Innovative bonding process for fastening of tertiary steel

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Résumé :

La corrosion est un problème coûteux dans l'industrie du Pétrole et du Gaz car la maintenance liée à la corrosion est estimée à plus de 1,3 milliards de dollars par an selon NACE international (association nationale des ingénieurs de la corrosion). Elle affecte tous les éléments en acier, y compris les aciers tertiaires (supports de tuyaux, chemins de câbles, escaliers, garde-corps). La maintenance de ces éléments devient difficile et coûteuse lorsqu'elle doit être effectuée sur des plateformes offshore flottantes dont l'environnement peut être inflammable et explosif. La réparation de l'acier tertiaire au-dessus d'une citerne de pétrole nécessite un permis feu et peut occasionner une interruption de la production pour des raisons évidentes de sécurité. La citerne doit alors être vidée, nettoyée et inertée. Il peut être nécessaire également de réaliser des retouches de peinture une fois la réparation à chaud réalisée. Les opérateurs des plateformes offshores (FPSO, Floating Production, Storage and Offloading) ont ainsi manifesté un intérêt pour des solutions d'assemblage collés « froides » pouvant être mises en place au cours de la maintenance générale plutôt que pendant les arrêts programmés. L'autre avantage des assemblages collés, est que, contrairement aux assemblages soudés, ils n'impliquent pas d'empreintes néfastes, comme des contraintes résiduelles, des concentrations de contraintes, des zones affectées thermiquement, sur le substrat où ils sont collés. Les assemblages collés sont utilisés dans diverses industries comme l'aéronautique, mais leurs capacités nominales sont rarement au-delà de la centaine de kilogrammes. Aussi, il est indispensable de les mettre en œuvre dans des atmosphères contrôlées étant donné que l'humidité a un impact négatif sur les performances du collage.

Dans ce papier sera présenté une solution froide et innovante pouvant être utilisée pour la maintenance des aciers tertiaires comme une alternative au soudage sur des plateformes FPSO ou tout autre usine de production de pétrole et de gaz comme des raffineries ou des usines pétrochimiques. Ce nouveau produit, appelé C-Claw™, est un connecteur mécanique collé avec une capacité mécanique nominale garantie et qui peut être utilisé sans compromis sur la sécurité ou la durabilité. Cette technologie innovante consiste à mariniser les techniques de collage notamment lors de phases critiques telles que la mise en œuvre et la vie en service dans des environnements extrêmes comme les conditions offshores. Cette marinisation composée d'une barrière physique sera décrite dans ce papier également. Aussi, le procédé de mise en œuvre industrielle et répétable sera également exposé. Enfin, quelques applications comme la maintenance d'une marche et de supports de tuyaux

seront montrées. Les performances, la sécurité, le planning et les dépenses en jeu lors d'assemblages collés seront également comparées aux solutions soudées.

Abstract :

Corrosion is a costly issue in the oil and gas industry as maintenance linked to corrosion is estimated at more than $1.3 billion per year according to NACE international (National Association of corrosion engineers). This also affects tertiary steel (pipe supports, cable trays, stairs, handrails) whose maintenance can become challenging and expensive when located in offshore flammable/explosive environment such as Floating Production, Storage and Offloading (FPSO) platforms. A repair of tertiary steel on top of Crude Oil Tank needs hot work permits and may lead to production disruption. Hence, the tank needs to be emptied, cleaned and inerted and paint touch up may be required after the hot work repair. FPSO operators have then shown their interest in "cold work" solutions for fastening that could be implemented in the general maintenance instead of planned shutdown. One of the other advantages of bonded fastening is that, contrary to welded supports, it does not have a detrimental footprint (i.e. residual stresses, Stress Concentration Factor, Heat Affected Zone) on the substrate it is bonded to. Bonded fastening is used in various industries like aeronautics, but its nominal capacity is rarely above hundreds of kilograms and it is preferably installed in controlled atmosphere as humidity has a detrimental impact on bonding.

