REVIEW OF NON-WELDED PIPING TECHNOLOGIES ON OFFSHORE EQUIPMENT PROJECTS

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Abstract

The aim of this article are considerations on welded and non-welded tube connection technologies, with advantages and disadvantages of both. After choosing non-welded solutions as the assembly method of choice, the thesis progresses to describing the most widely-used tube connection technologies (JIC, Ermeto, retain ring flanges, flared tube flanges and other, minor, solutions) and their properties.

Keywords: non-welded piping technologies, offshore industry, offshore equipment projects.

1. Introduction

The aim of this article are considerations on welded and non-welded tube connection technologies, with advantages and disadvantages of both in the delivery of offshore equipment projects. After choosing non-welded solutions as the assembly method of choice, the article progresses to describing the most widely-used tube connection technologies (JIC, Ermeto, retain ring flanges, flared tube flanges and other, minor, solutions) and their properties.

Projects related to the construction of offshore pipehandling need to follow strict technical requirements. A drilling platform in an open sea needs to provide adequate safety for the drilling operation and the crew. This is achieved not only through special equipment (sensors, blowout prevention equipment, drift compensators etc.) but also by following technical procedures in the construction of all the platform's hardware in the mechanical, hydraulic, and electrical areas.

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Making the proper design choices is usually an art of making compromises, but with the safety and efficiency of operations as the primary concerns, certain parameters can be reliably set.

2. Welded versus non-welded solutions

This article focuses on the non-welded tube connection technologies, but in order to understand why the industry uses such connections, one first needs to justify the advantage of such methods over welding.

The process of welding, as defined by the Encyclopaedia Britannica[3], is the technique of joining metal components by the application of heat, which is generated by one of various methods – it may be e.g. flame, electric arc, laser, electron beam, friction or ultrasound.

Subject literature[4] mentions welding as the method with which contamination is sure to enter the constructed hydrostatic system. Since welding requires the use of precise movements of a human hand, certified welders raise the cost of welding considerably [Cundiff, 2002, p. 360].

There are not many further subject literature references to the process of welding and its implications on the quality of a hydrostatic drive system, but product literature confirm some of the industry practices and their implications. System cleanliness and its operational reliability[5] are brought up, while 80 percent of the operational problems is blamed on cleanliness issues and, in turn, the welding process is to be blamed for cleanliness problems. Parker product catalogues bring forth the issue of the speed and ease with which non-welded solutions (in this case: the company's EO2-Form and Parflange P37 solutions, which will be discussed in greater detail later) are assembled in comparison to welded solutions – non-welded connections are 8–12 times less time-consuming than welding or brazing. Installation processes referred to in the catalogues require neither the specific tube treatment not the use of heat and chemicals which makes them environmental-friendly and safe for the assembly operation teams; energy efficiency is also a consideration with this type of tube connections[6]. Surface quality of the joints, which prevents leakage is brought up. In comparison to welded systems, non-welded solutions can also be disassembled, reassembled and exchanged, sometimes even without discarding any components that were used in the process of building a hydrostatic drive system.

Industry practice adds a few more elements to the list of advantages of non-welded solutions over welded ones. Welding is usually a manual process, dur-

[3] http://www.britannica.com/EBchecked/topic/639223/welding, accessed January 7, 2017.

[4] Naval Education and Training course 14105: Fluid Power, Naval Education and Training Professional Development and Technology Centre, Pensacola, 1990, p. 3–8.

[5] GS-Hydro 2012 product catalogue, p. 486.

[6] Cat 4100-9/UK, p. A15.

ing which human-specific errors may occur. To eliminate their detrimental effects on the functioning system, tests need to be applied to all individual critical welds, requiring the use of chemicals and specialised equipment, prolonging the total time of constructing a complete device and immensely increasing construction costs. Since welding occurs at temperatures exceeding the melting point[7], it also needs to be a carefully controlled process, requiring e.g. fire prevention installations and services on-site.

