Technical Report

Diesel Hydrocarbon Measurement - Series Filter Test

by

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NOTICE

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Office of Air and Waste Management
U.S. Environmental Protection Agency

Filters were loaded by driving various cycles (FTP, LA-4 and 50 mph SS) and collecting the particulate material. Wet filters are those on which particulate was collected and no drying steps were taken. Dry filters were prepared by baking wet filters at 380°F for one hour.

Two different particulate collection systems were used for loading the second filter. One was an isokinetic particulate collection device. designed to collect a large volume of diesel exhaust, and is called a high volume sampler. The other was the existing Scott filter holder and heated probe set-up which is used to sample exhaust from the dilution tunnel.

Results

The graphs attached are reduced reproductions of representative heated FID traces taken during this testing. Presented on these graphs are the level of hydrocarbon in the exhaust passing straight to the heated FID (dashed line) and the level of hydrocarbon in the exhaust after passing through the "loaded" filter (solid line). Both are graphed as a function of time.

The data displayed in Figures 2, 3, and 4 were collected using wet (unbaked) filters in the second filter holder while Figures 5, 6, and 7 used dry filters in the second holder. The dry filters removed somewhat more hydrocarbon than wet filters, as might be expected due to a lower level of saturation. No meaningful differences are evident due to the other variables involved such as driving cycle, probe temperature, and the holder used to preload the second filter.

From these graphs the following additional observations can be made:

1. The level of hydrocarbon concentration remaining in the exhaust sample after it passed through the loaded filter (solid line) is definitely lower than the concentration level in the once filtered exhaust sample (dashed line).

2. Hydrocarbons in the exhaust were removed by all combinations of hot and cold probe, and wet and dry filters.

3. In most cases the particulate indicated a trend toward saturation. However, the particulate remained unsaturated after seven to ten minutes of exposure to the hydrocarbons (i.e., the filtered HC concentration never reached the once filtered level of HC). This is probably due to insufficient time for the gaseous hydrocarbon to saturate the carbon on the filter at the low concentrations and flows involved.

These observations form the basis for concluding that carbonaceous diesel particulate is capable of removing hydrocarbons from a diluted exhaust sample, and that some or all of the hydrocarbon material exists in a gaseous form in the tunnel as well as the atmosphere.

Summary

The intent of the current light-duty diesel hydrocarbon certification test procedure is to measure total hydrocarbon emissions. Arguments have been put forth that this intent may not be correct for diesel hydrocarbon measurements because some of the heavier hydrocarbons may appear in the atmosphere as diesel particulate and may be non-reactive in the atmosphere. Testing has been conducted to determine whether or not the carbonaceous particulate material collected on diesel exhaust filters absorbs hydrocarbon material at ambient ("cold") temperatures. The preliminary results of this testing indicate that the carbonaceous diesel particulate is capable of removing hydrocarbon from a diluted exhaust stream sample. The implication of this testing is that some or all of the hydrocarbon material collected on an unheated filter may exist in the gaseous rather than the aerosol state in the tunnel as well as in the atmosphere.

Discussion

The current test procedure specifies that light-duty diesel hydrocarbons are to be measured at a temperature range of 300° to 390°F by the heated FID system. However, some hydrocarbons measured by this system may not contribute to the formation of atmospheric photochemical oxidant (i.e. may be non-reactive). This statement is based on the presumption that the higher molecular weight hydrocarbons in diesel exhaust would be particulate material if they were not heated to the temperatures specified. Therefore, one of the basic questions that must be answered is whether or not the carbonaceous material collected on an exhaust filter has the capability of absorbing hydrocarbon material in a diluted (i.e., "cold") exhaust stream sample.

Testing has been conducted with the EPA Mercedes 300 D diesel automobile in order to help answer this basic question. The results of this testing indicate that the particulate material collected on a diesel exhaust filter does absorb hydrocarbon material. This in turn implies that at least part or possibly all of the hydrocarbon material in the dilution tunnel, and hence in the atmosphere as well, is in a gaseous state rather than an aerosol state.

Test Procedure

Two filters were installed in series immediately downstream of the dilution tunnel sample probe. The sample lines were configured so that the second filter, which was loaded with diesel particulate from a previous run, could be quickly switched in and out of the diluted sample stream. (See Figure 1 attached.) Response of the hydrocarbon to the loaded filter was measured by direct hot FID reading while the vehicle was operated in a 50 mph steady state cruise mode. Two series of tests were conducted; one with the first filter and probe both operated hot (380°F) and the other with the first filter and probe cold ($\sim$ 100°F).