In this paper, a key product for an innovative cold solution that can be used for tertiary steel maintenance as an alternative to welding tertiary steel supports on FPSO platforms or other oil and gas industry plants like refineries and petrochemical plants will be presented. This new product, called C-Claw™, is a bonded mechanical fastener with a guaranteed nominal mechanical capacity and that can be used with no compromise on safety and durability. The way this innovative technique has made it possible to marinize bonded techniques even in critical stages like installation and in-service life in harsh environments such as offshore conditions will be then described. The installation process under vacuum of this fastener and the unique protection of the adhesive in an encapsulated volume make the C-Claw™ bonding durable and reliable. Finally, some applications like the maintenance of a stair and pipe supports will be shown. The performance, safety, planning and economies at stake will be compared with welded solutions.

Keywords : cold work, seal-bonded, fastening, bonding

1 Introduction

The offshore market comprises 250 FPSO/FSO (Floating Production Storage Offloading / Floating Storage Offloading) and an increasing number of them are entering a mature age (> 10 years) requiring costly maintenance operations linked to corrosion not only on structural parts but also on tertiary steel (pipe supports, cable trays, stairs, handrails…). The total annual cost of corrosion in the oil and gas production industry is estimated to be over $1.3 billion according to NACE international [1]. A significant part of this cost is linked to the challenge to repair corroded tertiary steel in offshore flammable / explosive environment. Indeed a conventional repair of tertiary steel on top of a Crude Oil Tank (COT) needs hot work permits and may lead to production disruption if the tank needs to be emptied, cleaned and inerted. FPSO operators have therefore shown an interest in "cold work" solutions for fastening to avoid hot work constraints such as: safety issues, detrimental footprint (i.e.

residual stresses, Stress Concentration Factor, Heat Affected Zone) on substrate, paint touch-ups on the other side of the substrate, production disruption.

COLD PAD has then developed a bonded mechanical fastener with a guaranteed design mechanical capacity of 1 tonne in shear and tension and that can be installed in harsh environments, which is a new feature since classical bonded fastening needs to be performed in controlled atmosphere to avoid detrimental impact of humidity. This new innovative product, called C-Claw™, is an alternative to welded tertiary steel supports and can be used with no compromise on safety and durability.

This paper will present C-Claw™ bonded mechanichal fasteners and how its installation process makes the technology reliable and durable even in humid atmosphere. Some examples of C-Claw™ applications will be finally described as well as a comparison with a welded solution.

2 A bonded mechanical fastener reliable and durable in offshore environment

2.1 C-Claw™ fastener

C-Claw™ is an innovative mechanical fastener that can be bonded on steel flat surfaces. Its purpose is to bring an anchor point without hot work such as welding to fasten any kind of outfitting to structural steel. It is composed of a dish, a threaded rod and a seal that protects the hardened adhesive from an uncontrolled degradation in an offshore environment. Its main dimensions and guaranteed nominal mechanical capacity are presented in Figure 1.

Figure 1: C-Claw™ mechanical fastener representation

2.2 Marinization of bonding

Bonded assembly presents undeniable advantages compared to other assembly technologies such as welding, bolting and riveting:

- No high stresses concentration;
- No residual stresses inherent;
- No heat affected zones;

- Multi-material assembly;
- Damping function and others…

However, up to now, there is not a lot of bonded assembly records in marine environment which makes it questionable regarding reliability for the Offshore Industry. To safeguard a reliable bonding, various parameters linked to the bonding operations need to be controlled: the surface preparation, the humidity rate, the temperature. Humidity is indeed a detrimental factor for bonded assembly not only for their installation but also during the service life. But as it depends on meteorological conditions it is hard to be managed.

COLD PAD came up with a concept of triangle of reliability (see Figure 2) to theorize how to obtain a reliable bonded assembly in offshore environments. It is to be noted that a joint paper with Bureau Veritas was presented at ATMA conference [2] on this topic. The technical limitations inherent to classically bonded reinforcement technology have been identified to address them one by one. Reliability can therefore be achieved by overcoming the following obstacles:

- Perfect control of bonding operations, even in offshore conditions;
- Design and strength;
- Durability in marine environments.