Non-welded solutions, which will be described later, make use of a limited range of standardised components, machined with tight tolerances. This naturally increases the assembly costs over non-welded systems, where cheaper components with high tolerances may be used. However, their advantages referenced above make non-welded tube connection systems the standard method of assembling off-shore drive and control systems working with hydraulic oils.

3. Overview of the prevailing non-welded tube connection technologies

The industry makes use of a few standards for connecting pipelines without the need of welding them together. This section will describe these which are found in European product literature and standards for assembling offshore equipment, also mentioning the assembly process for each technology, devoting only cursory descriptions to less popular solutions.

The two most commonly used connection technologies for tubes of outside diameter ranging from 4 to 42 mm are the JIC (SAE J514) 37-degree flared tube fittings and derivatives of the DIN 2353 24-degree cone fittings. Pipelines of the outside diameter exceeding 42 mm are most commonly assembled with the use of flared-tube flanges or retain ring flanges developed in 1974 by GS-Hydro.

3.1. SAE J514

The latest edition of the SAE J514/1 standard[8], produced by SAE International, is currently a work in progress, seeking to harmonise the said document with ISO 8434-2, published in 2005. Product literature makes reference to both the above standard codes, but industry practice makes more frequent use of the original SAE code; these two will be used interchangeably in this section.

[7] Melting temperature for pure iron is 1811 K, while for stainless steel it is 1783 K, and for carbon steels – between 1698 and 1803 K.

[8] http://standards.sae.org/wip/j514/1/, access date January 10, 2017.

Flaring tubes and thus providing the system with sealing and holding power is an idea born in the early automobile era[9] and present in a number of versions, including varying flare angles and setups. Parker Hannifin claims to have pioneered[10] the 37-degree flaring fitting technology which they market under the name Triple-Lok as a high-pressure version of the varying flared connections, and expanded the design to Triple-Lok Plus, after export sales of machines in post-World War 2 economy grew.

The ISO 8434-2 norm specifies design pressures for the fittings as between 105 and 350 bar (larger pressures are available for small size tubing and fittings, and decrease as the size grows). The materials that are available for this fitting standard are usually zinc-plated carbon steel and stainless steel, with brass fittings (offering lower pressure ranges) as an option.

In order to manufacture a SAE J514 connection, the tube needs to be bent, cut at a 90-degree angle, cleaned and deburred before the assembly – these three steps are universal for each connection type described in this work and may be omitted in subsequent technology descriptions. Tubes may be bent with a variety of tools, from simple hand bending machines, where the tube is inserted into a set of guides and hand force is applied to bend it to a desired angle, through electrically-driven die or mandrel mobile bending units to complex numerically-controlled bending centres[11]. Tube cutting is usually performed with the use of band saws, after which the 90-degree cutting angle needs to be checked. Cleaning is usually performed by shooting one or more polyurethane plugs through the tube with a pneumatic device. There should be no sharp edges, neither on the outside nor on the inside of the tube, so the tube needs to be deburred.

In the first phase of connection assembly, the nut and sleeve need to be inserted onto the tube. After the tube is reshaped, it will not be possible. The end of the tube is afterwards inserted into a flaring machine, which cold-forms a 37-degree flare. After applying oil on the tube, the nut and the fitting, the parts are assembled with spanners (the nut is of a hex design, and a hex profile is also present on the body of the fitting). The nut and fitting body have matching UNF threads, and the sleeve acts to spread the mechanical load on the whole setup, as well as provide support for the individual components.

Because hydrostatic drive pipelines are practically never laid out in a two-dimensional space, their geometry can be defined using tube bends, which have been mentioned earlier, or differently shaped fittings. The basic design is a straight coupling, of a symmetrical shape, having identical ports for tube connection on its both ends. Couplings can, however, reduce the tube sizes, be shaped in forms of 45/90

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9 Additionally, SAE, the organisation behind the J514 standards, stands for the Society of Automotive Engineers, which additionally underlines the origins of the concept.

