Background Report Reference

AP-42 Section Number: 12.20

Background Chapter: 4

Reference Number: 48

Title: Chevrolet Livonia Bumper Plant No. 4 Heil Evaporator

Chevrolet Central Office of Environmental Engineering Department

September 1979

ELECTROPLATING
REF. 4-48

CHEVROLET-LIVONIA-BUMPER PLANT
No. 4 Heil Evaporator
Tested by the Chevrolet Central Office of Environmental Engineering Department
Tested September 24, 1979

UNACCEPTABLE

This report is unacceptable for the following reasons: First, the necessary field data sheets to determine the correctness of the values in the report are not available. Second, all points at the inlet were not sampled (see further comments). Third, this test effort was made to gather data to correct emission problems, not to sample the control device in normal operating conditions. Fourth, there appears to be a large discrepancy between the volumetric flow rates found by the EMB test and this test.

This facility has been tested by EMB, but only at the inlet location. EMB testing performed in the normal production mode. The test done by the Chevrolet environmental group was done in an effort to maximize collection efficiency, and two parameters of the evaporator operation were monitored and/or altered to simulate conditions which could exist within the system, possibly causing an upset in the collection efficiency of the unit. Thus data generated on this test may not be typical of normal operating conditions.

The Chevrolet test sampled the inlet location at only two ports and chose sampling points of average velocity. While the points may be of average velocity, it does not necessarily follow that the distribution of chromium in the duct is uniform. Furthermore, the outlet volumetric flow rate was also used to determine emissions at the inlet. If leakage occurs between the inlet and outlet, the mass emission rates at the inlet will be biased high and the control device efficiency will also be biased high. When comparing the inlet volumetric flow rates, the EMB flows are about 28 percent lower than company flows.

In checking the outlet data, there are no field data sheets or other associated data sheets that were generated at the site; only typewritten data are provided. It appears that the calculations were done based on 70 degrees as standard temperature rather than 68.

It appears that the outlet data might be usable if the data sheets from the test could be provided. One item to consider, however, is whether or not this test represents process conditions that could be used in determining chromium emission standards.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

122 [illegible]

MEMORANDUM

SUBJECT: Acceptability of Test Reports for Use as a Data Base for Chromium NESHAP

FROM: Frank R. Clay FRC
Field Testing Section, EMB, TSD (MD-14)

TO: Andrew Smith
Industrial Studies Branch, ESD (MD-13)

I have reviewed the test reports that are attached. Some of the reports are acceptable while others are not. The reports are listed below, and unacceptable reports are described in detail as to why they should not be used. I will continue to review the other reports that you have given to me and will send another group of reports as soon as the review has been completed.

TRUESDAIL LABORATORIES, INC.
Test of Dames and Moore
222 E. Annapamu
Santa Barbara, California 93101

UNACCEPTABLE

In reviewing the data, the outlet location gives the moisture content at the outlet as 2.50 percent. At 66°F, saturation moisture content at the absolute stack pressure and this temperature is 2.16 percent.

There are no meter box calibration sheets present, and consequently, no meter box correction factor.

There are no delta p values on the field data sheets to determine the point velocities during sampling.

The nozzles do not appear to have been measured with a micrometer.

TRUESDAIL LABORATORIES, INC.
Source Test of Intermetro Industries
9393 Arrow Highway
Cucamonga, California 91730

UNACCEPTABLE

Page 1 of the report describes cyclonic flow that was found at the outlet. The page also mentions that sampling was done at the angle of maximum velocity head which was 45 degrees. When testing for cyclonic flow, the angle of maximum delta p is not the angle of flow. The angle of flow is 90 degrees from the null reading on the pitot tube which is not the same as the angle of maximum delta p. When cyclonic flow is present, the sampling time per point must also be adjusted based on the angle. If all the angles are the same, the time adjustment is not necessary, however, in this case, it is not possible to know what the true angles were.

EMBEE PLATING TEST
2136 South Hathaway
Santa Ana, California 92705

UNACCEPTABLE

This report should not be used. First, there are not enough data sheets and related forms/sheets to tell how precisely the test was performed. On System 1, the moisture content was given at 3.7 percent. Saturation moisture content at 70 degrees F is 2.47 percent Emission data based on 3.7 percent are incorrect. The text also mentions that a piece of 3/8 inch Teflon tubing was used to collect the sample. There is no mention of a nozzle so it must be assumed that the tubing is also the nozzle. To sample isokinetically, the sample size should have been around 90 cubic feet an hour. The sample volume was about half that so the sampling was not within the acceptable isokinetic limits. For System 2, the runs are not within the isokinetic limits that the Agency requires.

SOURCE EMISSION TESTING AND INDUSTRIAL VENTILATION SURVEY
OF BUILDING 210 PLATING SHOP
Long Beach Naval Shipyard
Long Beach, California
7 May - 2 June 1984

ACCEPTABLE

SOURCE EMISSION TESTING OF THE BUILDING 195 PLATING SHOP
Norfolk Naval Shipyard
Portsmouth, Virginia
11-18 March 1985

ACCEPTABLE

CHEVROLET

Livonia Plant

1979 Chevrolet Air

February 5, 1980

Wayne County Department of Health
Air Pollution Control Division
1311 East Jefferson
Detroit, Michigan 48207

Attn: Frank O'Connor, Combustion Equipment Inspector

Dear Mr. O'Connor:

We are submitting to you a copy of the test results of a series of tests made on the #4 Evaporator Chrome Recovery System in September 1979, as you requested in your letter of January 22, 1980.

As you were previously told, the tests were conducted with the intent of determining operating conditions that might result in an upset in the evaporator system and cause chrome particulate emissions to the atmosphere.

The operating guideline recommendations are being implemented.

C. J. Stahl
Plant Engineer

RPS
EPA

LCS/mlr

Attachments

Copy - E K Bangel
File (2)

CHEVROLET

Livonia Plant

February 5, 1980

Wayne County Department of Health
Air Pollution Control Division
1311 East Jefferson
Detroit, Michigan 48207

Attn: Frank O'Connor, Combustion Equipment Inspector

Dear Mr. O'Connor:

We are submitting to you a copy of the test results of a series of tests made on the #4 Evaporator Chrome Recovery System in September 1979, as you requested in your letter of January 22, 1980.

As you were previously told, the tests were conducted with the intent of determining operating conditions that might result in an upset in the evaporator system and cause chrome particulate emissions to the atmosphere.

The operating guideline recommendations are being implemented.

C. J. Stahl
Plant Engineer

PPS
EPA

LCS/mlr

Attachments

CHEVROLET Chevrolet Motor Division General Motors Corporation

Inter-Organization Letter

Lakeland 525-8201

To	E. R. Bangel	Location	Administrator - Facilities & Environmental Engineering Dept.
From	C. J. Stahl	Location	Plant Engineer
Subject	Request by Wayne County for Air Pollution Test Data	Date	January 29, 1980

The Wayne County Department of Health, Air Pollution Control Division, has requested that Chevrolet-Livonia submit a copy of the attached test data related to your office's testing of the Chevrolet-Livonia #4 Evaporator Chrome Recovery System of September 1979.

