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# New Technology Research & Development Program
# Grant Contract 582-5-65591-0007

# Task 4 Deliverable Report

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by the State of Texas through a Grant from the
Texas Commission on Environmental Quality.

# Construction of Converter System, EGR, and Data Acquisition System

## Task 4

Prepared for the
Texas Commission on Environmental Quality
NTRD Contract No. 582-5-65591-0007
Converter Technology Inc.

February 22, 2007

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# Particulate Converter, Diesel Oxidation Catalyst, Moisture Separator, Mobile Data Acquisition System & Venturi-Meter

## 1. Diesel Particulate Converters

The initial design of the particulate converter for this project was based on the proven principle of "reverse pulse jet", which began commercialization in July, 2005 by CTI. However, due to difficulties encountered in our verification application with CARB and anticipating having similar expensive and delayed encounters also with EPA with regard to the treatment of collected diesel soot as hazardous waste, CTI dropped the reverse pulse jet concept.

Next, CTI focused on the incineration approach, which is also documented in our latest patent application. The development cycle including testing continued through most of 2006. Two rounds of development have taken place, one with centrifugal separator based on a previous patent by CTI and the second one is simplified through the elimination of the centrifugal separation, but at the expense of increased surface area of the incinerator. Due to the cyclic nature of mobile diesel engines operability and the ensuing fluctuation in centrifugal separation, it was decided to better eliminate this method for mobile application, although it would be desirable for stationary application operating at mostly steady-state conditions.

The current design was tested extensively. A major competitive advantage is the "simple passive design", which would lead to high durability and reliability in operation compared to "active particulate trap" system currently in implementation on 2007 model year on-highway heavy-duty vehicles.

The core component of the current particulate converter is referred to as "the candle". The candle simply consists of a perforated tube as a structural support where the composite wire mesh media is wounded. The composite wire mesh functions as a "particulate agglomerator". This is followed by a fine mesh stainless steel screen grade 316. The stainless screen is followed by ceramic net or wrapped ceramic yarn made out of alumina/silica combination. The ceramic yarn is followed by a fine Dutch stainless steel screen also grade 316. The ceramic yarn provides electrical insulation and can withstand temperatures up to 2012°F (1100°C) which is much higher than soot ignition temperature. The two metallic screens and the ceramic yarn form the incinerator.

Incineration is achieved through the application of electric voltage to the outer Dutch screen. No current flows as long as the gap between the Dutch screen and the ground screen is empty. As agglomerated soot migrates from the agglomerator media to the Dutch screen, which functions as a filter, a soot cake builds up on the upstream side of the Dutch screen. The build up continues until the cake thickness and density reaches the ground screen, at which location an electrical circuit is established. Current consumption heats the soot and in the presence of oxygen in the exhaust, soot is incinerated.

The incineration process as employed herein is quite innovative and efficient. Several observation and techniques were developed/discovered mostly through experimentation. A summary is briefly outlined. First, soot electrical resistivity decreases with increase in temperatures (opposite characteristics to all metals). This is desirable to increase soot temperature through electric heat. Incineration is a difficult process to initiate, but once initiated, the heat generated from burning of the soot accelerates the process. Further, alternating current was more effective than direct current to initiate incineration. This led to the development of a DC chopper, which is even more effective even than AC. If soot does not incinerate in 60 seconds, it is heated instead of being incinerated. This led to applying chopped voltage for 60 seconds to incinerate spots having heavy soot and high current density, then turn the power off for about 60 minutes to allow for the added soot build up at other locations to reach incineration temperature. This scenario led to the development of a customized power supply for the incineration process herein called DC chopper-sequencer. The power supply switches power automatically from one candle to the next and then turns power off until the next cycle (about an hour) starts. The chopper mode of operation logic and the associated electronic are shown on page 9 and 10, respectively. It should be noticed that the electric power utilization is used exclusively to heat soot and that corresponds to a very low fuel penalty (currently estimated at less than 0.1%), and is substantially less than the heat energy used to regenerate a particulate trap (incineration energy consumption is estimated at 1-4% of the energy used in regeneration). Converter Technology constructed 3 power-supplies and will construct additional 5 power-supplies over the next 2 to 3 months.

As described before, incineration does not take place at all physical locations on the Dutch screen at any given time, as is the case with all regeneration processes. As such, incineration as defined herein is characterized as "continuous intermittent process". Further due to the limited amount of soot burned, incineration is controlled by the thickness of soot layer which ranges from 10-20 mills (0.25 -0.5 mm), the heat generated from soot incineration is small and limited. As such, no rise in temperature of incineration is detected in the exhaust, as is the case with almost all particulate trap regenerations which could be high and destructive. It should be noticed that incineration takes place at the outer prefery of the candle and only the Dutch screen is exposed to it. The screen is cooled from the downstream side. In conclusion, damages that could result from the combustion of soot is greatly minimized (almost eliminated) in the incineration process in comparison with the regeneration process primarily due to fragmented, limited soot combustions.

Ceramic traps are notorious for accumulating ashes in the wall rendering them clogged up after a few regenerations. Although the Dutch screen functions as a retaining filter for the agglomerated particles, ashes generated from incineration will be blown away through the Dutch screen. Openings in the Dutch screen stand at 70 microns, which are sufficiently large enough to allow ashes to escape and thus prevents ash accumulation, as is the case with particulate traps.

Converter Technology constructed 2 pulse-jet converters, 2 incineration converters with centrifugal separators and 2 incineration converters. Further, we are planning to construct additional 4 to 5 converters for demonstration purposes to be installed in Jackson, MI, Dallas and Houston, TX over the next 2 to 3 month.

