



**Greenzyme® Flood Summary**  
Greenzyme® - Brazilian Crude Oil

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## Enhanced Oil Recovery Testing

Experimental Objective: To show the effects on residual oil saturation that the introduction of an enzyme solution (GreenZyme<sup>®</sup>) will have in a homogeneous oil-saturated sandstone formation.

1. Acquire a 1.5" x 2.5" piece of 500 md, Berea sandstone having a porosity near 25%.
2. Acquire filtered crude oil having an oil gravity less than 25 degrees API
3. Saturate sample using brine solution and measure Kw at 1000 psi. stress.
4. Flow filtered erode oil across length of sample until the plug sample reaches Swi renditions. Measure KoSwi.
5. Row brine solution across length of sample until the plug sample reaches conditions and measure KwSor.
6. Age sample at 180 degrees F. for two weeks.
7. Flow 5 pore volumes of enzyme solution across length of core plug collecting effluent. Option: Monitor pore volumes of enzyme solution vs. oil cut until there is a 99.9% enzyme quality produced.
8. Let sample soak for 2 days. Flush with brine solution and collect any final effluent that might be removed from the core sample.
9. Determine final KwSor using brine solution.
10. Calculate Sor change triggered from the enzyme solution by Dean-Stark extracting the sample. Dean-Stark oil saturation combined with oil removed by enzyme flow will yield original Sor. Reduction of Sor created by enzyme influence will determine a calculated oil recovery percent using this methodology.

## **GreenZyme® Coreflood Unsteady-State Method**

### **•Sample Preparation**

One 1.50-inch diameter Berea core sample was selected for GreenZyme® coreflood tests under overburden conditions. The sample was cleaned, dried and properties were measured at 1000 psi net confining stress.

### **•Fluid Preparation**

Synthetic brine was prepared using deionized water and reagent grade chemical. The brine was filtered and degassed prior to use. An approximately 20 gravity crude oil sample was selected for the test. The crude oil sample was filtered and degassed prior to use.

### **•Pre-Test Procedure**

The sample was vacuum saturated with brine and loaded into overburden cells at 1000 psi simulated reservoir stress.

To ensure full saturation, brine was injected against backpressure. Water permeability,  $K_w$ , was determined at 100 percent brine saturation. Crude oil was injected at constant rate to drive the sample to residual water saturation,  $S_{wr}$ .

Water and oil volumes produced were recorder.

Oil permeability at residual water saturation,  $K_{oSwr}$ , was determined.

Water was injected at a constant rate of 4 cc/minute to drive the sample to residual oil saturation,  $S_{ur}$ . Incremental volumes of water and oil production were collected as a function of time.

Permeability to water and residual oil saturation ( $K_w S_{ur}$ ) was measured.

### **•Sample Aging**

Following the  $K_{wSor}$  measurement, the sample was heated to 180°F while maintaining 1000 psi stress.

The sample was aged under these conditions for two weeks.

Upon completion of aging the sample was allowed to cool to room temperature.

### **•GreenZyme® Flood**

Five pore volumes of full strength GreenZyme® was flowed through the sample, oil volumes produced were monitored and recorded.

Once sufficient GreenZyme® was injected into the sample, flow was stopped and a 48 hour soak was conducted. After 48 hours flow was resumed using the simulated formation brine, flow was continued until a water cut of 99.9 percent was obtained. Oil volumes produced were monitored and recorded. Permeability to water at residual oil saturation ( $K_{wSor}$ ) was measured at the end of the test.

This test was repeated using GreenZyme® diluted to 3, 5 and 7 percent solutions. Test results are presented in tabular and graphical format.

## Greenzyme® Flood Summery

Simulated Reservoir Stress: 1000 psi  
Test Temperature 77.0° F

Field: Berea Test Sample  
Location: N/A

| Test Time, min. | Fluid Injected Pore Volume | Oil Produced, cm <sup>3</sup> | Oil produced % Original Oil, in place |
|-----------------|----------------------------|-------------------------------|---------------------------------------|
|-----------------|----------------------------|-------------------------------|---------------------------------------|