Please review the attached report and advise whether or not the entire report or only portions of it can be submitted to them.

C. J. Stahl
Plant Engineer

RPS GPA RJL

LCS/mlr

Attachments

cc: File (2)

WAYNE COUNTY
DEPARTMENT OF HEALTH

AIR POLLUTION CONTROL DIVISION

1311 EAST JEFFERSON
DETROIT, MICHIGAN 48207
Telephone: (313) 224-4650

MORTON STERLING
Director
Air Pollution Control Division

January 22, 1980

Chevrolet Livonia Plant
13000 Eckles Road
Livonia, Michigan

Attn: Mr. Larry Siersma, Environmental Engineer

Dear Mr. Siersma:

As you indicated in our recent phone conversation, I am subsequently requesting a copy of Chevrolet's report to you on the investigation made in late 1979. This study concerned the exhaust and control systems for your five chrome plating lines.

Very truly yours,

Frank O'Connor
Combustion Equipment Inspector

FO/mb

Branch: DOWNRIVER OFFICE
152 ELM STREET
WYANDOTTE, MICHIGAN 48192
Telephone: (313) 2844664

CHEVROLET Chevrolet Motor Division General Motors Corporation

Inter-Organization Letter

To Location

From Location

Subject No. 4 Evaporator Test Results Date October 26, 1979

MR. C. J. STAHL:

Enclosed please find three copies of the results from the recent testing conducted on the No. 4 Evaporator Chrome recovery system. Should any questions arise or require clarification on any of the report contents, please contact either myself or Reggie Sobczynski at 8-535-8951 or 8711.

At this point I would like to express my appreciation to both the plant engineering department and chemistry lab for all of the assistance and cooperation received during this testing program.

Timothy M. Strauss

T. M. STRAUSS
Facilities & Environmental
Engineering Department

TSM:djd
Enclosure

cc: Messrs. G. Allen
(w/attach.) E. R. Bangel
G. E. Calhoun
J. C. Cragen
L. Siersma
R. Sobczynski

APPROVED:

G. E. Calhoun

R. Sobczynski

I. OBJECTIVE

On September 24, 1979, a study was undertaken by the Chevrolet Central Office Environmental Engineering Department to evaluate the chrome collection efficiency of the No. 4 Heil evaporator and provide operating guidelines for system operation to maximize collection efficiency and minimize chrome emissions beyond the evaporator unit.

Two parameters of the evaporator operation were monitored and/or altered to simulate conditions which could exist within the system, possibly causing an upset in the collection efficiency of the unit. Tests were conducted simultaneously at the evaporator inlet and outlet, (prior to the rooftop impingement tanks) which provided chrome emission rate values and thus a measure of efficiency.

The study was initiated as a result of a reoccurrence in the complaints of automobile paint spotting by employes of Hydramation Inc., and subsequent violation notice from the Wayne County Air Pollution Control Division.

Chevrolet Motor Division - General Motors Corporation - 30001 Van Dyke Avenue - Warren, Michigan 48090