It should be noted that the exhaust sample was passed through a clean filter in order to establish that it was in fact the particulate, and not the filter that was removing hydrocarbon from the exhaust sample. The clean filtered exhaust gave the same heated FID response as the unfiltered exhaust. Hence the conclusion was that the carbon particulate was removing the hydrocarbon from the diluted exhaust.

It should also be noted that the base or once filtered levels are not constant from test to test. This is considered to be due primarily to the background hydrocarbon level varying from test to test. However, this does not affect the conclusion of this testing because they are based on differences between the once filtered hydrocarbon level and the twice filtered hydrocarbon level.

FIGURE 1

SERIES FILTER TEST SET-UP

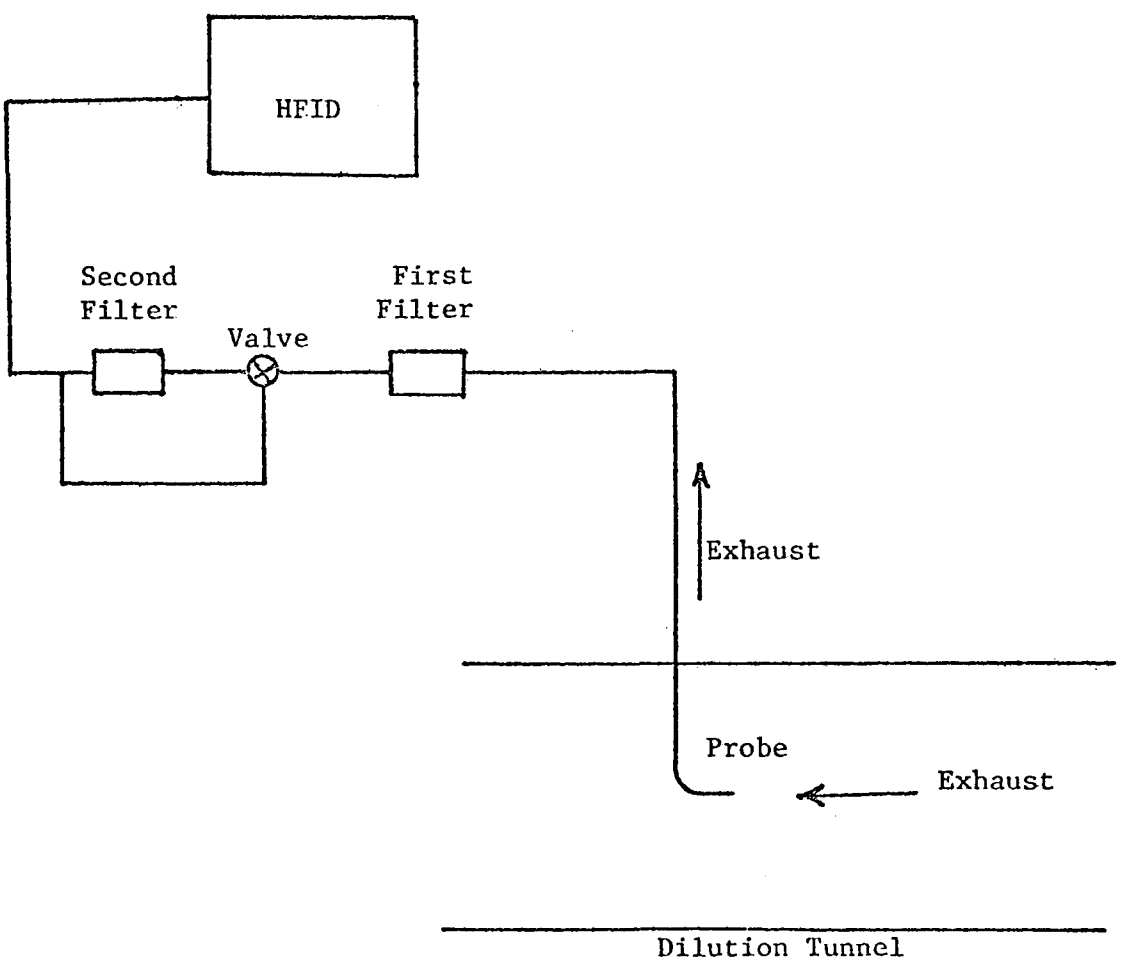

FIGURE 2

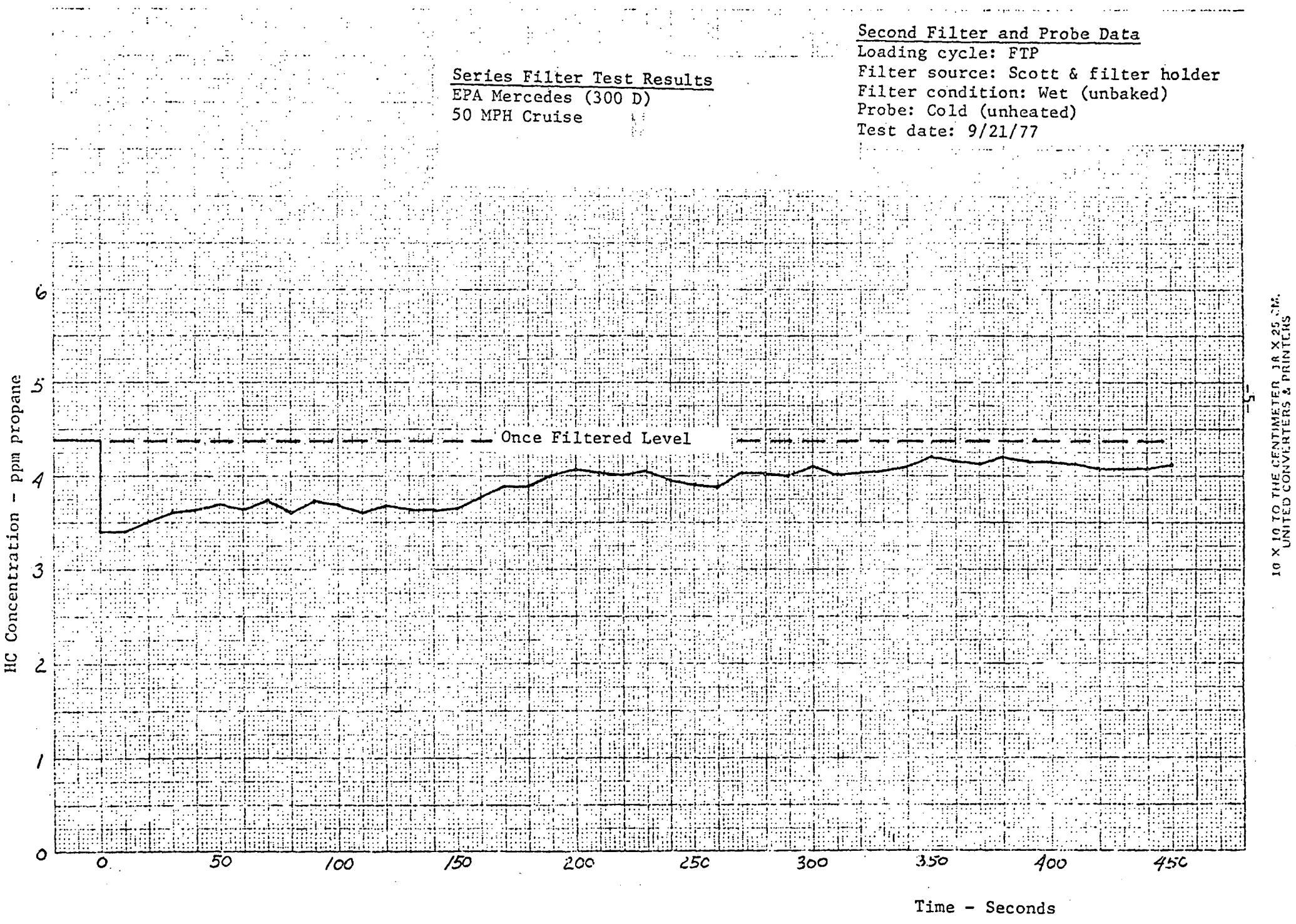
Series Filter Test Results
EPA Mercedes (300 D)
50 MPH Cruise
Second Filter and Probe Data
Loading cycle: FTP
Filter source: Scott & filter holder
Filter condition: Wet (unbaked)
Probe: Cold (unheated)
Test date: 9/21/77
Once Filtered Level
HC Concentration - ppm propane
Time - Seconds
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
400
450
10 X 10 TO THE CENTIMETER 18 X 25 C.M.
UNITED CONVERTERS & PRINTERS