# Schematic Diagram for PM & NOx Control Strategy Production Hardware

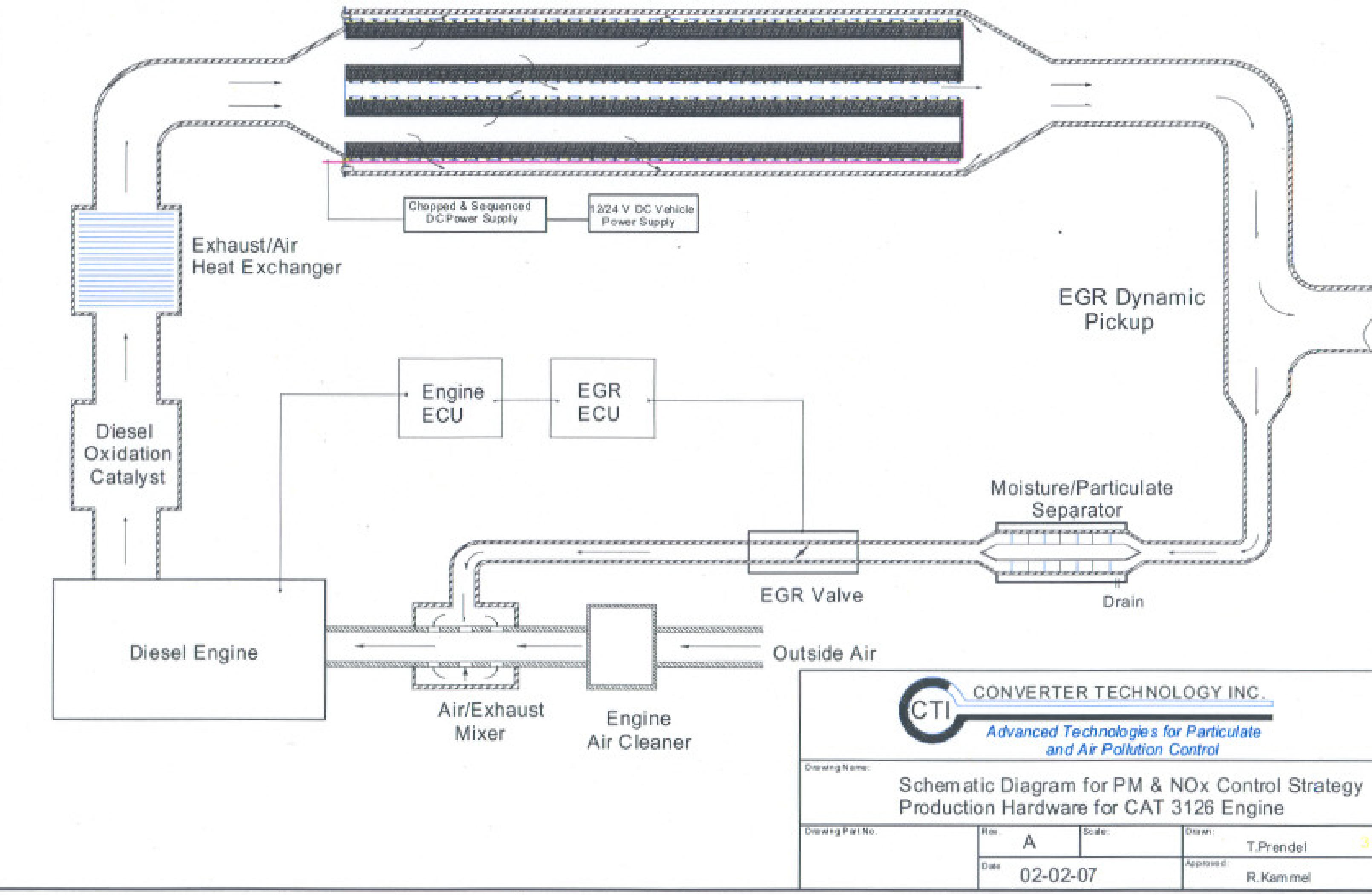
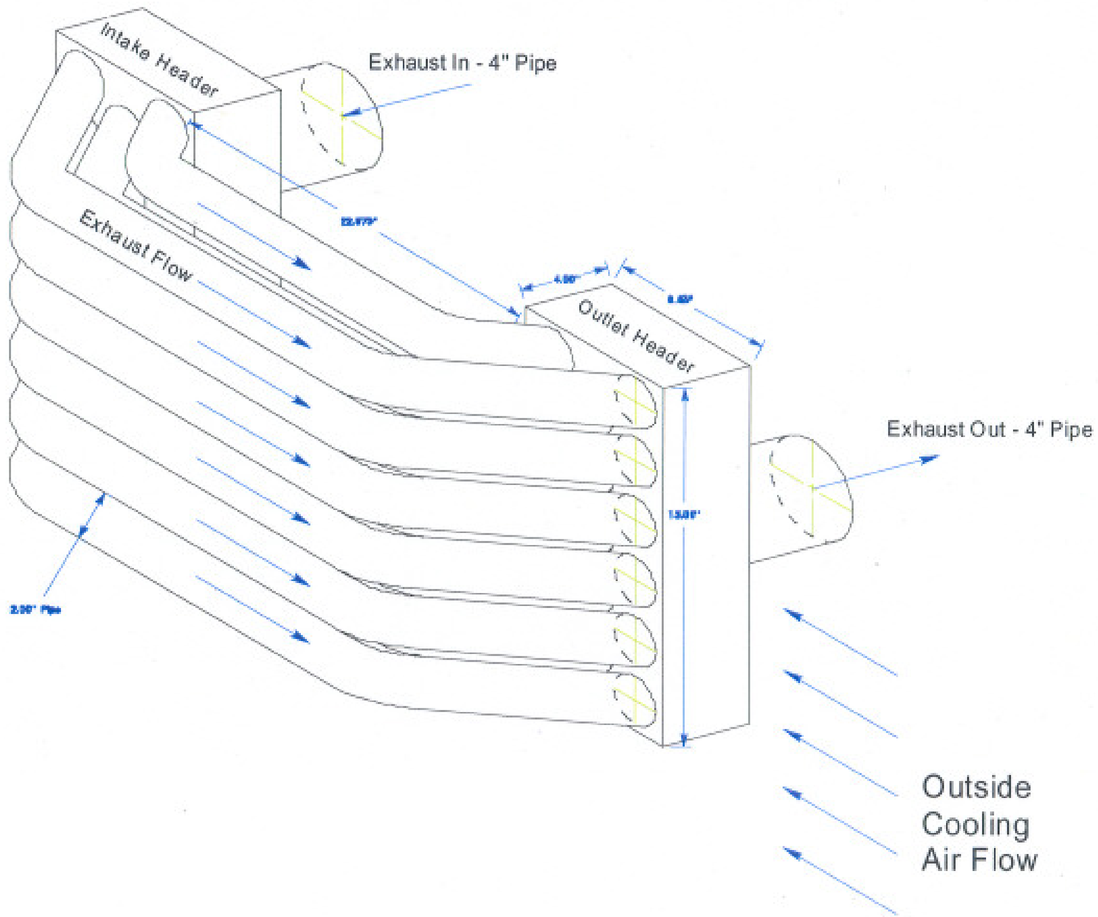