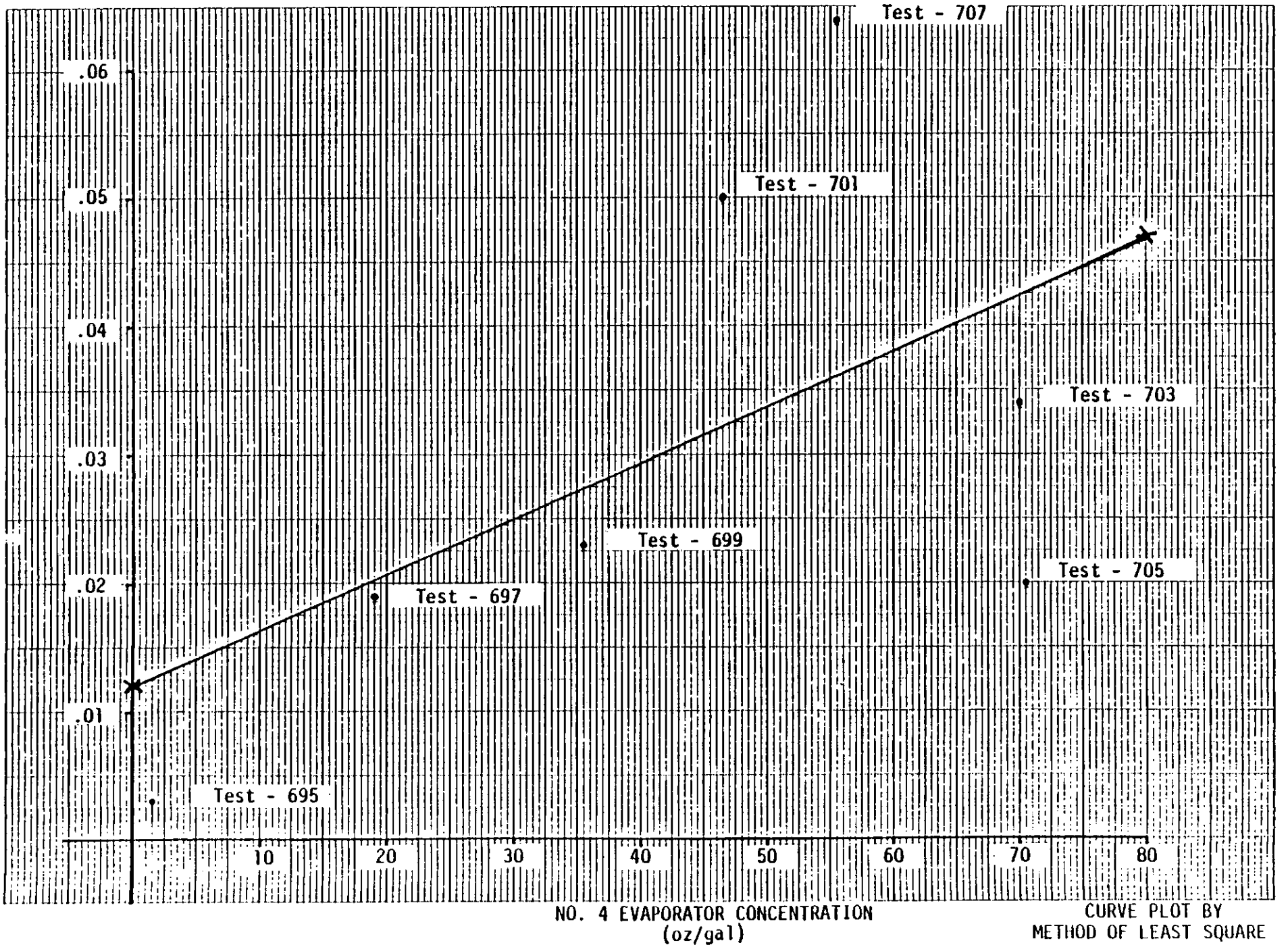
II. RESULTS

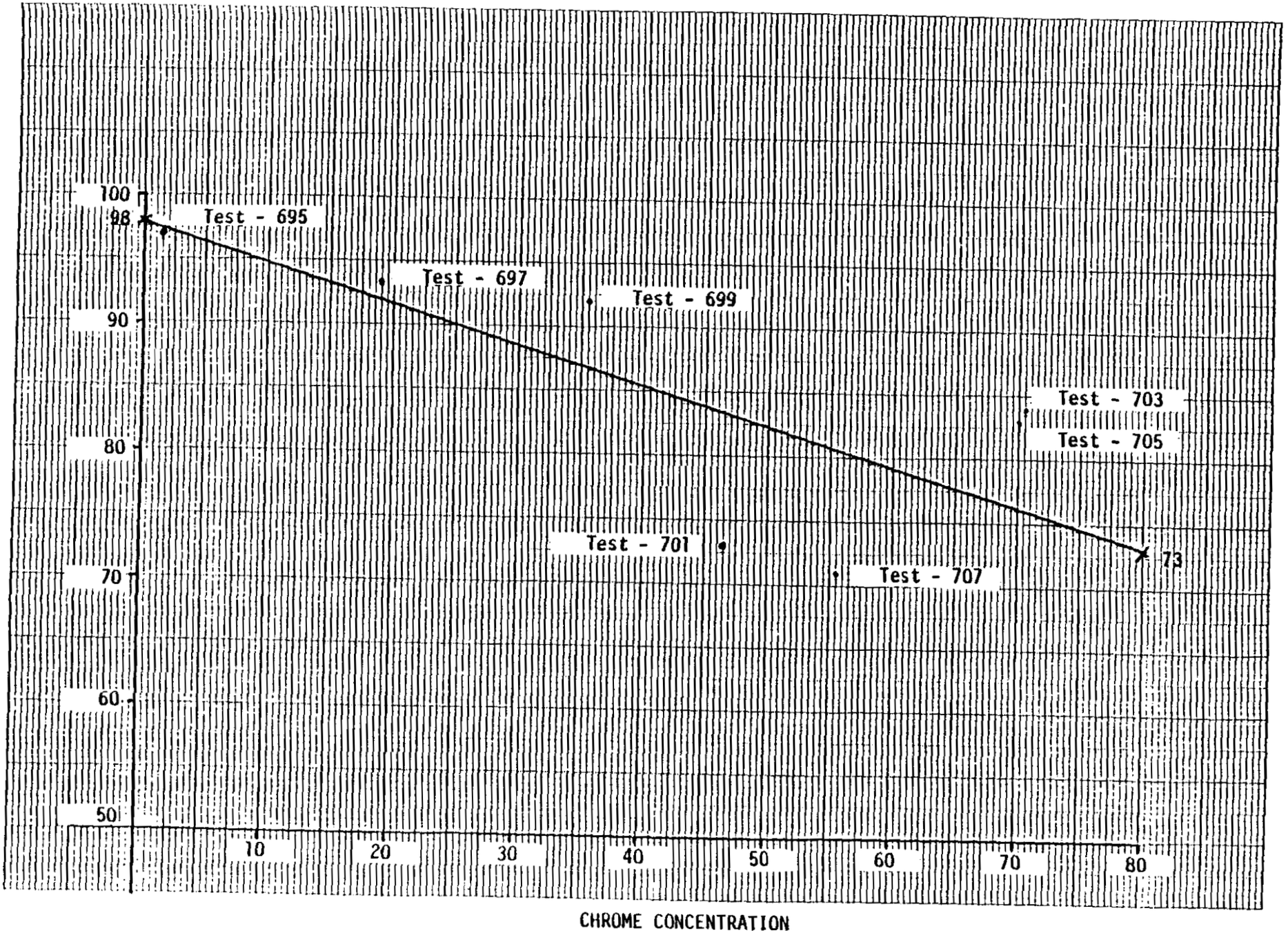
Listed below in Table I are the results from the tests conducted on the No. 4 Heil evaporator, and following Table I is a graphical presentation of Cr concentration vs. measured Cr emission rate at roof level and % chrome collection efficiency vs. chrome concentration.

Table I

Test No.	Date/Time	Cr Conc. @ Evap. (oz/gal)	Pump Feed (gpm)	Gas Flow (DSCFM)	Emission Rate (lbs/hr)	Collection Efficiency (%)
695 Outlet 696 Inlet	9/26/79 11:00-12:30 p	1.58	190	32,642	.003 .113	97.3
697 Outlet 698 Inlet	9/27/79 1:20-2:20 p	18.9	195-200	32,328	.019 .290	93.4
699 Outlet 700 Inlet	9/28/79 12:00-1:00 p	35.5	205	32,432	.023 .284	92
701 Outlet 702 Inlet	10/1/79 12:30-1:30 p	46.4	195-200	31,620	.05 .187	73.2
703 Outlet 704 Inlet	10/2/79 10:30-11:30 a	70.0	200	31,789	.034 .202	83.1
705 Outlet 706 Inlet	10/3/79 10:10-11:10 a	70.5	100	32,196	.02 .125	84
707 Outlet 708 Inlet	10/4/79 10:00-11:00 a	55.5	215	31,625	.064 .223	71.3

See Data & Test Condition Summary located in the Appendix for additional system operation during each test.


Test - 707
Test - 701
Test - 703
Test - 699
Test - 705
Test - 697
Test - 695
.06
.05
.04
.03
.02
.01
10
20
30
40
50
60
70
80
MASS EMISSION RATE @ OUTLET (Lbs/Hr)
NO. 4 EVAPORATOR CONCENTRATION
(oz/gal)
CURVE PLOT BY
METHOD OF LEAST SQUARE


100
98
90
80
70
60
50
% CHROME COLLECTION EFFICIENCY
Test - 695
Test - 697
Test - 699
Test - 703
Test - 705
Test - 701
Test - 707
73
10
20
30
40
50
60
70
80
CHROME CONCENTRATION
oz/gal

III. RECOMMENDATIONS

Through observation of the evaporator system operation during the testing program and analysis of the data displayed on the preceding pages, the following suggested recommendations to minimize the occurrence of chrome entering the rooftop impingement tank are listed below:

Operating Guidelines

1. Daily measurement on all evaporator pump extension tanks to monitor chrome concentration of the evaporator liquid and include measured values on the daily plating line operation sheets which is circulated interdepartmentally.

2. Limit chrome concentration to a nominal working value of 20 oz/gal; not to exceed a maximum value of 25 oz/gal in order to maintain collection efficiency above 90%.

Maintenance

1. To facilitate a low chrome concentration in the evaporator; investigate the possibility of a recirculative piping arrangement between the evaporator and chrome recovery storage tank on the first floor.

