PROGRESS REPORT NO. 11

KINETICS OF OXIDATION AND QUENCHING OF COMBUSTIBLES IN EXHAUST SYSTEMS OF GASOLINE ENGINES

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JANUARY 1970

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ARPAC-Cape 8-68 Steering Committee

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LONG-RANGE OBJECTIVES

It is well-known that a significant amount of CO and unburned fuel may be consumed in the exhaust system of gasoline engines. Such combustion phenomena in exhaust reactors may be used to advantage to reduce the emission of these undesirable constituents. This process is the basis of exhaust air injection systems currently installed on some automobiles.

The overall objectives of this three-year research program are:

- To determine the chemical and physical processes which affect the emission characteristics of exhaust reactors installed on selected typical engines operating at various conditions on a dynamometer test stand.
- To identify the chemical species and significant chemical reactions present before, within, and after the reactor.
- To obtain information which will be helpful in predicting the design of the next generation of gasoline engine exhaust reactors.

PHASE I PROGRESS

Progress this month has centered about fabrication of the two tank exhaust reactor system, construction of the hydrogen meter, upgrading of records, and revision of data gathering and data reduction. Additional test data have been gathered on the base engine system.

Fabrication of the two tank reactor system described in last month's progress report is underway at Walker Manufacturing. This will be used for measuring basic kinetic data. We expect completion of fabrication during February. The next step is installation on the single cylinder engine.

Design of a hydrogen meter has been completed and fabrication is underway. The basic concept was suggested by Richard Schwing, General Motors Research. The meter employs a thermal conductivity detector to sense the concentration of H_2. A more complete description of the hydrogen meter will be included in a future report. Fabrication should be completed in February.

Principal changes in data gathering and reduction place emphasis upon obtaining corrected emission values directly from the instruments and consequently a reduction in the amount of data processed by the computer. Future data reduction will include pounds of emission/bhp-hr and pounds of emission/pound of fuel for each constituent.

Some additional engine emission data has been gathered to check the repeatability of the engine and instrumentation and in particular to further evaluate the subtractive column analyzer and the NDIR NO analyzer.

Figure 1 shows dry percent CO_2, CO, and O_2 together with ppm NO as a function of measured air-fuel ratio. The engine was run at 1200 rpm, 50% full load, and MBT spark. Indolene clear fuel was used. Figure 2 shows comparative FID and NDIR hydrocarbons and total aldehydes by the DNPH method. This data is similar to that presented in the November progress report for regular gasoline.

Figures 3, 4, and 5 show the individual hydrocarbon class percent versus air-fuel ratio. The absolute hydrocarbon values may be obtained by multiplying the percents by the FID hydrocarbon ordinates of Figure 2. Note that percent paraffins decrease slightly and olefins increase slightly as the mixture is leaned. Aromatics are about constant.

