STEADY STATE HYDROGEN OXIDATION
ON PLAT NICKEL CATALYSTS

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BY

STEADY STATE HYDROGEN OXIDATION
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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

ENTITLED...

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF...

on...

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Approved:

Instructor in Charge

HEAD OF DEPARTMENT OF

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UNIVERSITY OF ILLINOIS
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CONFRONT
The catalytic combustion of hydrogen on a flat nickel plate was studied at steady state conditions. Results were compared with numerical solutions to two-dimensional reactive flow problems. As predicted by theory, two steady states were found, one chemically controlled and one heat and mass transfer controlled. Radiative heat losses were indicated which influenced the temperature profile on the catalyst.
INTRODUCTION

Catalytic combustion on a flat plate has been the subject of several investigations. However, there is little theoretical work available on the reactive fluid mechanics involved. Lindberg and Schmitz [1], and Ahluwalia and Chung [2] computed the steady state solution of the two-dimensional boundary layer flow for carbon monoxide combustion over a flat catalytic plate. They predicted that at low temperatures, there is very little reaction. At moderate temperatures, they predicted that the reaction rate is controlled by the rate of diffusion to the surface. At high temperatures, the reaction rate is controlled by the rate of catalytic combustion close to the leading edge of the plate. Far from the leading edge, however, there is some reaction. These results are similar to those obtained by Kumar and Chung [2].

Figure 1 shows a typical temperature profile of the plate. The surface temperature is plotted as a function of the distance down the plate from the leading edge. The surface temperature is plotted as a function of the distance down the plate from the leading edge. Figure 1 shows a typical temperature profile of the plate.
Both models predicted ignition distances of about 16 cm, which indicates that ignition would not occur unless the catalyst was at least 16 cm long. They also predicted flat temperature profiles after the ignition point.

Experiments performed by Seebauer et al. [31] on hydrogen combustion over a nickel catalyst did not quantitatively agree with their results. Seebauer et al. [31] had catalysts that were only 0.7 cm long, yet they consistently found ignition phenomena. A photograph of the glowing catalyst showed an ignition distance of about 0.1 mm. The maximum temperature rise was very short, and the temperature clearly dropped over the back 2/3 of the plate. Furthermore, the temperature profile of the plate was much closer to the boundary layer equations predicted and bucking ([4] used a different numerical technique). Fakheri et al. [4] performed their calculations using the boundary layer equations. They predicted a much shorter ignition distance, less than 1 mm, and the maximum temperature was much closer to their prediction than to the Lindberg and Schmitz [1] and Ahluwalia and Chung [2] predictions from the calculation of the boundary layer equations.

Temperature rise versus distance down the plate for different wall emissivities is shown in Figure 2 for their model. Although homogeneous reactions have not been included, these results do indicate the performance of the plate for different wall emissivities, as shown in Figure 2 for the temperature rise versus distance down the plate.
The work presented in the following pages was done in an attempt to more accurately determine the temperature profile on a flat catalyst and to experimentally model the steady state temperature rise during the catalytic combustion of hydrogen over a nickel plate.

When converted to X, the results show that a majority temperature drop over the back part of the plate.
APPARATUS

The reactor vessel was constructed of quartz glass.

The reactor is diagramed in Figure 4. It was the mixing point into the reactor.

Part way through the experiments, a purge valve and a nitrogen line was also connected to purge the reactor.

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The reactor vessel was constructed of quartz glass.
The reactor was heated by two four foot long bead-type resistence heaters which were wrapped around the reactor. The reactor was heated by two four foot long bead-type resistence heaters which were wrapped around the reactor.

Opposite the sidearm was a 2 cm. diameter window for viewing or photographing the catalyst. Refer to Figure 4 for further dimensions.

The lower sections were filled to approximately 80% of their volume with Pyrex beads, and the top section was filled to within 1.5 cm. of the sidearm. A plug of glass wool was placed in each constriction to keep the Pyrex beads secure in each section. The catalyst was mounted via the sidearm in the top section and centered in the reactor. The mount was connected to the sidearm with a spring clamp and the joint sealed with an O-ring. The mount was a glass joint with a plastic cap on the end through which three two-holed ceramic rods, and to an Omegatemp digital thermometer and a strip chart recorder to record temperature versus time.

The thermocouple tubes, which were welded to the nichrome foil on the front, middle, and back of the catalyst, which was positioned vertically, supported the catalyst. The three thermocouple wires and 0.003 inch, chromel-alumel thermocouple wires and the end through which extended three two-holed ceramic rods, and to an Omegatemp digital thermometer and a strip chart recorder to record temperature versus time.

