Technische Überwachung

Bayer

D.I. von Arnim
D.I.Schumacher

Telefon: 3105
Telefax: 4614

Geb.: B 19

Dormagen, 02.12.1998

Zulassung für das Pop-a-plug-Verfahren (Verschließen von Wärmetauscherrohren)

Hersteller: Expando Seal Tods - Europa, 3931 MS Wondenberg, Niederlande

Verfahrensbeschreibung:

Das Pop-a-plug-Verfahren besteht aus einem zweiteiligen mechanischen Verschluß, der durch einen hydraulischen Kolben in einem Wärmetauscherrohr expandiert wird und das Rohr abdichtet. Der Kolben zieht einen zentralen konischen Mittelstift durch einen außen geriffelten Dichtring. Dabei dehnt sich der Ring aus und dichtet gegen die Rohrwand ab. Bei einer berechneten Kraft reißt die Sollbruchstelle des Losbrechelementes.

Einsatzgrenzen

Das Verfahren wurde von den Fachabteilungen ZF-FM Schweißtechnik, WD-SI VA Explosionsschutz und WD-SI TÜB untersucht (siehe Bericht von IN-FM ST vom 01.07.96) und folgende Einsatzbedingungen und -grenzen festgelegt:

Dieses Verfahren ist nur anzuwenden bei Rohrundichtheit, wenn eine Rohrstopfeneinschweißung aus betrieblichen Gründen nicht möglich ist und bisher mit konisch eingeschlagenen Stopfen repariert wurde.

Konstruktion:

- Wärmetauscherrohre ≤ 33,7 mm
- Rohrwanddicke (bzw. Rohrrestwanddicke) größer 1,6 mm
- Rohrovalität < 0,4 mm
- Wärmetauscher mit Rohren aus 1.4541, 1.4301, 1.4571 oder 1.4404
- Plug-Werkstoffe aus 1.4401 oder 1.4436
- Plugtypen P2 840S, P2 860S, A837S für eingewalzte Rohre
- Ohne Rohre ist Plugtype P2 1000S zu verwenden
- Bei Wärmetauscherrohren, die nicht in die Rohrplatte eingewalzt worden sind, muß mit dem Plug Typ A 837 S (mit großem Expansionsbereich) verschlossen werden.

Betrieb:

- Für Wärmetauscher mit Beschickungsmedien mit hohen Gefährdungspotential bzw. wenn durch Schädigung oder Korrosion die Stoffe des RudR mit den Stoffen des RddR reagieren können, ist das Verfahren nicht anzuwenden.

Montage:

- Im Rahmen der Vorbereitung müssen die anfallenden Späne entsprechend der betrieblichen Notwendigkeit entfernt werden.
- Korrosion, Abplatzungen, Mulden, Unebenheiten etc. an der Dichtfläche zum Stopfen sind zu beseitigen. (Auf die Restwandstärke ist zu achten).
- Die Wärmeentwicklung durch das Reiben und Reinigen der Rohre und die Zündquellen der Bohrmaschinen müssen im Erlaubnisschein vom Betrieb zugelassen sein.

TRANSLATION

Technical Monitoring **BAYER**

D. I. von Arnim Telephone: 3105 Geb.: B 19 Dormagen 12/2/1998
D. I. Schumacher Fax: 4614

Mr.
D. J. Bardt
ZT-FM LEV 5
Leverkusen
Geb. B 401

∅ Dr. Schacke
Mr. Psyk

Dear Mr. Bardt,

We are sending you the process approval as enclosure, with the request that you forward it to the producer, Expando Seal Tods.

Best regards,

D. I. von Arnim
Specialist

Enclosure

Technical Monitoring **BAYER**

D. I. von Arnim Telephone: 3105 Geb.: B 19 Dormagen 12/2/1998
D. I. Schumacher Fax: 4614

Approval for the pop-a-plug-process (Sealing of heat exchanger tubes)

Producer: Expando Seal Tods – Europe, 3931 MS Wondenberg, The Netherlands

Process description:

The pop-a-plug process consists of a two-part mechanically sealing device, which is expanded into a heat exchanger tube by a hydraulic piston and thereby seals the tube. The piston pulls a central conical pin through a conical nipple, which is furrowed on the outside. The nipple thereby expands and seals against the wall of the tube. The predetermined breaking point of the beakaway element ruptures at a calculated force.

Application boundaries

The process was investigated by the departments ZF-FM Schweisstechnik (welding technology), WD-SI VA Explosionsschutz (explosion protection) and WD-SI TUB (see the report by IN-FM ST of 7/1/96) and the following application conditions and –bouindaries were determined:

This process must only be used for tube leakage if tube plug welding is not possible because of operational considerations and/or repairs were previously carried out with conically "force-fit" plugs.

