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# COMPARATIVE ANALYSIS BETWEEN RADIAL DRILLING AND CONVENTIONAL PERFORATING RELATIVE TO THE FLOW AREA IN VERTICAL WELLS

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**ABSTRACT**

With the development of multilayer well drilling technology, this procedure has been applied for the perforating of the producing strata in the wells, making drill holes with ¾ inch thicknesses and with depths of up to 300 feet from the sheath traveling in the formation, as expressed by Radial Drilling serviceinc. Company, performing this drilling technique in the oil wells; in mature fields as in the development of new fields and promises a new horizon of increase of production applying the technology of Coiled tubing. This article shows mathematically the areas that are exposed to flow in the well wall, in vertical wells for conventional perforated and for the radial perforating technique, showing numerically the amount of fluid to be produced using each of the techniques, Also providing a model for the calculation of the possible flow within a radial drilling taking into account petrophysical and geometric parameters which is a contribution to have a starting point when making decisions as to the termination of a producing well or injector.

**Keywords:** perforating, radial perforating, cool tubing technology, completion well.

## 1. INTRODUCTION

One of the most important operations carried out in a well is production shots (PEMEX, 2009), that is the one that finally manages to communicate the well with the production formation through the damaged zone which is the one that the greatest fall of pressure presents.

The correct selection of the firing system is the most important since this will depend on the productivity of the well and the reduction of additional interventions involving high costs (PEMEX, 2009).

The controlled detonation of the loads manufactured and designed for wells cased, produce holes in the lining, cement and formation that are in adjacent form. Injection optimization demands careful designs, pre-job planning and field implementations, to obtain clean conductive shots that extend beyond the damage of the formation (Parada, 2013).

The advances over time in perforated materials provide better results at the time of application, the different methods that today apply for this purpose provide optimal results which go hand in hand with operations with high degrees of complexity (PEMEX, 2014), All with the purpose of being able to increase the production of an oil field.

The technique of radial drilling developed in order to penetrate the formation and establish communication of this with the well is carried out thanks to the technology of coiled tubing which guides the tools inside the well so that they perforate one or more holes perpendicular To the training well, this technique has been developed for improved recovery of hydrocarbons in new and / or mature fields (RDS, 2014),with this technique, it is sought to improve the production profile around the well, the application of this technique gives the possibility of creating up to 10 sides of 100 m in length and 50 mm in diameter at the desired depth in the main well (RDS, 2016).

## 2. METHOD AND PROCEDURE

In order to develop the research, different stages were taken from the collection of information to the mathematical development of the parameters required for the analysis, which contributed to reach a conclusion.

The stages that were developed throughout the investigation were:

**Stage 1.** (collection of information)

In the first stage of the investigation the compilation of texts, manuals, articles and more documents related to both conventional and radial drilling techniques was carried out; Where more information on conventional perforated was found.

**Stage 2.** (selection of information)

At this stage began to select texts that had contents related to research, equations, definitions and topics related theoretically to the definition of conventional cannon, in relation to radial drilling was taken into account documents that have a theoretical relationship with technology since the related to the mathematical definitions with respect to the areas of flow provided by the technique were not evidenced in some of the documents collected.

**Stage 3.** (validation of selected documents)

The selected information was verified with the purpose of finding a relation of this with the purpose of

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the investigation; it was found that 14 documents of 54 consulted had any relation with the required purpose.

**Stage 4.** (structuring the analysis)

The methodology was defined to continue the analysis of the validated data, whereby it was determined that the respective areas that are directly exposed to the flow in the conventional perforated technique would be calculated and then compared with the flow areas provided by the perforation Radial whose equations were not defined in any consulted document, so that a mathematical equation was generated taking into account geometric parameters.

## 3. RESULTS AND DISCUSSIONS

Because of the analysis of the different texts consulted, the application of the equations found for the calculation of the flow areas of conventional cannons, and the application of the equations to determine the flow area in the radial perforations, was obtained:

For a well that has a producer interval of 15 feet which is desired to intervened, the results shown in Tables 1 and 2 are obtained.