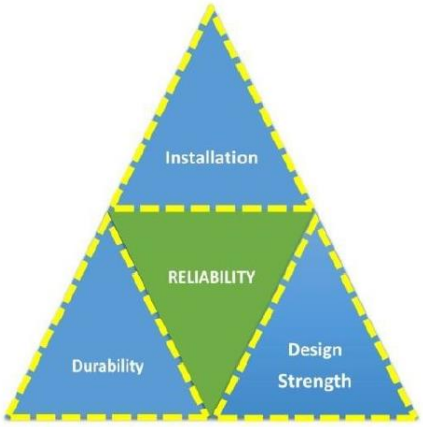

Figure 2: Triangle of reliability

2.2.1 Design and strength

C-Claw™ fasteners have been designed to limit peel and shear stresses at the edges of the bonding surface and to be able to use the load and resistance factor design (LRFD) method to derive the nominal capacity of bonded mechanical fasteners considering relevant safety factors. However, this will not be further detailed in the present article for confidentiality reasons.

2.2.2 Process-controlled installation

A surface preparation is necessary before bonding. Various surface preparations have been qualified to bond C-Claw™ fasteners. Once the surface is prepared and degreased with a dedicated solvent, C-Claw™ fastener is bonded thanks to a specific industrial tool designed for this purpose and called C-

Hawk (see Figure 3 and Figure 4). The objective of this tool is to minimize human intervention during the bonding process and to control and record relevant parameters such as humidity rate and temperature (see Figure 4). This is a key element to guarantee the reliability of the process. This enables to:

- Create a favorable environment for bonding by positioning the C-Claw™ in a bell where a relative humidity is kept below 25% (even in marine environment);
- Degassing the adhesive;
- Pushing down the fastener to spread evenly the adhesive between the fastener and the substrate and to compress its seal;
- Curing the adhesive at a temperature above ambient temperature if needed.

Figure 3: C-Claw™ (right) bonded on a steel plate with C-Hawk bell (left)

The bell is controlled thanks to a control box presented in Figure 4. A screen on the control box allows checking important parameters during bonding such as temperature, relative humidity and pressure.

Figure 4: C-Hawk (bell + control box on the left) with detail on its screen (on the right)

According to norms such as DIN6701 or marine reference NI613 [3], to guarantee a bonding is correct, it is important to rely on quality control and monitoring at all stages of the process: qualification, design, surface preparation, bonding atmosphere, bonding curing, systematic installation procedure, control at each step.

For C-Claw™, that means the following:

- Clear procedure for surface preparation;
- Proper training staff;
- Bonding in controlled atmosphere locally;
- Repeatable installation procedure;
- Adhesive thickness check after the bonding;

2.2.3 High Durability

Material selection is important to ensure durability of the bonded assembly. Once C-Claw™ is bonded on the substrate, its peripheral seal is permanently compressed. A durable protection is thus provided to the adhesive through:

- The Stainless Steel Fastener that resists to corrosion
- The compressed seal: custom-made and qualified for this application. This seal offers a sufficient contact pressure in the long-term to protect the adhesive in marine environment.

Thanks to this envelope, the adhesive is no longer submitted to photodegradation, chemical degradation due to fluid contact, hygrothermal, relaxation absorption/desorption. The only remaining mechanisms acting on the adhesive are thermal and mechanical mechanisms (see Figure 5). To assess the thermal and mechanical resistance of the adhesive, several short-term and long-term mechanical tests at ambient temperature and at high temperature have been performed at IFSTTAR [4]. However, this will not be further detailed in the present article for confidentiality reasons.