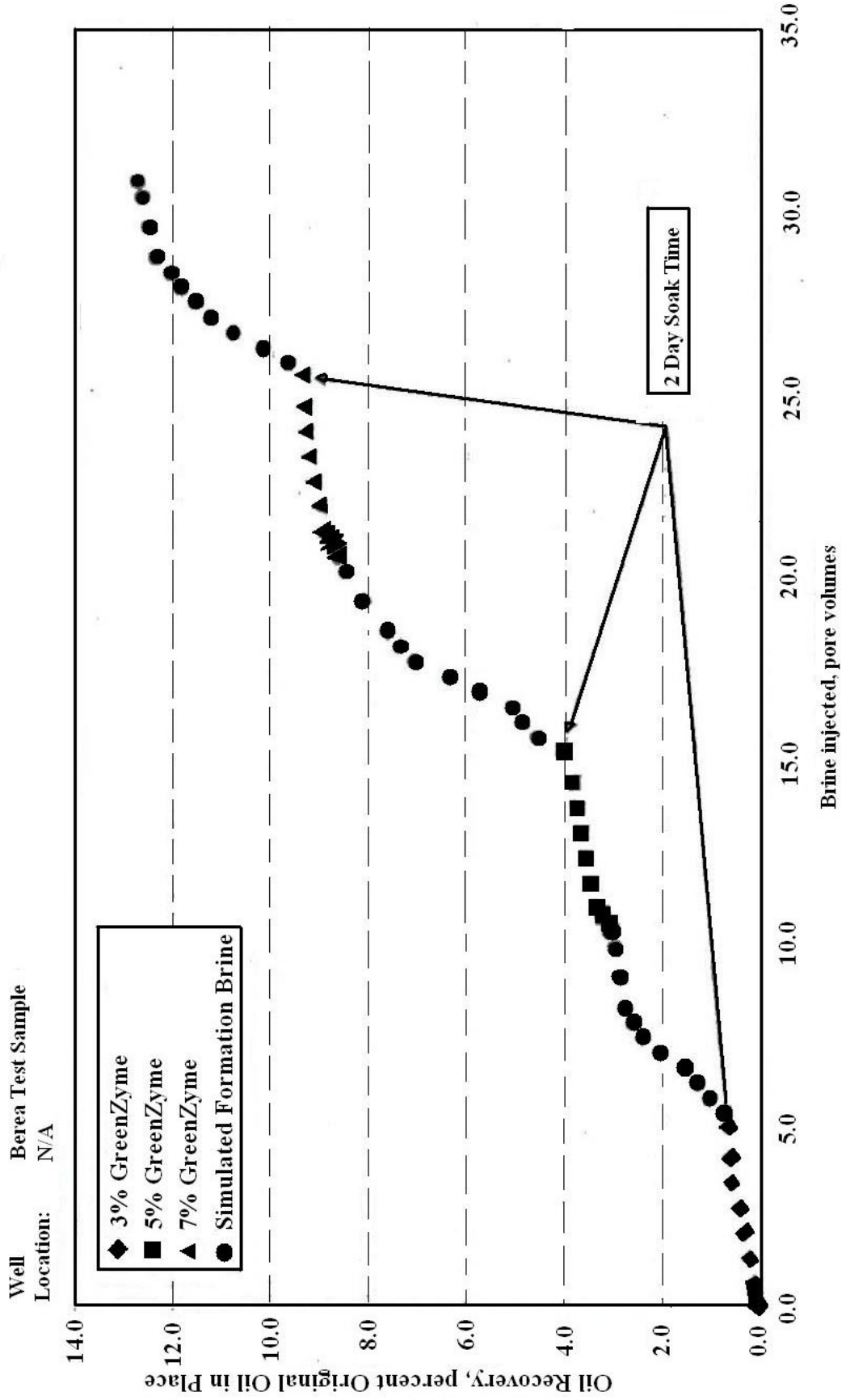
**7% GreenZyme (®) in Simulated Formation Brine**

|      |       |       |      |
|------|-------|-------|------|
| 0.2  | 20.68 | 0.000 | 8.67 |
| 0.6  | 20.69 | 0.000 | 8.67 |
| 0.8  | 20.72 | 0.000 | 8.67 |
| 1.0  | 20.74 | 0.000 | 8.67 |
| 1.5  | 20.77 | 0.002 | 8.69 |
| 2.0  | 20.83 | 0.005 | 8.72 |
| 3.5  | 20.94 | 0.010 | 8.77 |
| 5.0  | 21.07 | 0.015 | 8.82 |
| 6.5  | 21.21 | 0.023 | 8.90 |
| 7.5  | 21.35 | 0.033 | 9.01 |
| 16.5 | 22.04 | 0.039 | 9.07 |
| 25.0 | 22.73 | 0.049 | 9.17 |
| 35.0 | 23.41 | 0.058 | 9.26 |
| 42.0 | 24.10 | 0.065 | 9.33 |
| 50.0 | 24.79 | 0.068 | 9.36 |
| 61.0 | 25.69 | 0.071 | 9.39 |