10 CAT 4100-9/UK, page A25.

11 An advanced example of a CNC bending solution can be found here: http://www.youtube.com/watch?v=yigRgG_NIyU.

degree elbows, tees (with options of reducing the tube size on one of the ports – they are therefore called either symmetrical or unsymmetrical) or crosses. Couplings can also be used in combination with other couplings, so instead of the connecting thread / cone on one port they can be equipped with a swivel nut which connects to a standard port on another fitting[12]. Swivel nut couplings can – again – be either of straight, elbow or tee design, and straight couplings with two swivel nuts can also be found in the producers' delivery range. When a pipeline goes through a bulkhead, welded or screwed couplings (straight and elbow) are used. Plugs are available. J514 fittings can also interconnect with other standards (e.g. in case of connecting a pipeline to a pump, when combining two machines build using different technologies into one bigger unit, when using valves with standard threads instead of the more expensive J514/UNF standards, etc.) and varying combinations of J514 straight, elbow and tee fittings where one of the ports has been replaced with a BSPP, BSPT, UNC, metric, NPTF or other threads exist. Product catalogues of different producers list between 20 (PH Hydraulik) and 84 (Parker Hannifin) different J514 component types. The fittings come in 9 sizes, encompassing 13 tube outside diameters from 6 mm to 38 mm (1/4" to 1 1/2").

As noted before, the norms specify the working pressures of the ISO 8434-2 fittings as between 105 and 350 bar, but in the certification process of the components the producers raise the working pressures considerably and notify the customers of the available maximum pressures on the type approval certificates. GS-Hydro offers the J514 fittings as being able to carry between 250 and 430 bar depending on the size, both in their carbon steel and stainless steel programme, and raises the ranges to between 420 and 600 bar when the 37-degree cone of the fitting is equipped with an additional NBR O-ring seal[13]. Cast keeps to the 240–450 bar range in both material types, Parker Hannifin offers between 140 and 500 bar in their carbon steel range and 150–350 bar in the stainless steel range, and PH Hydraulik, being the producer of exclusively stainless steel components, states their working pressures as between 150 and 350 bar.

3.2. DIN 2353 / ISO 8434-1 and derivatives

As mentioned by the product literature[14], the idea of the cutting ring connection first arose in the late 1920s and was patented in 1934. Today's version of a cut-

[12] As mentioned before, this is a standard connection method of a majority of hydraulic hoses. The swivel nut is the only rotating element of a coupling / hose assembly and hose twisting is to be avoided.

[13] It is worth noting, however, that GS-Hydro does not manufacture the J514 fittings (not the DIN 2353 fittings, discussed later), but retails the products of different manufacturers.

[14] CAT 4100-9/UK, p. A4.

ting ring fitting is naturally a development of the original idea, but the basic concept stays the same.

The cutting ring connection consists of a tube, a fitting, a cutting ring and a nut. The components may come in three series – very light (LL), light (L) and heavy (S). Apart from the very light series, whose dimension range covers only outside diameters of 4 and 6 mm (with some producers, 8 mm tube fittings are supported in very light series), the available tube sizes for light series overlap to cover the whole dimension range – light series is available for outside diameters of 6, 8, 10, 12, 15, 18, 22, 28, 35 and 42 mm, while the heavy series connects tubes of 6, 8, 10, 12, 14, 16, 20, 25, 30 and 38 mm. The differences between the individual series lie in the tube thicknesses (heavy series tubing has thicker walls, which translates to the ability of carrying higher pressures) and the mass of the connection components (with heavy series the components are bigger, heavier and thicker, so they also can carry higher pressures safely, which translates, however, to their higher costs). Connecting metric threads on the components are also larger for heavy series. In consequence, according to the Parker Hannifin catalogue, a heavy series coupling for 6 mm tubing (commonly referred to as an 06S coupling) can work with nominal pressure of 800 bar in carbon steel design, 630 bar in stainless steel and 400 bar in brass, while the light series (06L) coupling of the same dimension works with pressures of 500, 315 and 200 bar, respectively. Very light (06LL) couplings carry up to 100 (carbon and stainless steel) or 63 bar (brass).

