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135. Emissions Control Unit for Diesel Engine Exhaust

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Abstract

The diesel engines contribute to ecological contamination and they are the fundamental driver of a few health issues. They add to an unnatural weather change through Hydrocarbons (HC), Particulate Matter (PM), Carbon Oxides (COx) and Nitrogen Oxides (NOx) discharges. Different viable strategies are at present accessible for decreasing PM, HC, COx and NOx but this paper illustrates a method to control PM and HC discharges from diesel engine fumes. Smoke from the diesel engine goes through the heat exchanger (shell and tube). After Heat exchanger, low-temperature smoke is coordinated to the oil bath cleaning unit (OBCU). The surface area of the smoke is expanded to allow most extreme contact with lubricating oil. The substantial particles (PM, HC) present in smoke is expelled with the assistance of the filter element and the clean air (except NOx and COx) is rerouted upwards to nature. This test was performed on diesel engine MF-260 turbo having 60 HP. Looking at the outcomes, it is examined that installing emission control unit (ECU) in diesel engine, pollution level (PL) diminishes up to 14.7-29.10%, Soot Concentration (SC) level decreases 22.2-50.8 % and in filter smoke number (FSN) contamination lessens 12.78-26.07%.

Keywords: *Diesel engine, shell and tube heat exchanger, oil bath cleaning unit.*

1. Introduction

The formation of HC in diesel engines is caused by incomplete combustion and insufficient temperature in the combustion chamber which occur due to the lake supply of oxygen for combustion in the combustion chamber. Near to cylinder wall, HC formation is high because the temperature of the air-fuel mixture is higher in the centre of the cylinder than near the wall of the cylinder [1]. Thousands of species contribute to making HCs most prominent of these are alkenes, alkanes and aromatics [2]. HC emissions occur normally at high load [3]. The environment is badly affected by HCs emissions. The formation of Ground-level ozone results [4, 5].

Insufficient supply of oxygen in combustion chamber produce incomplete combustion of the HCs which produce PM.
An experimental study describe that PM consists of sulphates, moisture, unburnt lubricating oil, carbon element, unburnt fuel and metals and others substances [6]. There are main three types of Diesel particle emissions: soot, inorganic fraction (IF) and soluble organic fraction (SOF). Black smoke (Soot) contribute above than 50% of the entire PM emissions. SOF contains heavy hydrocarbons (HHC) which are adsorbed on the soot. At low exhaust temperatures with light engine loads, the values of SOF are too high. It is the combination of lubricating oil, unburned fuel and compounds which are produced during combustion. [7-11]. Different health issues, for example, lung disease, cardiovascular issues and other are created by inhaling of these particles [12-14].

This research work describes a technique to control HC and PM emissions from the exhaust of diesel engine. Fig 1 represents the schematic diagram of ECU with diesel engine exhaust and this model was generated in AutoCAD 2013. The emission control unit (ECU) works in such a way that exhaust fumes from the engine's exhaust pass through the shell & tube heat exchanger. After passing through a heat

exchanger, low-temperature smoke is directed to the OBCU. The heavy particles (PM, HC) present in smoke are removed in OBCU because PM are solid in nature and HC are thick liquid like honey. When smoke passes through OBCU, the surface area of the smoke is increased to allow maximum contact with lubrication oil. HC and PM contaminate of lubricating oil and filter element and clean air is rerouted upwards to the environment. In the present study, experiments were performed on MF-260 Turbo engine to investigate the performance of ECU using oil bath cleaner with shell & tube heat exchanger. ECU has the capability to reduce the emission from PM and HC.