2. Removal of the PVC restriction plates in the top section of those evaporators that have not been done, thereby increasing usable surface area of the four bend eliminator in the top section of the evaporator, lower the face velocity across the eliminator, and lower system operating pressure. This recommendation was per Wayne Co. inspectors who advised a maximum face velocity of 400 fpm across the collector,

III. RECOMMENDATIONS (CONT'D)

even though the manufacturer reports collection efficiencies in excess of 95% for face velocities of 410 fpm to 1507 fpm.

3. Installation and/or connection of a control switch to interlock fan operation with a minimum pump feedrate, i.e. 100 gpm.

4. Determine chrome buildup in rooftop impingement tank over a time span of one week. These values can then be used to determine the effectiveness of the tank in capturing chromic acid.

5. Contact the Heil representative and have them inspect the installation of their 4 bend eliminators, with the possibility of retaining them as consultants.

6. Further testing to determine the impact these modifications have made.

IV. DISCUSSION

System Operation

The purpose of the evaporator collection system is recovery of chromic acid from the air stream being exhausted over the chrome plating cells, and in doing so, prevent chromic acid from being emitted to the atmosphere.

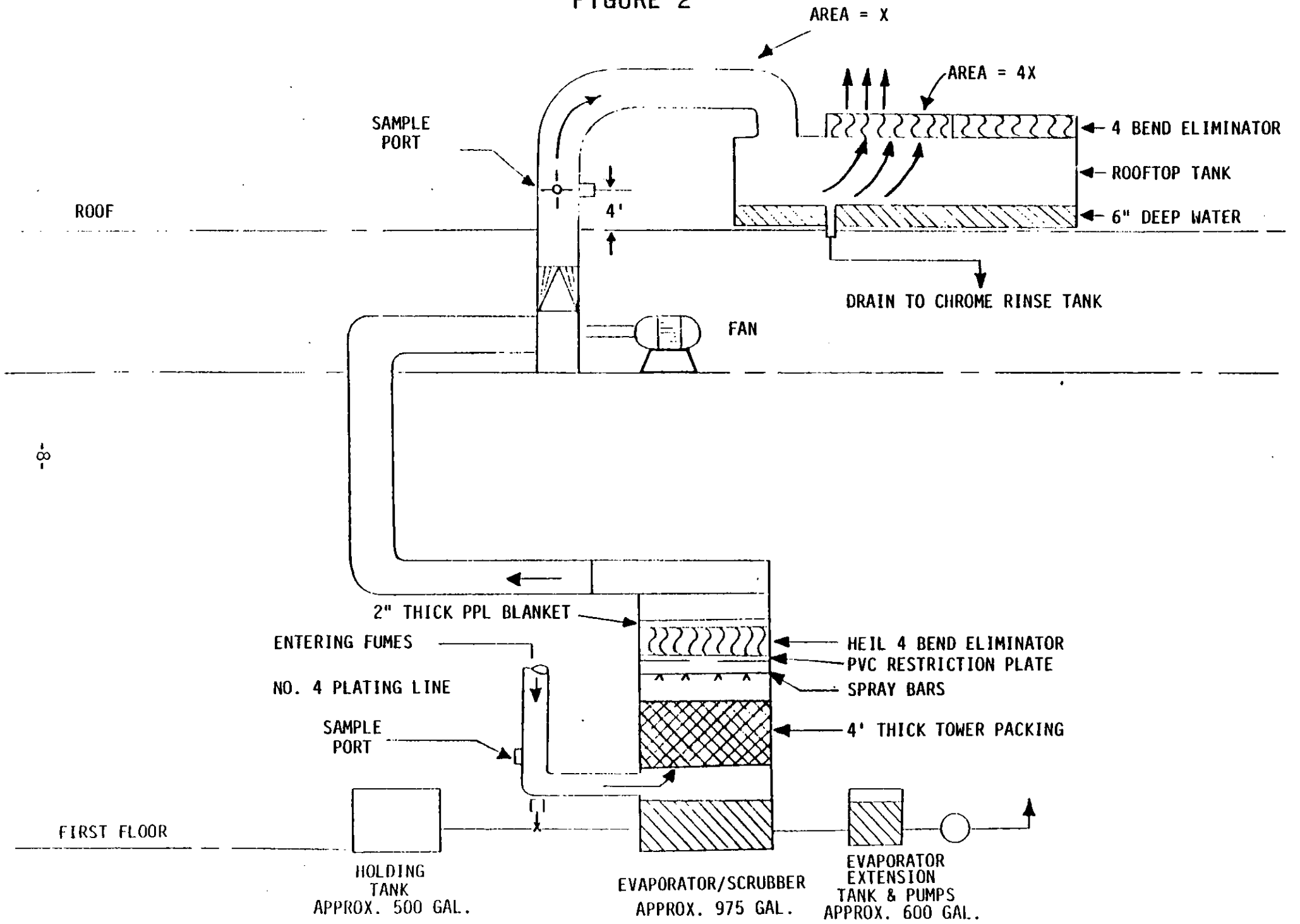
Figure 2, page 8 , illustrates the air flow diagram for the No. 4 evaporator. Air is drawn from over the plating tanks which captures chromic acid fumes generated during the plating process. Once in the evaporator, the air travels through a four foot thick section of ~~Maspac polypropylene~~ MASPAC JARAN packing material which provides a surface for the fumes to impinge upon. The Maspac is subjected to a spray of a water-chromic acid solution, for which the incoming fumes are soluble in. The chrome from the plating fumes is recovered within the solution, and the air stream becomes saturated at the evaporator temperature, therefore, increasing chrome concentration and lowering the level of the evaporator solution due to water evaporation.

For an increased chrome recovery rate, the evaporator system is equipped with the #3 heat exchanger , which elevates solution temperature thereby increasing the evaporation rate of water from the solution. Because the evaporator solution recirculation is a closed loop system, make-up water is required. This is supplied from a 500 gallon holding tank adjacent to the unit, which is fed from the rinse tanks after the plating cells on the second floor.

The system is equipped with two pumps to provide solution to the spray bars. Normal operation requires one pump operating and one on standby, with exhaust fan operation interlocked to pump operation.

NO. 4 CHROME RECOVERY EXHAUST SYSTEM

FIGURE 2



IV. DISCUSSION (CONT'D)

Over an undetermined period of time, the evaporator solution can reach high concentrations of chromic acid. Levels as high as 70 to 80 oz/gal have been recorded, which is approximately double the concentration necessary for the plating process.

As the air stream flows past the spray bars, it travels through a restriction plate, which was installed to increase air velocity across the first Heil four bend mist eliminator. Atop the Heil unit, is a two inch thick polypropylene mesh mist eliminator and connecting ductwork to the fan. The fan exhausts air through the roof level, where the ductwork makes a 180° bend back toward the roof and into an impingement tank. The rooftop tank contains a six inch deep level of water, which is drained and refilled on a weekly basis. The tank outlet is equipped with a second set of Heil four bend eliminators and ~~two inch thick polypropylene~~ A Piece of Roll Filter mesh blanket for droplet removal.

