# PT ZYX OPERATION TEAM ACIDIZING-SOLVENT STIMULATION CANDIDATE PROCESS IMPROVEMENT LEAN SIGMA

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## Abstract

In this paper the main focus is how to determine candidate stimulation program that is easy and fast with optimal gain. There are any initiative to conducted many process improvements since 2000 is to do trial and error to total usage of chemical used, fix standard operating procedures stimulation job. Process improvement is done only focuses on the dominant factor without doing a review of other parameters such as fluid flow, temperature and water cut. A lean sigma project that was initiated in 2004 standardized the Simple Acidizing (stimulation) process, including the Well Selection Criteria. This revised process improved the job success rate of Simple Aacidizing jobs as well as increased the average oil gain per job associated with Simple Acid efforts.By continue using lean sigma method, the team conducted a review using data on wells stimulation ever undertaken in the previous year, so we get a baseline and stimulation program that generates large oil gain. Stimulation of the review of data, there are four parameters that affect the measured gain obtained oil. All 4 of these parameters is the decline fluid, water cut, wellhead temperature and scaling index. Each data obtained in accordance with the given score gains generated so by merging all 4 of these parameters will result in oil optimum gain. The improvement in the method of selecting candidate wells will allow employees to do the job seeking candidate's stimulation.

**Key words:** lean sigma, well selection criteria

## 1. Introduction

Acidizing and Solvent treatment had been very crucial activity in Production Team, this stimualtion Jobs had huge impact on production recovery. Formation Damage near wellllbore had been such an Issue in heavy oil reservoir. Its fields proven that with well stimualtion we could increase our well recoverale reserves and increase its economical value. Production Team Acid-Solvent Stimulation Candidate Selection Process Improvement Lean Sigma was created and developed with objective to regain revenue by increasing number of Acid and Solvent stimulation Jobs, with highly considering not reducing success ratio and average oil gain. Develop new recommendation and Tools that simplify selection process of identifying successful candidates. Project Background: 1. Reduced # of acid treatments performed 2005-08 following 2004 Lean Sigma Project Review, (more rigid candidate selection criteria). 2. Resulted in improvement in overall acid stimulation success ratio. 3. Resulted in reduction in overall NPV, (fewer jobs performed). Project Objectives: 1. Review the existing Criteria used for selecting Stimulation Candidates. (Stmulation Acid & Solvent Treatments) 2. Increase the number of candidates identified while maintaining a reasonable success ratio 3. Out of scope: Changes to stimulation design.

Acidizing is a process for dissolving material from a well to improve production. Most acidizing treatments can be categorized as either: (a) wellbore cleanout, (b) removal of damage from a sandstone formation by matrix acidizing, (c) improvement of production from carbonate formations by matrix acidizing, and (d) improvement of production from carbonate formations by fracture acidizing.

A fundamental requirement for successful wellbore cleanout is that the material be acid soluble. If a well is plugged with an acid soluble scale such as carbonate scale, then acid can be very effective at removing the scale and restoring production. Acid will not dissolve paraffin deposits, which are not acid soluble. Acid can be very effective at removing iron scales such as iron sulfide.
Matrix acidizing of sandstones is considered when radial flow production is restricted by damage in the matrix, and requires the use of acid blends containing hydrofluoric acid (HF). This means that fractured wells are not candidates for sandstone acidizing, and neither are undamaged wells. In fact, the first requirement for a sandstone formation to be a candidate for acidizing is a skin damage of greater than +5. The second requirement is that the damage be HF soluble. The third requirement is that the well be capable of economically acceptable production in matrix radial flow conditions with a skin of zero, which generally means a permeability of greater than 10 md for an oil well, and 1 md for a gas well. In essence, sandstone acidizing is not really stimulation, but a method of damage removal.
Matrix acidizing of carbonates can be very effective in long intervals, though zonal coverage is usually the dominant issue in acidizing horizontal wells.

Declining fluid production normally seen once the scale built up and getting severe when most of surface of screen liner already plugged up. Acidizing job is the common stimulation treatment recently to handle this problem and seem effectively recover the fluid production back to previous trend. Current practice, hydrochloric acid (HCl) and solvent are conveyed through 1.5” coiled tubing with jet nozzle on it. This technique promotes both mechanical effect by jetting the scale deposits and chemical or soaking process. Historical data shown that the acid job performance was relatively fair, however the acid oil gains didn’t significantly change even we made some operational improvement. The low acid oil gains performer (less than 10 BOPD economic limits).

## 2. Research Methodology

One cause of the reduced number of candidates stimulation (acidizing) is a long process in determining the selection criteria of stimulation, this causes a reduction in the number kandidaite to stimulation (acidizing). Unavailability of standardized criteria in determining the criteria that the Petroleum Engineer stimulaian takes a lot just to determine candidate stimulation. The team developed input-process-output (IPO) diagram to figure out the acid job process in general and map the entire input factors and expected outputs from the acid job execution. Detailed child IPO’s were developed for critical process which felt to be much influence the over all acid job performance, such as candidate selection process, water analysis process, program generation and scheduling process.

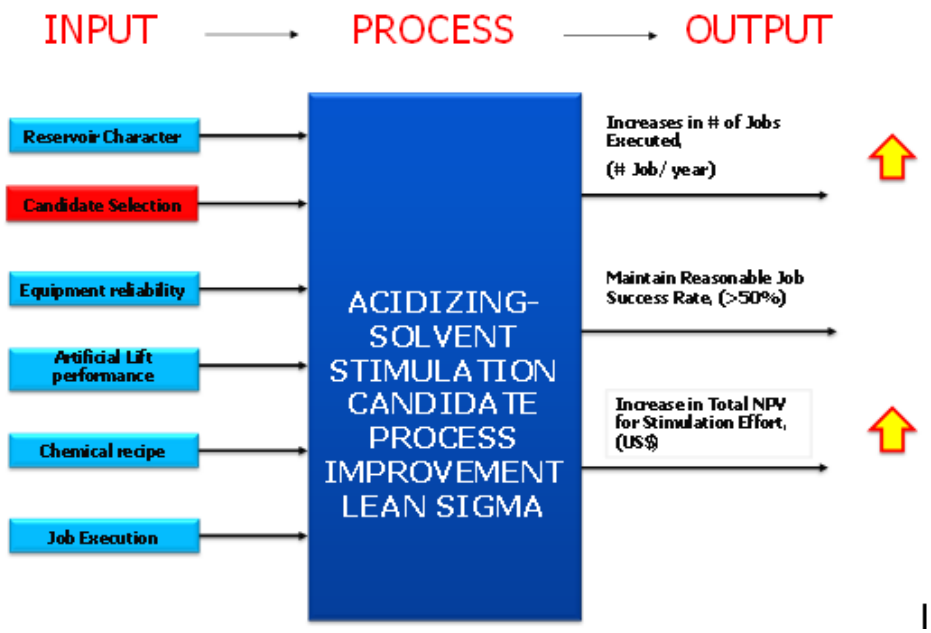


Figure 1: IPO Diagram

The team also brainstormed the possible causes that affect acid job success ratio and developed the causes and effect diagram as illustrated on figure below:

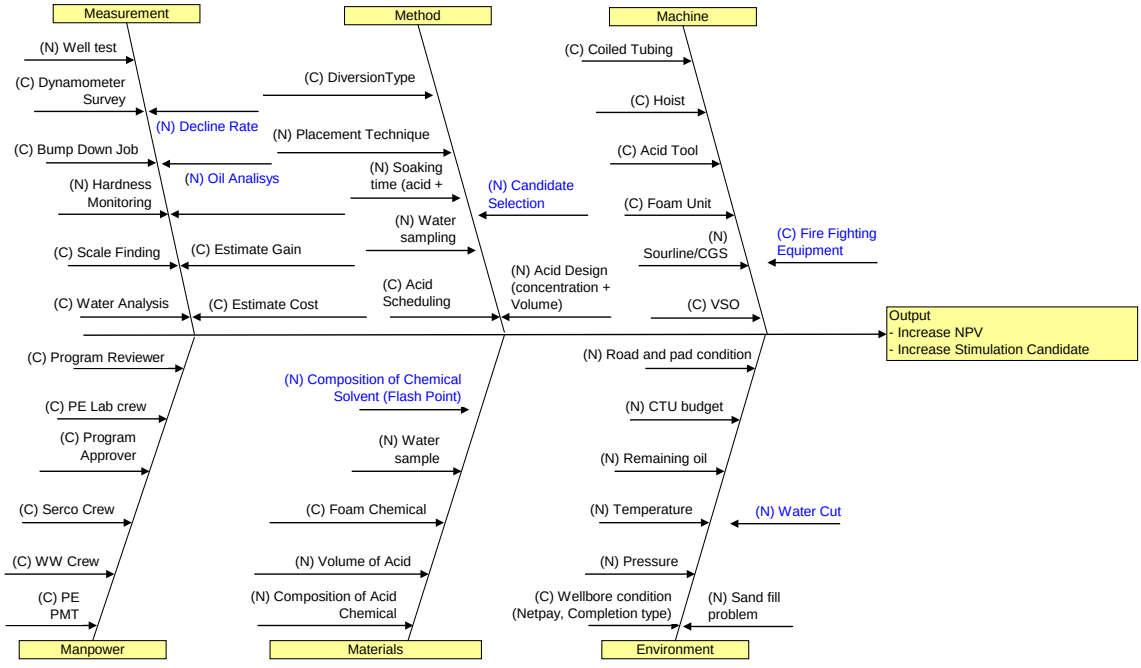


Figure 3: Cause and Effect Diagram (Fish Bone Diagram)

After performing analysis on the current acid job process with lean sigma tools, the team then identified some 'Noise Factors' (uncertainty) in the Fish Bone Diagram which become focus item for improvement and standardization to become 'Constant Factor'. The main actors that significant

impact to the selection criteria area Decline Rate, Water Cut, Well Head Temperature and Scale Indicator. By using historical stimulation data, Acid Lean sigma team determines each criterion to be given score. The splitted of population data based on oil gain (economic >10 Barrel Oil Per Day/BOPD). The data splited into 3 categories such as mostly below average gain and mostly economic (score 5).