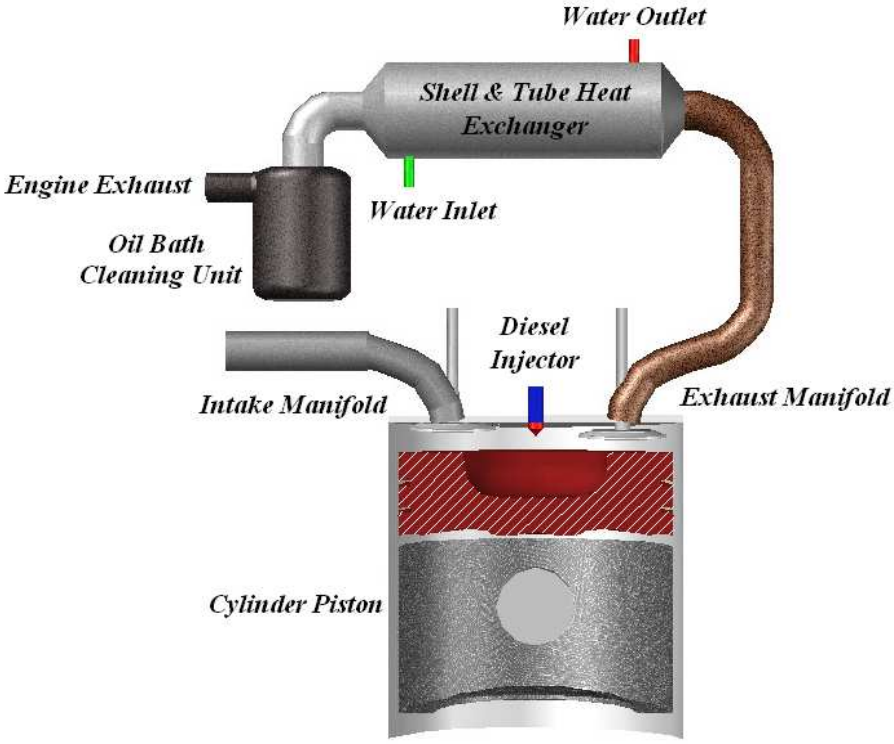


Fig. 1. Schematic diagram of ECU

2. Experimental setup

2.1. Engine specification

In this experiment, the MF-260 turbo engine has used that consists of three cylinders (two valves per cylinder), turbocharger and common rail fuel injection system. The engine was coupled to an eddy current dynamometer to apply different loads at various RMP of an engine to investigate engine emissions. Other engine's specifications are given in table 1.

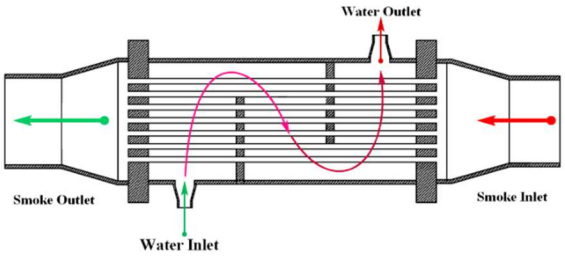
Table 1. Specification of diesel engine

Description	Column 2
Type	Diesel
Aspiration	Turbo
Number of cylinders	3
Compression ratio	16.5:1
Maximum engine RPM	2250
Maximum power	60 HP
Type injection	Direct
Bore	91.5 mm
Stroke	127 mm
Type of cooling	Water cooled
Engine manufacturer	Millat Tractors Ltd Lahore

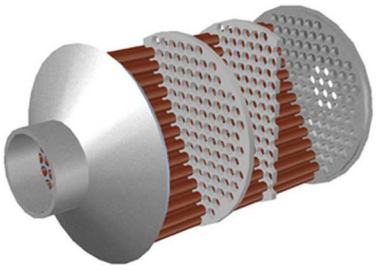
2.2. Shell and tube heat exchanger

A shell and tube heat exchanger is a smoke-to-water heat exchanger device that uses cooling water from water tank of the engine to reduce exhaust gas temperatures. The exhaust gas flow in the tubes and the

water as a cold medium flow outside of tubes. A cross flow heat exchanger was used in this experiment as shown in Fig 2(a). The diffuser is used to reduce the flow velocity. Fig 2 displays the 3d model of heat exchanger and flows of smoke and water in it. These models were generated in AutoCAD 2013.



(a)

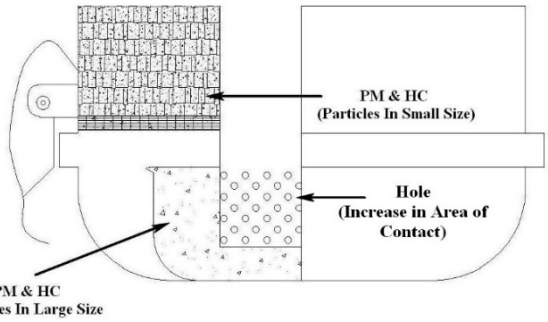


(b)

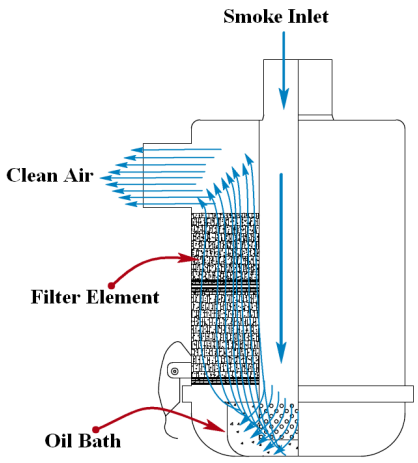
Fig. 2. Cross flow heat exchanger (a) and 3D model of the heat exchanger with header (b).