Construction:

- Heat exchanger tubes ≤ 33.7 mm
- Wall thickness of the tube (and/or residual wall thickness of the tube) greater than 1.4404
- Ovalness of the tube, < 0.4 mm
- Heat exchangers with tubes consisting of 1.4541, 1.4301, 1.4571 or 1.4404
- Plug materials consisting of 1.4401 or 1.4436
- Plug types P2 840S, P2 860S, wtubes
- With heat exchangers, which were not rolled into the tube plate, one must seal with plug type A 837 S (with large expansion area).

Operation:

- The process must not be used for heat exchangers with charge media having a high danger potential and/or if the materials of the RudR can react with the materials of the RddR as a result of damage or corrosion.

Installation:

- In accordance with operational necessity, the accumulating splinters must be removed within the context of the preparations.
- Corrosion, chipping, valleys, unevennesses etc. on the sealing surface of the plug must be removed. (One must pay attention to the residual wall thickness).
- The development of heat due to rubbing and cleaning of the tubes and the power sources of the drills must be approved by Operations via a permission document.
- Setting of the plugs is only permitted by trained and instructed workers. In particular, the instructions must include the regulation of this matter as well as information from the test report; and it must be documented in writing. This procedure must be repeated at least once a year.
- The information from the producer regarding plug selection (diameter, tolerances, surface quality, permissible operating pressure, permissible operating temperature, etc.) and its installation procedure must be thoroughly understood and carried out, respectively.

Safety Considerations:

- The accessibility for setting the plug, as well as the rubbing and cleaning of the sealing surface must be assured.
- During the pressure test one must proceed according to AD-HP 30, paragraph 4.16 and work safety procedures must be followed to protect against plugs that may fly out.
- The plugs must be removed prior to transport or covers must be provided so that the plugs cannot fly out.
- The process is not intrinsically free of ignition sources, thus any danger of explosion must be eliminated from the area of application.

The specialists

Enclosure 4 Test Protocol

No.	Type of test	Date	Execution	Verifiable leakage rate in mbar 1 s^{-1}	Results
1	Helium leakage test	3/12/96	No water pressure test prior to helium leakage test Container interior evacuated, then rinsed with He2 and charged with 2 bars of pressure	10^{-8} x 10^{-11}	7 x 10^{-3}
2	Bubble method	3/12/96	Lid removed Container interior charged with 2 bars of helium, tube seals lathered	10^{-3}	Bubbles at the plug 2.3
	Repair	3/12/96	Plug was hydraulically tightened to a pressure of 5000 psi		
3	Bubble method	3/12/96	Container interior charged with 2 bars of helium, tube seals lathered	10^{-3}	no bubbles
4	Helium leakage test	3/12/96	Container interior evacuated (zero point 9.85 10^{-2} mbar and 5 10^{-9} mbar l/s), then rinsed with He2 and charged with 2 bars of pressure	10^{-8} x 10^{-11}	4 x 10^{-8}
5	Water pressure test	3/12/96	Fill container with water, connect calibrated manometer,apply max. test pressure of 20.8 bar at room temperature (Official pressure test)	0.5	no visible leakage
6	Steam pressure test	3/14/96 3/15/96	Steam line connected with calibrated manometer, max. pressure corresponds to approximately 100°C, 24 hours long	10^{-1}	no visible leakage
7	Wet area test	3/15/96	Lid removed, tube weldings sprayed with penetration developer and checked for wet areas	10^{-1}	no visible moisture was found
8	Swelling stress	3/18/96 3/14/96	Container connected to steam line, 16 bar Container operated alternatively between Steam and no pressure charged with pressure for 1 to 1.5 hours 1 to 1.5 hours without pressure altogether 11.5 hours, 6.5 hours of which with steam pressure	10^{-1}	no visible leakage
9	Wet area test		Spray tube weldings with penetration developer and check for wet areas	10^{-1}	no visible moisture was found
	Drying		Container was dried for 8 hours at 260°C		
10	Helium leakage test	3/22/96	Container interior evacuated (zero point 1.05 10^{-1} mbar and smaller 1 10^{-9} mbar l/s) then rinsed with He_2 and charged with 2 bars of pressure	10^{-8} x 10^{-11}	1 x 10^{-1}
11	Bubble method	3/22/96	Lid removed, container interior charged with Helium 5.5 bars of pressure, tube seals lathered	10^{-3}	Bubbles at the plug 2.3
12	Surface analysis of the plugs	4/18/96	(see report Expando) Plug removed Surface viewed with microscope		Scratches in the rubbing surface between wedge and sealing ring

IN-FM Welding Technique
Leverkusen Build. B 303
Tel: +49 - (0- 214 - 30 - 27288

Author
von Arnim, D. DI

Dept
IN-FM LEV 2.1 Welding Technique

Subject:
Testing of heat exchanger plugs of Expansion Seal Technologies Page1

Place, country, building of issue
Germany, Leverkusen, B303

Ordered by
IN-FM LEV 2.5 Appartus Repairs

Test goal:
The goal is to test whether the Pop-A-Plug System is resistant against mechanical and thermical loads and remains leak tight.