The reactor was heated by two four foot long bead-type resistence heaters which were wrapped around the reactor. The reactor and heating coils were insulated with several layers of asbestos tape and covered with aluminum foil.
EXPERIMENTAL PROCEDURE

Two rectangular nickel catalysts were used. Catalyst 1, 10.5 x 8.5 x 0.125 mm, was soaked in trichloroethylene for ten minutes, then rinsed in acetone, then methanol, and 9.0 mm. from the lower, or leading, edge of the plate, welded to one side of the cataly.

Three 0.003 inch chromel-alumel thermocouples were spot-welded to the side of the catalyst. They were 2.5, 5.5, and 9.0 mm. from the lower, or leading, edge of the plate, and approximately centered horizontally.

To initially activate the catalyst, it was mounted in the reactor, oxidized in a stream of pure oxygen at 300°C for 5 hours, then reduced in pure hydrogen at 320°C for 6.5 hours. The procedures for catalyst 2 were similar, except the plate dimensions were 11.5 x 8.0 x 0.125 mm. The nickel plate was soaked for 15 minutes in trichloroethylene, 10 minutes in acetone, and 10 minutes in ethanol. The thermocouples were spot-welded 1.5, 5.5, and 9.3 mm. from the leading edge of the plate. For activation, the catalyst was oxidized for 4.5 hours at 500°C, and reduced with hydrogen for 5.5 hours at 450°C.

Each time a series of runs were performed, the activation procedure was repeated with oxidation and reduction times about 20 minutes each. Before each run, the temperature was allowed to come to steady state with hydrogen flowing. Hydrogen flows rates from 500 to 5000 ml/min.
were used. The oxygen was then turned on to the desired value from 0.5 to 6.0% oxygen, and the temperature was allowed to come to steady state. The plate temperature values were recorded at both the initial temperature (inlet temperature) and after the reaction was allowed to proceed. At the end of each run, the oxygen was turned off and the plate temperature was allowed to return to its initial value before starting another run.
RESULTS AND DISCUSSION

When oxygen was introduced into a flowing stream of hydrogen, three types of temperature versus time plots were obtained. Figure 5a shows the temperature quickly rising, in this case, about 50°C, then staying stable. This steady state was observed at low inlet temperatures and sometimes at low inlet oxygen concentrations. In this case, the temperature quickly rose to a higher temperature steady state. The length of time to reach this state or low temperature state, at intermediate gas flows, this state was referred to as the first, or low temperature state. The difference between the wall temperature and the jet temperature was illustrated in Figure 5, where the temperature went directly to the high temperature state. Hereafter, the temperature was increased until, as in Figure 5c, the temperature went directly to a higher temperature steady state, the second state. The length of time to reach the second state decreased with increasing inlet temperature.

The two apparent steady states were predicted by Ahluwalia and Chung [2], who also stated that the first temperature will be referred to as T1, under similar flow conditions, results are presented here which support their statement.

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Fig. 6 is a plot of the measured temperature rise versus inlet oxygen concentration for two inlet temperatures. It illustrates the behavior of the temperature rise as a function of inlet oxygen concentration.
great difference in temperature rise for the high and low temperature states. For example, a 14°C AT was obtained at 3% oxygen in the first state, whereas for the second state, was 150°C. Distinctly different trends for the two states are shown in Fig. 7 for varying flowrates, and in Fig. 9 shows a plot of AT versus oxygen concentration at high temperature data, where the plate temperature was observed to exhibit behavior similar to that in Fig. 8.

Kinetically controlled state.

At given flowrates, this is the expected behavior of a temperature-dependent state. High temperature data, where the plate temperature was 150°C, showed little or no dependence on inlet temperature.

Data taken at low temperatures showed a distinct catalytic state.

With increasing temperature, with increasing inlet temperatures at a given flowrate, the rate of reaction of the reactants to the surface of the catalyst is increased more than the chemical reaction rate. These variables, flowrate and oxygen concentration, affect the rate of transfer of the reactants, to the surface of the catalyst, diffusion-controlled state, to, naturally, temperature-controlled states. For example, a significant difference in temperature rise for the high and low temperature states. For example, a 14°C AT was obtained at 3% oxygen in the first state, whereas for the second state, was 150°C.
the lowest surface temperatures are observed, again
each time. The nearer to the window the plate is placed,
difficult to position the catalyst exactly in the reactor
although there is a lot of scatter in the data. It is
increasing with increasing inlet and surface temperatures,
the temperature drop over the plate generally seemed

Theory and Equipment.