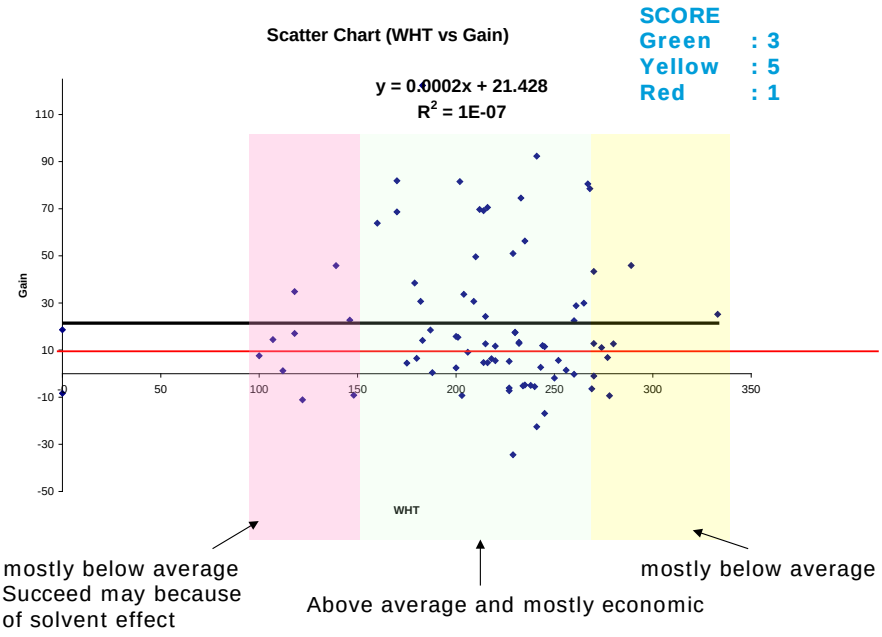


Figure 2: Well head tempetaure vs oil gain

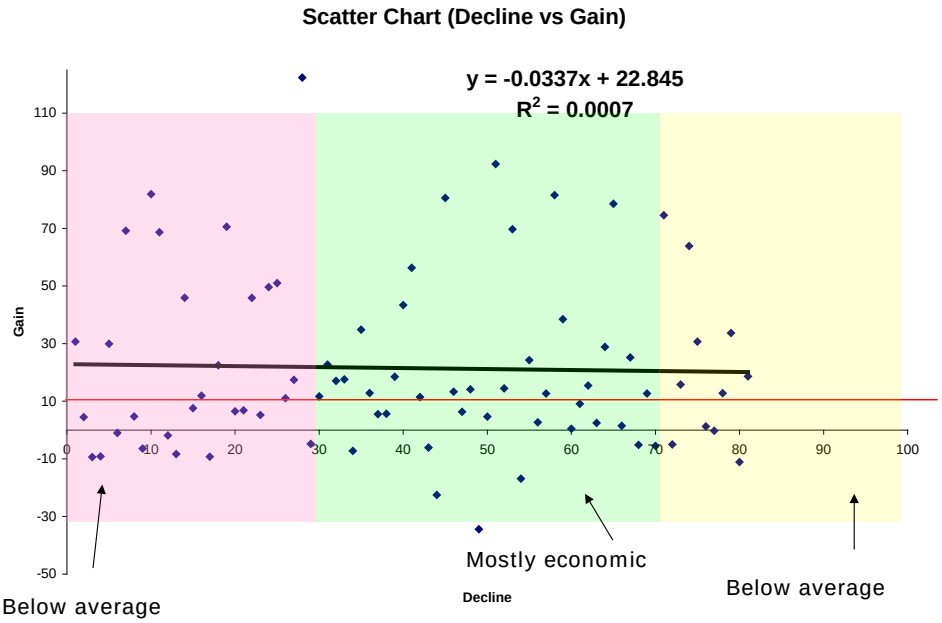


Figure 3: Well head tempetaure vs oil gain

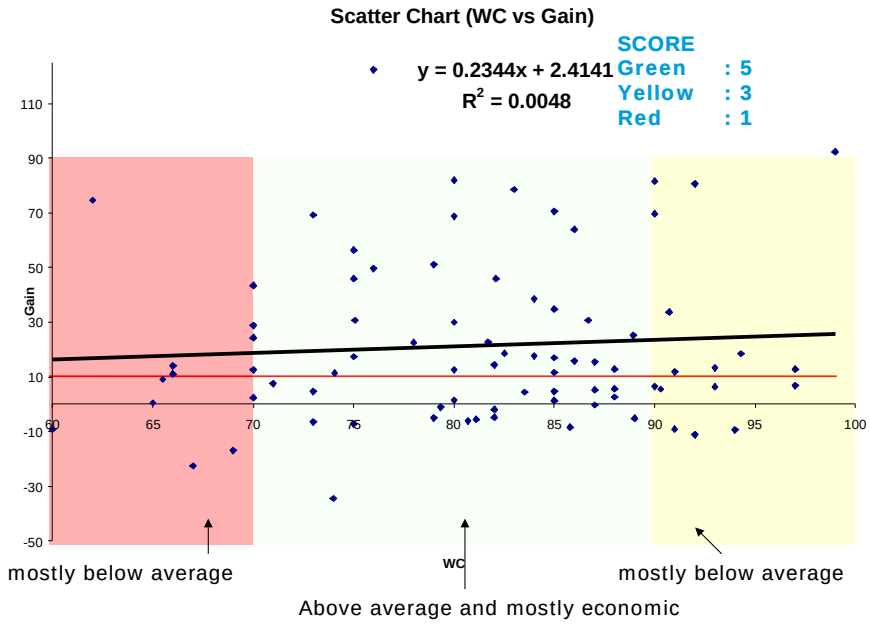


Figure 4: Well head tempetaure vs oil gain

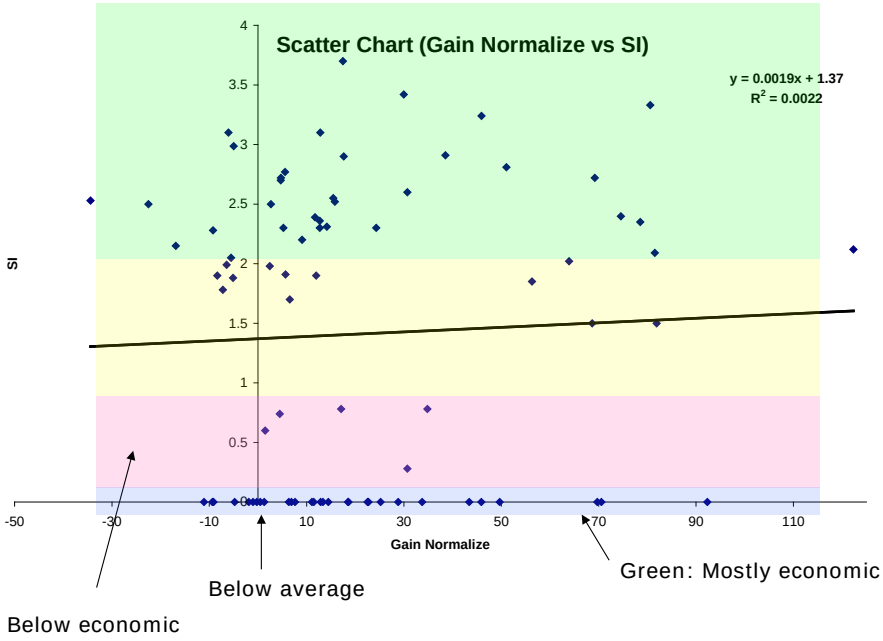


Figure 5: Well head tempetaure vs oil gain

The new proposed recommendation is same with the existing criteria, the new proposed more detailed than existing. The team reviewed 4 parameters that very significant on oil gain result, by splitted the historical data so the team confined that by implemented the new criteria, determining the candidate is very easy & fast and the team will be get oil gain result.

| | existing Lean Sigma Recommendation | Proposed Recommendation | Justification For Change: |
|---|---|---|---|
| Fluid Decline Trend | > 30% | Weighted Scoring System:<br><30%: 1<br>30% - 70%: 5<br>>70%: 3 | These key Stimulation Candidate Selection Variables were evaluated for jobs completed from 2004 - 2008. The Weighted Averages were determined based on the average incremental oil gain & the job success rates identified within that specific range. |
| Water Cut | < 80-85% | Weighted Scoring System:<br><70%: 1<br>71% - 90%: 5<br>>90%: 3 | |
| Wellhead Temperature | 180 - 250 F | Weighted Scoring System:<br>< 150 F: 1<br>150 F - 250 F: 5<br>> 250 F: 3 | |
| Scale Index | > 2.15 | > 1.6 | |
| SARA | Not Included | SI < 1.6 & SARA > 0.9 | For Solvent Treatment |

Figure 5: Summary of Improvement

By reviewing the previous acid job data, the team realizes that the acid candidacy process, acid design and acid placement technique procedure are the most influencing factors of acid success and has to be the main focus of the improvements. Statistical analysis then performed to see relationship between those input factors to the acid oil gains. Based on statistical analysis result and combining with technical aspect, the team then built the flow process of acid selection candidate.Here is some process improvements were proposed by the Acid Lean Sigma team:

***Acid Job Selection Candidate Check List***

| Production Trend | Unit | Six Sigma Team Recommendation | Proposed Changes in Stimulation Candidate Selection Criteria |
|---|---|---|---|
| **Fluid decline trend** | % | Ensure the decline is not caused by measurement problem (Decline rate > 30%) | Preliminary Candidate Screening Criteria uses ***Weighted Average Scoring*** system, (1-5), depending on specific Fluid Decline Rate |
| **Net Displacement decline trend** | % | Net displacement trend should follow the fluid production decline | No Change |
| **Oil decline trend** | % | Ensure the decline is not caused by increasing water cut | Focus is on Fluid Decline Rate not Oil Decline Rate |
| **Water Cut** | % | Be careful for high water cut wells, average water cut prior to declined should be less than 80%-85% | Preliminary Candidate Screening Criteria uses ***Weighted Average Scoring*** system, (1-5), depending on specific Water Cut |
| **Artificial Condition lift (from Dynamometer Survey and BDJ) - Ensure good artificial lift** | | | |
| **Pump Fillage** | % | Low Pump Fill indicate scaling tendency at production zone. The lower pump fillage the smaller fluid coming into the wellbore (Recommended PF < 50%) | **Current Pump Condition**: Pump in good condition, (no TV or SV leaks), Pump Fillage <90%<br><br>**Post-Treatment Pump Requirements**: need to adjust pump size for anticipated production, (if necessary). Pump fillage target 50-90%. |
| **Pump Slip** | % | Pump slip should be less than 5% - ensure the decline production not caused by mechanical pump problem | |
| **Pumping Card** | lbs/div | Ensure load of pump is weight enough (Recommended Dyno Card Scale > 300 lbs/div). Ensure WHT less than 250 F for light load dyno card | |
| **Bump Down Job** | psi/psi | Good Bump Down job result (hold 300/300 psi) is required to ensure mechanical pump in good condition | |
| **Well History Data** | | | |
| **Scale Index** | | Scale index shown scale deposition tendency (recommended SI >2.15 - Stiff davis) | **Acid Candidate**: SI > 1.6<br>**Solvent Treatment Candidate**: SI < 1.6 and SARA > 0.9<br>**No Stimulation**: SI < 1.6 and SARA < 0.9 |
| **Well Head Temperature and Casing Pressure** | deg. F and psi | Ensure there was no steam breakthrough history (recommeded Temperature : 180 - 250 Deg F) and pressure less than 40 psi | Preliminary Candidate Screening Criteria uses ***Weighted Average Scoring*** system, (1-5), depending on specific Well Head Temperature |
| **PS History** | #PS job last 1 year | Ensure there was no sand fill problem history (avoid repeated stuck after perform acid job), maximum number PS job before acid job = 4. | No more than (2) PS jobs completed in last 12 months |
| **Killing Problem** | | There was no killing problem history | No History of killing problems in last year or last (3) WRO jobs |
| **Pattern Performance** | | | |
| **Recovery Factor (RF)** | % | Low RF equal to good remaining oil | Not considered in proposed Candidate Selection process. |
| **Per Volume Injection (PVI)** | | High PVI indicated mature zone (PVI > 1.1) | Not considered in proposed Candidate Selection process. |
| **Surrounding steam injection performance** | | Ensure no steam injection changing might cause decreasing production | No Change |
| **Acid Chemical Compositions** | | | |
| **HCL** | % | 15% Concentration | Not considered in this Lean Sigma Project |
| **Acid Volume** | Gall/ft | Recommended acid volume : 5-10 Gall/Ft | Not considered in this Lean Sigma Project |
| **Solvent** | Gall/ft | Recommended solvent volume : 3-6 Gall/Ft | Not considered in this Lean Sigma Project |

Figure 6: Selection Candidate Check List Improvement

To ensure all Petroleum Engineering production consistently apply the standard candidacy process, the team was also developed selection candidate tool which has to be attached in the Acidizing Program Recommendation. The team build the simple excel tool to help Petroleum engineer to find the candidate (appendix 1, 2 & 3).

Clear flow process among multi-functional team (Senior Field Operator, Petroleum Engineer Production Team, Service Well Work, Routine Service and Business Partner) was also developed and combined with regular Acid meeting which involved those respective teams to ensure the smooth coordination during execution process.