In the cutting ring assembly, the tube is held between the coupling and the nut by means of a compression ring, which bites into the tube material (with two cutting edges) as it is compressed between the components during tightening[15]. Additionally, the cutting ring bends upwards, providing additional holding power with a spring effect.

The first assembly steps are as with J514 fittings – the tube needs to be cut, deburred, cleaned, and bent according to the geometry of the connection being assembled. After the nut is inserted onto the tube, the cutting ring ought to be pre-assembled, which means cutting the edges into the tube material, at a distance and with a force designated by technical specifications. There are specialised machines that – after specifying the preassembly parameters – cut the ring onto a tube so that it may only rotate, but not move along the tube, and so that it leaves a characteristic "collar" above the cutting point, which is a visual sign that the precutting has been performed properly. The final assembly (tightening the nut on the fitting body, compressing the ring further and securing the tightness of the connection) is performed to a torque specified by the fitting manufacturers or according to their instructions (a specific number of turns or turn fractions beyond reaching a point of resistance is usually specified).

[15] Hence, some literature, like the GS-Hydro catalogue, refer to the DIN 2353 fittings as "bite-type".

Again, the range of DIN 2353 fittings is quite extensive, covering similar geometries as with the J514 fittings, adding an extensive range of stud connections, where one of the ports is a connecting thread of one of several types, equipped with a soft sealing ring or not, adjustable fittings, weldable fittings or banjo fittings (elbows whose one port can rotate freely around the axis, or tees whose two ports can rotate). The core DIN 2353 chapters in product catalogues list between 46 (GS-Hydro) and 132 (Parker Hannifin) different item codes for DIN 2353 components. Also similarly to the notes on the SAE J514 fittings, the basic ISO 8434-1 nor specifies the nominal pressures for the fittings at certain levels, individual manufacturers exceed these minimal values and offer their products at increased pressure ratings, supporting these claims with type approval certifications, in which established classification societies (of which Det Norske Veritas seems to be most frequently targeted for the offshore market, but Bureau Veritas, Lloyd's Register, Germanischer Lloyd and a few others are also frequently found; one company and even one product range may – and very often is – supplied with a variety of type approval certificates from different societies) approve individual dimension ranges for specific pressures – see Table 1.

The composition of a DIN 2353 cutting ring connection requires a mechanical operation of preassembling the cutting ring on the tube and verifying whether the ring has cut into the tube correctly where the only means are visual inspection of the appearance of a "collar" of material on the tube above the cutting edge and the fact that the ring may rotate around the tube, but not move along its length. There has also been a drive at reducing the number of required components and providing increased reliability on terms of leakage protection. This has caused the industry to develop their own, mutually non-interchangeable, connection technologies involving the use of DIN 2353 fitting bodies and nuts, but without the cutting rings. The Walform system, developed by Eaton in their Walterscheid product range[16] uses a tube reshaped in a special machine, to give it the shape of the preassembled cutting ring with the 24-degree sealing cone. The only element which is added in place of the removed cutting ring is a synthetic rubber (Viton) seal. There is also a less popular Walform-M technique, using a metal-to-metal seal, where the sealing point is located between the mechanically reshaped tube and the fitting body, without the Viton ring. All the assembly steps for the Walform connection are the same as for the cutting ring connection, with only one exception where the process of cutting ring preassembly is replaced with the reshaping of the tube.