**Table-1.** Results of flow area provided by conventional perforated intervention.

| TPP | FA |
|---|---|
| 4 | $0.327249\ ft^2$ |
| 6 | $0.490874\ ft^2$ |
| 9 | $0.736311\ ft^2$ |
| 12 | $0.736311\ ft^2$ |

Where:

TPP = Shots per foot
Af = Flow area

**Table-2.** Results of the flow area provided by the intervention of radial perforation.

| NR | FA |
|---|---|
| 1 | $215.984\ ft^2$ |
| 2 | $431.969\ ft^2$ |
| 3 | $647.953\ ft^2$ |
| 4 | $863.938\ ft^2$ |

Where:

NR =Number of Radials
Af =Flow area

It is evident that the flow area directly exposed to the reservoir fluids provided by only one radial perforation is 293.33 times larger than the flow area provided by the highest shot density (TTP) analyzed.

The equations and graphic descriptions of the analyzed parameters are shown below.

For the conventional perforated we have:

$$Af = \pi * \frac{r^2}{144} * n \quad (1)$$

Equation 1 expresses the flow area of the perforated with conventional perforated in one foot

Where:

Af = Flow area directly exposed to fluids
R = Average radius of perforated
N = Number of perforations per foot

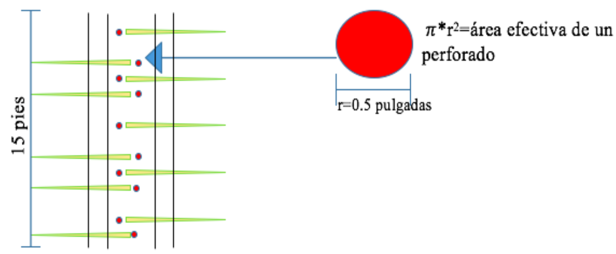


**Figure-1.** Schematic of the well operated with conventional cannon.

For radial drilling we have:

$$Af_{pr} = 2\pi \frac{r}{12} * L \quad (2)$$

Equation (2) expresses the flow area provided by a radial perforation.

Where:

Afpr = Flow area provided by radial perforation
R = Average radius of perforated
L = Length of perforated

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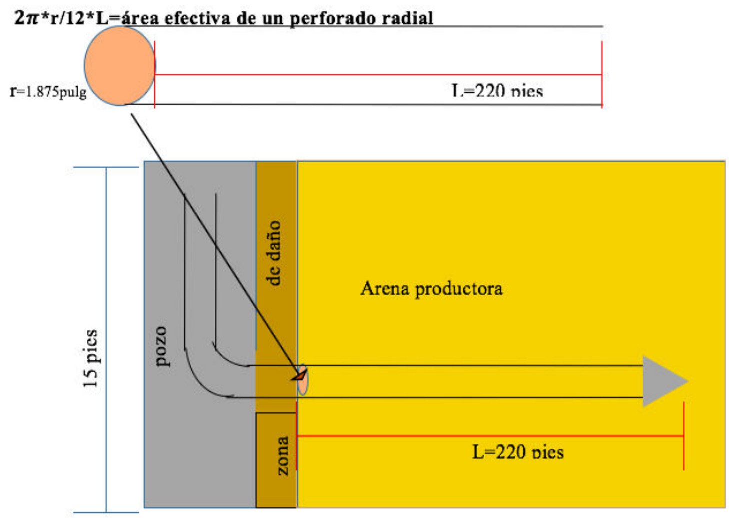


**Figure-2.** Schematic of the geometric parameters governing a radial perforation.

Due to the length of penetration obtained with radial drilling (Figure-2), the area provided for the flow of reservoir fluids to the well is much larger than in conventional perforated (Figure-1).

Once the results of the flow areas provided by each of the techniques were obtained, the amount of flow that can be contributed by the reservoir in each of the completion cases was analyzed. (Table-3)

**Table-3.** Petrophysical and geometric parameters of a reservoir (Magdalena, 2009).

| h | Pe | Pwf | Pb | k | $\mu_o$ | $\beta_o$ | $r_e$ | $r_w$ | S |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 1600 | 850 | 800 | 100 | 1.0 | 1.2 | 1000 | 0.25 | 4 |

The optimum conditions of a conventional perforated imply that the damage caused by drilling and cementing operations becomes zero (Halliburton, 2005), the application of equation 3 results in the possible flow by applying conventional cannon.

$$Q = 0.00708 \frac{K * h * (P_e - P_{wf})}{\mu_o * \beta_o * \left[Ln\left({r_e}/{r_w}\right) + s\right]} \qquad (3)$$