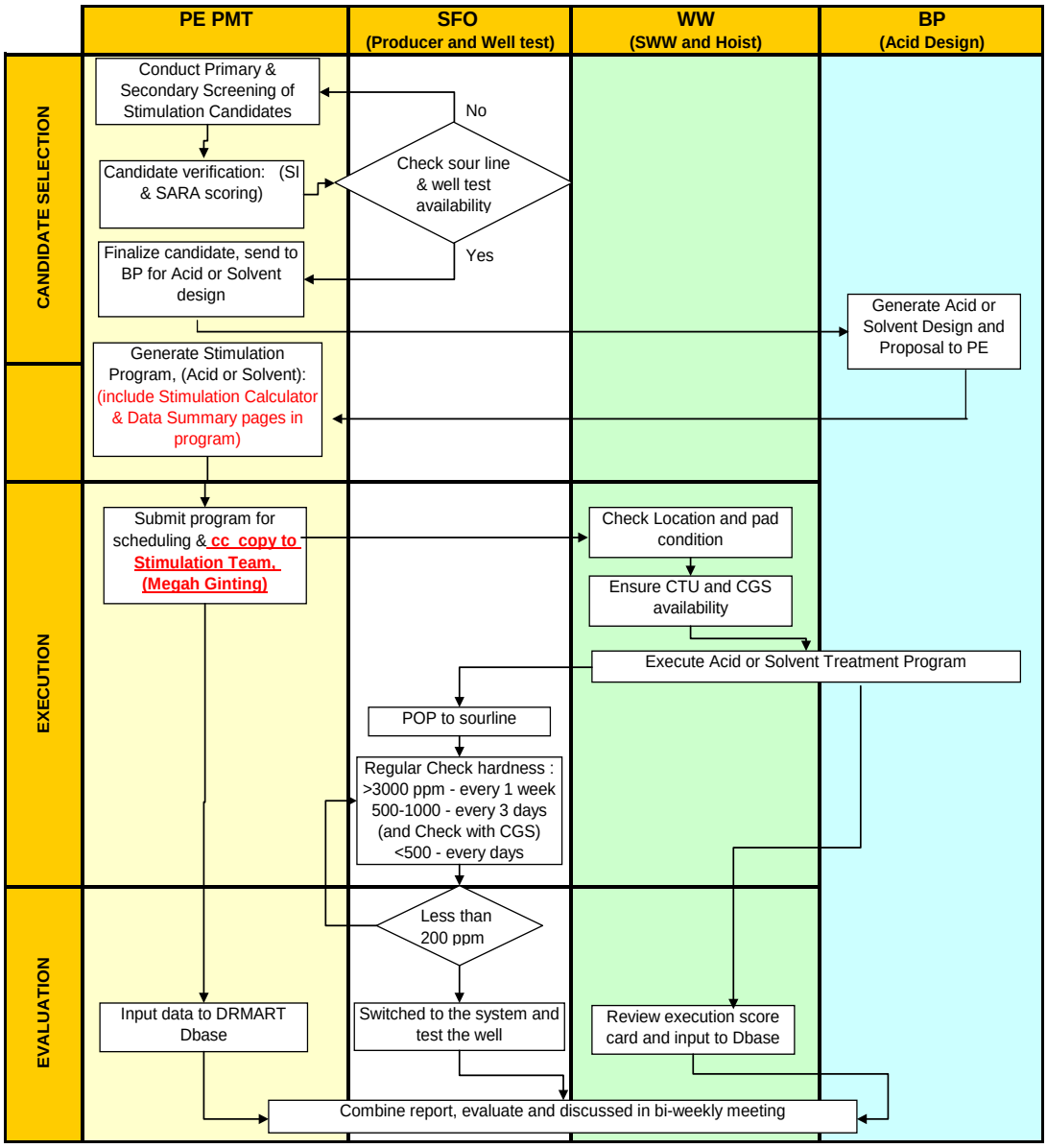


Figure 7: Flow Chart Diagram

## 3. Research Result and Discussion

Revised the new tool to selection acidizing candidate starting June 2009 and there are significant improvement on candidate acidizing and solvent treatment at well. Eventhough the candidate's insceased significant but the oil gain lower than before new tool implemented. The reason is increasing on recovery factor or decreasing the oil in the subsurface (reserved oil decreased) since the status well is on the production keep going. The financial reported that success ratio for acidizing treatment higher than before ( 58% to 67%) but the solvent treatment was 52%.

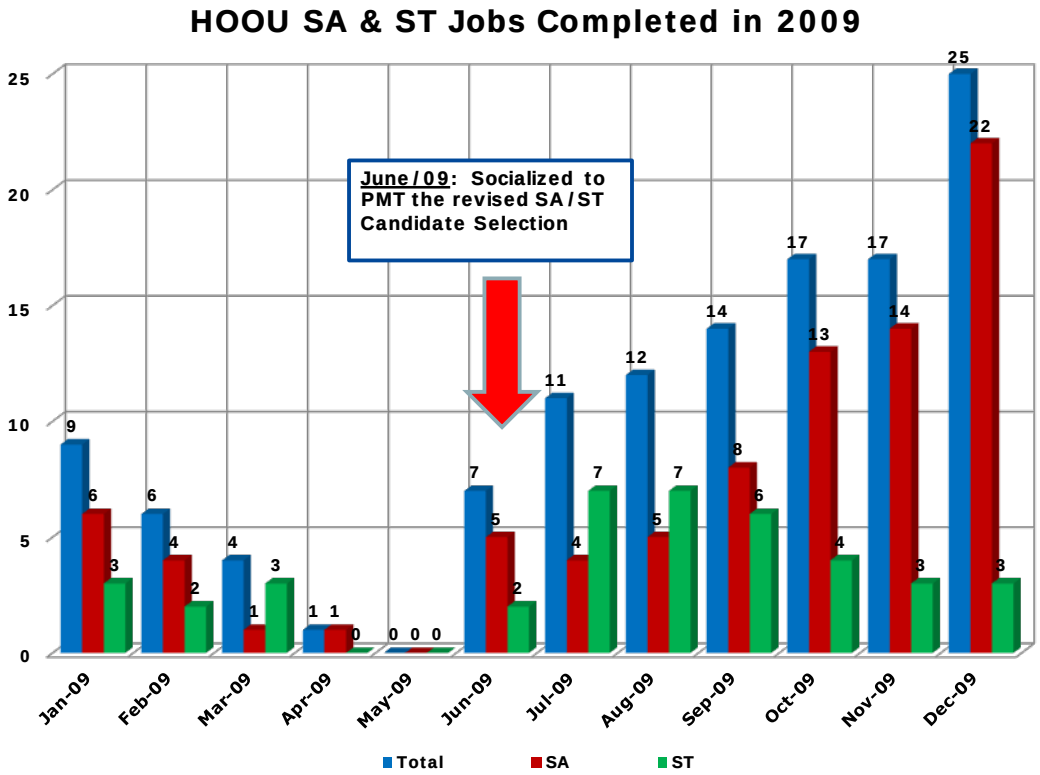


Figure 8: Stimulation Acdizing and Solvent Treatment job commpleted

The financial result mentioned that increasing on NPV due to higher job completed both acidizing stimulation and solvent treatment (31 vs 103 job completed).

| | 2008 Data | 2009 Data SA | ST | Total |
|---|---|---|---|---|
| # of Post_Mortems Completed | 31 | 21 | 23 | 44 |
| Average Job Cost | $33,391 | $33,391 | $41,026 | $36,870 |
| Avg. Incremental Oil Gain, First (60) days, (bopd) | 35.6 | 20.4 | 11.2 | 15.7 |
| DPI | 2.24 | 1.75 | 1.34 | 1.54 |
| % Successful Jobs, (> 1.2 DPI) | 58% | 67% | 52% | 59% |
| NPV | $39,052 | $24,816 | $10,137 | $17,142 |

| | | | | |
|---|---|---|---|---|
| Total Jobs Completed, (Jun - Dec/09) | | 71 | 32 | 103 |
| Average # of Jobs Completed/Month (Jul - Dec/09) | | 11 | 5 | 16 |
| Yearly Projected # of Stimulation Jobs | 31 | 132 | 60 | 192 |
| Est. Yearly Projected NPV | $1,211,000 | $3,276,000 | $608,000 | $3,884,000 |

| | |
|---|---|
| Improvement in NPV, (2009 vs. 2008) | $2,673,000/yr |

Oil Price: $50.00/bbl / OPEX: $3.20/bbl / Economic Life: 1 year

Figure 9: Financial Report

## 4. Conclusion

Acidizing stimulation and solvent treatment are the best stimulation job that have oil gain 20 BOPD incremental for acidizing and 11 BOPD for solvent treatment, this activity was easy to increase the production and to hold the yearly decline rate. Stimulation acidizing more economic than the solvent treatment since the cost higher than acidizing and the gain oil result lower than acidizing. The solvent treatment was just temporary action to dilute oil that content asphaltine and the lifetime is about 30 month (appendix 5). After 3 months of the job, the physical properties of the oil return to normal physical properties, difficult oil flows into a holding tank.