It must be kept in mind that the subtractive column analyzer includes

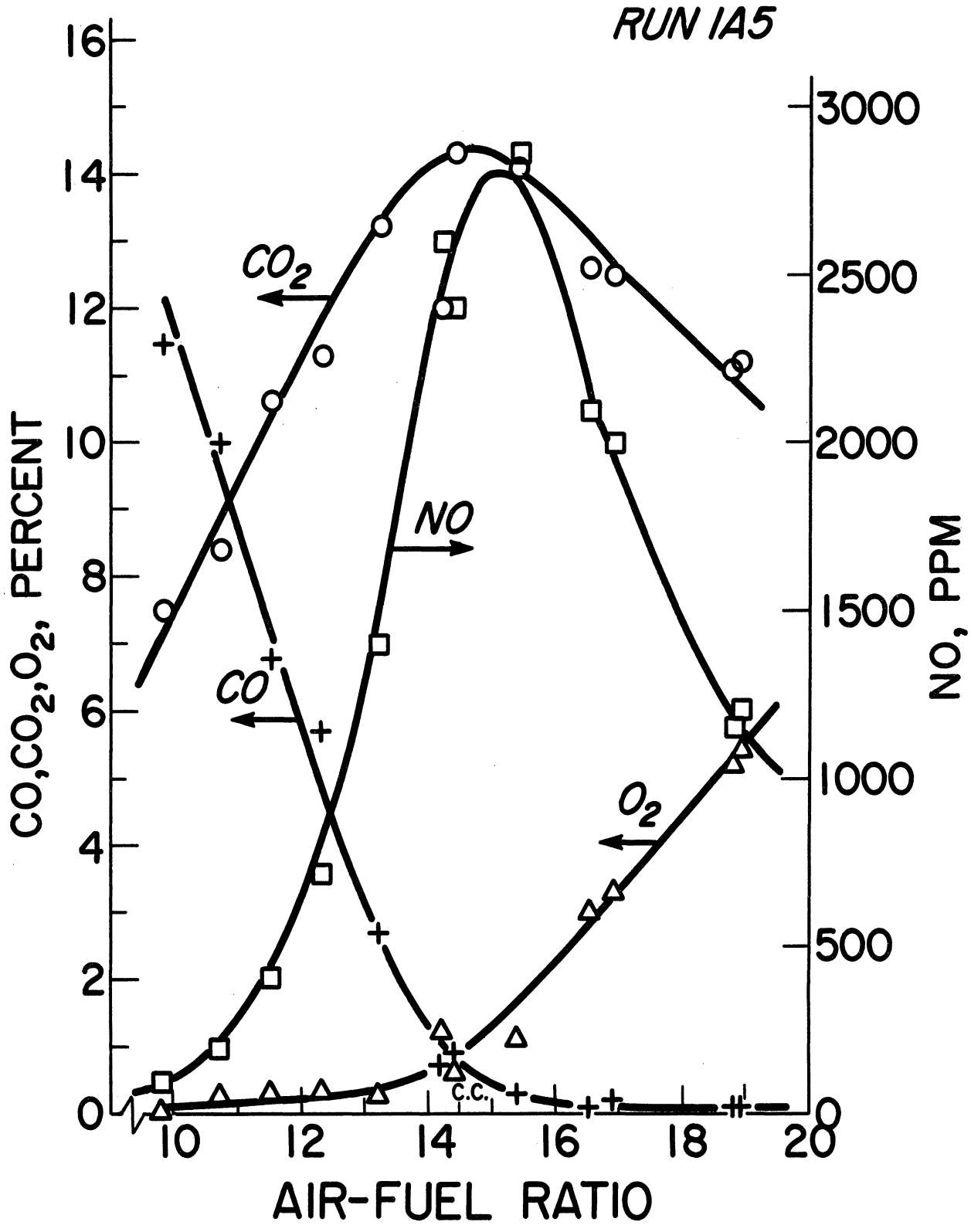


Figure 1. CO_2, CO, O_2, and NO emission vs. air-fuel ratio. 350 CID, V-8, 1200 rpm, 50% load, MBT spark, Indolene clear fuel.