**Photo of 2 converters built for the CAT 3126 engine**

**Photo of 4 converters built for CAT 3406 engine**



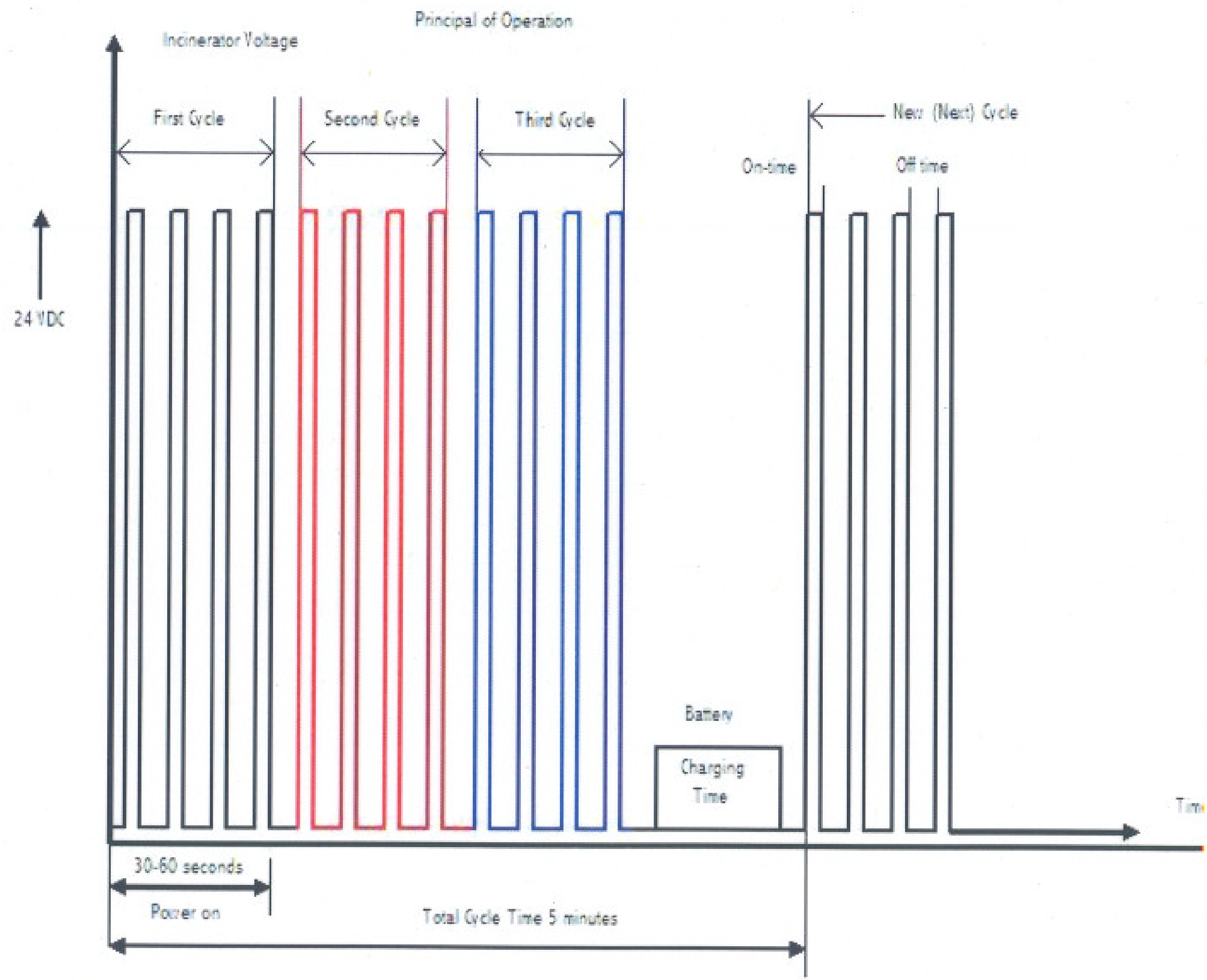

# Exhaust Heat Exchanger

Exhaust / Ambient Air
Maximum Exhaust Outlet Temperature 500° F
Under all Driving Conditions