Parker Hannifin has also developed a ringless connection with the use of DIN 2353 fittings, which they have called EO2-Form and which they market as an extension of the EO2 system. EO2 was in turn a development of the cutting ring system, in which the system nut was integrated with the cutting ring and an elastomer seal, to form an integrated preassembly tool and thus not requiring the precutting of the

[16] Eaton product catalogue, p. A30.

ring into the tube material. A similar solution to the EO2 system was marketed by Eaton as the WALRing technology. EO2-Form does not break entirely with metal components of the connection, since the sealing ring is composed of metal and NBR or FKM. Other producers also market their derivatives of ringless connection technologies, such as the VOSS-Form, offered by the German-based VOSS.

Table 1. Nominal pressures according to the ISO 8434-1 norm and the individual manufacturer literature

Size		Working pressure									
		Carbon steel					Stainless steel				
		ISO 8434-1	Parker	PH	Eaton	GS-Hydro[16]	ISO 8434-1	Parker	PH	Eaton	GS-Hydro
LL	4–8	100	100	n/a	100	100	100	100	100	100	100
L	6–15	250	400–500	n/a	400–500	400–500	250	315	400–500	315–400	315–400
	18–22	160	250–400	n/a	250–400	250–400	160	160–315	250–400	160–315	160–315
	28–42	100	250	n/a	250	250	100	160	250	160	160
S	6–12[17]	630	630–800	n/a	630–800	630–800	630	630	630–800	630	630
	16–25	400	420–630	n/a	420–630	420–430	400	400	420–630	400–630	400–630
	30–38	250	420	n/a	420	420	250	315–400	420	315–400	315–400

3.3. Flange systems

The SAE J514 and DIN 2353 (combined as parts of ISO 8434) have one disadvantage in the maximum tube size the systems can cover. It is limited upwards to 38 mm for the J514 connection and to 42 mm (only in light series, carrying lower pressures) for the DIN 2353 couplings with different sealing methods. Hydrostatic drive systems in applications demanding efficiently manipulating big and heavy ob-

[17] Again, GS-Hydro is not a manufacturer of the DIN 2353 / ISO 8434-1 fittings, but offers the solutions of other manufacturers, primarily Eaton, which reflects the identical pressure values.

[18] Note that the 14S size (14 mm, heavy series) does not appear in the ISO 8434-1 document.

jects, such as in the offshore segment, need larger diameters for their activity speed to remain efficient. National Oilwell Varco produces winches which can lift up to 400 tons and cranes with safe working loads of 700 tons, where one needs to keep in mind that the 55 metre radius of the crane introduces additional forces. Higher pressures are therefore also required, apart from higher flow rates.

In 1974, a Finnish company GS-Hydro marketed their first flange system, and has been developing non-welded solutions for hydrostatic drive piping ever since. Currently, since the company's inventions have not been patented (except one, less frequently used solution), the flange systems are copied by other industry leaders, such as Parker Hannifin (Parflange P37 system) and Eaton (SAE 37 range). GS-Hydro markets their flange systems as "Original Provider".

Currently, the available flange connection pressure classes, as defined by the GS-Hydro 2012 product catalogue, are:
1. 90 degree flare flange connections for 10–40 bar pressures;
2. 37 degree and retain ring flanges for 50 bar pressures;
3. 37 degree and retain ring flanges for high pressures – 3000 psi and 6000 psi series;
4. GS-HP Retain Ring system, the only patented non-welded flange solution, available in the 6000 psi range;
5. DIN 350–400 bar flanges, with flared and retain ring flanges available, also with the GS-HP system as an option;
6. SAE 10000 psi retain ring flanges.

The individual ranges differ in supported tube sizes, flange dimensions (including the positioning of holes for bolts) and operating pressures, but three main categories can be distinguished here, namely the 90 degree flared tube flanges, 37 degree flared tube flanges and the retain ring flanges (including GS-Hydro's patented HP Retain Ring flanges). This work will describe system assembly steps according to this division, since assembly steps for one flange connection type are the same regardless of the subsystem which it belongs to, but later will move back to GS-Hydro's original division to summarise the working conditions for the individual systems.

