IN-SERVICE FLARES INSPECTION BY UNMANNED AERIAL VEHICLES (UAVs)

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Abstract
Unmanned Aerial Vehicles (UAVs) have been recognized as tools applied to remote inspection of opened areas, equipments and industrial facilities, but they are still underestimated although their huge potential. This solution represents the best cost benefit for in-service flares inspection, and there are some service providers in Europe and USA performing this kind of service for Oil Companies: the inspection consists of visual and thermographic flare analysis. However, it has not find any evidence of this procedure applied to oil rigs’ flares. The Brazilian Energy Company, PETROBRAS, has many installations offshore and decided to provide the remote inspection solution at the national market through training Brazilian service providers already specialized in aerial photography with UAVs. These providers were submitted to evaluation tests and adapted their systems to use for onshore and offshore sites. This article aims to present a brief review about PETROBRAS’ flares as well to show the results of the first offshore inspection of each service provider. The test was a real challenger performed at the Company’s biggest flare system installed in an oil rig. Three Brazilian service providers were considered approved: Helicamera, Brendler Modelismo e Aerial Inspect.

Keywords: Remote in-service inspection, UAVs

1. Introduction
To meet a demand upstream segment of PETROBRAS, which longed for the possibility of carrying out an in-service flare inspection, without stopping the production of platforms, PETROBRAS Research Center (CENPES) studied the possibility of employ Unmanned Aerial Vehicles (UAVs). The solution began to be studied in 2009 by the inspection team of the CENPES, however, was not enough to conclude that the use of a VTOL (Vertical Take-Off and Landing) would be the best option: it was necessary to qualify Brazilian companies to make the service using UAVs. Also in 2009, three Brazilian companies were selected and participated in tests on onshore conditions. The chosen test sites were a huge refinery and the PETROBRAS’ unity in Amazon.

After the success in these conditions, companies were invited, at the end of 2010, for a second round of tests in a semi submersible offshore platform, P-52 which was chosen by owning the largest flare installed in a Brazilian platform, in addition to the challenges inherent in climatic conditions more stringent than those found on onshore unities. The successful results have suggested the technology is robust and the evaluated companies are able to work in any other PETROBRAS’ platform.

2. Flare Systems
The flare system has the function of safely discard the untapped gas platforms, avoiding the formation of flammable cloud that could cause explosion or fire [1]. The system works
efficiently when the Volatile Organic Compounds (VOCs) are completely converted into non-toxic combustion products, and without smoke generation [2]. According to the PETROBRAS’ standard [3], a flare system is defined as a set of equipment consisting of pressure vessels, pipes, pumps, burners and metallic structure, with the purpose of burning gases from a production unity.

2.1 Types of Flares
The PETROBRAS platforms are equipped with the following types of flares:

1 – Pipe flare or Utility flare – Is the simplest system and comprised an open tube. Figure 1 shows the pipe flare of Amazonas.

![Air Assisted Pipe flare](image)

**Figure 1 – Pipe flare of Amazonas**

This type of flare system is characteristic of older platforms and onshore units. Is the one that appears to offer less difficulty to remote inspection with UAVs.

2 - Multiflare – Composed of multiple sets of burners called stages. A process signal, generally pressure, is interconnected to the flare control panel which opens the valves of stages suitable for a range of gas flow rate [1]. Figure 2 shows multiflare.

Typical system installed on newer platforms. Due to its configuration, amount and arrangement of burners, can offer greater difficulties to inspection. The approximation of the vehicles tend to be smaller in relation to the central sets of burners, requiring more quality and resolution of visual and thermal inspection systems.
3 – Variable Slot Flare – A system whose actuating of stages is done depending on the calibration of the springs of the movable flare tips. The area at the bottom of the tip, where the gas flows, is variable according to the flow, because the flare tips moves according to the resulting from weight and buoyancy forces of gas in the spring that sustains it [1].

With regard to challenges to inspection with UAVs, the considerations are analogous to the previous case.