CONVERTER TECHNOLOGY INC.
*Advanced Technologies for Particulate and Air Pollution Control*

| | | | |
|---|---|---|---|
| Drawing Name: Exhaust Heat Exchanger | | | |
| Drawing Part No. | Rev: A | Scale: 1 : 6 | Drawn: T.Prendel |
| | Date: 02-09-07 | | Approved: R.Kammel |

**Photo of Heat Exchanger for CAT 3126 engine**




**DC Sequencer-Chopper Principle of Operation**

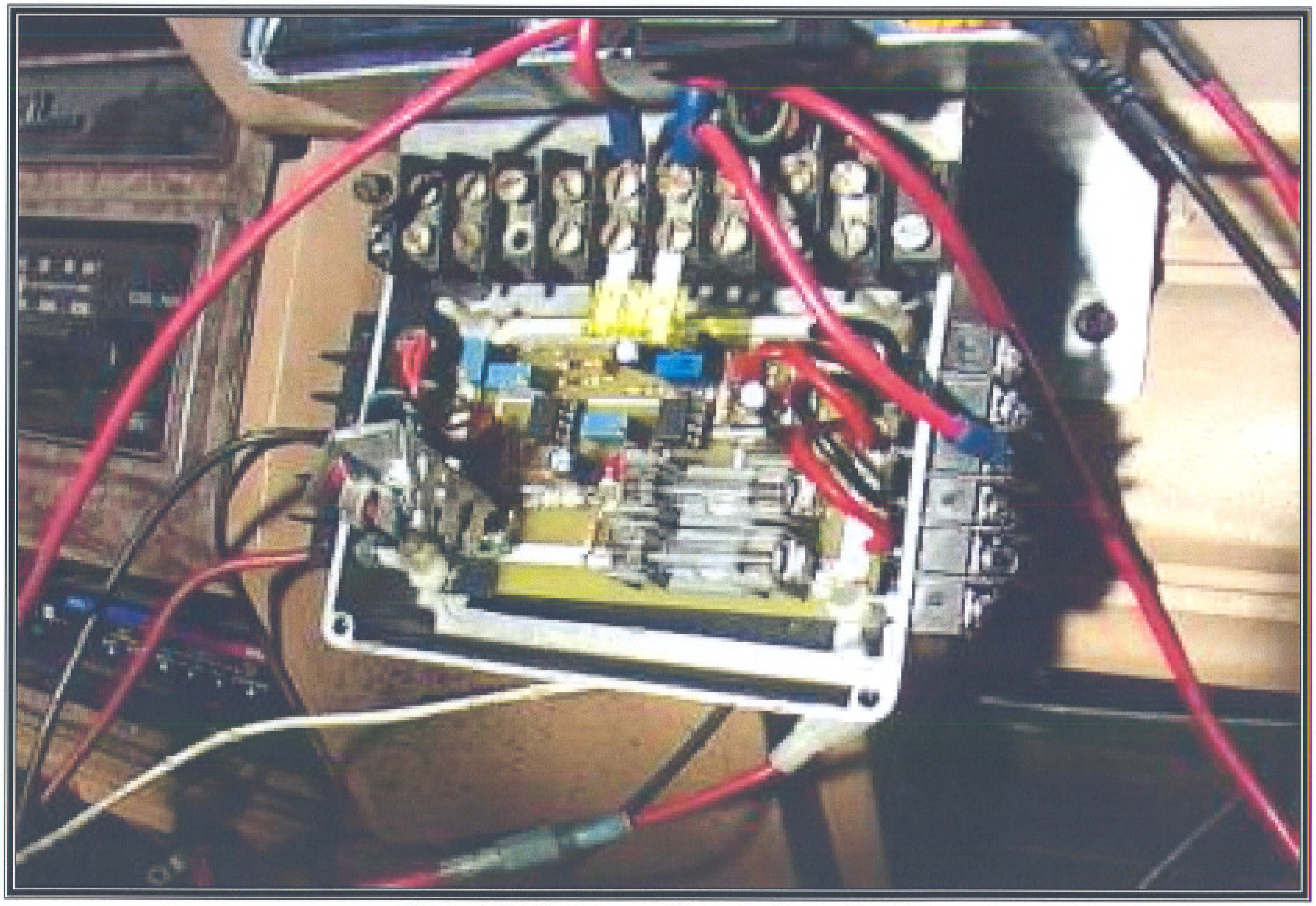


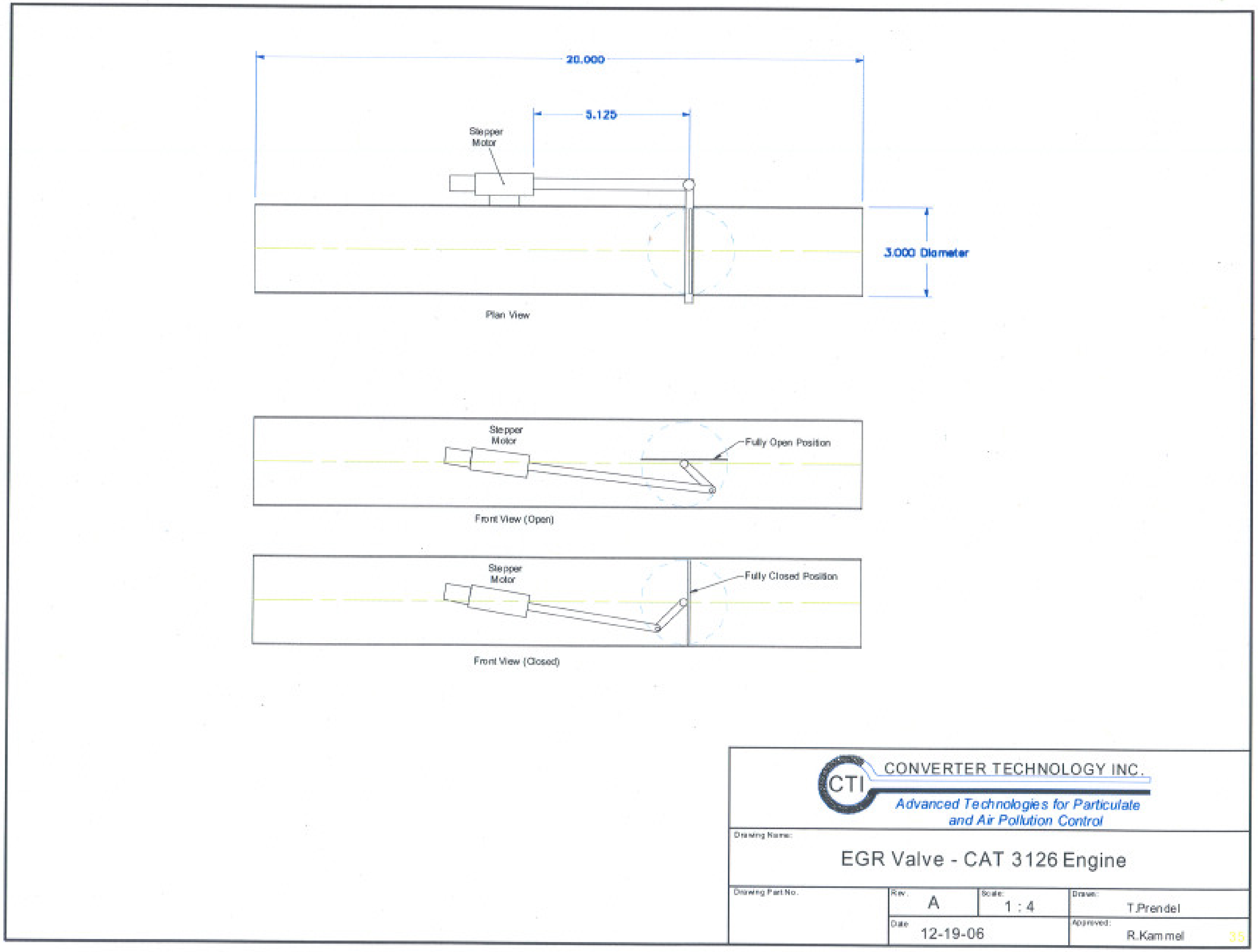
Photo of DC Sequencer-Chopper Power Supply