FIGURE 3

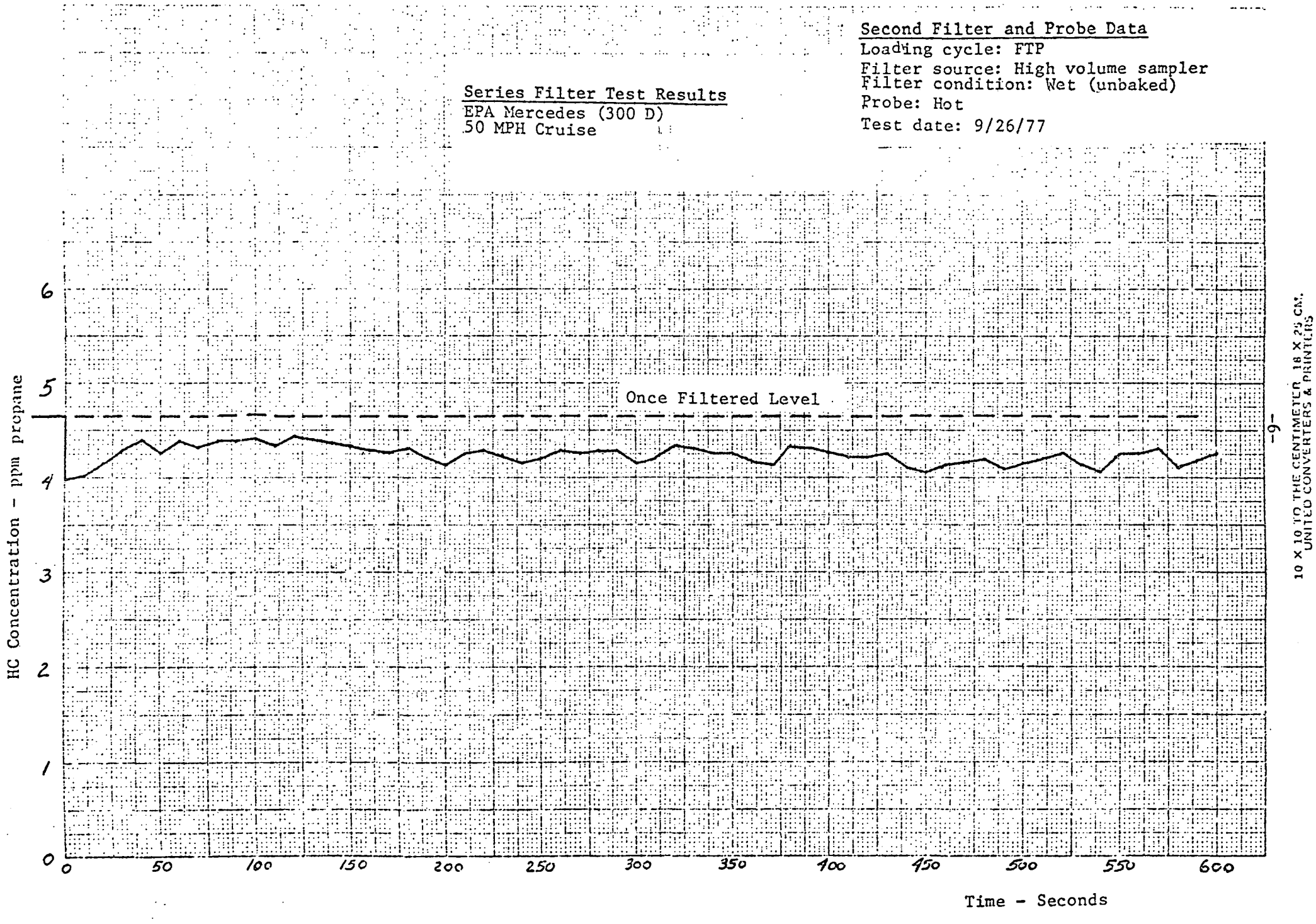
Series Filter Test Results
EPA Mercedes (300 D)
50 MPH Cruise
Second Filter and Probe Data
Loading cycle: FTP
Filter source: High volume sampler
Filter condition: Wet (unbaked)
Probe: Hot
Test date: 9/26/77
Once Filtered Level
HC Concentration - ppm propane
Time - Seconds
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
400
450
500
550
600
-9-
10 X 10 TO THE CENTIMETER, 18 X 25 CM.
UNITED CONVERTERS & PRINTERS