2.3. Oil bath cleaning unit

AutoCAD model of OBCU represents the flow of smoke. OBCU is a device which removes heavy particles (PM, HC) suspended in the smoke discharge from the exhaust of the engine. Low-temperature smoke coming from the heat exchanger makes contact with the lubricating oil and filter element present in OBCU. Particles large in size contaminates lubricating oil and tiny particles are collected by the filter element. Fig 3(a) shows OBCU and Fig 3(b) displays the flow of smoke in OBCU.



(a)



(b)

Fig. 3. OBCU (a) and flow of smoke in OBCU (b).

3. Results and discussion

The testing standard used for this experiment was BS-AU-141. At the initial stage, engine MF-260 turbo was started and gradually increased the speed of the engine by throttle control until high idling speed obtained. Eddy current dynamometer was used to apply gradual load unit engine came down to its rated RPM. After stabilising the rated RPM of the engine, take the measurements of requiring parameters (FSN, SC, PL, RPM, engine load and SFC). At that point engine loads of 0 to 15% were examined for 10 minutes at an engine speed of 1500-1600 RPM. After recording values at each 2 RPM difference, gradually decreased the load and speed of the engine to zero and shut down the engine. This experiment was performed two times (with and without ECU). Finally, the overall time of the analysis was 60 minutes, including the 40 minutes of idling to get steady state conditions before getting values.
This study Compares FSN, SC, PL, SFC and engine load (HP) for forty-nine observations utilizing ECU and without ECU. Graphs were plotted in MS Excel using observations are taken in X-axis and corresponding values of FNS, SC, PL, SFC and engine load (HP) in Y-axes.

3.1 Filter smoke number

In Fig. 4 represents that using ECU at high engine load, a considerable reduction in the value of FSN. The maximum value of FSN with ECU is 2.724 and the most extreme value of FSN without ECU is 3.685. This identifies the maximum percentage reduction in FSN 26.07%. Similarly the minimum value of FSN with ECU 2.559. The minimum value of FSN without ECU 2.934. The difference between FSN values is 0.375 and minimum percentage reduction in FSN are 12.78%.

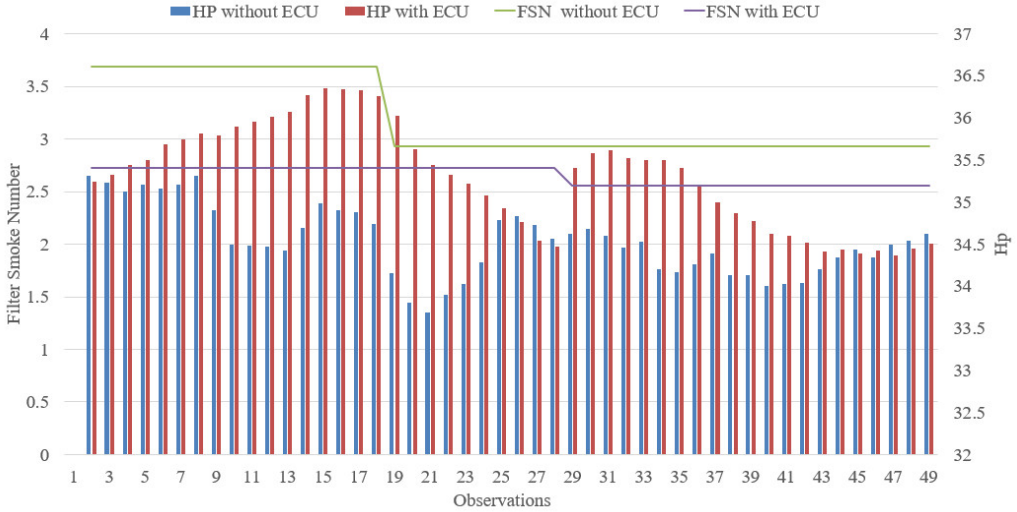


Fig. 4. Variations of FSN and engine load (HP)