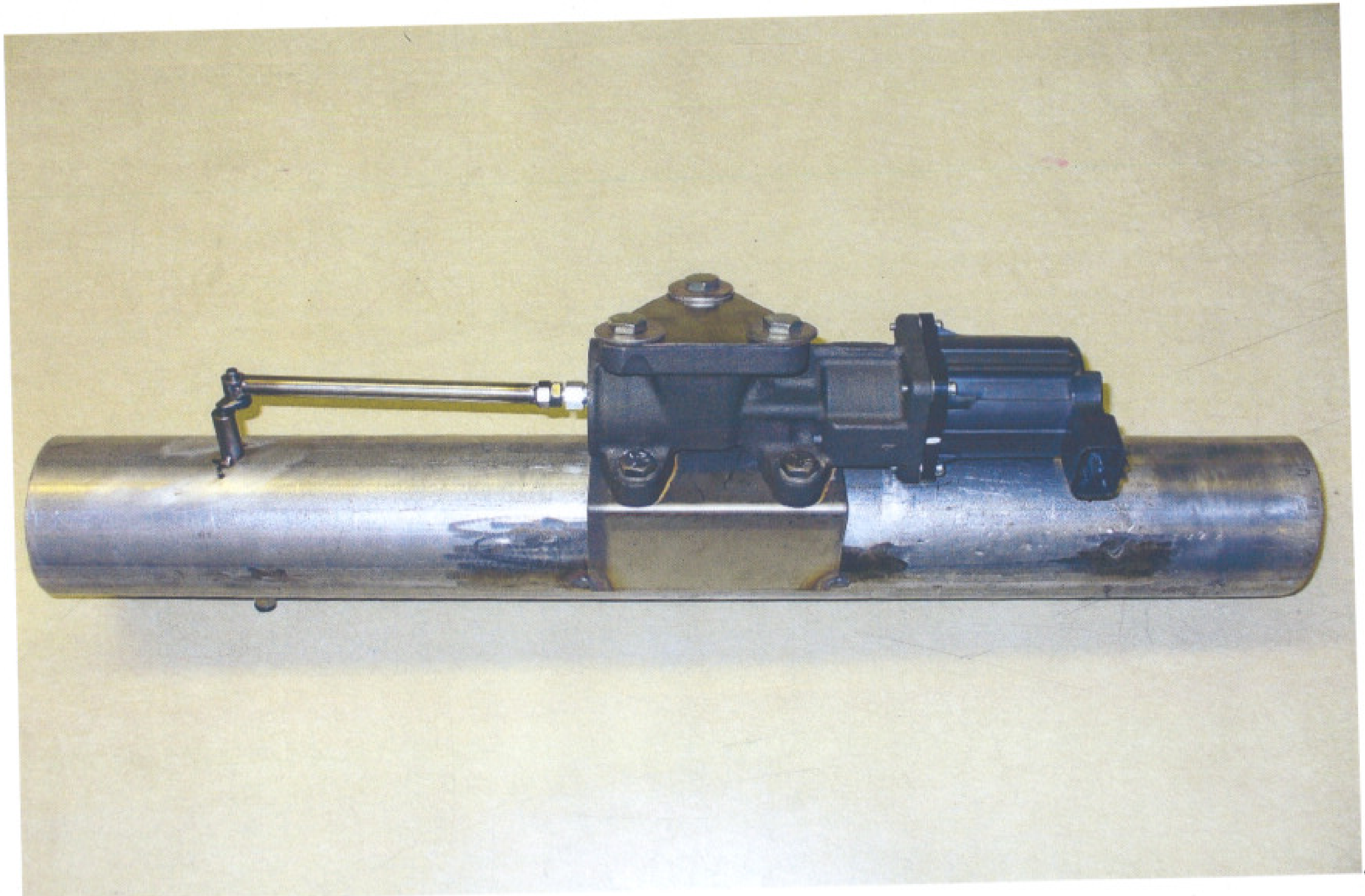
## 2. EGR System

EGR is a low-pressure exhaust gas recirculation. The system has a few advantages over the commonly popular high pressure exhaust gas recirculation used in most OEM applications.

CTI has designed an EGR system for the CAT 3406 engine, and constructed 2 units. The design had been upgraded for the CAT3126 engine and constructed 2 units.

The EGR control logic diagram is shown on page 12. Page 13 and 14 show mechanical design and a photo of an EGR valve.


20.000
5.125
Stepper Motor
3.000 Diameter
Plan View
Stepper Motor
Fully Open Position
Front View (Open)
Stepper Motor
Fully Closed Position
Front View (Closed)
CTI
CONVERTER TECHNOLOGY INC.
Advanced Technologies for Particulate and Air Pollution Control
Drawing Name:
EGR Valve - CAT 3126 Engine
Drawing Part No.
Rev.
A
Scale:
1 : 4
Drawn:
T.Prendel
Date
12-19-06
Approved:
R.Kammel



**Low-Pressure EGR Valve for the CAT 3126 diesel engine**

## Low-Pressure EGR Valve for CAT3406 engine

Digital photo of the low-pressure EGR valve, primary components are the housing, the valve and the Stepper motor. This valve is CTI's design and can deliver EGR ratios up to 90% if needed. The valve is being calibrated for EGR ratio vs. valve position vs. Stepper motor steps. Each step moves the valve 0.001", providing very accurate valve position to ensure precise EGR injection for each engine operation condition.

## 3. Mobile Data Acquisition System

The Mobile Data Acquisition System developed by CTI is dedicated for the measurement of PM, NOx, HC and CO among other gasses. The system is capable of interfacing with the CAT 3126 engine and downloading various engine operating parameters such as RPM, engine load, vehicle speed, among other data. TECT has designed and built 3 mobile data acquisition systems with software. The initial software has been developed and installed. Further debugging of the software is taking place now.