FIGURE 4

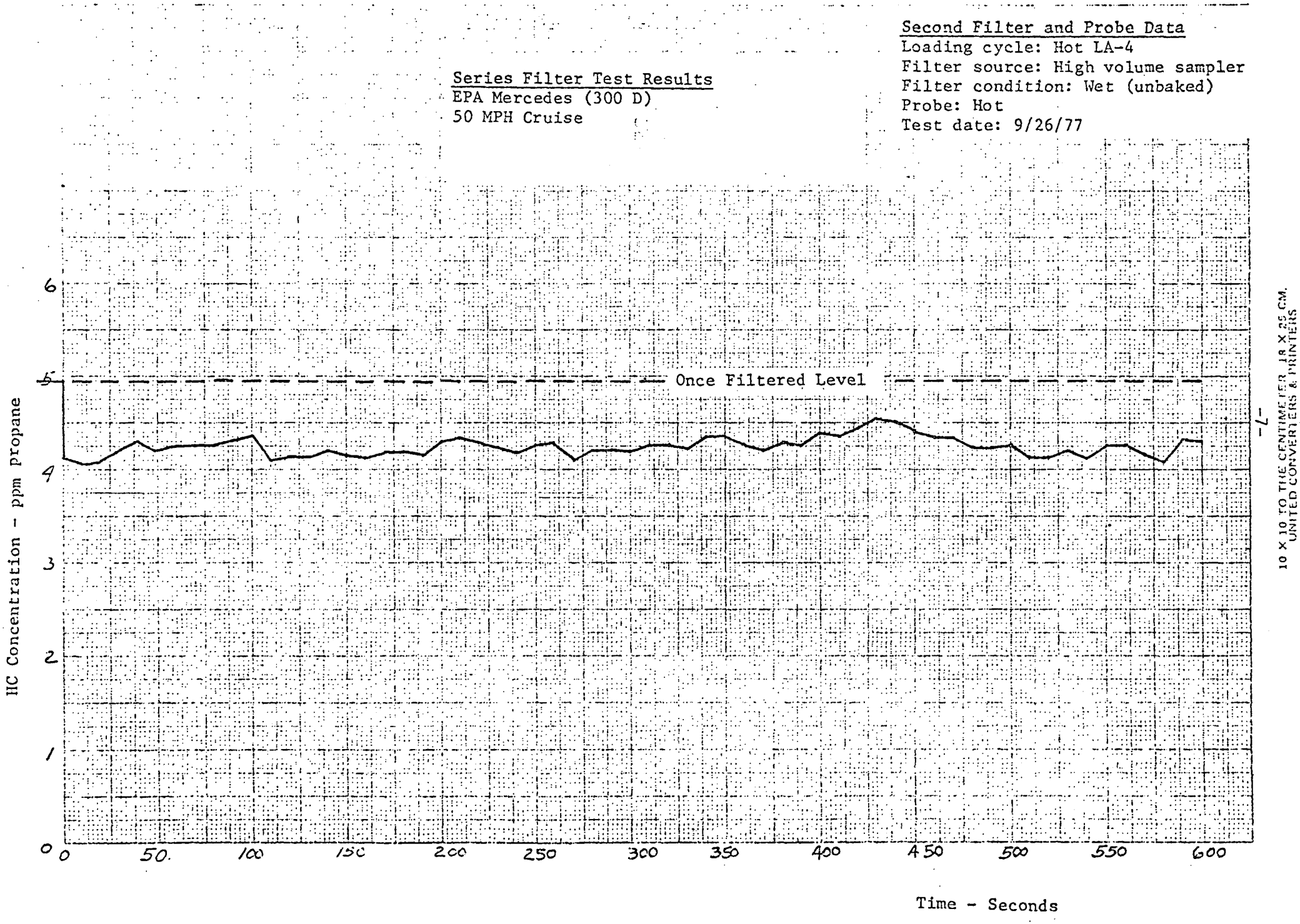
Series Filter Test Results
EPA Mercedes (300 D)
50 MPH Cruise
Second Filter and Probe Data
Loading cycle: Hot LA-4
Filter source: High volume sampler
Filter condition: Wet (unbaked)
Probe: Hot
Test date: 9/26/77
Once Filtered Level
HC Concentration - ppm propane
Time - Seconds
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
400
450
500
550
600
10 X 10 TO THE CENTIMETER 18 X 25 CM.
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FIGURE 5