Problem Definition and Test Parameters

On an intermittent basis, visual and actual chromic acid droplets have been observed from the second set of four bend eliminators on the roof level, or on surfaces surrounding the plant. This condition, that appears to be of short term, exists due to some type of upset condition within the evaporator system operation.

In an attempt to identify this upset condition, two parameters of evaporator operation were chosen to be monitored and/or altered to determine the effect on outlet levels of chromic acid entering the rooftop impingement tanks. These parameters included variance in concentration levels of chromic acid

IV. DISCUSSION (CONT'D)

Problem Definition and Test Parameters (Cont'd)

in the evaporator solution, and feedrate of solution to the spray bars, which are directly measurable by analysis of a solution sample obtained from the pump extension tank, and flowmeter on the pump feed line.

Discussion of Recommendations

The basis for the recommendations listed in Section II are the graphical presentations of chrome emissions and collection efficiency versus chrome concentration in the evaporator. The curve for the first graph relating emissions to concentrations illustrates an increasing trend of chrome emissions as the chrome concentration in the evaporator increases. The second graph demonstrates a decreasing efficiency for increasing levels of chrome concentration.

Chrome concentrations appears to be a measurable factor in regulating chrome emissions beyond the evaporator, therefore, the need to monitor and most importantly report the measured concentrations of chromic acid in each unit. A daily plating line operation sheet is now in use and circulated to inform personnel of line conditions. Measured concentrations could be included on this form thereby increasing the level of communication between persons responsible for the evaporator system operation and also provide a permanent log which could be referenced in the event of future problems.

To recommend a working range for chrome concentration in the evaporator is somewhat arbitrary. Observation of the efficiency versus concentration curve illustrates that even at the lowest measured concentration of 1.6 oz/gal, chromic acid is still present at the fan outlet prior to the impingement tank,

IV. DISCUSSION (CONT'D)

Discussion of Recommendations (Cont'd)

with the curve predicting a 98% efficiency for a 0 oz/gal concentration. In choosing 90% as a minimum, the range obtained is from 0 - 25 oz/gal as predicted by the curve, yet actual testing showed an efficiency for Test-699 at a concentration of 35.5 oz/gal, 92.5%. This is why the term arbitrary is used in setting a guideline for a workable range of evaporator chrome concentration, yet a value should be established and made part of the operating criteria for each evaporator.

To assist and/or facilitate the evaporator operation, several items were also suggested to improve or determine the effectiveness of other aspects of the total system. With the existing system, the exhaust fan is interlocked with pump operation to insure capture of chromic acid fumes from the plating cells. This measure does not guarantee solution feedrate which is essential to capture of fumes in the evaporator. Tests were conducted to establish a minimum pump feedrate for the system. One series of tests was conducted at a feedrate of 100 gpm and solution chrome concentration of 70.5 oz/gal. The emission rate values from this series was then compared to the previous days test at a feedrate of 200 gpm and virtually the same chrome concentration of 70 oz/gal. The results demonstrated a lesser emission rate for the lower pump feedrate of 100 gpm than the higher pump setting. It was not discovered until the test program was complete, that on the previous day with a 200 gpm feedrate the No. 4 plating line was not operating, whereas during the 100 gpm test the line downtime was 14 minutes. This condition should not have existed if emissions from the plating cells are only during line operation. Nevertheless, it does demonstrate that collection of chromic acid still occurs at a feedrate setting of 100 gpm.

IV. DISCUSSION (CONT'D)

Discussion of Recommendations (Cont'd)

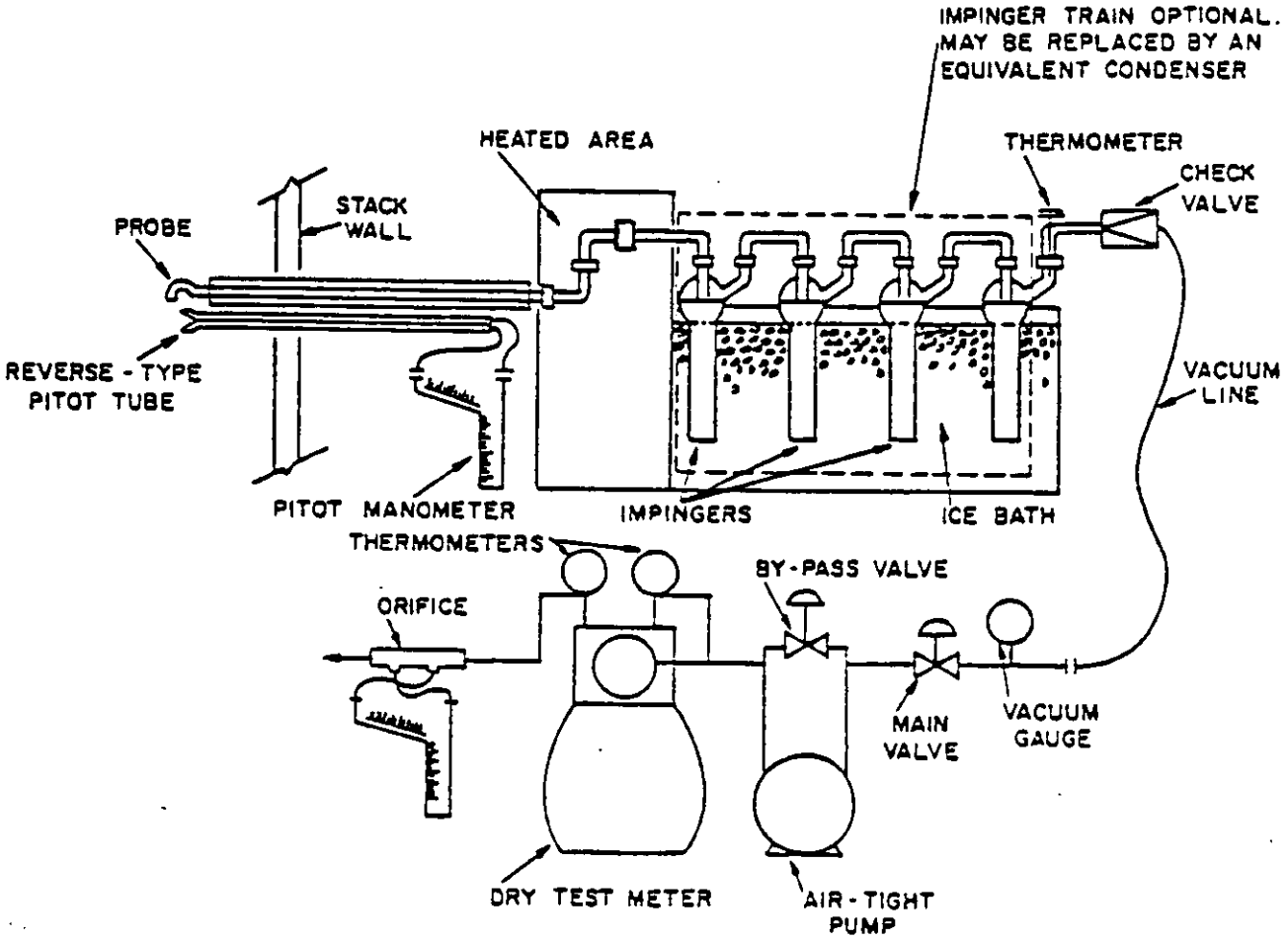
During the entire testing program it must be noted that all of the testing conducted on the evaporator outlet was prior to the rooftop impingement tank. The reported results could be used in determining the evaporator efficiency but not the effectiveness of the impingement tank in removing chromic acid. To determine the tanks effectiveness, a sequential sampler could be set up to obtain a sample of the water in the tank over a nominal time span of one week. This is the normal span between draining and refilling of the tank with fresh water. The values obtained could then be compared to emission rate values estimated from the chrome concentration versus emission rate curve within this report and determine the impingement tank usefulness.