**48 hours soak  
Simulated Formation Brine**

|     |       |       |       |
|-----|-------|-------|-------|
| 65  | 23.03 | 0.100 | 9.69  |
| 70  | 26.44 | 0.150 | 10.20 |
| 75  | 26.86 | 0.210 | 10.81 |
| 80  | 27.27 | 0.255 | 11.27 |
| 85  | 27.68 | 0.285 | 11.58 |
| 90  | 28.09 | 0.315 | 11.88 |
| 85  | 28.51 | 0.335 | 12.09 |
| 100 | 28.92 | 0.365 | 12.39 |
| 110 | 29.75 | 0.380 | 12.55 |
| 120 | 30.57 | 0.392 | 12.67 |
| 125 | 30.99 | 0.400 | 12.75 |

**Oil Produced vs Brine injected**



**FULL STRENGTH GREENZYME® FLOOD SUMMARY**

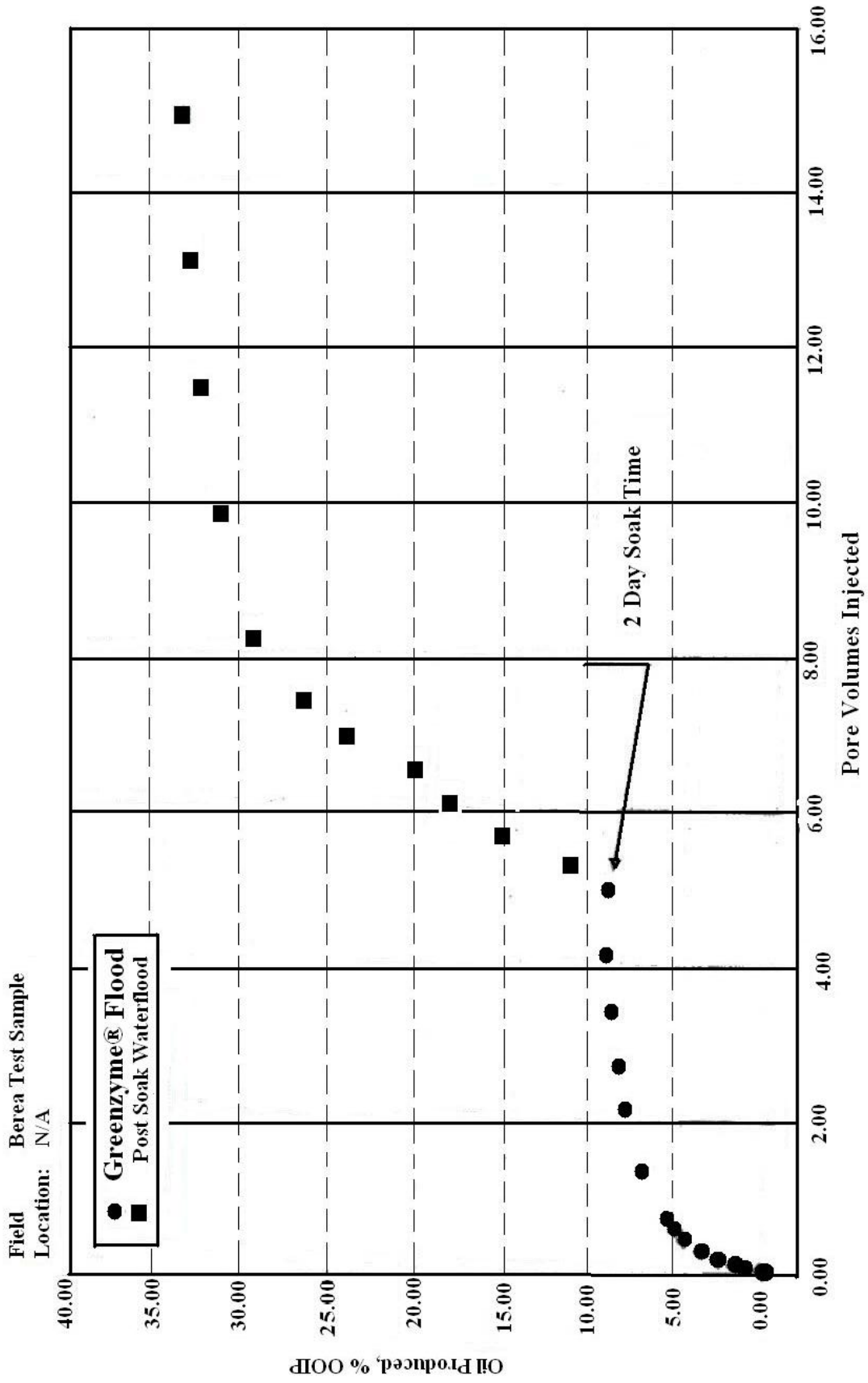
Simulated Reservoir Stress:  
1000 psi Test Temperature 77.0° F