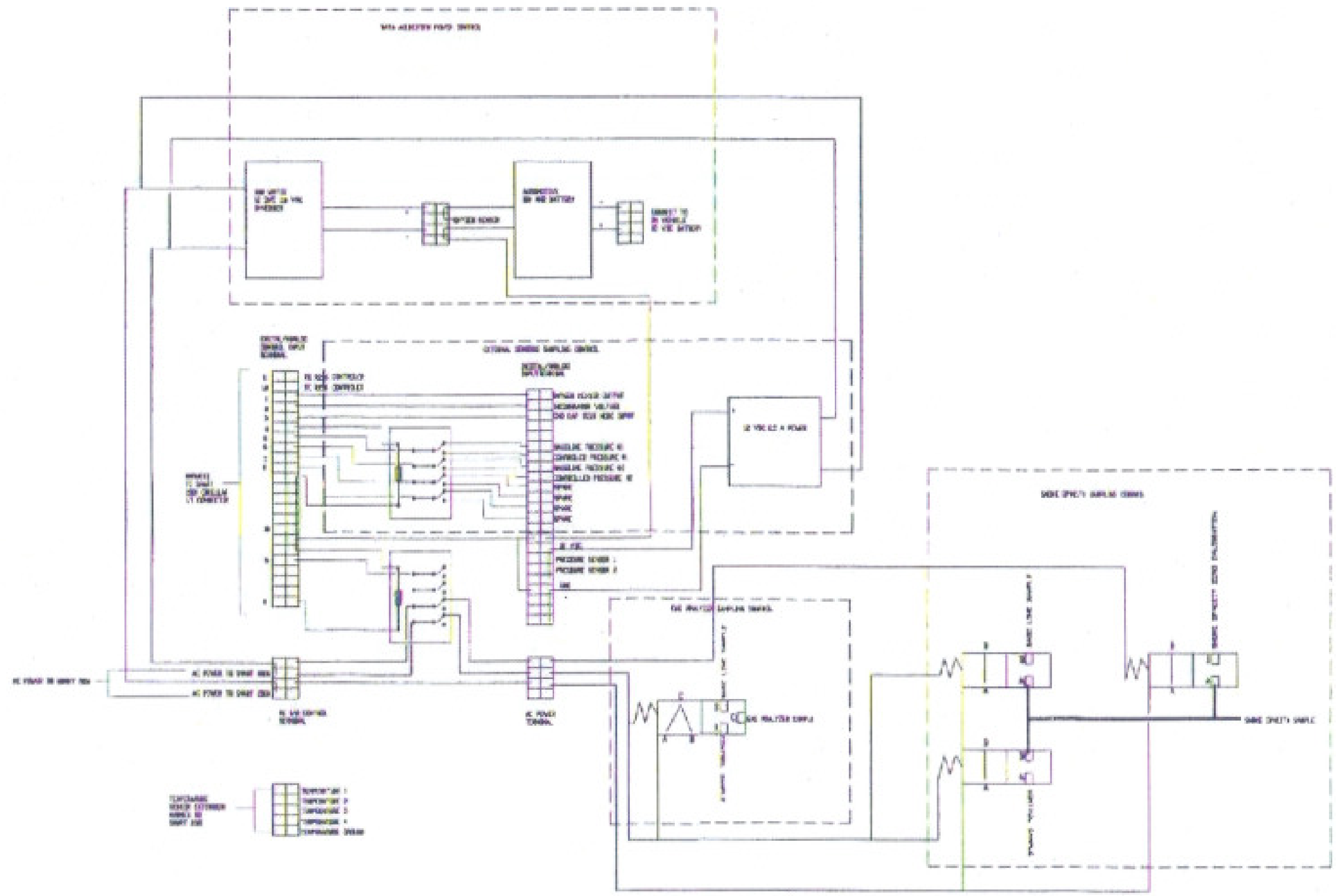
To convert emission data in PPM into mass emissions (grams/second), CTI designed, constructed and calibrated two Venturi meters, 3- 2" and 5 Venturi meters 5-3". The 3" Venturi is suitable for the CAT 3126 engine, while the 5" Venturi is suitable for the CAT 3406. Data calibration regarding the 3" Venturi meter is presented.

The Mobile Data Acquisition System monitors and computes parameters every 2 seconds during operation. Custom made software can generate specialty reports on the road with particular emphasis on specific emissions. In addition, the system monitors EGR operation and performance, exhaust temperatures at various locations, pressure drops, etc.

A schematic diagram for the mobile data acquisition input signals is presented. Also, electronic block diagram shows the major components. A photo of two of the three data acquisitions is shown. The data acquisition system is owned by Truck Emission Control Technology and an outside financing company. Their units are available for lease to CTI for the data collection and processing on the road.

### 5. 3" Venturi Meter

This Venturi meter was designed and constructed by CTI. It is custom-made to meet our specific needs and is capable of withstanding shock loading on the road. Attached is the calibration chart and photo.