In building a 90-dregree flared tube connection, the flange is first inserted onto the tube, which has been cut, cleaned, deburred, and bent. The tube is installed in a flaring machine whose cone is lubricated, together with the inside of the tube. The cold flaring process is performed in two steps, using two sets of dies, first flaring the tube to 37 degrees and then to 90 degrees. After lubricating the connecting bolts (plus nuts, if the flange connection is to be made between two tubes and not between a tube and a connecting block), a seal is centred on the connection using the bolts and bolt holes as guides and the bolts are tightened to the specified torque incrementally, in a diagonal sequence.

When constructing a 37 degree flared flange connection, the steps are identical up to the flaring of the tube, with the exception of the necessity of inserting a sleeve together with the flange if required. Since one flange can be used with more than one tube size (flanges are designed rather with schedule sizes in mind, while metric tubes have slightly different dimensions, which are filled with the use of sleeves) this serves to reduce the number of heavy and expensive components that flanges are. Flaring is performed only with one stage, to the degree of 37 degrees. Afterwards, depending on the type of connection one wishes to make, a cone is inserted into the flared port. Type A, B and C cones can be used to connect a tube to a port, since their outwards-facing side is flat (Type B, flat-face metal-on-metal sealing), has a groove with an O-ring (Type A) or a groove for a bonded seal (Type C). Two of these cones can be combined to connect a tube with another tube, but a Type D cone exists, which in practice is a double cone. Bolt / nut lubrication and tightening of the assembly is performed identically to the 90-degree flare flange system.

Construction of a retain ring system on a bent, cut, cleaned, and deburred tube starts with forming a groove near the end of the tube and grooving a place for the bonded seal on its face. At the time of assembly, a retain ring flange is placed onto the tube and the retaining ring is inserted into the groove. In the regular retain ring system, the ring is formed as a circular spring with strengthening half-rings inside; the GS-HP retain ring system consists of two semi-circular half-rings only. After inserting a lubricated bonded seal into the groove on the face of the tube, all the components are bolted together, with indications as for all the above systems[19].

The 10–40 bar 90-degree flared tube connections are available for tubes of 1/2” to 16” diameter. Low available working pressures make them most suitable for return lines.

The 37-degree low-pressure flange systems are designed for 1 1/2” – 10” tubing, and allow the constructor 50 bars working pressure, again making them most suited for low-pressured pipelines in the hydrostatic drive system.

The 3000 psi range is available in flared and retain ring variants[20]. In a 1/2” – 3” tube dimension range it offers 210–350 bar working pressures (retain ring flanges reach up to 2” diameter only). The SAE 6000 psi range, on tube ranges from 1/2” to 3” in both the retain ring and flared tube version, offers uniform working pressures of

[19] It is worth noting here that all the non-welded piping solutions described in this thesis can be disassembled and reassembled, but the retain ring system is the only one where disassembly is possible to the level of individual components – in other flange system the flange remains on the flared tube, in SAE J514 the nut remains on the flared tube as well, and in the various DIN 2353-based systems the nut stays on the tube (reshaped or equipped with a cutting ring), which necessitates an exchange of a pipeline section with these components.

[20] It needs to be added that wall thicknesses for all the retain ring systems need to be higher than for the flared systems, because of the need to cut a groove in the tube material. For example, the GS-HP retain ring solutions require that the tube of 56 or 66 mm (1 1/2” or 2”) outside diameter has a 8,5 mm wall, while the flared systems in the same diameter range use tubes of 3–6 mm (1 1/2”) or 5–6 mm (2”). Higher wall thicknesses, however, do not translate to raised working pressure ranges.

420 bar across the whole diameter range. The GS-HP retain ring system is available in 1 1/2” and 2” sizes in the 6000 psi version only.

The DIN 350–400 bar range makes use of 2” – 14” tubing in the retain ring technology and 1 1/2” – 2 1/2” in the flared tube technology. It offers 250–400 bar in the retain ring system depending on the tube size (the higher the size the lower the pressures, as with all the other systems differentiating working pressures across tube dimensions described in this article) and 400 bar in the flare flange system.