Description of the System

General description of the system
The Pop-a-Plug is a three piece mechanical tube plug that is expanded within a heat exchanger tube by means of an hydraulic ram in order to seal the tube. The ram pulls a centred conical pin through an internally and externally serrated ring, causing the ring to swell and seal against the tube wall. At an exctly calculated force the breakaway section of the breakaway breaks. As a result all plugs will be compressed with the same force and this enables conducting calculated and documented experiments to test the leak tightness of the plugs.

Materials
For the test plugs manufactured out of 1.4401 (rings and pins) were used. De manufacturer offers a variety of materials

Preparation of the test vessel
The dimensions and tolerances of the tubes were determined by picking these from different productions lots, in order to proof that the Pop-A-Plug System guarantees a realible seal within tubes with different tolerances and tube to tubesheet connections. (see drawing Nr LE 1 132 094 - 1). Most heat exchangers operate at 6 bar, but the design pressure was set to 16 bar, in order to subject the seal to higher temperatures and strenghts. The parts for the vessel were obtained in compliance with the drawing and were welded and the welds were inspected radiographically. To verify the weld quality visual examiniations were held before, during and after the welding. The weld preperation, the applied welding process and the used weld additives as well as the workmanship of the welding were subjected to visual weld examinitions. The result was in compliance with the norms. The official hydrostatic test was conducted during further testing.

Tube preparation before plugging
All welded tube to tubesheet connections were tested for leak tightness with a vacuum testing gun (EST G-650A testing gun) and no leakage could be detected. The weld droop at the inside of the tube was removed with conical reamer and a milling machine. With the Go/No-Go gage the tube ID was measured to the termine the plug size. At No-Go measurements another plug type had to be chosen. Scale and pitting were removed with a steel wire bush (a very hard, carbon steel steel) by moving the brush into and out of the tube. The steel wire brush was heated up very much during brushing. Afterwards a new measurement with the Go/No-Go gage was made to determine the correct plug size, in some cases the tubes were cleaned for another time. The chips were blown away by means of pressurized air. (see manufacturers instructions enclosement 2 had been followed stricktly).

Testing of the plugs
EST Inc. installed the plugs as described above (see enclosure 3). The tightness of the seal was subjected to various loads with the relevant proof techniques (see enclosure 4) The plug 2.3 showed leakuage and was "repulled" by EST. After all tests were conducted, EST Inc. analysed the cause of the malfunction (see letter dated 23.05.96 enclosure 5).

The plugs could be removed or repulled to reseal as follows:

1.1. hammer the pin back into the tube
1.2. tap a thread in the ring
1.3. thread an all thread into the ring and position it into the hydraulik ram to pul the ring out of the tube (tube extractor, support on the tubc sheet)
1.4. install a new plug

2. Drill out the plug and install a new plug

3. Repull the plug without breakaway if leakuage occurs (considering the residual length of the pin) (The manufacturer does not recommend this)

The installations of the new plugs were measured with a LVDT apparatus (Linear - Variable Differential Transformer) that documented the squeeze of the plugs (see attachment 6).

Recognition of the System

At present these tests are evaluated by the various departments involved

Expansion Seal Technologies-Europe
Parallelweg 9
3931 MS Woudenberg
The Netherlands

Tel +31-(0)33-286 71 47
Fax +31-(0)33-286 74 23

Bayer AG
Z.Hd. Herrn D. von Arnim
IN/BWT FM LEV
51368 Leverkusen
Germany

INVESTIGATION OF THE RESULTS OF THE BAYER TESTING OF POP-A-PLUGS®

(1) Background

22 plugs were installed in the test mock-up of a heat exhanger at Bayer in Leverkusen. Half of the plugs were of a new design (prototype A-837-S) yet to be released, especially intended for heat exchangers where the tubes are only welded within the tube sheet. The remaining plugs of the type P2 were installed directly within the tube sheet as well within the rolled and welded tubes.

A single plug of the typ P2-840-S leaked visibly, after being installed in a rolled and welded tube. Mr Seeger decided to further pull the pin on this plug using a high stength stud (instead of the break away) in attempt seal the leak. This reduced the leak to the point where it was no longer visible to the eye. However a leak of $8x10^{-3}$ cc/sec was detected. This value is about 1000 times greater than the sensitivity at which EST has a 100% helium tight seal record after testing over 30 plugs with sensibility of the measuring equipment that was used for those tests. After the termo cycling at Bayer the leak increased by a factor 2500 and could be seen by a stream of helium bubles a 4 bar differential.