## 5. REFERENCES

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5. ttps://www.rigzone.com/training/insight.asp?insight_id=320&c_id=4 *"How Does Well Acidizing Work to Stimulate Production?"*

**Appendix 1- Process Screening Candidate well (first screening)**

***Preliminary Stimulation Candidate Selection Criteria:***

***Killing Problem*** *: Candidates to have no current history of killing problems, (within last year or last 3 WRO jobs completed)*

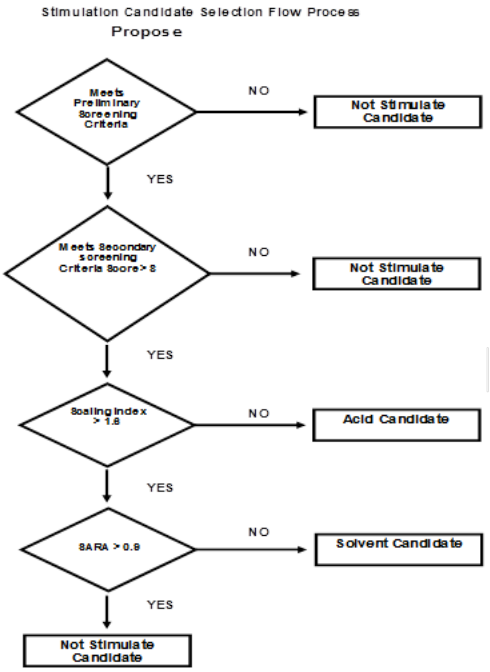
***PS History*** *: No more than (2) Pump Stuck jobs in last 12 months*

***Stimulation History*** *: No failed stimulation jobs in the last 12 months (no oil loss associated w/ previous stimulation treatment)*

***Pattern Injection****: No significant change in pattern injection from surrounding injection wells during evaluation period*

***Current Mechanical Condition****: Pump in good condition, (no Traveling Valve or Standing Valve leaks), pump fillage <90%*

***Post-Treatment Pump Requirements****: Need to adjust pump size for anticipated production gain, pump fillage target 50 - 90%.*




## Appendix 2- Process Screening Candidate well (second screening)

**Secondary Screening Criteria:**

**Use *Stimulation Calculator* to evaluate:**

**- Fluid Decline Rate**

**- Water Cut**

**- Well Head Temperature**

**Fluid decline rate (last 12 months)**

| <30% | 30% - 70% | >70% |
|---|---|---|
| 1 | 5 | 3 |

**Water cut**

| <70% | 71% - 90% | > 90% |
|---|---|---|
| 1 | 5 | 3 |

- **Well Head temperature**

| <150 F | 150-250 F | > 250 F |
|---|---|---|
| 1 | 5 | 3 |

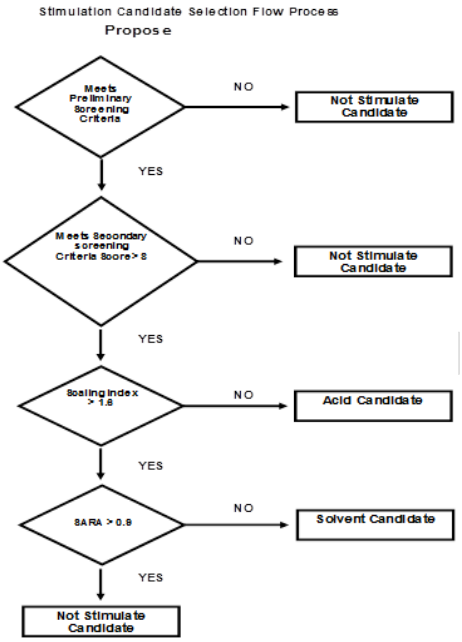
**Total Score must be > 8 to make forward with well as Stimulation Candidate**

**Final Screening Criteria (Use Stiff Davis & SARA Methods):**

**SI > 1.6 → Acid Candidate**

**SI < 1.6 & SARA > 0.9 → Solvent Candidate**

**SI < 1.6 & SARA < 0.9 → Not Stimulate Candidate**




## Appendix 3- Process Screening Candidate well (excel tool)

**Stimulation Candidate Selection Criteria, (Weighted System)**

*Preliminary Stimulation Candidate Selection Criteria:*
*Killing Problem : Candidates to have no current history of killing problems, (within last year or last 3 WRO jobs completed)*
*PS History : No more than (2) PS jobs in last 12 months*
*Stimulation History : No failed stimulaton jobs in the last 12 months (no oil loss associated w/ previous stimulation treatment)*
*Pattern Iniection : No significant change in pattern injection from surrounding injection wells during evaluation period*
*Current Mechanical Condition : Pump in good condition, (no TV or SV leaks), pump fillage <90%*
*Post-Treatment Pump Requirements : Need to adjust pump size for anticipated production gain, pump fillage target 50 - 90%.*

REFRESH | production Trend | GUIDE
attachment | production history

**Fluid decline rate (last 12 months)**

| <30% | 30% - 70% | >70% |
|---|---|---|
| 1 | 5 | 3 |

**Water cut**

| <70% | 71% - 90% | > 90% |
|---|---|---|
| 1 | 5 | 3 |

**Well Head temperature**

| <150 F | 150-250 F | > 250 F |
|---|---|---|
| 1 | 5 | 3 |

Max Score = 15
Min Score = 3
Required score to stimulate = 8

**Scale index**

| <1.6 | >1.6 |
|---|---|
| NO | ACID |

**SARA**

| 0.9< | >0.9 |
|---|---|
| NO | SOLVENT |

Criteria Selection :
SI > 1.6 --> Acid candidate
SI < 1.6 and SARA > 0.9 --> Solvent treatment
SI < 1.6 and SARA < 0.9 --> No stimulation

**ACID CALCULATOR**

WELL 4L89A *input GRID*

| Historical Well data | | | SCORE |
|---|---|---|---|
| Test Date | | 6-Jun-09 | |
| BFPD | | 208.8 | |
| BOPD | | 59.299 | |
| WHT | deg F | 263 | 3 |
| WC | % | 71.6 | 5 |
| Decline Rate | | 32 | 5 |
| | | Total Score | 13 |