The last category as defined by the 2012 GS-Hydro product catalogue is the SAE 10000 psi range, which offers retain ring flanges for 1/2” – 3” tubing, all with 690 bar as the nominal working pressure.

Apart from the core components mentioned above – flanges and cones for 37 degree flared tube connections – the producers provide access to additional components – flange connections with various female/male connecting threads, flanges to be welded with a pipeline, tee flange setups, elbow flange setups, tee and elbow blocks, blind flanges, reducer flanges and blocks, bulkhead flange components, tee-betweens (used to e.g. attach a pressure gauge), or seal carriers.

3.4. Other non-welded solutions

Apart from the solutions described above, there are a few other tube connection technologies that do not require welding, although they are not so widespread. A side note needs to be devoted to different adaptors, allowing various systems to be interconnected. Although metric and BSP (British Standard Parallel) threads seem to be most widespread – the former being primarily used in DIN 2353 fittings, the latter a prevailing connecting thread on pump / engine blocks and other devices, delivered also via flanges – the industry has developed other thread types. The UNF thread has been mentioned in connection with the SAE J514 fittings, where it is used. Other thread types used in the industry are: BSPT (British Standard Taper thread, similar to BSP, but whose outer threads are cut on a somewhat lower dimension, so that when the thread is tightened it also provides extra sealing thanks to its geometry), NPT (American-designed National Pipe Thread, also tapered) or a tapered metric thread. These are present in DIN 2353 / SAE J514 component catalogues, when the appropriate connection technology needs to be applied to a section of tubing of different construction, but there is also a wide range of adaptors, combining these threads in straight, elbow, tee or cross setups, having the same or varying threads on individual ports.

Product literature of the most notable component manufacturers mentions other connection technologies for non-welded hydraulic tubing. Parker Hannifin[21] claims to have developed in the early 1980s a system marketed under the name

[21] Cat-4100/9 UK, p. A17.

O-Lok[22]. Being a development of an ORFS (O-ring face seal) setup, it uses a tube flared to a 90 degree angle, a sleeve, a nut and a fitting whose face surface has been equipped with an O-ring groove. The 6–50 mm fittings can carry pressures of 200–630 bar in carbon steel and stainless steel design. Parker Hannifin's A-Lok technology[23], with a nut and two cutting rings integrated with the fitting body, provides the capability of transmitting pressures of 105–350 bar over 2–25 mm tubing. Swagelok fittings[24], operating on a similar principle, are rated for up to 1378 bar over NPT-threaded couplings. An interesting development of non-welded tube connection technology is Pyplok[25], formerly designed for military aircraft installations and now openly available from Tube-Mac Industries, which relies on crimping a ribbed ferrule on a tube and thus provides 6–66 mm connections with 316–598 bar working pressures, depending on material type.

4. Selection of non-welded solutions for offshore applications.

As noted above, cost, safety and performance considerations make non-welded tube connection methods superior to welded ones. The question of selected tube connection technology remains, though.

It is economically justified to limit the number of connection technologies present on a given project (with the "project" here defined as the completed oil drilling / exploration platform or a supply / maintenance vessel for such a platform) or even on a corporate scale. This serves two purposes: it allows for better price negotiations with suppliers / manufacturers who are more willing to lower the prices and provide other benefits (such as product readiness, consignment stock, custom marking, set packaging for individual projects, etc.) if a client company, such as a drilling equipment manufacturer, maintains or raises their purchasing prognoses. The second purpose is of a technical nature. A limited range of repair components not only limits the storage space and costs, together with capital frozen in the components stocked at the company, but also helps equip emergency technicians with the core necessary components if a problem occurs. The limitation needs not be made on the level of an individual producer (which makes sense in the area of electrics and automation, since products of different producers do not mix well), because all the connection technology components follow the same norms and one can safely expect that if a product line has been certified by a reliable certification society it will surely follow all the functional criteria and almost all the dimensions of individual

[22] Cat-4100/9 UK, section J.