Field: Berea Test Sample  
Location: N/A

| Sample ID | Permeability to Air, millidarcies | Porosity, percent | Permeability to Brine, millidarcies | Initial Condition Data                  |                                      |   | Post Waterflood Data                   |                             |  |
|-----------|-----------------------------------|-------------------|-------------------------------------|---|--------------------------------------|---|--|-----------------------------|--|
|           |                                   |                   |                                     | Initial Water Saturation (Swi), percent | Initial Oil Saturation (So), percent | Permeability to Oil at Initial Water Saturation (KoSwi), millidarcies | Residual Oil Saturation (Sor), percent | Oil Produced, percent OOIIP | Permeability to Water at Residual Oil Saturation (KwSor), millidarcies |
| Berea#2   | 427                               | 20.6              | 125                                 | 19.0                                    | 81.0                                 | 166   | 51.6                                   | 38.2                        | 16.9   |

| Sample ID | Post 5 PV GreenZyme Solution Flood     |  |  | Post Water Flood After Enzyme          |  |  |
|-----------|--|--|--|--|--|--|
|           | Residual Oil Saturation (Sor), percent | Additional Oil Produced, percent OOIIP | Permeability to Water at Residual Oil Saturation (KwSor), millidarcies | Residual Oil Saturation (Sor), percent | Additional Oil Produced, percent OOIIP | Permeability to Water at Residual Oil Saturation (KwSor), millidarcies |
| Berea#2   | 43.8                                   | 9.69                                   | 23.1   | 25.5                                   | 27.0                                   | 27.0   |

**Oil Produced vs. Pore Volume Injected**





### Greenzyme® Flood Summary

Simulated Reservoir Stress: 1000 psi

Test Temperature 77.0° F

Field: Berea Test Sample

Location: N/A

| Sample ID | Permeability to Air, millidarcies | Porosity, percent | Permeability to Brine, millidarcies | Initial Condition Data                  |                                      |   | Post Waterflood Data                   |                           |  |
|-----------|-----------------------------------|-------------------|-------------------------------------|---|--------------------------------------|---|--|---------------------------|--|
|           |                                   |                   |                                     | Initial Water Saturation (Swi), percent | Initial Oil Saturation (So), percent | Permeability to Oil at Initial Water Saturation (KoSwi), millidarcies | Residual Oil Saturation (Sor), percent | Oil Produced, percent OOP | Permeability to Water at Residual Oil Saturation (KwSor), millidarcies |
| Berea#2   | 427                               | 20.6              | 125                                 | 19.0                                    | 81.0                                 | 126   | 37.2                                   | 54.0                      | 18.3   |

| Sample ID | Greenzyme Solution | Post Water Flood After GreenZyme       |                                     |   |
|-----------|--------------------|--|-------------------------------------|---|
|           |                    | Residual Oil Saturation (Sor), percent | Additional Oil Produced Percent OOP | Permeability to Water at Residual Oil Saturated (KWSor), millidarcies |
| Berea #2  | 3%                 | 34.7                                   | 3.08                                | 1.9   |
|           | 5%                 | 30.2                                   | 5.61                                | 0.262   |
|           | 7%                 | 26.8                                   | 4.08                                | 0.111   |
|           | Total              |  | 12.76                               |   |



### Greenzyme® Flood Summary

Simulated Reservoir Stress: 1000 psi  
 Test Temperature 77.0° F

Field: Berea Test Sample  
 Location: N/A

| Test Time, min. | Fluid Injected Pore Volume | Oil Produced, cm <sup>3</sup> | Oil produced % Original Oil, in place |
|-----------------|----------------------------|-------------------------------|---------------------------------------|
|-----------------|----------------------------|-------------------------------|---------------------------------------|