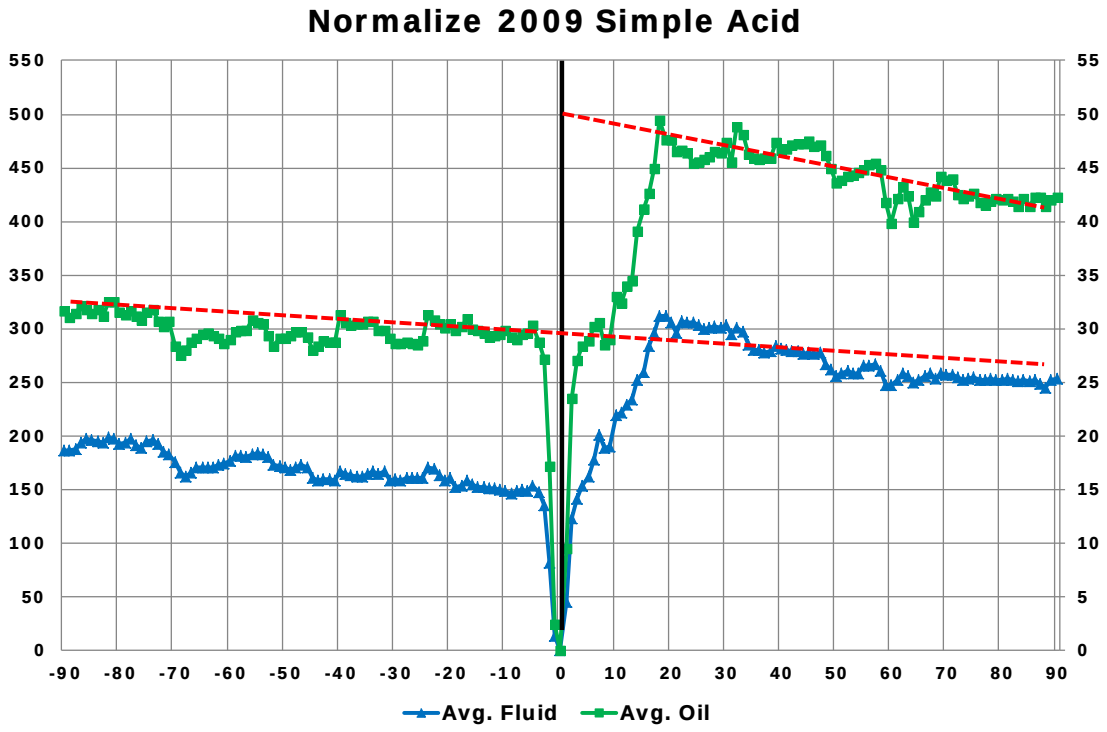
*go to oil & water analysis*

| WATER & OIL ANALIYSIS | |
|---|---|
| SI | 1 |
| SARA | 0.9 |

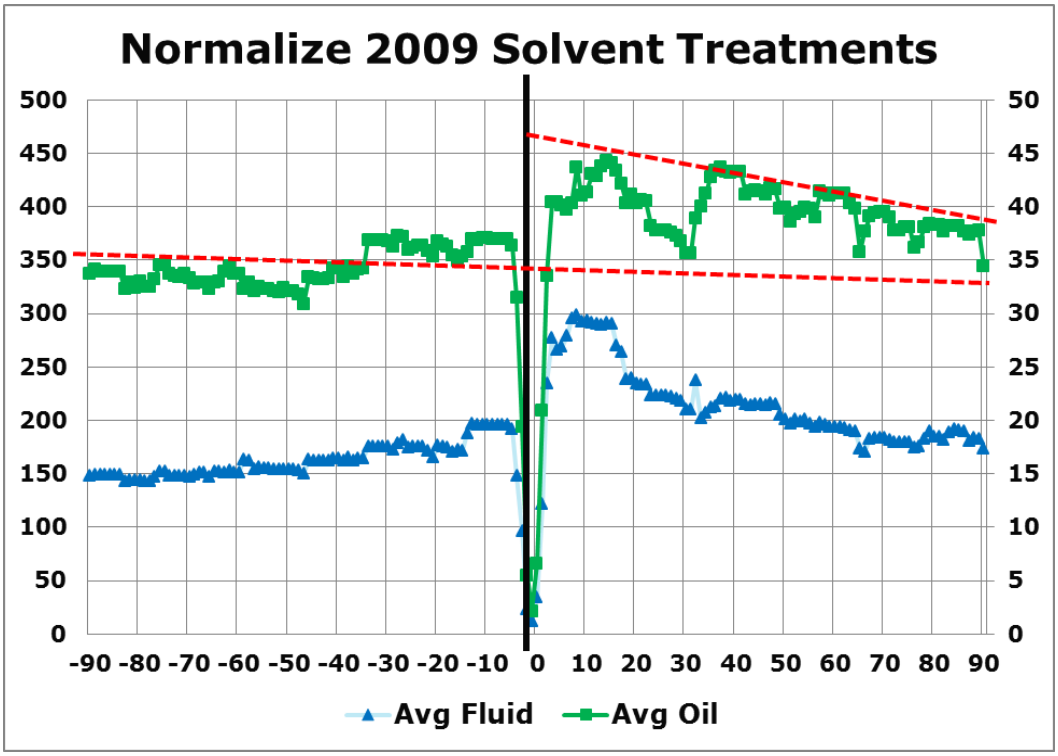
*go for solvent stimulation*

*note : please input only yellow cells*

## Appendix 4- Normalize Acid Job



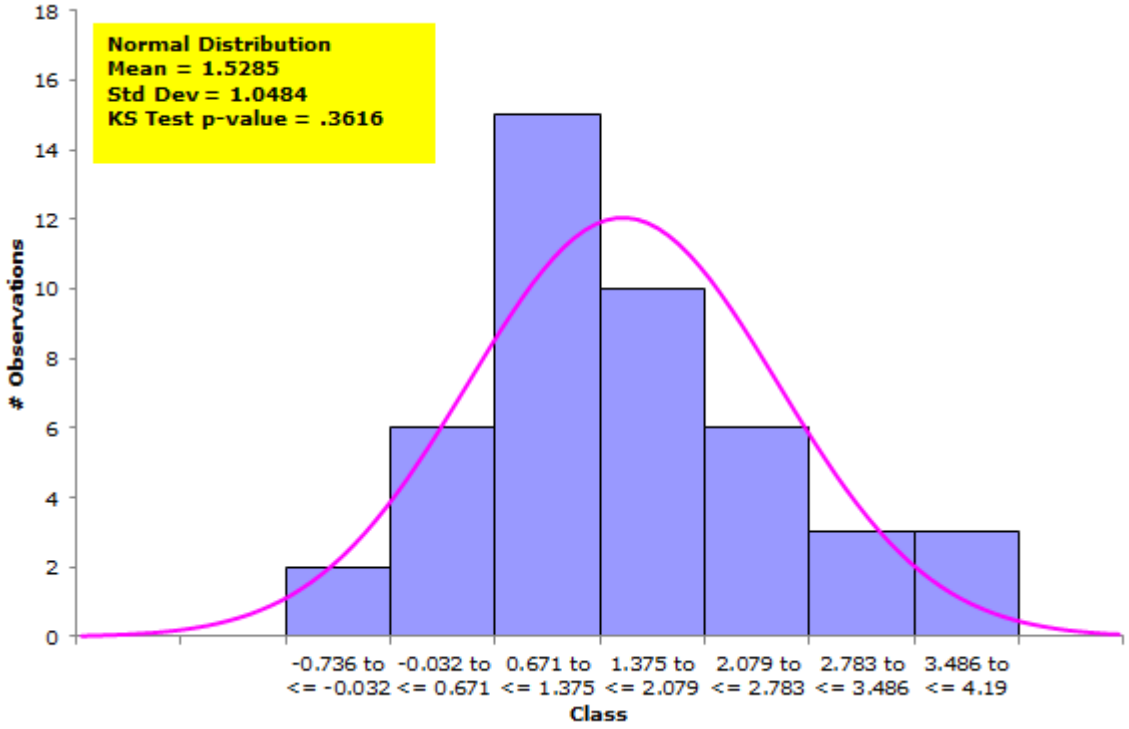

## Appendix 5- Normalize Solvent Treatments



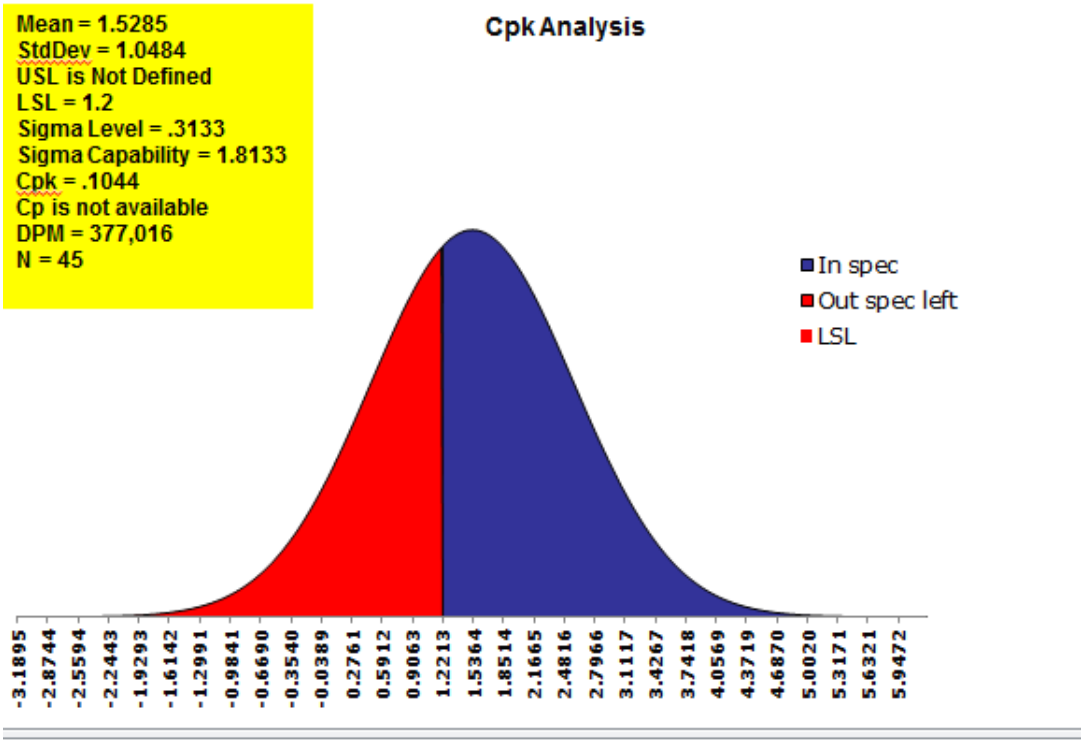

**Appendix 6- Acid & Solvent Lean Sigma Summary Metrics:2008, (Before) vs. 2009, (After) Data**

| | Before | After |
|---|---|---|
| Count | 26 | 45 |
| Mean | 2.2423 | 1.5285 |
| Median | 1.4421 | 1.3433 |
| Mode | None | None |
| Max | 6.6861 | 4.1902 |
| Min | 0.7511 | -0.7362 |
| Range | 5.9350 | 4.9265 |
| Std Dev (Pop) | 1.6963 | 1.0367 |
| Std Dev (Sample) | 1.7298 | 1.0484 |
| Variance (Pop) | 2.8773 | 1.0748 |
| Variance (Sample) | 2.9924 | 1.0992 |
| Skewness | 1.3163 | 0.4383 |
| Kurtosis | 0.8544 | 0.1510 |
| | | |
| 95% Conf. Interval for Mean | | |
| Upper Limit | 2.9410 | 1.8435 |
| Lower Limit | 1.5436 | 1.2135 |
| | | |
| 99% Conf. Interval for Mean | | |
| Upper Limit | 3.18799 | 1.94929 |
| Lower Limit | 1.29671 | 1.10772 |