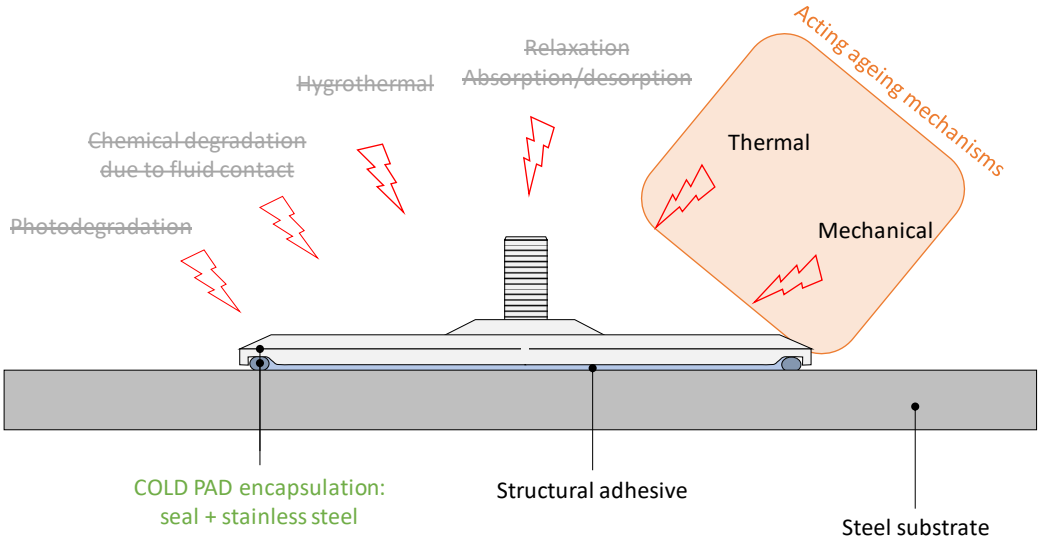

Figure 5: Analysis of ageing mechanisms

4 Examples of C-Claw™ applications

C-Claw™ can be used for various applications of tertiary steel connection to structural steel. Figure 6 and Figure 7 illustrate example of C-Claw™ applications for pipe supports and for a stair. For any application, first surface preparation is performed with grit-blasting or Bristle Blaster (Image n°2, Figure 6 and Image n°5, Figure 7) on the exact area the C-Claw™ will be bonded. Surface preparation can be performed through EX rated equipment for zone 1 [5] and [6]. Then C-Claw™ is bonded thanks to the installation tool C-Hawk (Images n° 3 to 5, Figure 6 and Image n°6 & 7, Figure 7). The tertiary steel support is then fixed to C-Claw™ (Images n°6, Figure 6 and Images n° 8 & 9, Figure 7).