(2) First observations

Upon receipt of the heat exhanger mock-up EST verified that the plug P2-840-S reported to have malfunctioned leaked at helium at 4 bar backpressure (tube 2.3). The leakuage was located on the circumference between the OD of the plug and the ID of the tube. The leak was reported on a diameter that was later confirmed as the location of the largest diameter of the out-of-round condition measured at the tube.

The plugs of the type A-837-S were installed flush with the weld. We advice an installation depth of about 4 times the wall thickness of the tube. In this way three consecutive outer serrations are sealing against the tube.

(3) Investigation to determine cause of the malfunction

The pin projected beyond the leaking ring and it prevented an accurate measurement of the tube ID. The ID is very important in order to estimate the fourth region travel of the plug. The fourth region travel of the pin is the amount of displacement of the pin from the point of first contact of the ring against the tube ID until the point where the break away "pops"

The fourth region travel is important to know because it tells the amount of compression of the ring against the tube.

Therefore it was decided to remove the leaking plug by first driving the pin back through the ring and then remove the ring with a valve seat lifting tool. This tool reaches behind the ring to pull it from the tube without expanding the ring. After removal the tube the ID was measured and an out-of-roundness of 0,1 mm could be measured and the basic ID measured 21,77 mm. With these measurements the fourth region travel could be calculated which appeared to be 3,0 mm. This is substantially less than our current minimum travel of at least 7,6 mm. If you consider that the pin was pulled with a force that was over 600 kilogramms greater than our normal break away, the fourth region travel was probably only 27% of our current fourth region travel that all our lots must pass. This small travel is insufficient to compress the ring against anything but a round ID and effect a reliable seal. Our present production has the capability to seal out-of-roundness up to 0,4 mm.

Additionally we inspected the pin surface under a 45 power microscope. There was evidence of extreme scratching of the pin starting with the last 3,0 mm travel of the pin. This is an evidence of the high friction between the pin and the ring which prevented the ring from being expanded and compressed sufficiently against the tube to produce an effective seal.

The residual P2-840-S plugs from the same lot were used for other installation tests and these were a 4 bar helium pressure under water. Under water no leakuage could be detected. These plugs showed no abnormal scratches. The fourth region travel measured 5,3 and 7,8 mm.

(4) Preventive action

Above mentioned P2-840-S plugs originated from the first production lot dated October 1994. Due to changes in manufacturing with respect to the surface treatment of the pin, the fourth region travel increased compared to the first production lots. This improved technique has been applied for all plugs that were manufactured afterwards.

Of late EST has decided to further develop the surface treatment, since this was neccesary for the development of titanium plugs. This resulted in an increased safety margin which is a minimum fourth region travel of 7,6 mm.

The tube at the leaking locations was rebrushed with a steel wire brush type HT-860 to permit installation of a plug type P2-860-S made with the new processing technique and the complete heat exchanger mock-up was subjected to a helium detector test with 2 bar absolute. No leakuage was detected at a leak detector sensitivity of 10^{-9} cc/sec.

Finally the installation instructions have been modified: in the event of a leak, the plug must be removed, rebrushed and afterwards another plug must be installed.

Attachement 1 comparison of techniques

criterion	pop-a-plug system	conventional technique 1	conventional technique 2
□description	compress sealing ring at predescribed force	hammer in pin & welding of pin	hammer in pin
□available materials	limited	equivalent possible	equivalent possible
□dimensional variety	+	++	+++
□weight and space req	+++	+	+
□operating pressures	48 - 410 bar +++	++	+
□withstanding loads	+++	++	+
□static support	+++	+++	+
□dynamic sopport	+++	+	+
□heat resistance	+++	+	+
□corrosion resistance	+	+	+
□influence on other components	very little	very large	little
□sealing shape	3 serrations that seal	one seal point and one weld	only one seal point
□exact dimensions	very accurate	rough	rough
□seal quality	very high	high	poor
□damping			
□removability	easy	difficult	easy
□additional features	plugging both ends of the tube from only one end	none	none
□productivity	+++	+	++
□automation possible	++	-	-
□preperation efforts	reaming of tubes	removal head clean weld	removal head
□efforts to install seal	little	very complex (welding)	simple
□efforts after plugging	none		
□maintenance of tools	++	+++	-
□ recycling	not possible	not usual	possible
□ applicable	Ex zones contaminated close working conditions	must be possible to weld	Ex zones contaminated
□manufacturing controle & QA	+++	+	-
□non-destructive tests	++	++	++
□maintenance of seal	+++	++	+++
□safe to use	++	+	+
□health protection	+++	+	++
□material requirement	+++	++	+
□energy consumption	++	+++	+
□ investment efforts	+++	++	+
□cost of plug	+++	+	+
□dependence supplier	+++	-	-