International Bureau on 10 October 2012 (10.10.2012)

1. A system for a continuous electrical well cable feed-through for a wellhead comprising:
- a non-ferromagnetic transition seal body providing at least three
- 5 foramen permitting passage of non-terminated electrical conductors and having an interior shoulder within each of the three foramen;
- at least three steel tubes for supporting the three non-terminated electrical conductors inserted into the non-ferromagnetic
- 10 transition seal body, said steel tubes seated on the interior shoulder in said transition seal body;
- a transition collar inserted in a non-ferromagnetic mandrel enclosing the non-terminated electrical conductors emerging from an armored pump cable in an interior of said mandrel; and,
- 15 epoxy packed between the non-ferromagnetic transition collar and the transition seal body covering the three steel tubes into which the three non-terminated electrical conductors are inserted, said epoxy filling the interior of the mandrel and the interior of each steel tube.
- 20 2. The system for continuous electrical well cable feed-through for a wellhead of claim 1 wherein the non-ferromagnetic transition

seal body has a chamfered edge around a proximal edge of the body and around a distal edge of the body to facilitate entry into the mandrel.

3. The system for continuous electrical well cable feed-through
5 for a wellhead of claim 1 wherein the opening on the transition seal body is chamfered to permit insertion of the steel tubes into the body for seating against the interior shoulder.

4. A sub-system for a continuous electrical well cable feed-through for a wellhead comprising:

10 a non-ferromagnetic transition seal body seated on an interior shoulder of a protective mandrel and sealed on an interior surface of said protective mandrel by a plurality of O-rings and a covering of epoxy extending from the well cable to the transition seal body; and providing three foramen for the
15 continuous passage of electrical conductors and having an interior shoulder in each of the three foramen; and,
at least three non-ferromagnetic tubes supporting the three non-terminated electrical conductors inserted into the non-ferromagnetic transition body seated on the interior shoulder
20 in said transition seal body.

5. A method for installation of a continuous electrical three-phase cable through a wellhead comprising:

stripping the protective outer sheath down to the insulation on each non-terminated electrical conductor of a down-hole three-phase

5 electrical cable;

inserting each of the insulated non-terminated electrical conductors into a non-ferromagnetic tubing;