3.2 Soot concentration

The comparison of SC and engine load (HP) using ECU and without ECU can be seen in Fig. 5. At the initial stage, both maximum value of SC with and without ECU are 73.58 mg/m3 and 149.58 mg/m3 and maximum percentage reduction in SC 50.8%. Similarly the minimum value of SC with ECU 73.58 mg/m3. The minimum value of SC without ECU 94.61 mg/m3. The difference between SC values is 21.03 and minimum percentage reduction in SC are 22.2%.

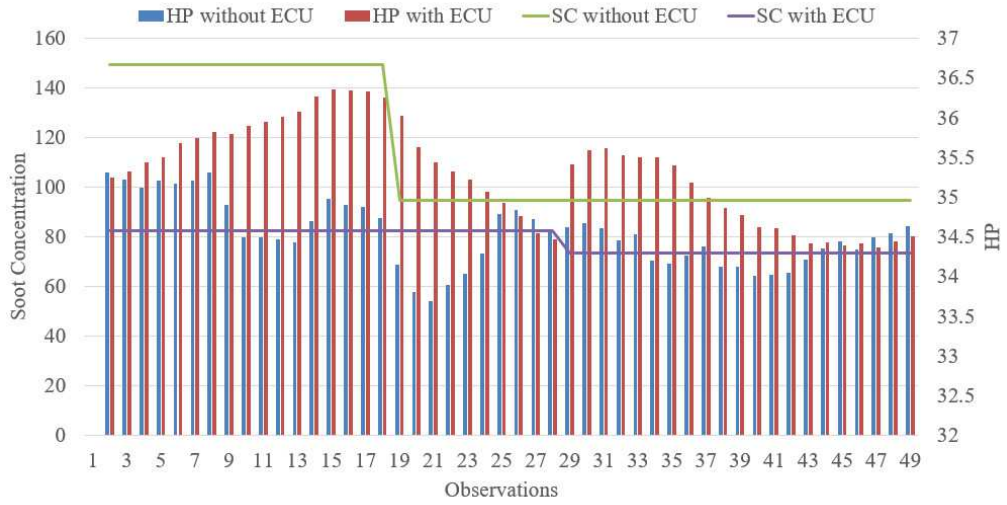


Fig. 5. Variations of SC (mg/m^3) and engine load (HP)

3.3 Pollution level

PM indicates the total estimation of emissions in a diesel engine. Fig. 6 clearly describes the maximum value of PL with and without ECU is 23.72 and 33.5 respectively and maximum percentage reduction in PL 29.10%. Similarly, the minimum values of PL with and without ECU are 22.05 and 25.85 respectively and minimum percentage reduction in PL is 14.7%. Fig 6 indicates a considerable reduction in PL high engine load.