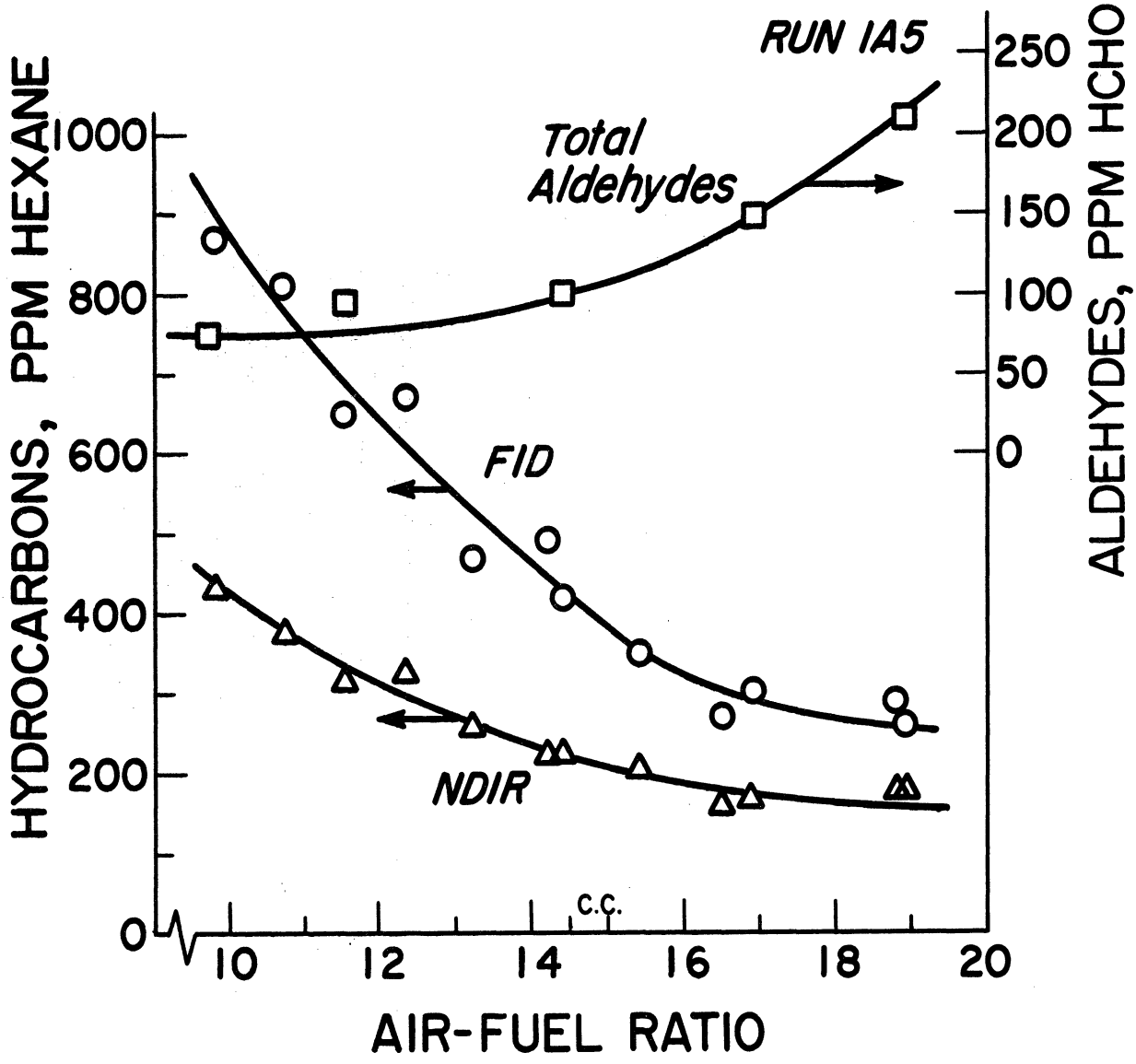


Figure 2. Hydrocarbon and aldehyde emission vs. air-fuel ratio. 350 CID, V-8, 1200 rpm, 50% load, MBT spark, Indolene clear fuel.