V. SAMPLING PROCEDURE

The sampling equipment used on both inlet and outlet testing was the Research Appliance Co. Model 2343 "Stacksamplr" a commercial version of the Method 5 sampling train described in the Federal Register. A schematic diagram appears on page 14. The sample train consisted of a nozzle tip and heated glass lined probe connected directly to the impinger condensing train. This modification deviates from the standard particulate sample train by not including a fiberglass filter between the probe and condenser. The impinger train consisted of 4 bottles immersed in an ice bath. The second bottle was the Greenburg-Smith design with tapered stem and impingement plate. The remaining three were modified with straight stems which extend to within one half inch from the bottle bottom, and use this as an impingement surface. The first two bottles contained 100 ml of distilled water; the third was dry, and the fourth contained 200 g of indicating silica gel absorbent. A digital readout potentiometer was used to monitor stack temperature at the evaporator inlet, and a mercury thermometer was used at the evaporator outlet.

Sampling Location

Figure 2, page 8 , illustrates the location of the sampling ports and diagrams the evaporator system for the No. 4 plating line. The evaporator inlet duct has an exterior dimension of 24" x 96" and the outlet duct an inside diameter of 42". Because of the large negative pressure exerted on the inlet duct, a slight concave configuration in the 96" dimension of the rectangular duct was observed. With a concave configuration existing, the actual area of the duct would be lessened, thereby increasing measured



CHROMIC ACID - SAMPLING TRAIN

V. SAMPLING PROCEDURE (CONT'D)

velocity readings. Using these readings in a velocity and air flow calculation would produce erroneous values. Therefore, all emission rate data calculated for the inlet duct was based on the measured flowrate at the stack outlet. Due to the location of the evaporator and the surrounding piping arrangement, a complete traverse at all six ports at the inlet was not possible. Therefore, two ports were selected which displayed velocity readings close to the average for the total duct, and each point sampled for 30 minutes. Standard procedure for sampling a round stack requires a sample traverse in two directions 90° apart. Due to the distance between the outlet duct at roof level and the impingement tanks being less than the total length of the sampling train, a single 12 point sample in one direction was performed.

Sample Analysis

Sample recovery took place in the Chevrolet Environmental Quality Assurance Van, and analysis of the collected samples was performed by the Chevrolet-Livonia and Central Office Laboratories.

The impinger contents were transferred to a graduated cylinder for volume measurement determination, and the silica gel absorbent weighed to determine the mass of moisture absorbed. The corresponding volume of water vapor at meter conditions was calculated and then divided by the sum of vapor volume plus dry gas volume to determine the stack gas moisture content. The impingers, connecting glassware, sample probe, and nozzle were then rinsed with distilled water and combined with the impinger contents and placed in a sample jar. Analysis was performed for chrome six (Cr^{+6}) and total chrome by spectrophotometric and atomic absorbtion analysis respectively and the results listed on the following page.

V. SAMPLING PROCEDURE (CONT'D)

Chevrolet-Livonia No. 4 Evaporator
Chrome Analysis of Collected Samples

Test No.	mg Total Chrome (AA Analysis)	(Cr^{+6}) Chrome Six (Spectrophotometer)
695 Outlet	.045	Non Detectable
696 Inlet	1.30	1.1
697 Outlet	.280	.2
698 Inlet	3.35	3.2
699 Outlet	.350	.2
700 Inlet	3.30	3.05
701 Outlet	.765	.6
702 Inlet	2.20	2.2
703 Outlet	.510	.5
704 Inlet	2.35	2.3
705 Outlet	.300	.2
706 Inlet	1.45	1.6
707 Outlet	.94	.85
708 Inlet	2.60	2.2

APPENDIX

NO. 4 EVAPORATOR
DATA & OPERATING CONDITIONS

Test No.	Gas Flow ACFM	Gas Flow DSCFM	% H_2O	Chrome Concentration @ Evap. (oz/gal)	Chrome Concentration Sample Train (mg cr)	* Mass Emission lbs/hr	% Efficiency
695 (Outlet)	35,046	32,642	2.9	1.58	.045	.003	97.3%
696 (Inlet)	-	-	2.1	1.58	1.3	.113	

Test Condition: Evaporator solution drained on third shift and refilled with D.I. water. Pump feed during test 190 gpm. #3 Heat Exchanger bypassed. Test date 9/26/79, @ 11:00 a.m. - 12:30 p.m.
T_e (Solution temp. to evaporator from control panel) T_e = 99°F
No. 4 plating line downtime during test - 7 min.

697 (Outlet)	34,770	32,328	2.75	18.9	.28	.019	93.4%
698 (Inlet)	-	-	1.1	18.9	3.35	.290	

Test Condition: Pump extension tank drained and refilled from tank 31-line 5 (25.5 oz/gal). Measured concentration of evaporator @ 10:00 a.m. - 11.1 oz/gal. Extension tank drained and refilled from plating cell on line 4 (approx. conc. 35↑). Pump feed during test 195-200 gpm. #3 H.E. bypassed. Test date 9/27/79 @ 1:20 - 2:20 p.m.
T_e = 97°F
No. 4 plating line downtime during test - 8 min.

699 (Outlet)	35,005	32,432	2.7	35.5	.35	.023	92%
700 (Inlet)	-	-	1.9	35.5	3.3	.284	

Test Condition: Pump extension tank drained and refilled with a plating solution made from 10 cans of chrome flake and 1000 gal H_2O. Measured concentration on evaporator @ 10:00 a.m. - 27.7 oz/gal. Added 4 cans of chrome flake directly to pump extension tank. Pump feed during test 205 gpm. #3 H.E. bypassed. Test date 9/28/79 @ 12:00 - 1:00 p.m. T_e = 98°F
No. 4 plating line downtime during test - 13 min.