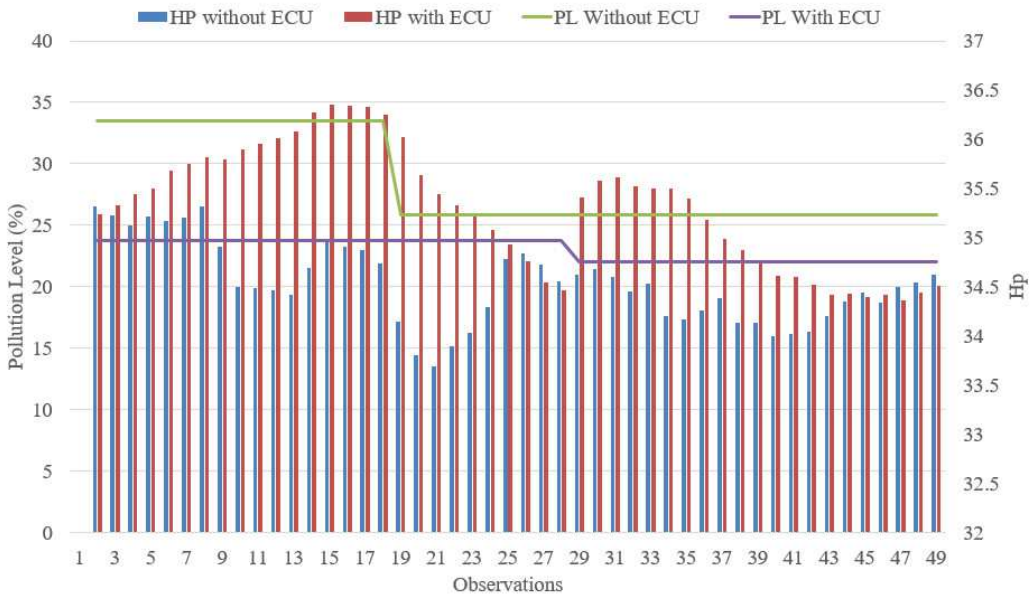


Fig. 6. Variations of PL (%) and engine load (HP)

3.4 Specific fuel consumption

SFC is most important factor in engine performance. Fig. 7 represents the comparison of SFC and engine load (HP). It is noticed that installation of ECU on diesel engine exhaust, the value of SFC is increased. The maximum value of SFC with and without ECU is 264.37 g/kWh and 260.22 g/kWh and maximum percentage increment in SFC 1.57%. Similarly the minimum value of SFC with ECU 255.77 g/kWh. The minimum value of SFC without ECU 253.43 g/kWh and minimum percentage increment in SFC is 0.91%.

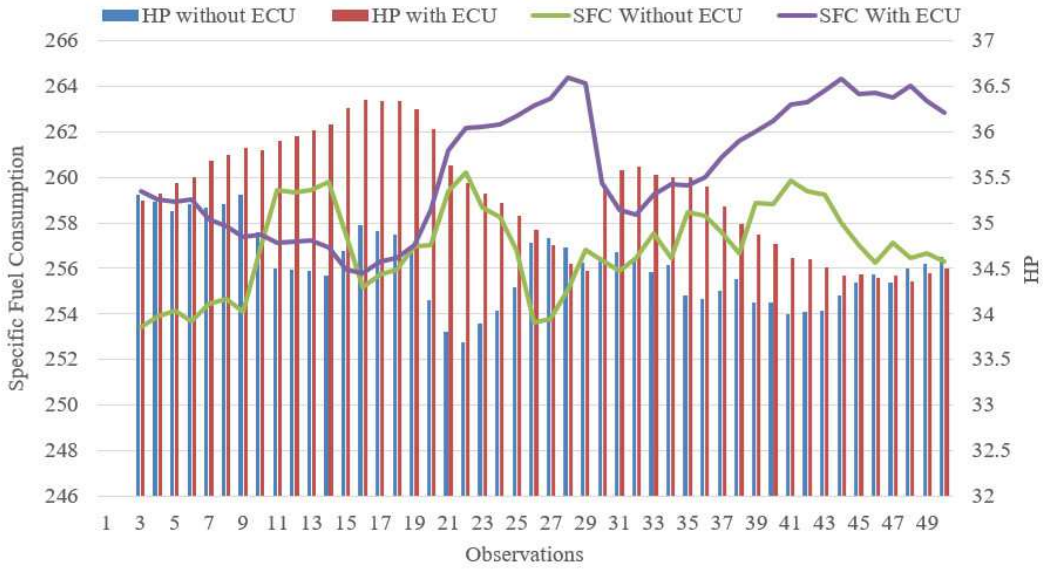


Fig. 7. Variations of SFC (g/kWh) and engine load (HP)

4. Conclusions

The ECU in diesel engine reduces FSN, SC and PL (PM and HC). The degree of reduction in FSN, SC and PL at higher loads is higher but as we increase engine load, the corresponding value of SFC also increase. The reasons for increment in SFC is back pressure [15]. Comparing all result with MF-260 Turbo and keeping it as a reference standard. The results show there is 14.7-29.10% reduction in pollution level, 22.2-50.8% reduction in soot concentration level and 12.78-26.07% reduction in filter smoke number and 0.91-1.57% increment in specific fuel consumption. This system control HC and PM emissions but the drawback of this system is back pressure [15] produce by shell and tube heat exchanger and OBCU (Lubricating oil and filter element).

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Appendix A:
Raw data obtained by experiment.