Equation (3) describes Darcy's law for stable radial flow:

After applying equation 3 with the parameters of the reservoir the data in table 1 the possible flow rate is:

$$Q = 800.273\ STB/dia$$

Having the value of the possible flow provided by applying the conventional gunning, a pressure profile was realized to determine the value of this in a radius of 250 feet which corresponds to the average length that can be reached by a radial perforation (W. Dickinson *et al.*, 1993) in order to determine the possible flow rate of a radial perforation taking into account the area provided by it.

$$P_{10pies} = P_{wf} + \left[\frac{Q * \mu_o * \beta_o}{0.00708 * K * h}\right] Ln\left({r}/{r_w}\right) \qquad (4)$$

Equation 4 is a modification of Darcy's law (Bonilla, 2013), which describes the pressure at a radius r; The application of this equation showed as results Table-4.

**Table-4.** Sample reservoir pressure profile.

| R (Ft) | P (Psi) | 130 | 1415,510773 |
|---|---|---|---|
| 10 | 1183,571822 | 140 | 1422,212085 |
| 20 | 1246,250576 | 150 | 1428,450857 |
| 30 | 1282,915297 | 160 | 1434,286839 |
| 40 | 1282,915297 | 170 | 1439,768901 |
| 50 | 1329,107382 | 180 | 1439,768901 |
| 60 | 1329,107382 | 190 | 1449,826626 |
| 70 | 1359,533331 | 200 | 1454,464891 |
| 80 | 1371,608085 | 210 | 1458,876806 |
| 90 | 1382,258772 | 220 | 1463,08344 |
| 100 | 1391,786136 | 230 | 1467,10305 |
| 110 | 1400,404686 | 240 | 1470,951559 |
| 120 | 1408,272805 | 250 | 1470,951559 |

Depending on the pressure profile above, the reservoir pressure can be identified at 250 feet radius from the well.

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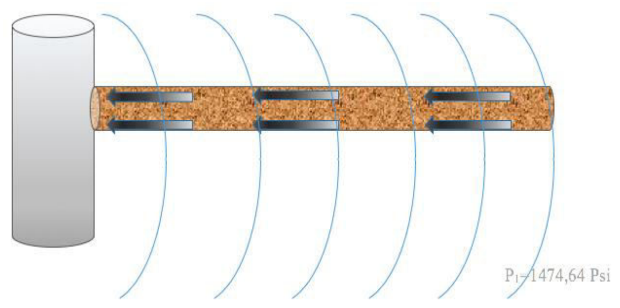


**Figure-3.** Diagram of well pressure, together with a radial perforation.

To calculate the possible flow rate provided by the effective area to the flow thanks to a radial perforation, equation 5 was applied.

$$q = \frac{0{,}001127 * K * A * (P_1 - P_2)}{\mu * L} \quad (5)$$

Equation 5 describes Darcy's law for linear flow.

Equation 5 was applied taking into account that the existing flow inside the radial perforation obeys to the linear luxury patterns, to obtain results that can be analyzed the equation was applied with different effective permeabilities provided by the radial perforations.

**Table-5.** Possible flow rates varying the effective permeabilities of the radial perforations.

| **K** (mD) | **q** (Bbls/day) |
|---|---|
| 1000 | 608.184 |
| 1315.84 | 800.273 |
| 2000 | 1216.37 |
| 3000 | 1824.55 |
| 4000 | 2432.74 |
| 5000 | 3040.92 |
| 6000 | 3649.11 |
| 7000 | 4257.29 |
| 8000 | 4865.48 |

## 4. CONCLUSIONS

This research was able to determine analytically the benefits that could have the implementation of radial drilling versus conventional cannon.

The calculations show that by correctly implementing the radial drilling, the production throughput in the intervened wells can be increased.

The radial drilling significantly increases the flow area of a well, which leads to a possible increase in the recovery factor; however this technique is restricted in the face of the well by the cross-sectional area of the radial perforation.

Radial drilling can be used alone or in conjunction with other well stimulation techniques such as acidification and hydraulic fracturing (García E, 2008), thanks to the fact that it guarantees direct and deep intervention in the reservoir.

Once correctly applied radial drilling technology in a field suitable for its operation we can have significant increases in the production flow as shown by the calculations, this due to the effective area to the flow provided by the radial perforations which is directly exposed to the flow of fluids within the reservoir.

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