Thus explains the apparent contradiction between previous
tried in the model, one does get a temperature drop.
recent unpublished work, show that, when radiation is
past the ignition point, rapid and bucking in the
Chung [2], which predicts a nearly constant temperature
the models of Lindberg and Simaiz [1] and Ahluwalia and
entrainment temperatures. The behavior appears in contradiction
to inlet oxygen concentration and flowrate, and at different
middle, and back of the plate were plotted as functions
seen in Figs. 6, 7, 10, and 11 where \( T \) is the temperature
was cooler than the leading edge. This effect can be
temperature states, the back edge of the nickel plate
in almost every case, when investigated the high

obvious dependence on inlet temperature.

Although there are few data points, again there is no
a function of hydrogen flowrate at two inlet temperatures.
of the catalyst. In a similar plot, Fig. 10 shows the
different controlling mechanism at these conditions.

This indicates that the reaction must have a

indicating that radiation is an important factor. Because of this and only having three thermocouples on the plate, it is difficult to accurately follow the temperature profile and its trends quantitatively.

An attempt was made to find conditions where the ignition point was past the leading thermocouple, so that the observed temperature at the front of the foil would be lower than at the middle. Ahluwalia and Chung [2] predicted that the ignition distance is proportional to the free stream velocity and the inverse of the oxidant concentration. Therefore, low flowrates with high oxygen concentrations were investigated in order to measure a cooler leading temperature. However, low flowrates with high oxygen concentrations were not investigated.

Therefore, the product of the free stream velocity and the inverse of the oxidant concentration at the ignition point was past the leading thermocouple, so that an attempt was made to find conditions where the observed temperature at the middle and the inverse of the oxidant concentration at the ignition point was past the leading thermocouple, so that it is difficult to accurately follow the temperature profile of this and only having three thermocouples on the plate, because indicating that radiation is an important factor.
Two stable steady states are possible for hydrogen combustion over nickel. The first, low temperature state is chemically controlled. The second, higher temperature state is controlled by the diffusion of reactants to the surface of the catalyst. Radiation of heat from the surface influences plate temperatures in the reactor used here. The results leading to the above conclusions are consistent enough to provide accurate modeling of the reaction on the catalyst. It is proposed that more careful control of the variables and further investigation would provide a good experimental model. In general, however, the data were not consistent or extensive enough to quantitatively support recent theoretical work which study reactive flow over catalytic plates. The results here lead to the above conclusions.
ACKNOWLEDGMENT

This work was supported by the Army Research Office under grant number DAAH-29-80-C-0111.

and guidance with my work.

Special appreciation to Dr. R.I. Masel for his support of the Masel research group. I would like to express for their advice and help, and for making the past year a more pleasant one. I sincerely thank every member for their support and guidance.
LITERATURE CITED


Figure 3
APPENDIX
1. Catalyst: 0.125 mm nickel foil

2. Temperature: 215-306°C

3. Reaction: Run with H2 at temps from 215-306°C to determine temperature profile on catalyst. The following profile was obtained:

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp</td>
<td>215</td>
<td>217</td>
<td>268</td>
</tr>
<tr>
<td></td>
<td>245</td>
<td>287</td>
<td>287</td>
</tr>
<tr>
<td></td>
<td>305</td>
<td>305</td>
<td>305</td>
</tr>
</tbody>
</table>

Back edge: Cleaned with water and alcohol.
For 1 hr @ 20
Reduced with H₂. Ten ppm Fe.

For 4 hr @ 41

Reacted with N₂ for 5 min.

At ~270 - 280°C

Return @ 30. Time At ~150°C.

Correctly: late time expanded to 0° for 1 hr.

Assume catalyst was not activated.

No reaction.

| 41 | 25 | 32 | 34 | 38 |
| 41 | 25 | 32 | 34 | 38 |
| 41 | 25 | 32 | 34 | 38 |

Run for 5 minutes.

H I II III I II III III

Fe₂N₂

Reduced w/ H₂ for ~40 min. At ~300°C

Active Fe. Reduced w/ N₂, Fe @ 550°C

At catalyst burn 30 min.

O₂ oxidized w/ O₂ for ~40 min

AC/ACT
No Rx

15 min

Reduction - 3:30 - 0.7

Turn on O2, no results

3x 3x 3x 3x

4 more hours

2 L quickly added, turn O2 on, 200 oz reduced

with hydrogen for 4 hours at 900°C

Experiments for 6 hours, then reduced

Catalyst was pretreated by first

he at 600°C

Again no reaction

H2, CO, C02
Oxidized @ 341°C, 16-11 30. Reduced @ 375°C, 16-11 2:30 A.M. Pulsed catalyst further into reactor. Brine C.