**Mobile Data Acquisition System Block Diagram**

**Photo of three Mobile Data Acquisition Systems.**

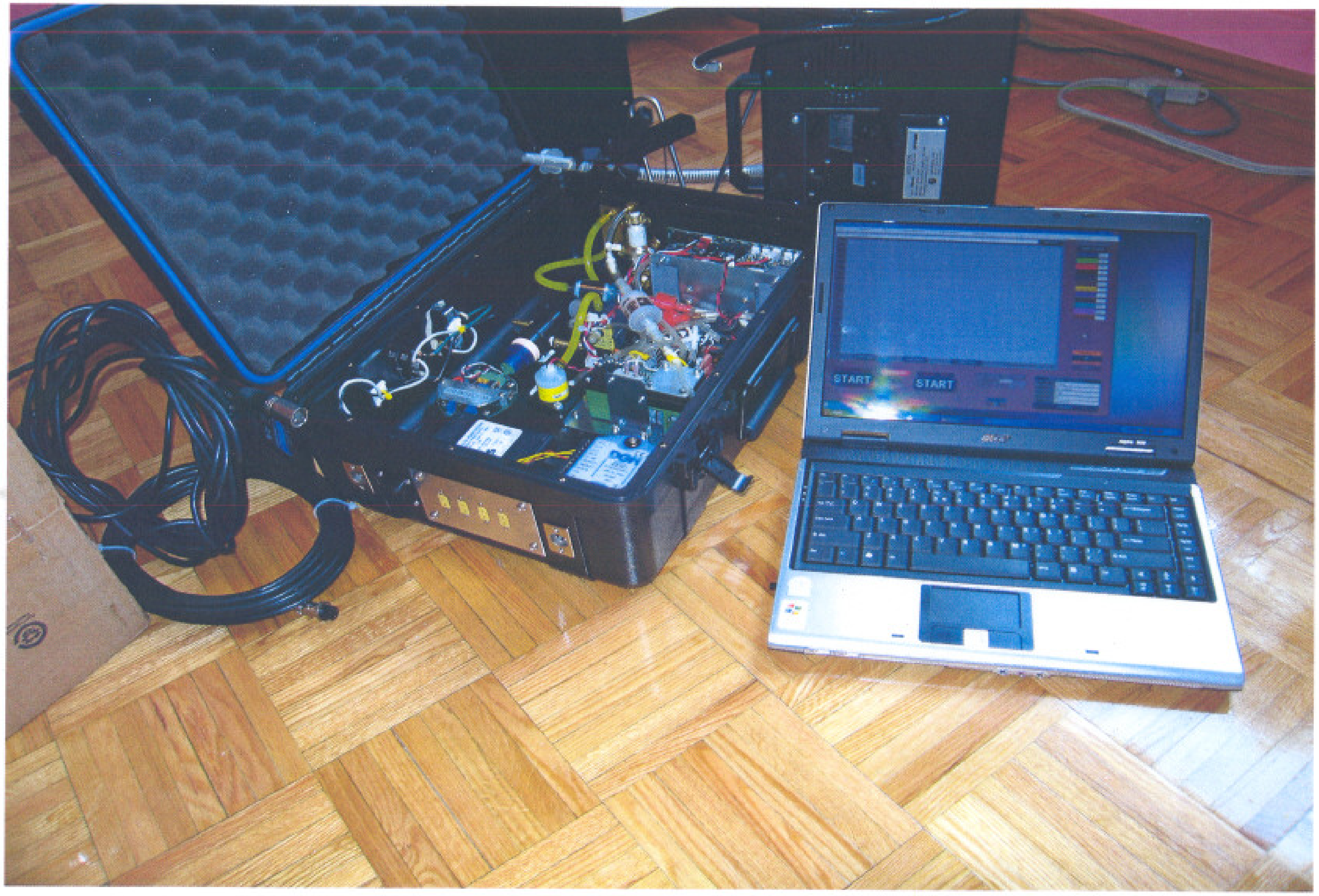
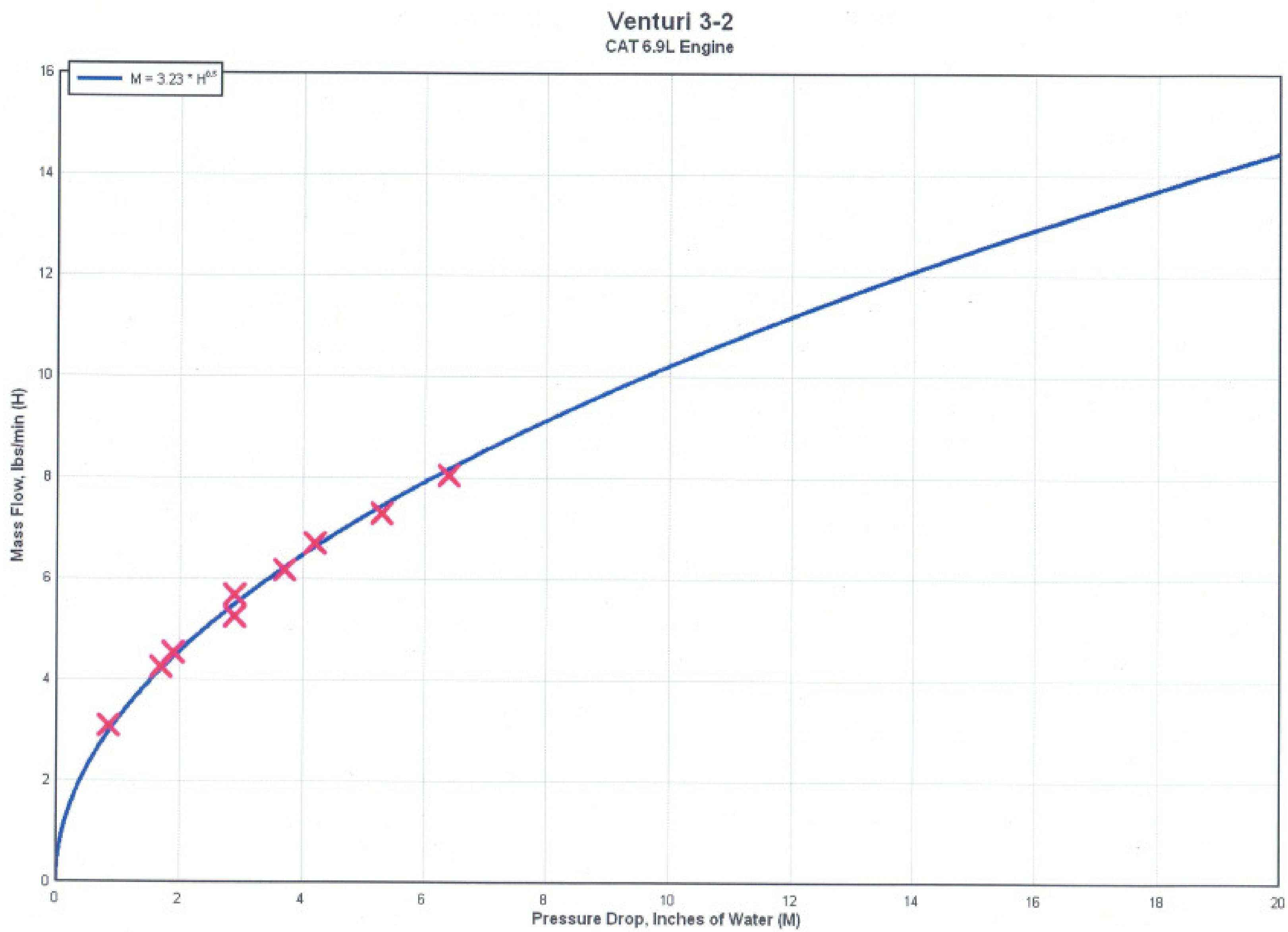



**Photo showing complete Mobile Data Acquisition System of one unit with software display on the laptop computer.**

**Photo of Venturi Meter**



Venturi 3-2
CAT 6.9L Engine
M = 3.23 * H^0.5
Mass Flow, lbs/min (H)
Pressure Drop, Inches of Water (M)
0
2
4
6
8
10
12
14
16
18
20