701 (Outlet)	35,009	31,620	3.7	46.4	.765	.05	73.2%
702 (Inlet)	-	-	1.9	46.4	2.2	.187	

Test Condition: Measured concentration @ 10:00 a.m. - 49.7 oz/gal. #3 Heat Exchanger turned on to increase evaporation rate thereby increasing Cr concentration. Test date 10/1/79 @ 12:30 - 1:30 p.m.
Note: After the outlet test was completed, an excessive buildup of chromic acid was noted on the lower side of the sampling probe, than had been encountered in previous tests. Pump feedrate 195-200 gpm. T_e = 150°F
No. 4 plating line downtime during test - 11 min.

* Based on Outlet Flowrate Measurements

NO. 4 EVAPORATOR (CONT'D)

Test No.	Gas Flow ACFM	Gas Flow DSCFM	% H2O	Chrome Concentration @ Evap. (oz/gal)	Chrome Concentration Sample Train (mg cr)	• Mass Emission lbs/hr	% Efficiency
703 (Outlet)	35,175	31,789	3.5	70.0	.51	.034	83.1%
704 (Inlet)	-	-	2.0	70.0	2.35	.202	

Test Condition: Measured concentration @ 8:00 a.m. 50.4 oz/gal. #3 H.E. turned on to increase Cr concentration. Test date 10-2-79 @ 10:30 - 11:30 a.m. Note: Very little chromic acid buildup on sample probe compared to the previous day, (outlet test). T_e = 150°F Pump feedrate 200 gpm No. 4 plating line downtime during test - entire test period.

705 (Outlet)	35,435	32,196	3.3	70.5	.3	.02	84%
706 (Inlet)	-	-	1.9	70.5	1.45	.125	

Test Condition: Measured concentration @ 8:30 a.m. 51.75 oz/gal. #3 H.E. turned on to increase Cr concentration. Pump feedrate lowered to 100 gpm. Test date 10/3/79 @ 10:10 - 11:10 a.m. Note: Excessive buildup of chromic acid on sample probe used during the outlet test. T_e = 126°F No. 4 plating line downtime during test - 14 min.

707 (Outlet)	34,847	31,625	3.6	55.5	.94	.064	71.3%
708 (Inlet)	-	-	1.6	55.5	2.6	.223	

Test Condition: Measured concentration @ 8:30 a.m. 48.45 oz/gal. #3 H.E. turned on to increase Cr concentration. Pump feedrate at maximum level with two pumps operating at a flowrate of 215 gpm. Test date 10/4/79 @ 10:00 - 11:00 a.m. Note: Excessive buildup of chromic acid on sample probe used during the outlet test. T_e = 118°F No. 4 plating line downtime during test - None.

Note: Average face velocity from all tests @ the four bend mist eliminator on the roof is 550 AFPM assuming equal air distribution.

• Based on Outlet Flowrate Measurements

FORMULAS AND DEFINITIONS

VOLUME OF WATER VAPOR COLLECTED

$$Vw_{std} = \frac{Vlc\ p\ H_2O\ R\ Tstd}{Pstd\ M_{H20}} = .0474\ \frac{ft^3}{ml}\ (V_{l_c})$$

Vw_{std} = Volume of water vapor in gas sample (std conditions) ft^3

V_{l_c} = Total volume of liquid collected in impingers and silica gel, ml.

R = Ideal gas constant, 21.83 in Hg-cu.ft./lb mole-°R.

H_2O = Density of water, 1 g/ml.

Tstd = Absolute Temperature at standard conditions, 530°R.

Pstd = Absolute Pressure at standard conditions, 29.92 in Hg.

M_{H20} = Molecular wt of water, 18 lb/lb-mole.

GAS VOLUME

$$V_{m_{std}} = Vm\ \left(\frac{Tstd}{Tm}\right)\left(\frac{Pbar + \frac{\Delta H}{13.6}}{Pstd}\right) = ft.^3$$

$V_{m_{std}}$ = Dry gas volume through meter at std conditions, $ft.^3$.

Vm = Dry gas volume measured by meter, $ft.^3$. (Meter conditions).

Pbar = Barometric pressure at dry gas meter, in Hg.

Pstd = Pressure at std conditions, 29.92 in Hg.

13.6 = Specific gravity of mercury.

Tstd = Absolute temperature at std conditions, 530 °R.

ΔH = Average pressure drop across orifice, in H_{20}.

Tm = Absolute temperature at meter (°F + 460), °R

MOISTURE CONTENT

$$B_{wO} = \frac{Vw\ std}{Vw_{std} + Vm_{std}}$$

B_{wO} = Proportion by volume of water vapor in the gas stream.

Vw_{std} = Volume of water vapor in the gas sample (std conditions), $ft.^3$.

MOISTURE CONTENT (CONT'D)

Vm_{std} = Dry gas volume through meter (std conditions), ft^3.

MOLECULAR WEIGHT (DRY AND WET)

Md = Dry molecular weight, lb/lb mole.
.44 (% CO_2) + .32 (% O_2) + .28 (% N_2 +% CO).

Ms = Wet molecular weight, Md (1 - B_{wo}) + 18 B_{wo}.

% CO_2 = Percent carbon dioxide by volume (dry basis).

% O_2 = Percent oxygen by volume (dry basis).

% N_2 = Percent nitrogen by volume (dry basis).

.44 = Molecular weight of carbon dioxide divided by 100.

.32 = Molecular weight of oxygen divided by 100.

.28 = Molecular weight of nitrogen and carbon monoxide divided by 100.

B_{wo} = Proportion by volume of water vapor in the gas stream.

STACK GAS VELOCITY

$$(Vs)_{avg} = Kp\ Cp\ (\sqrt{\Delta}p)_{avg} \sqrt{\frac{(Ts)\ avg}{Ps\ Ms}}$$

(Vs)avg = Stack gas velocity, feet per second.

Kp = 85.48 ft/sec (lb/lb mole-$^oR)^{1/2}$

Cp = Pitot tube coefficient, dimensionless

(Ts)avg = Average absolute stack gas temperature, ^oR.

$(\sqrt{\Delta P})$avg = Average velocity head of stack gas, inches H_2O.

Ps = Absolute stack gas pressure, in Hg.

Ms = Molecular weight of stack gas (wet basis).

STACK GAS VOLUMETRIC FLOW RATE

$$Qs = 3600\ (1 - B_{wo})\ Vs\ A\ \left(\frac{Tstd}{(Ts)avg}\right)\left(\frac{Ps}{Pstd}\right)$$

Qs = Volumetric flow rate, dry basis, standard conditions, $ft.^3/hr.$

A = Cross sectional area of stack, $ft.^2$.

Tstd = Absolute temperature at std conditions, 530°R.

Pstd = Absolute pressure at std conditions, 29.92 in Hg.