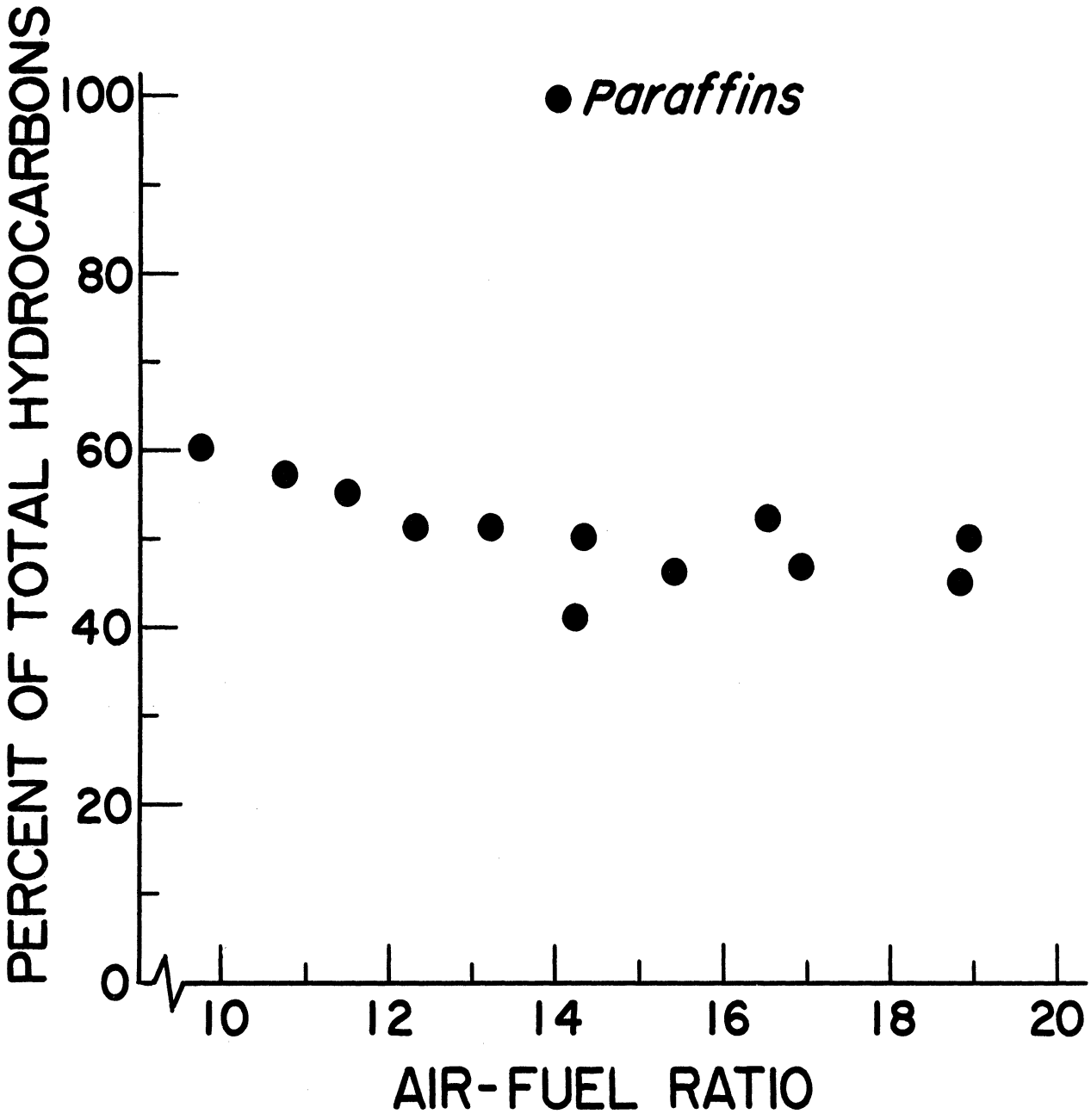


Figure 3. Paraffins vs. air-fuel ratio.