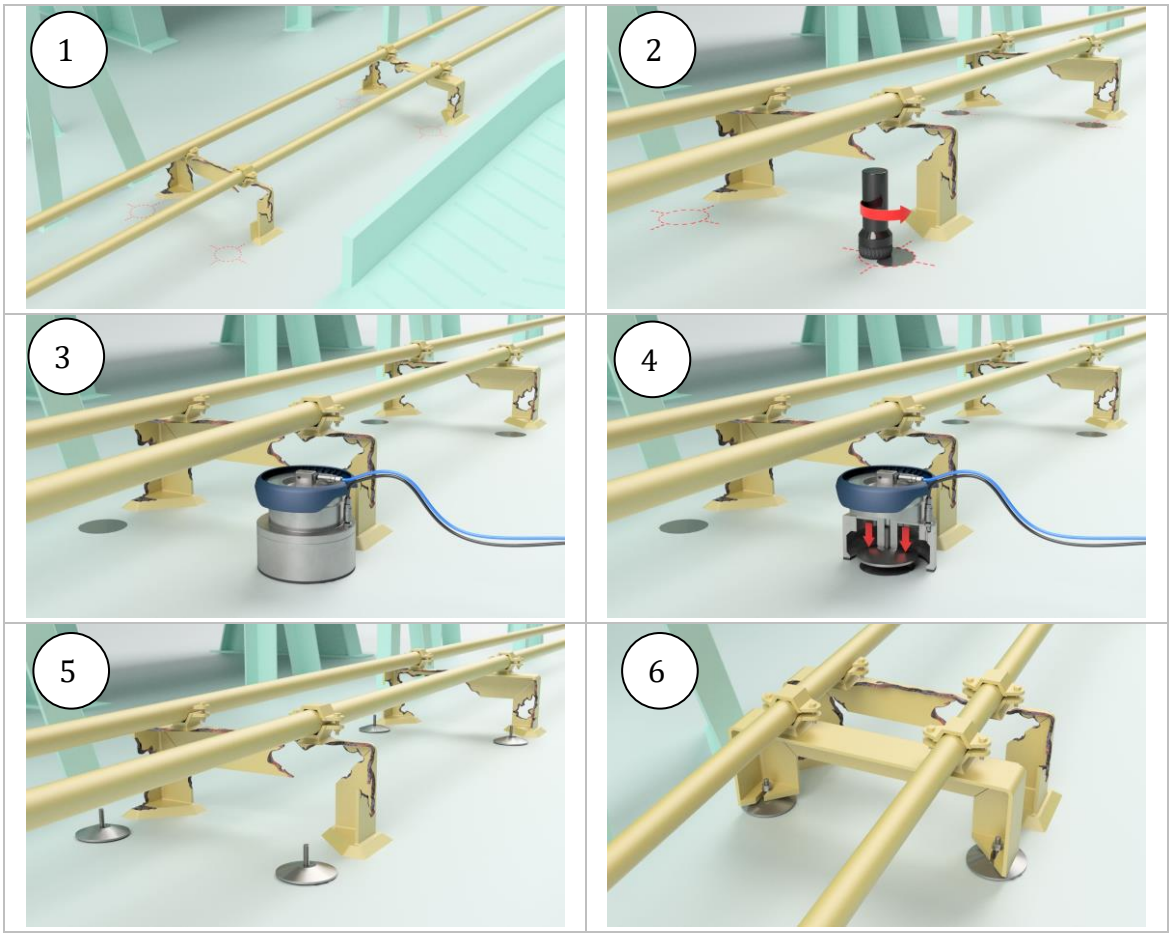

Figure 6: Steps of Pipe supports repair with C-Claw™

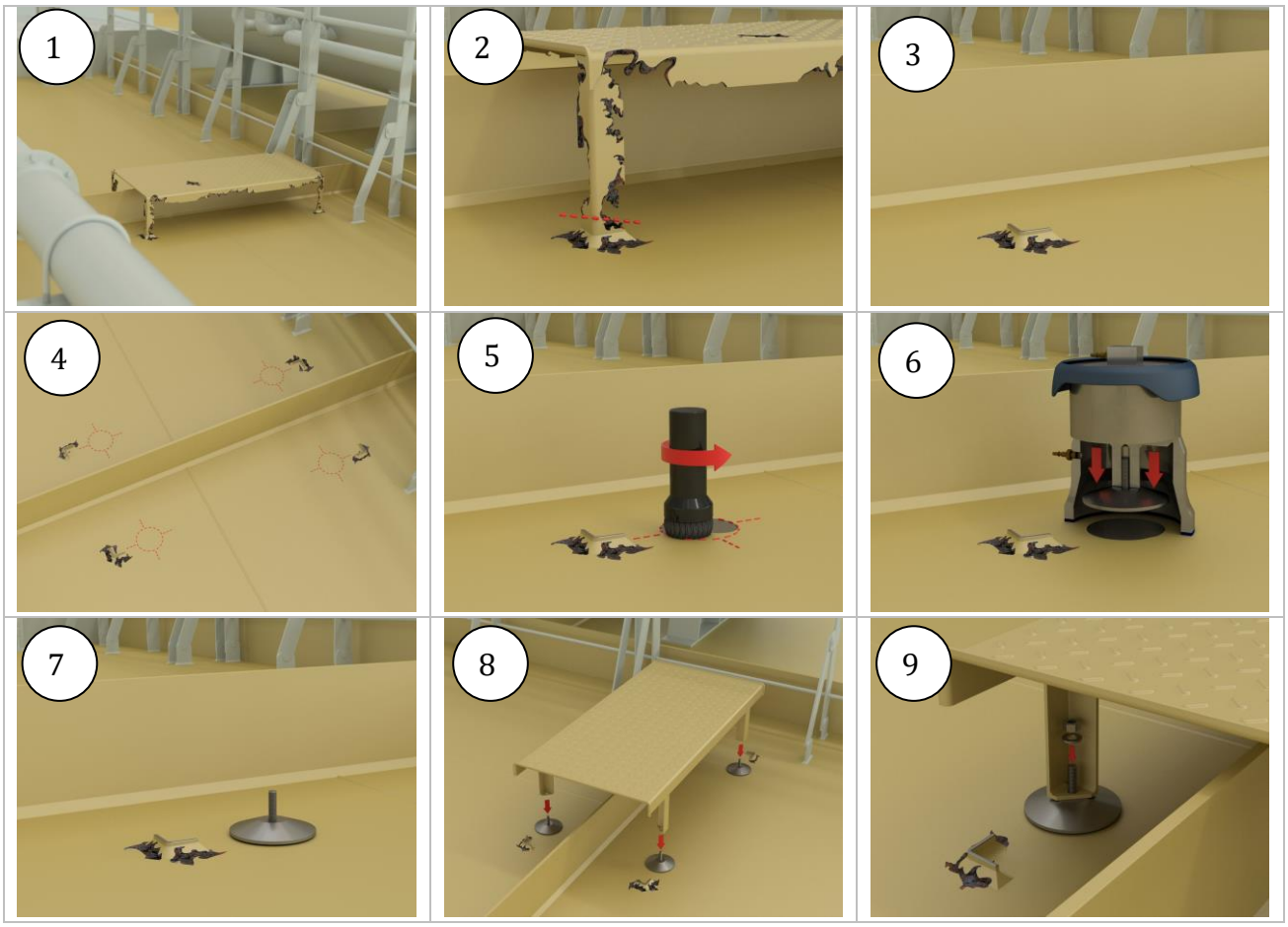

Figure 7: Stair repair with C-Claw™

5 Value proposal of C-Claw™ versus welded supports

Standard hot work techniques come with several associated costs in ATEX /explosive environments. For example, the repair operations of a pipe support on top of a crude oil tank (see Figure 8) may represent a significant challenge for an operator. Table 1 provides three different scenarios which are offered to an operating and comparing hot works with cold work techniques for the repair of two pipe supports.

Figure 8: Corroded pipe support on top of FPSO Crude Oil tank

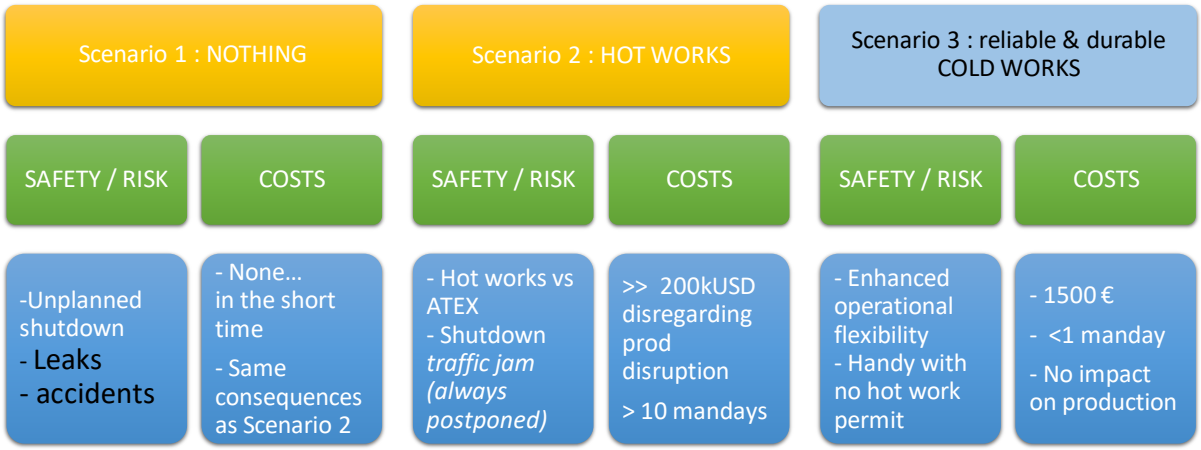

Table 1: Repair scenarios

In addition, Table 2 presents a comparison between C-Claw™ cold work solution to fasten tertiary steel supports and welding. C-Claw™ allows to save money while improving safety if it is at stake in ATEX zone.

Item	C-Claw™	Welding
Safety	No hot work permit	Hot work permit if ATEX zone
Duration	< 1 manday for a stair	< 1 manday for a stair
Production disruption	Not necessary	Could be necessary
Paint touch-up (on the other side of substrate)	Not necessary	Necessary

Table 2: Comparison between cold and hot work solution to fasten tertiary steel supports

6 Conclusion

The idea to bond two metal assemblies has been under development for many years but this assembly mode is not suitable for offshore environment unless bonding environment is controlled. C-Claw™ fastener offers the possibility to replace classical welded supports by bonded supports without compromising durability and safety. A qualification campaign is planned to be launched to confirm the regulatory design capacity of the mechanical fastener. A safety factor between 5 and 10 is expected according to exploratory tests performed with IFSTTAR laboratory. Accelerated ageing tests will also be carried out to validate the durability and an intended service life of 15 years in a harsh environment.

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