Millat test cell results

Without Emission Control Unit					With Emission Control Unit				
HP	FSN	SC (mg/m^3)	P L (%)	SFC (g/kWh)	HP	FSN	SC (mg/m^3)	P L (%)	SFC (g/kWh)
35.31230	3.685	149.58	33.5	253.43124	35.24201	2.724	82.39	23.72	259.41268
35.22608	3.685	149.58	33.5	253.89481	35.32838	2.724	82.39	23.72	259.00721
35.12410	3.685	149.58	33.5	254.16220	35.44047	2.724	82.39	23.72	258.93045
35.21281	3.685	149.58	33.5	253.66924	35.50055	2.724	82.39	23.72	259.00699
35.16544	3.685	149.58	33.5	254.42865	35.68108	2.724	82.39	23.72	258.14564
35.20240	3.685	149.58	33.5	254.64878	35.74465	2.724	82.39	23.72	257.86475
35.31420	3.685	149.58	33.5	254.11080	35.81833	2.724	82.39	23.72	257.36329
34.90282	3.685	149.58	33.5	256.91892	35.79294	2.724	82.39	23.72	257.46681
34.49707	3.685	149.58	33.5	259.45663	35.89879	2.724	82.39	23.72	257.12064
34.48777	3.685	149.58	33.5	259.36559	35.95111	2.724	82.39	23.72	257.17048
34.46723	3.685	149.58	33.5	259.43781	36.01386	2.724	82.39	23.72	257.21857
34.42351	3.685	149.58	33.5	259.80924	36.07551	2.724	82.39	23.72	256.91537
34.69218	3.685	149.58	33.5	257.44146	36.26713	2.724	82.39	23.72	255.91926
34.98095	3.685	149.58	33.5	255.17896	36.35642	2.724	82.39	23.72	255.76974
34.90576	3.685	149.58	33.5	255.73908	36.34097	2.724	82.39	23.72	256.30894
34.87628	3.685	149.58	33.5	255.95491	36.33413	2.724	82.39	23.72	256.44694
34.73538	3.685	149.58	33.5	256.97762	36.25314	2.724	82.39	23.72	257.00360
34.14979	2.934	94.61	25.85	257.02765	36.02533	2.724	82.39	23.72	258.58654
33.80333	2.934	94.61	25.85	259.38549	35.63021	2.724	82.39	23.72	261.21584
33.69151	2.934	94.61	25.85	260.22219	35.44043	2.724	82.39	23.72	262.19442
33.89285	2.934	94.61	25.85	258.66041	35.32827	2.724	82.39	23.72	262.20290
34.03127	2.934	94.61	25.85	258.24086	35.22414	2.724	82.39	23.72	262.33391
34.28969	2.934	94.61	25.85	256.81168	35.07337	2.724	82.39	23.72	262.71178
34.78297	2.934	94.61	25.85	253.63168	34.92804	2.724	82.39	23.72	263.16974
34.83407	2.934	94.61	25.85	253.76159	34.76129	2.724	82.39	23.72	263.47834
34.72720	2.934	94.61	25.85	255.05614	34.54592	2.724	82.39	23.72	264.36856
34.55960	2.934	94.61	25.85	256.80098	34.46682	2.724	82.39	23.72	264.14613
34.62295	2.934	94.61	25.85	256.34478	35.40708	2.559	73.58	22.05	259.74413
34.67755	2.934	94.61	25.85	255.90539	35.58408	2.559	73.58	22.05	258.57055
34.60333	2.934	94.61	25.85	256.45340	35.61809	2.559	73.58	22.05	258.34998
34.45690	2.934	94.61	25.85	257.51571	35.52485	2.559	73.58	22.05	259.25293
34.53117	2.934	94.61	25.85	256.45928	35.50243	2.559	73.58	22.05	259.68314
34.20073	2.934	94.61	25.85	258.46073	35.50290	2.559	73.58	22.05	259.63977
34.16799	2.934	94.61	25.85	258.29336	35.40149	2.559	73.58	22.05	260.00722
34.25967	2.934	94.61	25.85	257.57416	35.18483	2.559	73.58	22.05	260.85974
34.38440	2.934	94.61	25.85	256.66344	34.99190	2.559	73.58	22.05	261.61071
34.12942	2.934	94.61	25.85	258.85792	34.86961	2.559	73.58	22.05	262.01379
34.12965	2.934	94.61	25.85	258.84583	34.77171	2.559	73.58	22.05	262.46218
34.00315	2.934	94.61	25.85	259.83550	34.61711	2.559	73.58	22.05	263.18603
34.02390	2.934	94.61	25.85	259.39887	34.60384	2.559	73.58	22.05	263.27920