**Appendix 7-Histogram: 2009 Stimulation Jobs, (w/ revised well candidate selection recommendations implemented**




**Appendix 8 – CPK Analysis**




**Appendix 9 – Hyphotesis Test Result (Discounted Profitability Index)**

| t Test Analysis (Mean) | | | |
|---|---|---|---|
| | 2008 | 2009 | |
| 2008 | 1.0 | 0.033544 | 96.6% Confidence |
| 2009 | | 1.0 | |
| **Summary** | | | |
| Mean | 2.2423 | 1.5285 | |
| StDev | 1.7298 | 1.0484 | |
| Count | 26 | 45 | |

The results below represent the p-values from a two sample, 2-tailed t-test. This means that the probability of falsely concluding the alternative hypothesis is the value shown (where the alternate hypothesis is that the means are not equal). Another way of interpreting this result is that you can have (1-pvalue)*100% confidence that the means are not equal.

| F Test Analysis (Std Dev) | | | |
|---|---|---|---|
| | 2008 | 2009 | |
| 2008 | 1.0 | 0.003581 | 99.6% Confidence |
| 2009 | | 1.0 | |
| **Summary** | | | |
| Mean | 2.2423 | 1.5285 | |
| StDev | 1.7298 | 1.0484 | |
| Count | 26 | 45 | |

The results below represent the p-values from a 2 sample F-test. This means the probability of falsely concluding the alternative hypothesis is the value shown (where the alternate hypothesis is that the variances are NOT equal). Another way of interpreting this result is that you can have (1-pvalue)*100% confidence that the variances are not equal.