It perforated only approx. 2.3 mm into the body. Whereas now it is... Reducing 2:50 - 9:00

Ox. 20 min. Reduc. 10 cm1. NC Raw.

Carefully working more carefully now...
New Catalyst (e)

\[ A \rightarrow \text{L.E.} \]

1. Rinse with acetone.

\[ \text{Methanol} \]

2. Rinse with water.

\[ \text{Nitrobenzene} \]

3. Rinse with acetone.

\[ 50 \text{mM} \]

4. Rinse with water.

\[ \text{Phenylmethyl ether} \]

5. Rinse with acetone.

\[ \text{Nitrobenzene} \]

6. Rinse with water.

\[ \text{Methanol} \]

7. Rinse with acetone.

\[ \text{Nitrobenzene} \]

8. Rinse with water.

\[ \text{Nitrobenzene} \]

9. Rinse with acetone.

\[ \text{Nitrobenzene} \]

10. Rinse with water.

\[ \text{Methanol} \]

11. Rinse with acetone.

\[ \text{Nitrobenzene} \]

12. Rinse with water.

\[ \text{Methanol} \]

13. Rinse with acetone.

\[ \text{Nitrobenzene} \]

14. Rinse with water.

\[ \text{Methanol} \]

15. Rinse with acetone.

\[ \text{Nitrobenzene} \]

16. Rinse with water.

\[ \text{Methanol} \]

17. Rinse with acetone.

\[ \text{Nitrobenzene} \]

18. Rinse with water.

\[ \text{Methanol} \]

19. Rinse with acetone.

\[ \text{Nitrobenzene} \]

20. Rinse with water.

\[ \text{Methanol} \]

21. Rinse with acetone.

\[ \text{Nitrobenzene} \]

22. Rinse with water.

\[ \text{Methanol} \]

23. Rinse with acetone.

\[ \text{Nitrobenzene} \]

24. Rinse with water.

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25. Rinse with acetone.

\[ \text{Nitrobenzene} \]

26. Rinse with water.

\[ \text{Methanol} \]

27. Rinse with acetone.

\[ \text{Nitrobenzene} \]

28. Rinse with water.

\[ \text{Methanol} \]

29. Rinse with acetone.

\[ \text{Nitrobenzene} \]

30. Rinse with water.

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31. Rinse with acetone.

\[ \text{Nitrobenzene} \]

32. Rinse with water.

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33. Rinse with acetone.

\[ \text{Nitrobenzene} \]

34. Rinse with water.

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35. Rinse with acetone.

\[ \text{Nitrobenzene} \]

36. Rinse with water.

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37. Rinse with acetone.

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38. Rinse with water.

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39. Rinse with acetone.

\[ \text{Nitrobenzene} \]

40. Rinse with water.

\[ \text{Methanol} \]

41. Rinse with acetone.

\[ \text{Nitrobenzene} \]

42. Rinse with water.

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43. Rinse with acetone.

\[ \text{Nitrobenzene} \]

44. Rinse with water.

\[ \text{Methanol} \]

45. Rinse with acetone.

\[ \text{Nitrobenzene} \]

46. Rinse with water.

\[ \text{Methanol} \]

47. Rinse with acetone.

\[ \text{Nitrobenzene} \]

48. Rinse with water.

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49. Rinse with acetone.

\[ \text{Nitrobenzene} \]

50. Rinse with water.

\[ \text{Methanol} \]

51. Rinse with acetone.

\[ \text{Nitrobenzene} \]

52. Rinse with water.

\[ \text{Methanol} \]

53. Rinse with acetone.

\[ \text{Nitrobenzene} \]

54. Rinse with water.

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56. Rinse with water.

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57. Rinse with acetone.

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58. Rinse with water.

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59. Rinse with acetone.

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61. Rinse with acetone.

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62. Rinse with water.

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63. Rinse with acetone.

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64. Rinse with water.

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65. Rinse with acetone.

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66. Rinse with water.

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67. Rinse with acetone.

\[ \text{Nitrobenzene} \]

68. Rinse with water.

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\[ \text{Nitrobenzene} \]

70. Rinse with water.

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71. Rinse with acetone.

\[ \text{Nitrobenzene} \]

72. Rinse with water.

\[ \text{Methanol} \]

73. Rinse with acetone.

\[ \text{Nitrobenzene} \]

74. Rinse with water.

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75. Rinse with acetone.

\[ \text{Nitrobenzene} \]

76. Rinse with water.

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77. Rinse with acetone.