4 – Gas Assisted Multiflare – It is used as a low pressure gas burner. Has the configuration of a multiflare plus a high-pressure system gas output next to each one of the burners. The high-pressure gas increases the air mixture and improves the combustion process [1]. Figure 3 shows variable slot flares and a gas assisted multiflare.

Figure 3 – (a)Variable Slot Flare and gas assisted multiflare; (b) Variable Slot Flare (1).
Using conventional methods, an intervention in a flare varies from 10 to 20 days, which represents a significant loss of revenue, and a large mobilization of equipments. The in-service inspection of a flare tip represents a gain for the company's units, since it generates information that subsidise the decision on the operational continuity of the system. Performing this inspection by UAVs provides an additional gain of security, since it does not expose individuals to any risk.

By 2010, PETROBRAS already had 90 flare systems installed, including onshore and offshore plants.

3. Unmanned Aerial Vehicles (UAVs)

UAVs are uninhabited, motorised aerial vehicle, which is remotely controlled, semi-autonomous, autonomous, or has a combination of these capabilities, that has a loitering capability and can carry various types of payloads, making it capable of performing specific tasks within the earth’s atmosphere, or beyond, for a duration, which is related to its mission [4].

In recent years, the development and improvement of UAVs for employment in the civil environment have continuously advanced. Stating the frequent interest on this segment, international organizations as the European UVS International (Unmanned Vehicle Systems International), were created for the exchange of information with regard to the development, production and operation of UAVs on companies, industries, research centres and universities.

There are many types of UAVs which can be categorized according to the UVS International in three distinct families, each with several subdivisions, totaling 16 different types of models. The vehicles used by Brazilian companies participating in this project fit in the mini category, which is characterized by the following features: flight autonomy always less than 2 hours, payload up to 30 kg, range up to 10 km and flight altitude and between 150 and 300 m [5]. The UAVs can be moved to electrical batteries, propelled by combustion engines or turbine. We can say that the propulsion type influences flight autonomy and payload.

VTOL-type UAVs are preferred to flares inspection because of their efficiency, quality, versatility and security. The vehicle is remotely controlled by a pilot, who is responsible for landing, takeoff and maneuvers. The camera movement control (for filming, photographing or thermographing) is performed by a professional camera operator. The two experts should work in close proximity, in a safe place to the route of flight.

4. Onshore Tests

4.1 Searching Companies in the National Market

After a considerable period of searches and contacts with Brazilian companies which could provide the desired service in future, PETROBRAS mapped three service providers interested in servicing the equipment inspection segment. At first, these companies were tested in onshore environment. If considered capable, the providers were invited to new and more decisive tests, conducted on the high seas.
The first to be tested was the company Helicamera, running an aerial photography service at a huge refinery (REPLAN). Helicamera operates an electric battery-powered model, whose flight autonomy is 7 minutos (which may be extended by the arrangement of batteries in series) and the payload is of about 3,0kg.

The second and the third onshore tests were executed in the PETROBRAS’ unity in Amazon, at the request of this unit, which wanted to get pictures of a plant's flare system. The companies Aerial Inspect and Brendler Modelismo conducted aerial photography services and thermography. Both used vehicles powered internal combustion engines, gasoline-powered, which have roughly the same autonomy (approximately 20minutes) and payload (up to 10 kg). The differences between one UAV and other are some aerodynamic modifications that the pilots performed in order to optimize the characteristics of their vehicles according to their perceptions and abilities. Thermography was held with employment of a PETROBRAS’ camera (Flir model P-65), since companies do not have termocâmeras and nor are trained in the technique.

5. Offshore tests: Submersible Platform P-52

After the onshore tests, CENPES forwarded some technical recommendations to companies, so that they perform some adaptations in vehicles before the qualification final tests. The three companies were considered approved, and were invited, at the end of 2010, for a second round of tests in a semi submersible offshore platform, P-52 which was chosen by owning the largest flare installed in a Brazilian platform, in addition to the challenges inherent in climatic conditions more stringent than those found on onshore unities. With 124 meters long, inclination of approximately 45 º, the flare of P-52 represents approximately an elevation of 90 metres, which is equivalent to a 30-storey building. Companies Helicamera, Brendler Modelismo and Aerial Inspect were evaluated, at different times, in the in-service flare inspection.