3% GreenZyme® in Simulated Formation Brine

|      |      |       |      |
|------|------|-------|------|
| 0.3  | 0.02 | 0.000 | 0.00 |
| 0.5  | 0.03 | 0.000 | 0.00 |
| 0.8  | 0.06 | 0.002 | 0.02 |
| 1.0  | 0.08 | 0.003 | 0.03 |
| 1.5  | 0.11 | 0.005 | 0.05 |
| 2.0  | 0.17 | 0.006 | 0.06 |
| 3.5  | 0.28 | 0.007 | 0.07 |
| 5.0  | 0.41 | 0.008 | 0.08 |
| 6.5  | 0.55 | 0.009 | 0.09 |
| 8.5  | 0.69 | 0.010 | 0.10 |
| 17.0 | 1.38 | 0.020 | 0.20 |
| 25.0 | 2.07 | 0.030 | 0.31 |
| 35.0 | 2.75 | 0.040 | 0.41 |
| 40.0 | 3.44 | 0.055 | 0.56 |
| 50.0 | 4.13 | 0.060 | 0.61 |
| 60.0 | 5.03 | 0.065 | 0.66 |

48 hours soak  
 Simulated Formation Brine

|     |       |       |      |
|-----|-------|-------|------|
| 65  | 5.37  | 0.070 | 0.71 |
| 70  | 5.78  | 0.100 | 1.02 |
| 75  | 6.20  | 0.125 | 1.28 |
| 80  | 6.61  | 0.150 | 1.53 |
| 85  | 7.02  | 0.200 | 2.04 |
| 90  | 7.43  | 0.235 | 2.40 |
| 95  | 7.85  | 0.255 | 2.60 |
| 100 | 8.26  | 0.270 | 2.76 |
| 110 | 9.09  | 0.280 | 2.86 |
| 120 | 9.91  | 0.292 | 2.98 |
| 125 | 10.33 | 0.300 | 3.06 |

## Greenzyme® Flood Summery

Simulated Reservoir Stress: 1000 psi

Test Temperature 77.0° F

Field            Berea Test Sample  
 Location:        N/A

| Test Time, min. | Fluid Injected Pore Volume | Oil Produced, cm <sup>3</sup> | Oil produced % Original Oil, in place |
|-----------------|----------------------------|-------------------------------|---------------------------------------|
|-----------------|----------------------------|-------------------------------|---------------------------------------|

**5% GreenZyme® in Simulated Formation Brine**

|      |       |       |      |
|------|-------|-------|------|
| 0.3  | 10.35 | 0.000 | 3.06 |
| 0.3  | 10.36 | 0.000 | 3.06 |
| 0.7  | 10.35 | 0.002 | 3.08 |
| 1.0  | 10.41 | 0.003 | 3.09 |
| 1.3  | 10.44 | 0.005 | 3.11 |
| 2.0  | 10.50 | 0.006 | 3.12 |
| 3.3  | 10.61 | 0.007 | 3.13 |
| 5.0  | 10.74 | 0.018 | 3.24 |
| 6.7  | 10.88 | 0.021 | 3.27 |
| 8.3  | 11.02 | 0.030 | 3.37 |
| 16.7 | 11.71 | 0.043 | 3.50 |
| 25.0 | 12.40 | 0.053 | 3.60 |
| 33.3 | 13.08 | 0.062 | 3.69 |
| 41.7 | 13.77 | 0.070 | 3.77 |
| 50.0 | 14.46 | 0.080 | 3.88 |
| 60.8 | 15.36 | 0.100 | 4.08 |

**48 hours soak  
 Simulated Formation Brine**

|     |       |       |      |
|-----|-------|-------|------|
| 65  | 15.70 | 0.150 | 4.59 |
| 70  | 16.11 | 0.180 | 4.90 |
| 75  | 16.53 | 0.200 | 5.10 |
| 80  | 16.94 | 0.265 | 5.7  |
| 85  | 17.35 | 0.325 | 6.38 |
| 90  | 17.76 | 0.395 | 7.09 |
| 95  | 18.18 | 0.425 | 7.40 |
| 100 | 18.59 | 0.450 | 7.65 |
| 110 | 19.42 | 0.500 | 8.16 |
| 120 | 20.24 | 0.535 | 8.52 |
| 125 | 20.66 | 0.550 | 8.67 |