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78. Rinse with water.

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79. Rinse with acetone.

\[ \text{Nitrobenzene} \]

80. Rinse with water.

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81. Rinse with acetone.

\[ \text{Nitrobenzene} \]

82. Rinse with water.

\[ \text{Methanol} \]

83. Rinse with acetone.

\[ \text{Nitrobenzene} \]

84. Rinse with water.

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85. Rinse with acetone.

\[ \text{Nitrobenzene} \]

86. Rinse with water.

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87. Rinse with acetone.

\[ \text{Nitrobenzene} \]

88. Rinse with water.

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89. Rinse with acetone.

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90. Rinse with water.

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91. Rinse with acetone.

\[ \text{Nitrobenzene} \]

92. Rinse with water.

\[ \text{Methanol} \]

93. Rinse with acetone.

\[ \text{Nitrobenzene} \]

94. Rinse with water.

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95. Rinse with acetone.

\[ \text{Nitrobenzene} \]

96. Rinse with water.

\[ \text{Methanol} \]

97. Rinse with acetone.

\[ \text{Nitrobenzene} \]

98. Rinse with water.

\[ \text{Methanol} \]

99. Rinse with acetone.

\[ \text{Nitrobenzene} \]

100. Rinse with water.

\[ \text{Methanol} \]

101. Rinse with acetone.

\[ \text{Nitrobenzene} \]

102. Rinse with water.

\[ \text{Methanol} \]

103. Rinse with acetone.

\[ \text{Nitrobenzene} \]

104. Rinse with water.

\[ \text{Methanol} \]

105. Rinse with acetone.

\[ \text{Nitrobenzene} \]

106. Rinse with water.

\[ \text{Methanol} \]

107. Rinse with acetone.

\[ \text{Nitrobenzene} \]

108. Rinse with water.

\[ \text{Methanol} \]

109. Rinse with acetone.

\[ \text{Nitrobenzene} \]

110. Rinse with water.

\[ \text{Methanol} \]

111. Rinse with acetone.

\[ \text{Nitrobenzene} \]

112. Rinse with water.

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113. Rinse with acetone.

\[ \text{Nitrobenzene} \]

114. Rinse with water.

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115. Rinse with acetone.

\[ \text{Nitrobenzene} \]

116. Rinse with water.

\[ \text{Methanol} \]

117. Rinse with acetone.

\[ \text{Nitrobenzene} \]

118. Rinse with water.

\[ \text{Methanol} \]

119. Rinse with acetone.

\[ \text{Nitrobenzene} \]

120. Rinse with water.
The text is not legible due to the quality of the image. It appears to be a page from a mathematical or scientific document, but the content cannot be accurately transcribed.
INVERTED CATALYST AGAIN TO II 12 LEADING
EDGE - RESTORE THE IMAGE AT 5 X 5

Every 10 min. (10 times) there were
small scale leaks; no oxygen was in.

Temperature readings after 15 min.

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>383</td>
</tr>
<tr>
<td>15</td>
<td>383</td>
</tr>
<tr>
<td>30</td>
<td>383</td>
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<td>45</td>
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<tr>
<td>270</td>
<td>383</td>
</tr>
<tr>
<td>285</td>
<td>383</td>
</tr>
</tbody>
</table>
### Calibration of Thermocouples

All using #27C plug inlet on digital thermometer

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Value (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.9</td>
<td>11.8</td>
</tr>
<tr>
<td>12.8</td>
<td>11.9</td>
</tr>
<tr>
<td>11.5</td>
<td>11.0</td>
</tr>
</tbody>
</table>

9.23

With Pure H₂ at 4.80 cm, min.
After 1st ORALATION (Artn)

\[
\begin{align*}
1^\text{st} & : 326 \\
2^\text{nd} & : 361 \\
3^\text{rd} & : 360 \\
3^\text{rd} & : 355 \\
\text{Average} & : 349
\end{align*}
\]

\[
\text{When } T = 0^\circ \text{C,}\text{ the reaction rate is } \text{ negligible.}
\]

\[
\begin{align*}
\text{II} & : \text{Runs down to } 325 \text{ to } 325 \\
\text{III} & : \text{Runs down to } 68.2 \text{ to } 68.2 \\
\text{IV} & : \text{Runs down to } 68.2 \text{ to } 68.2
\end{align*}
\]

\[
\begin{align*}
\text{III} & : \text{Runs down to } 325 \text{ to } 325 \\
\text{II} & : \text{Runs down to } 68.2 \text{ to } 68.2 \\
\text{IV} & : \text{Runs down to } 68.2 \text{ to } 68.2
\end{align*}
\]
Run 10: INLET TEMP ~ 348° C