In all cases, the adjustments of UAVs was made at the helipad of the platform, and companies were subjected to the same routine of work. Nearby flare, a little helipad was improvised in a strategic location of the plant to guarantee the security and to facilitate the route of the vehicle. PETROBRAS technicians actively participated in the inspection, advising the service providers. An UAV can get a much larger approach of flare that a conventional helicopter, positioning yourself to get pictures from angles that would not be accessible in a traditional inspection.

Figure 4 shows some moments of inspection carried out by each of the three companies. Stands out, however, that due to the PETROBRAS’ policies of information security, will not be displayed any images relating to the flare systems, as well as photographs of the platform facilities.
The only obstacle to carrying out operations with UAVs is the atmospheric instability, because the strong wind and rain impede the safe operation of the vehicle. For this reason, the wind speed was monitored before and during the execution of the tests. The company Helicamera faced the worst wind conditions (between 45 and 57 km/h, with peaks of up to

Figure 4 – (a) Helicamera adjusting its UAV at the helipad, and (b) Take off; (c) Brendler photographing the flare tip; (d) Brendler’s pilot and camera operator; (e) Aerial Inspection: pilot and camera operator; (f) some tests before the second take off.
95km/h). Brendler Modelismo worked under wind conditions more favourable (average speed of 33km/h, with peaks of 54km/h), allowing several aerial photographs and films, and the execution of a thermographic inspection. The company Aerial Inspect worked with the best wind conditions (average speed of 29km/h, with peaks of 36km/h), and acquired big number of aerial photographs.

CENPES recommend other improvements in their vehicles, such as installing anemometers, temperature sensors, etc. Companies reported that they are providing as far as possible.

6. The Positive Impact

Without the use of this pioneering technology, a platform like P-52 would need to be stopped for inspection by technicians, who would rise through the various steps until the flare tip. The platform would need to stop by at least one day; in more complicated cases, maintenance could reach seven days. Each day of interruption of the activities in a platform the size of P-52 means a loss of about $9 million dollars.

Currently, the internal recommendation is that flares’ inspection occur every 24 months, according to PETROBRAS standard N-2665. The advantage of new technology is not having to wait this long to get information about the flare, since it is possible to analyze the system, their burners and structure without stopping the operation or offer any risk to the workers, the company's facilities or to the environment. The N-2665, which has been revised, considers the employment of UAVs in flare systems inspection, however, it is noteworthy that the intrusive inspections, and consequent operational stop, continue to be necessary and should be performed at most every 72 months.

The UAVs may be required not only for in-service flare inspection but to any other demand in inaccessible points of platforms or other unities. However, if the unity wants to perform aerial thermography, should make a IR camera available for the service provider and a thermographer, own or hired, must support the operation.

Eventually other companies can join the register of providers able to meet the demands of PETROBRAS, however, such undertakings must first be evaluated technically by the team of CENPES. Nowadays there is one company being evaluated. It is already approved in onshore facilities and the offshore test will be conducted soon.

7. Conclusions

UAVs are uninhabited, motorised aerial vehicle, which is remotely controlled, semi-autonomous, autonomous, or has a combination of these capabilities, that has a loitering capability and can carry various types of payloads, making it capable of performing specific tasks within the earth’s atmosphere, or beyond, for a duration, which is related to its mission. They represent a technological way very interesting for many kinds of remote inspection and or monitoring services.
The project led by PETROBRAS has resulted in the selection and qualification of three national providers for performing in-service flare inspections with use of UAVs. It is also possible to execute thermography inspection, under professional support of a thermographer.

The advantage of this technology is the possibility of obtaining information about the flare without interrupting system operation, since it is possible to analyze the burners and structure without offering any risk to the workers, the company's facilities or to the environment.

The cost savings from employment of UAVs in in-service flare inspection makes the project of high interest to the petroleum industry.

The solution is very interesting for application in inspection of structures, open areas, industrial equipment and facilities, in addition to answering several demands of civil society.

Knowledgements

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