[23] CPI™ A-Lok® Tube Fittings, Catalogue 4230/4233 Parker Hannifin Corporation, Mayfield Heights, 2009.

[24] https://www.swagelok.com/products.aspx, accessed January 7, 2017.

[25] http://www.pyplok.com/en/, accessed January 7, 2017.

components will be identical[26]. For these reasons, global supply contracts are established such as the one between National Oilwell Varco, a drilling solution provider, and Parker Hannifin, the producer of tube fittings[27].

The need of limiting the number of technologies used to such a minimum that still allows for efficient connection of all the tube sizes in all the circuits of a hydrostatic drive and control system (pressure, suction and return) is also reflected in the internal regulations of equipment manufacturers. National Oilwell Varco, in their HLA-4A Rev. 8 document which specifies the basic principles of hydraulic assembly for their equipment packages, limits the connection technologies used only to two methods: DIN 2353 fittings for tube sizes of up to 42 mm, which covers all the fitting program, and for tube sizes of 25 mm and above, the flared flange and retain ring flange connections. In the overlapping size area the preferred tube connection technology depends on the pressures and flows expected in the system and is decided by the system designer. This recommendation is reflected in NOV's previous supplier's product catalogue[28].

5. Conclusion

The matter of connecting pipelines in an oil-based hydrostatic drive and control system first raises the issue of whether such connections should be made with or without the use of welding. Safety of an offshore application dictates that welding be discarded, as a mainly manual process, requiring additional testing to prove its efficiency. The cost of high quality welders, materials, tests, assembly time, power and other services is higher than costs of standardised fittings, machined to high tolerances. Non-welded solutions are therefore the method chosen for the connecting of pipelines in such systems.

There is a large variety of pipeline connection methods that do not require welding. DIN 2353 fittings have a wider tube diameter range and offer higher operating pressures than SAE J514 fittings, offering additionally higher assembly and functional reliability when developed to the EO2-Form / Walform technology. Their added strength lies in the fact that two series covering approximately the whole diameter range exist, which lets designers choose between lower pressures at lower component prices and higher pressures with heavier and more expensive compo-

[26] Including the crucial dimensional characteristics, such as threads, tube sizes, ports, sealing cones, bolt spacing, etc. The only cases where a dimension may vary are non-crucial for the operation of a fitting / flange, such as coupling length.

[27] http://www.motioncontrol.co.za/7665a, accessed December 14, 2013. It is worth noting here that previously the fittings were supplied by GS-Hydro, which is the producer only in the flange sector, but resells products of other companies, mainly Eaton, in the smaller diameter fitting sector.

[28] GS-Hydro 2012 product catalogue, p. 486.

nents. Non-welded connection of tubes from 25 mm upwards leaves only one choice, being the flange systems.

Thus, on the equipment for the offshore exploration of oil and natural gas resources, non-welded solutions are to be preferred, with DIN 2353-derived systems for small tube diameters and retain ring and flared tube flanges for large diameters, while the choice of connection technology in overlapping sizes depends on the application and is to be decided upon by the designer. This series of choices is confirmed by the industry's internal project design documentation.

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Streszczenie

Celem artykułu jest przedstawienie rozważań na temat spawanych i niespawanych połączeń rurociągów, wraz z wadami i zaletami tych dwóch podejść do łączenia rur. Wybrawszy metody niespawanego budowania rurociągów, praca opisuje najpopularniejsze techniki łączenia rur (JIC, Ermeto, kołnierze z pierścieniem oporowym, kołnierze do rur kielichowanych i inne, rzadsze systemy), wymieniając ich charakterystyczne cechy.

Słowa kluczowe: niespawane techniki łączenia rurociągów, przemysł *offshore*, projekty urządzeń *offshore*.