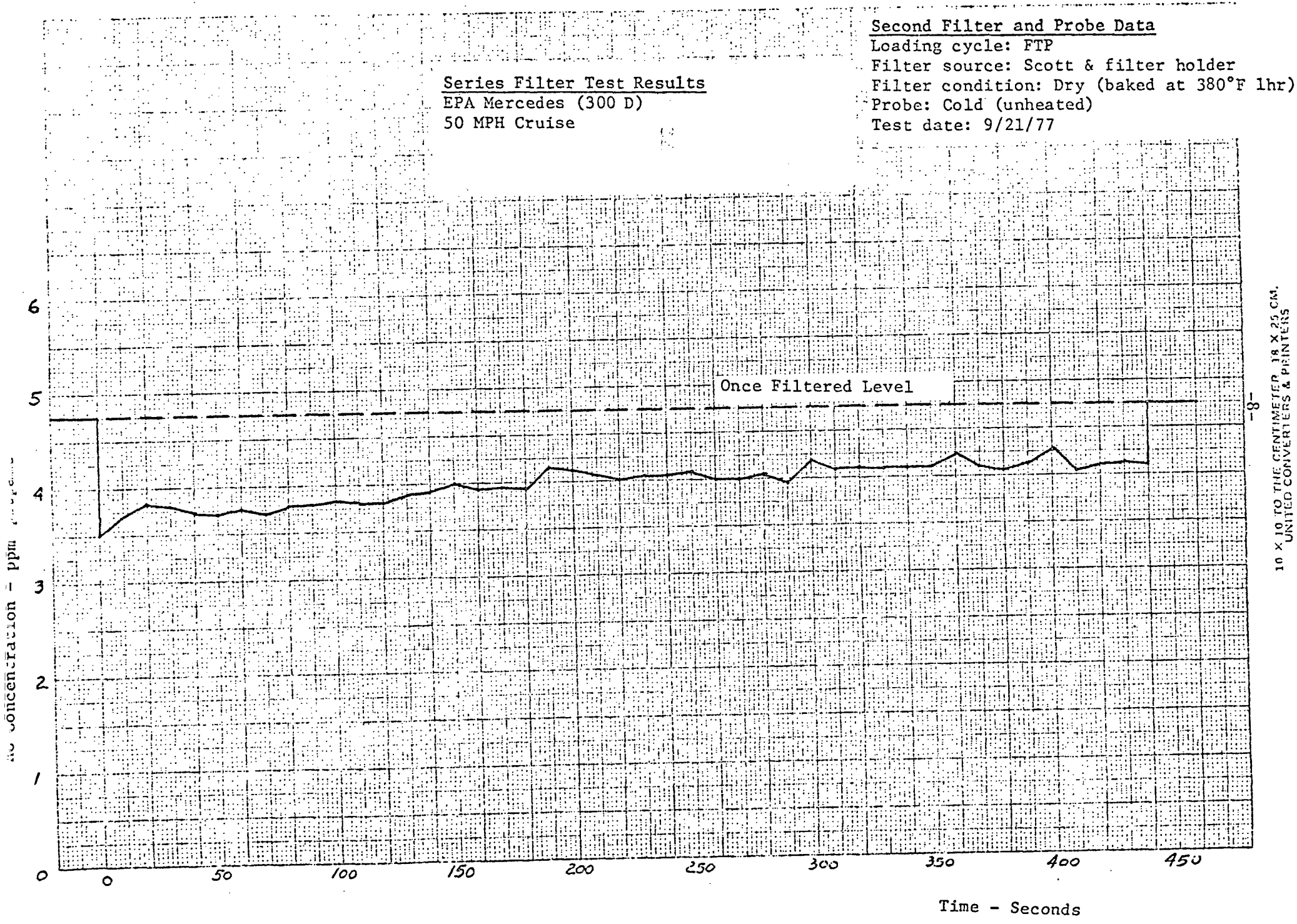
Series Filter Test Results
EPA Mercedes (300 D)
50 MPH Cruise
Second Filter and Probe Data
Loading cycle: FTP
Filter source: Scott & filter holder
Filter condition: Dry (baked at 380°F 1hr)
Probe: Cold (unheated)
Test date: 9/21/77
Once Filtered Level
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
400
450
Time - Seconds
-8-
10 X 10 TO THE CENTIMETER, 18 X 25 CM.
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FIGURE 6