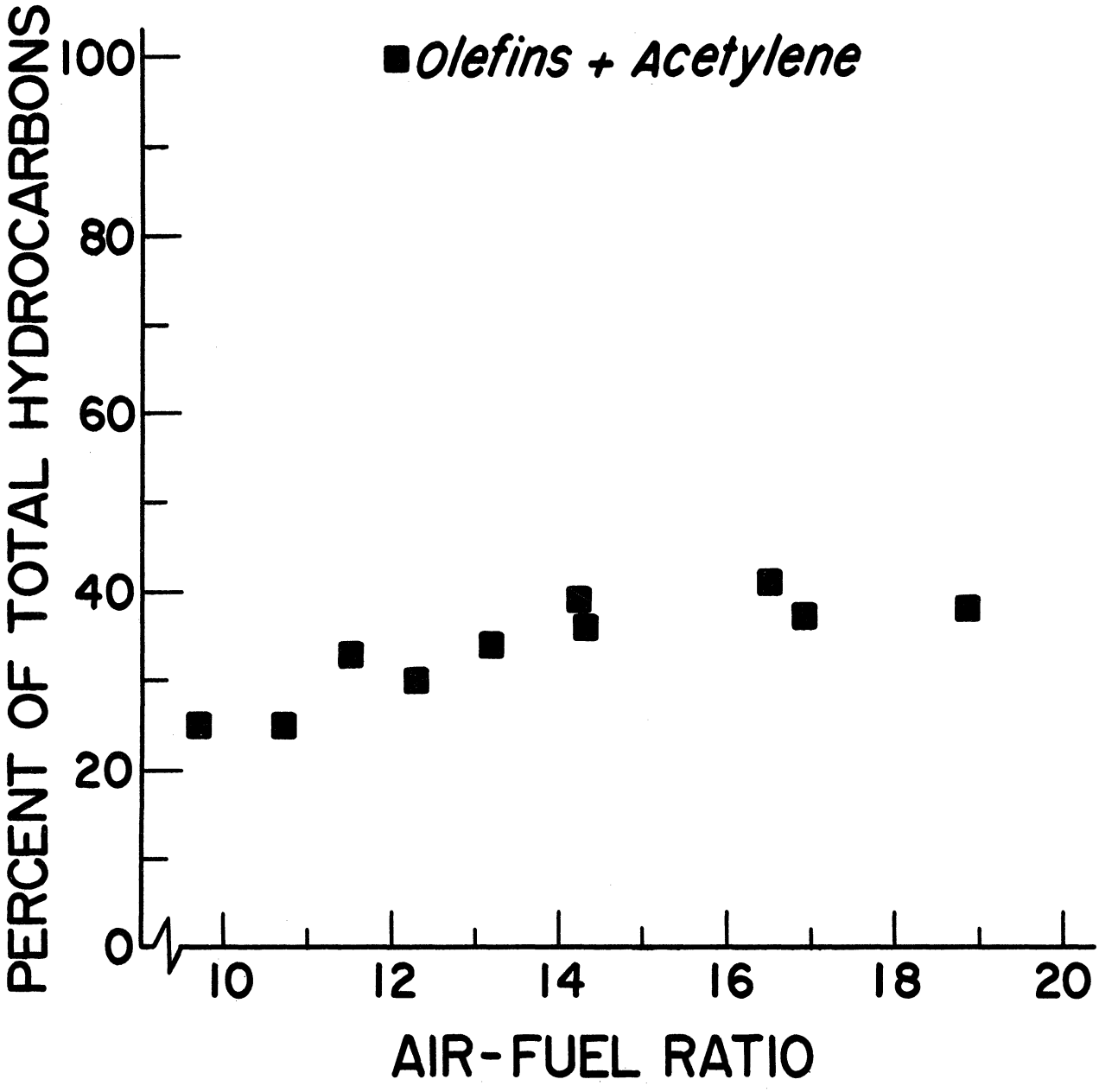


Figure 4. Olefins plus acetylene vs. air-fuel ratio.