Run 11: INLET TEMP ~ 413° C

Run 12: INLET TEMP ~ 455° C

Run 13: INLET TEMP ~ 490° C

Run 14: INLET TEMP ~ 564° C

O₂: 2.38
H₂: 2.48

C₁:<br>2 = 0.5
C₂:<br>2 = 0.5
C₃:<br>2 = 0.5
C₄:<br>2 = 0.5
C₅:<br>2 = 0.5
C₆:<br>2 = 0.5
C₇:<br>2 = 0.5
C₈:<br>2 = 0.5
C₉:<br>2 = 0.5
C₁₀:<br>2 = 0.5
C₁₁:<br>2 = 0.5
C₁₂:<br>2 = 0.5
C₁₃:<br>2 = 0.5
C₁₄:<br>2 = 0.5
C₁₅:<br>2 = 0.5
C₁₆:<br>2 = 0.5
C₁₇:<br>2 = 0.5
C₁₈:<br>2 = 0.5
C₁₉:<br>2 = 0.5
C₂₀:<br>2 = 0.5
C₂₁:<br>2 = 0.5
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C₂₃:<br>2 = 0.5
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C₇₂:<br>2 = 0.5
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C₉₄:<br>2 = 0.5
C₉₅:<br>2 = 0.5
C₉₆:<br>2 = 0.5
C₉₇:<br>2 = 0.5
C₉₈:<br>2 = 0.5
C₉₉:<br>2 = 0.5
C₁₀₀:<br>2 = 0.5
TRY TO DETERMINE RESULTS OF RUN 2

Inlet: 515

O₂: (21.5) 2

O₂: 22

In: 643

E: 493

Run 1

Intermediate Value, e.g.,

\( H₂O + CO₂ = H₂ + CO₂ \)

Run 2

\( \text{Inlet} - (\text{Intermediate Value}) \)

\( H₂ - 3 \)

472

684

691 (70.1)
Run 3
Again try to duplicate results of Run 2, 10/5

INLET -5.35
H₂: 24
c
O₂: 24

Temp only inlet to 54 (new single RNL)

INCREASE H₂ FLOW RATE TO 8000 mL/min

Run 4
INLET 411 vars. 6.3
O₂: 51
Rerun, struck again
Attempts to use tent profile for II /II leading 3% O₂

<table>
<thead>
<tr>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Run 4</th>
<th>Run 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂ = 24</td>
<td>H₂ = 24</td>
<td>H₂ = 24</td>
<td>H₂ = 24</td>
<td>H₂ = 24</td>
</tr>
<tr>
<td>C₂H₂ = 23</td>
<td>C₂H₂ = 23</td>
<td>C₂H₂ = 23</td>
<td>C₂H₂ = 23</td>
<td>C₂H₂ = 23</td>
</tr>
<tr>
<td>No. of cycles</td>
<td>397</td>
<td>305</td>
<td>305</td>
<td>305</td>
</tr>
<tr>
<td>E₁ = 200</td>
<td>E₁ = 200</td>
<td>E₁ = 200</td>
<td>E₁ = 200</td>
<td>E₁ = 200</td>
</tr>
<tr>
<td>E₂ = 80</td>
<td>E₂ = 80</td>
<td>E₂ = 80</td>
<td>E₂ = 80</td>
<td>E₂ = 80</td>
</tr>
<tr>
<td>E₃ = 52</td>
<td>E₃ = 52</td>
<td>E₃ = 52</td>
<td>E₃ = 52</td>
<td>E₃ = 52</td>
</tr>
<tr>
<td>E₄ = 48</td>
<td>E₄ = 48</td>
<td>E₄ = 48</td>
<td>E₄ = 48</td>
<td>E₄ = 48</td>
</tr>
</tbody>
</table>

II: (227°C)
TCL Longing

<table>
<thead>
<tr>
<th>Run</th>
<th>Net (kg)</th>
<th>I 306</th>
<th>II 326</th>
<th>III 326</th>
<th>IV 246</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.24</td>
<td>0.25</td>
<td>0.34</td>
<td>0.34</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>324</td>
<td>324</td>
<td>324</td>
<td>324</td>
<td>324</td>
</tr>
</tbody>
</table>

Note: checked tensions with pure 12.