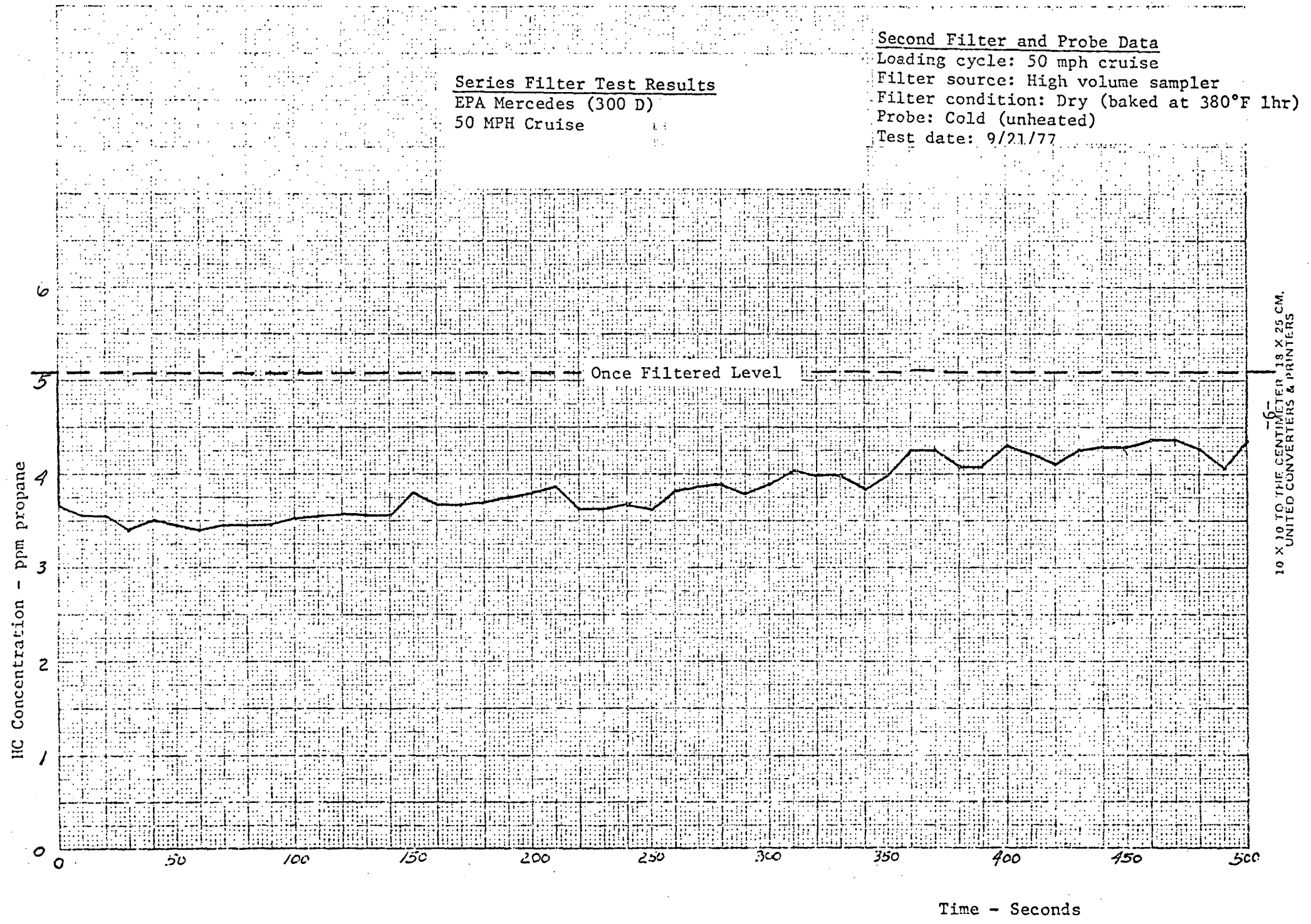
Series Filter Test Results
EPA Mercedes (300 D)
50 MPH Cruise
Second Filter and Probe Data
Loading cycle: 50 mph cruise
Filter source: High volume sampler
Filter condition: Dry (baked at 380°F 1hr)
Probe: Cold (unheated)
Test date: 9/21/77
Once Filtered Level
HC Concentration - ppm propane
Time - Seconds
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
400
450
500
10 X 10 TO THE CENTIMETER 18 X 25 CM.
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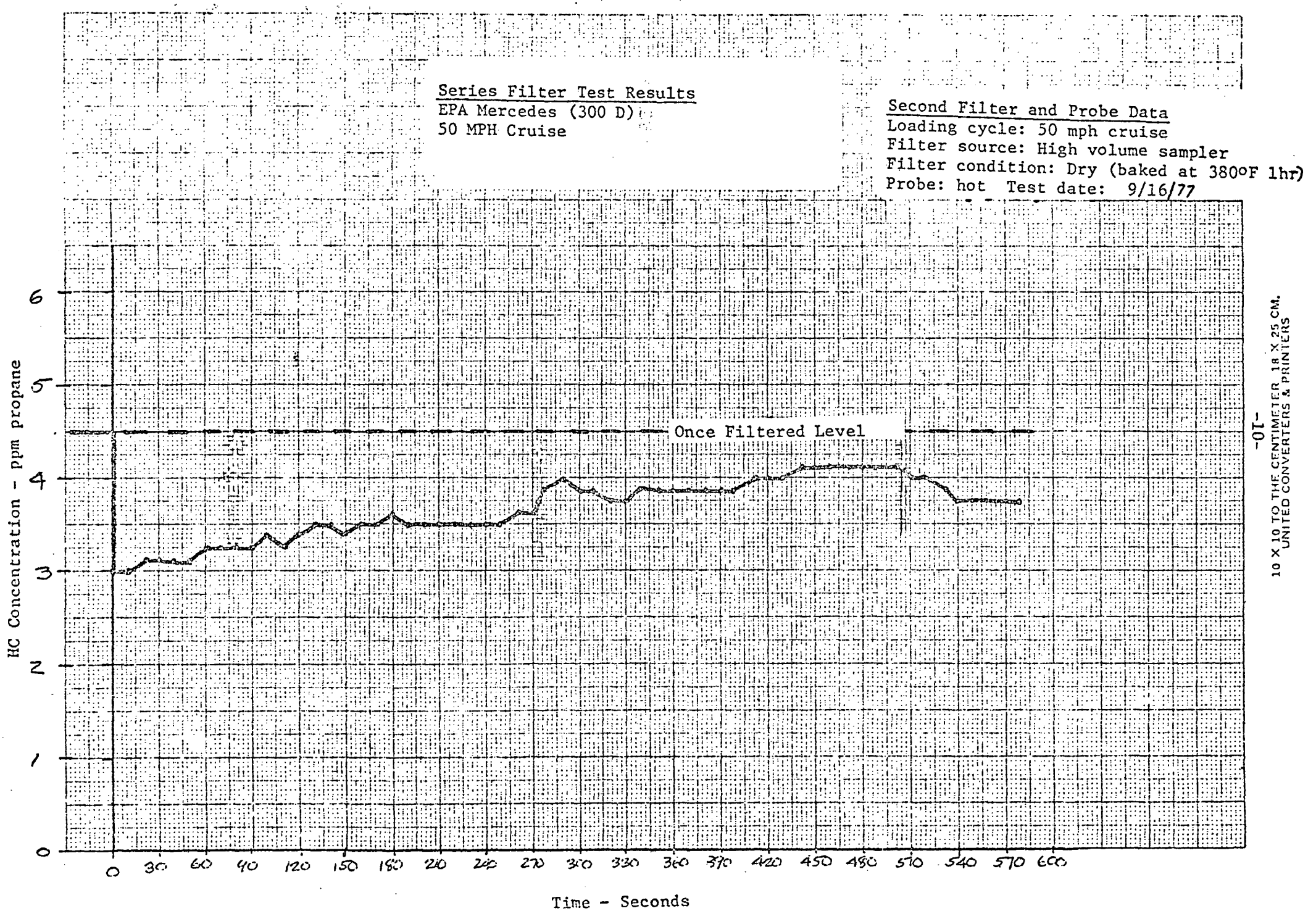
FIGURE 7


Series Filter Test Results
EPA Mercedes (300 D)
50 MPH Cruise
Second Filter and Probe Data
Loading cycle: 50 mph cruise
Filter source: High volume sampler
Filter condition: Dry (baked at 380°F 1hr)
Probe: hot Test date: 9/16/77
Once Filtered Level
HC Concentration - ppm propane
0
1
2
3
4
5
6
0
30
60
90
120
150
180
210
240
270
300
330
360
390
420
450
480
510
540
570
600
Time - Seconds
-10-
10 X 10 TO THE CENTIMETER 18 X 25 CM.
UNITED CONVERTERS & PRINTERS