% ISOKINETIC VARIATION

$$I = Ts\left[\frac{V_{lc}(pH_2O)R}{M_{H2O}} + \frac{Vm}{Tm}\left(Pbar + \frac{\Delta H}{13.6}\right)\right] \text{ X } 100$$

$$\theta\ Vs\ Ps\ An$$

$$I = \left[1.667\ \frac{min}{sec}\right]\left[\frac{(.00267\ in\ Hg\text{-}cu.ft)}{ml\ -°R}\ V_{lc} + \frac{Vm}{Tm}\left(Pbar + \frac{\Delta H}{13.6}\right)\right] T_S$$

$$\theta\ Vs\ Ps\ An$$

I = Percent of isokinetic sampling.

V_{lc} = Total volume of liquid collected in impingers and silica gel, ml.

H_{20} = Density of water 1 g/ml.

R = Ideal gas constant, 21.83 in Hg-Cu.ft./lb mole-°R.

M_{H20} = Molecular weight of water, 18 lb/lb-mole.

Vm = Volume of gas sample through the dry gas meter (meter conditions) $ft.^3$.

Tm = Absolute average dry gas meter temperature, °R.

Pbar = Barometric pressure at sampling site, in Hg.

ΔH = Average pressure drop across the orifice, in H_20.

Ts = Absolute average stack gas temperature, °R.

θ = Total sampling time, min.

Vs = Stack gas velocity, ft/sec

Ps = Absolute stack gas pressure, in Hg.

An = Cross-Sectional area of nozzle, ft^2

SPECIFIC VOLUME ft^3/lb gas

$$V = \frac{21.83 \text{ in Hg-ft}^3 \times 530^{\circ}R}{\text{mole-}^{\circ}R \quad \text{md } \frac{lb}{mole} \times 29.92 \text{ in Hg}}$$

v = Specific volume of dry stack gas at std. conditions, ft^3/lb.

CONCENTRATION gr/SCF, Mg/SCM, and lb/1000 lb gas

$$Csv_{ft^3} = (0.0154 \frac{gr}{Mg}) \frac{(Mn)}{Vm_{std}} \; ; \; Csv_{m^3} = \frac{Mn}{Vm_{std} \; (.02832 \; CF/CM)}$$

$$Csm = \frac{Csv_{ft^3} \; (v) \; (10^3)}{7000 \text{ gr/lb}}$$

Csv = Concentration of chrome in stack gas, gr/SCF, Mg/SCM (Dry Basis).

Csm = Concentration of chrome in stack gas, lb/1000 lb gas.

Mn = Total amount of chrome collected, Mg.

Vm_{std} = Volume of gas sample through dry gas meter. (std. conditions) ft^3.

EMISSION RATE lb/hr

ER_{hr} = (C_S gr/SCF) (Q_s SCF/hr) (1 lb/7000 gr)

C_S = Concentration of chrome in the stack gas-- grains per standard cubic feet.

Q_s = Volumetric flow rate, dry basis standard conditions-- cubic feet per hour.

PLANT Chevrolet-Livonia

DATE 9-26-79

RUN NO. Test-695

STACK DIAMETER, in. 42

BAROMETRIC PRESSURE, in. Hg. 29.49

STATIC PRESSURE IN STACK (P_g), in. Hg. +.96

OPERATORS T. Strauss

Traverse point number	Velocity head, in. H_2O	$\sqrt{\Delta_p}$	Stack Temperature (T_S), °F	ΔH
1	.60	.774	86	2.7
2	.85	.922		3.8
3	.92	.959	86	4.1
4	1.3	1.140		5.8
5	1.3	1.140	86	5.8
6	1.4	1.183		6.2
7	1.4	1.183	86	6.2
8	1.35	1.162		6.0
9	1.3	1.140	86	5.8
10	.95	.974		4.2
11	.84	.916	86	3.7
12	.67	.818		3.0
AVERAGE		1.026	86	4.775

EXAMPLE CALCULATIONS

TEST - 695

NO. 4 EVAPORATOR OUTLET

VOLUME OF WATER VAPOR COLLECTED

$$V_{w_{std}} = 0.0474 \ (\ 40.9 \ ) = 1.938 \quad \text{SCF}$$

GAS VOLUME SAMPLED

$$V_{m_{std}} = 68.58 \quad \frac{(530)}{555} \left(\frac{29.49 + \frac{4.775}{13.6}}{29.92} \right) = 65.32 \quad \text{DSCF}$$

MOISTURE CONTENT

$$B_{wo} = \frac{1.938}{1.938 + 65.32} \times 100\% = 2.9\ \%$$

MOLECULAR WEIGHT (DRY AND WET)

$$Md = 0.44 \ (\ 0 \ ) + 0.32 \ (\ 21 \ ) + 0.28 \ (\ 79 + 0 \ )$$

$$= 28.84 \quad \text{lb/mole}$$

$$Ms = Md \ (1 - .029) + 18 \ (.029)$$

$$= 28.53 \quad \text{lb/mole}$$

STACK GAS VELOCITY

$$Vs_{avg} = 85.48 \ (\ .86 \ ) \ (\ 1.026 \ ) \sqrt{\frac{546}{(28.53) (29.56)}}$$

$$= 60.69 \quad \text{ft/sec} \times 60 = 3,641 \quad \text{ft/min}$$

STACK AREA

$$A = 0.7854 \ (\ 3.5' \ )^2 = 9.62 \quad ft^2$$

or

$$A = \frac{(\quad X \quad)}{144} = \quad ft^2$$

STACK GAS VOLUMETRIC FLOW RATE

$$Qs = 3600\,(1-.029)\,(60.69)\,(9.62)\,\frac{(530)}{546}\,\frac{(29.56)}{29.92}$$

$$= 1{,}957{,}222 \text{ SCFH} \div 60 = 32{,}620 \text{ DSCFM}$$

ISOKINETIC VARIATION

$$\%I = \frac{1.667\left[.00267\,(40.9) + \frac{(68.58)}{(555)}\left(29.49 + \frac{4.775}{13.6}\right)\right](546)}{(60)\,(29.56)\,(60.69)\,(.000338)}$$

$$\%I = 94.9$$

SPECIFIC GAS VOLUME

$$v = \frac{21.83\,(530)\,(10^3)}{Md\quad(29.92)} = \frac{386694.35}{(28.84)} = 13{,}408 \ \frac{ft^3}{1000 \text{ lb gas}}$$

CONCENTRATION (BY VOLUME AND WEIGHT)

$$Csv_{ft^3} = \frac{0.0154\,(.045)}{(65.32)} = .00001 \text{ gr/DSCF}$$

$$Csv_{m^3} = \frac{(.045)}{(65.32)\,.02832} = .024 \text{ Mg/DSCM}$$

$$Csm = \frac{(00001)}{7000}\,(13{,}408) = .00002 \text{ lb/1000 lb gas}$$

EMISSION MASS RATE

$$ER_{hr} = \frac{(.00001)\,(1{,}957{,}222)}{7000} = .003 \ \frac{lb}{hr}$$