Profile was II 324. I III 309. 0.25 degrees. Hence, where there was only 0.2 of herring when they were calibrated (76C).

See next page for more calibration.
<table>
<thead>
<tr>
<th>14.2</th>
<th>325</th>
<th>320</th>
<th>325</th>
<th>320</th>
<th>325</th>
<th>320</th>
<th>325</th>
<th>320</th>
</tr>
</thead>
<tbody>
<tr>
<td>143</td>
<td>325</td>
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<td>325</td>
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<td>325</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>143</th>
<th>325</th>
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<th>325</th>
<th>320</th>
<th>325</th>
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<th>325</th>
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<tbody>
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<td>325</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>143</th>
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<td>320</td>
<td>325</td>
<td>320</td>
<td>325</td>
<td>320</td>
</tr>
</tbody>
</table>
I will not try a new approach. I will try to get the learning rate low enough to stabilize the actual flow. The actual flow is what we are measuring, not the measured flow into the reactor.
Run 1  INLET  307

\[ \begin{align*}
C_2 & \quad 2.4 \\
H_2 & \quad 3.6 \\
F & \quad 5.6
\end{align*} \]

Run 2  INLET  301

\[ \begin{align*}
C_2 & \quad 2.4 \\
H_2 & \quad 3.6 \\
F & \quad 5.6
\end{align*} \] (28 mm)

Run 3  INLET  301

\[ \begin{align*}
C_2 & \quad 2.4 \\
H_2 & \quad 3.6 \\
F & \quad 5.6
\end{align*} \] (28 mm)

Run 4  INLET  301

\[ \begin{align*}
C_2 & \quad 2.4 \\
H_2 & \quad 3.6 \\
F & \quad 5.6
\end{align*} \] (32 mm)
Any previous inhibits ignition. Monitor the heat out, get it down to 150°F. This will

slow the reaction rate to the point where it will not ignite. Once ignition occurs,

at a low rpm (1200-1500), increase

as small an rpm as possible and start

Next, I will reduce rpm to

Kamis
10/24 INLET 188

Run 1  VARIANS 40  INLET 2 26
  I 20.2  I  229.7  I  228.7  II  229.6  III  228.7
  O  28  0.5  III  267  01 hr (N. 0.8)

Run 2  VARIANS 70  INLET 2 26
  I  229.7  I  229.7  II  228.7  III  229.7
  O  28  0.5  III  267  01 hr (N. 0.8)

Notes:
- All recordings at this low flowrate will be at 20 cm/hr from now on. All previous recordings were chart speed 30 cm/hr.
<table>
<thead>
<tr>
<th>Run</th>
<th>Inlet Time</th>
<th>Temp. (°C)</th>
<th>Feeding Rate (g/h)</th>
<th>CO Conversion (%)</th>
<th>NOx Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 1</td>
<td>300</td>
<td>324</td>
<td>325</td>
<td>40</td>
<td>1.5%</td>
</tr>
<tr>
<td>Run 2</td>
<td>300</td>
<td>324</td>
<td>325</td>
<td>40</td>
<td>0%</td>
</tr>
<tr>
<td>Run 3</td>
<td>30</td>
<td>320</td>
<td>321</td>
<td>3.7</td>
<td>0.5%</td>
</tr>
<tr>
<td>Run 4</td>
<td>30</td>
<td>320</td>
<td>321</td>
<td>3.7</td>
<td>0.5%</td>
</tr>
<tr>
<td>Data: 1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>---------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>r(100°C)</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>w(15°C)</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>58</td>
<td>58</td>
</tr>
<tr>
<td>L</td>
<td>58</td>
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<td>58</td>
</tr>
<tr>
<td>0°C</td>
<td>58</td>
<td>58</td>
<td>58</td>
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<td>58</td>
</tr>
</tbody>
</table>
Rose to 10.0 C.

To 50 C when I turned off Hz.

But could not turn out. At 9.19, 300 ml/min)

Temp w/purge Hz. Attempted to get a steady inlet.

Run 1

3%. 1

Run 2

50 ml/min

Run 3

Init. 31.2 3.755 C

Run 4

Init. 31.2 3.755 C

Init. 31.2 3.755 C
Here above was quite substantial. I assume that in the air was circulating.

This caused the temp to drop again.

I put a metal tube over the air, and placed in the air. When I covered the exit hole in the tube, the air temperature appeared steady at 30 ml/min.