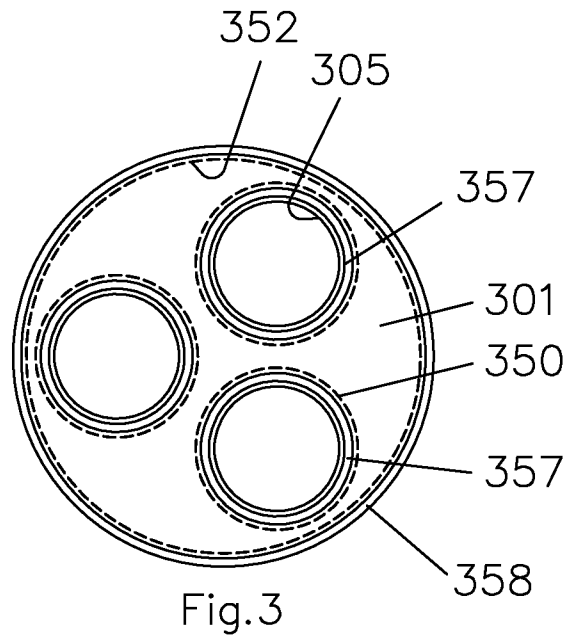
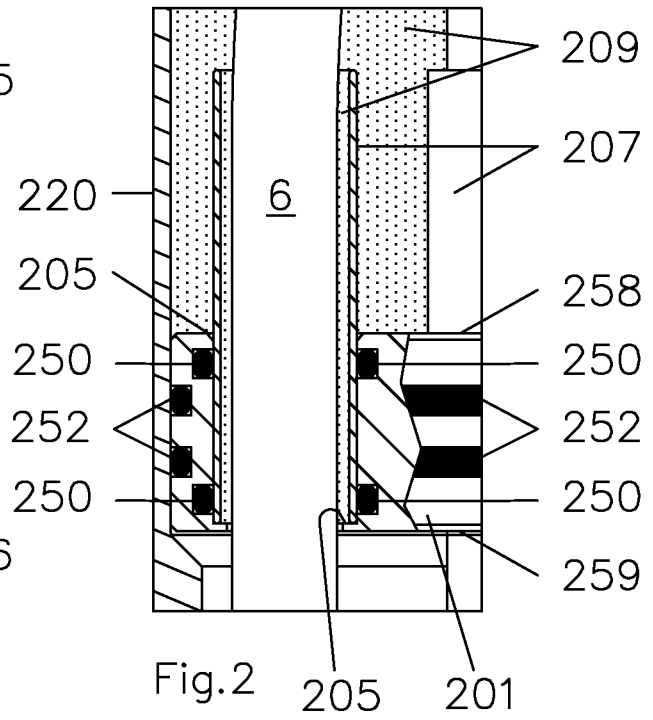
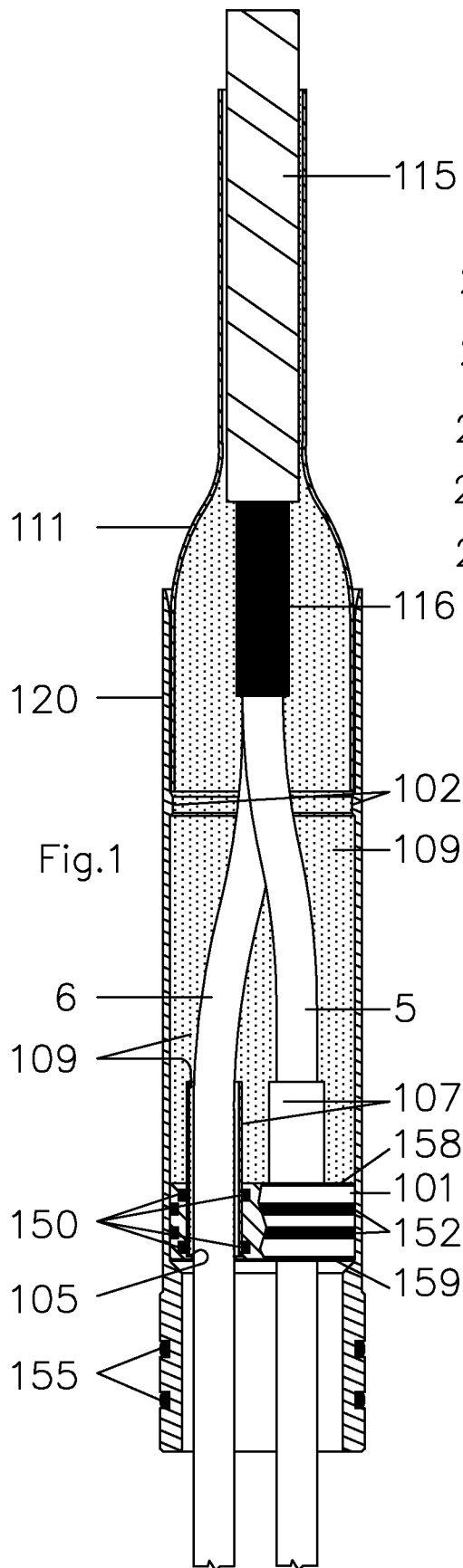
inserting each non-ferromagnetic tubing into a non-ferromagnetic transition body seating the end of each non-ferromagnetic tubing against an interior shoulder in said transition
10 body;

distributing epoxy around the insulated non-terminated electrical conductors covering the exposed end of the protective outer sheath of the electrical three-phase cable and covering each of
15 the tubes extending from the non-ferromagnetic transition body;

enclosing the non-ferromagnetic transition body, seal and epoxy covered non-terminated electrical conductors within a protective mandrel; and,

inserting the mandrel into the wellhead hanger.

20



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/041669

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 19/08 (2012.01)
USPC - 166/380
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - E21B 19/00, 19/02, 19/08 (2012.01)
USPC - 166/65.1, 379, 380

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patbase, Google Patent, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---	US 5,762,135 A (MOORE) 09 June 1998 (09.06.1998) entire document	4 ---
Y		1-3, 5
Y	US 6,409,102 B1 (LUTTRELL et al) 25 June 2002 (25.06.2002) entire document	1-3, 5
A	US 2010/0326725 A1 (EMERSON et al) 30 December 2010 (30.12.2010) para 0030, 0037 fig 3, 8	1-5
A	US 5,289,882 A (MOORE) 01 March 1994 (01.03.1994) col 4, lines 15-68, fig 3, 7	1-5

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
 "A" document defining the general state of the art which is not considered to be of particular relevance
 "E" earlier application or patent but published on or after the international filing date
 "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
 "O" document referring to an oral disclosure, use, exhibition or other means
 "P" document published prior to the international filing date but later than the priority date claimed
 "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
 "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
 "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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Date of the actual completion of the international search
31 July 2012

Date of mailing of the international search report
10 AUG 2012

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