11/2 Aamn; could not get steady inlet temp.
<table>
<thead>
<tr>
<th>Catalyst</th>
<th>3 cm</th>
<th>Angle</th>
<th>Lower</th>
<th>Upper</th>
<th>Lower</th>
<th>Upper</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>3 cm</td>
<td>45°</td>
<td>30°</td>
<td>60°</td>
<td>45°</td>
<td>60°</td>
<td>535</td>
</tr>
<tr>
<td>Type 2</td>
<td>3 cm</td>
<td>45°</td>
<td>30°</td>
<td>60°</td>
<td>45°</td>
<td>60°</td>
<td>540</td>
</tr>
</tbody>
</table>

**Notes:**
- C: Catalyst, not sufficiently oxidized
- K: Catalyst, oxidized
- R: Raising temperature to 700°C
- G: Good yield
- E: Excellent yield
- U: Unsuccessful experiment

**Remarks:**
- Temperature rise only to 535°C first, then gradually raise to 800°C.
Cleaned catalyst in a 10% bath of 5-20% scandium nitrate in ethanol, agitated for 20 seconds, allowed to stand about 6 times. This was done in an attempt to get catalyst more active as that it would go to higher inlet concentrations. When finished with an initial temp of about 300°C, temp rose steadily to 637°C, 48% O₂, 2000 mL/min H₂, 3% O₂. Note: AT 1211L - DILUTION 1:1.8, 37°C. E. E. LEADING Edge... THE MIDDLE (2:1).
Turn on H₂. Carefully, return the crimping tool to shiny new, clean 15 ft. of oxerize, but don't tense the oxerize. Start with the least one or two pieces of flint. Carefully, unscrew all.

"Prep" 1 ft. & ½ ft. of oxerize, ca. 8 2200 (2200 m²) square ft. of oxerize, coming from at or below steam or air, could feel hurt.

"Oxerize" in a heavy stream of air to clean all. The oxerize is now:

They were wedged, T.C.'s. on.

3 in. deep, 1 ft. off. 1 ft. on.

Soaked IC dyes, dyes, dyes in acetone.

Also rinsed, rinsed, rinsed in acetone and
1 cm in acetone, and 10 min. in ethanol.

Towel, soaked 15 min. in Trichloroethylene, pre-treatment buffer with white paper.

Put on a new coat. From the same.

"Leuck" removed, cut to catalyst (ca. 1 ft. and

1/10 removed, cut to catalyst (ca. 1 ft.)
ANO (I) 1, 3%.

Mass 3% 3.4%, acetone, static, 45 65%.

Run at 3% 32.5, after a 270h, only 45 pump.

Am 0.5%, acetone, 639 pump. Need

BAD RUN

If 40 4c, 290c.

If 40 4c, 3c, 17c.
11/13

Run 1 INLET 380

H₂ 39
O₂ 39

1 0.24
II 627
III 645

Run 2 INLET 380

H₂ 39
O₂ 39

I 430
III 435

Varies: 60

with 4 cog

2 hr 15 min

var: 65
TIME ESTIMATE: 45 minutes

ALLOWS FOR COMPLETION OF OTHER ITEMS

THE WORK: I will do me, Also

1. For 30 min at 40% - 60% in. (445, 80)

2. For 20:30 min at 

SUGGESTED TIMES FOR EXAMINE:

In other articles:

Kings, which to 2:30, since when if you will - 60,70
ten BA more or less, 1.5, XLS to 480, 580
3, more responsible, 1, (985) to 460,
4, and so going to be seen later, have
is accordingly, can I, at nearest, have.
Not: n. set me I can any -
Note: Additional notes are:

48 and the area of the

56.8 = 32.4 - 15.8

as in Figure... (Fig. 8.23)
12/5

General 300 400 250mm
Reduced 130 160 100

\[ 364 \]

\[ 1.40 \] (400)

\[ 1.42 \] (400)

\[ 1.43 \] (400)

\[ 1.43 \] (400)

\[ 360 \text{ ml/min} \times 2 \]

\[ 4.7 \% \text{ O}_2 \]

Run 2

\[ 369 \text{ ml/min} \]

\[ 1.9 \text{ %} \text{ O}_2 \]

\[ 2.29 \text{ %} \text{ O}_2 \]

\[ 1500 \text{ ml/min} \times 2 \]

\[ 4.7 \% \text{ O}_2 \]

Run 3

\[ 369 \text{ ml/min} \]

\[ 0.5 \text{ %} \text{ O}_2 \]

\[ 0.5 \text{ %} \text{ O}_2 \]

\[ 0.5 \text{ %} \text{ O}_2 \]

\[ 0.5 \text{ %} \text{ O}_2 \]