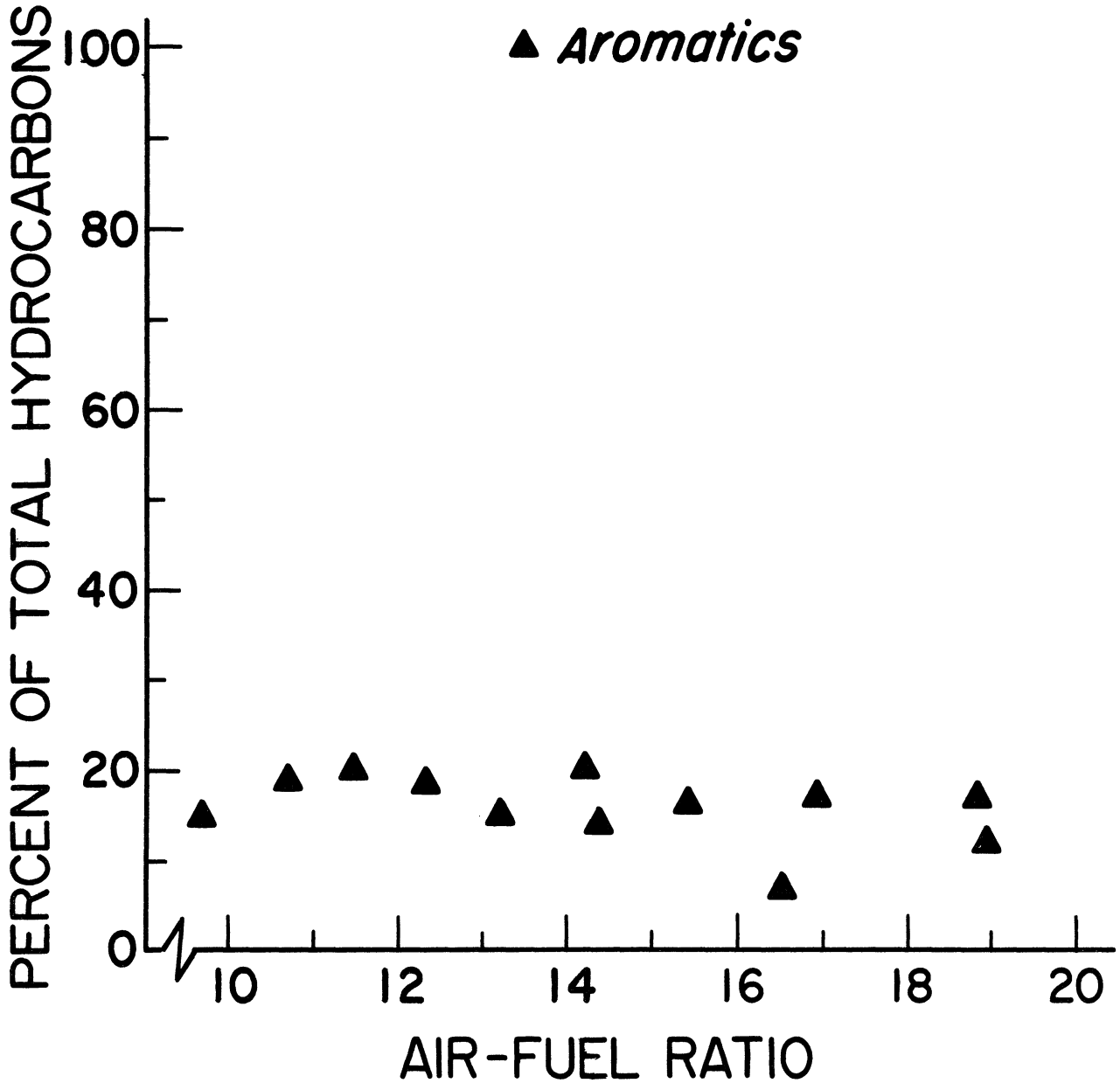


Figure 5. Aromatics vs. air-fuel ratio.

acetylenes as olefins. We do not have back up G. C. data to verify the subtractive column results.

Next the evaluation of the base engine system will be completed. We are especially interested in the effect of speed and load on NO, hydrocarbon, class percent, and aldehydes. Following this work, the duPont reactors will be installed.

PHASE II PROGRESS

Preliminary computer results from the first generation exhaust reactor simulation have lead to the following observations.

Use of an "enthalpy-averaged" temperature (defined as the temperature which preserves the same energy input as the assumed variation in temperature) was found to give results that were in good agreement with results for a time-varying temperature. This contrasts with earlier results using a time-averaged temperature. These were in considerable error. Other runs using time-averaged flow and flow-averaged compositions along with the enthalpy-averaged temperature produced results that were also in good agreement with time-varying data inputs.

Equilibrium concentrations of methane, carbon monoxide, and hydrogen were computed to be vanishingly small in the presence of moderate concentrations of oxygen (6%). Hence the water gas shift reaction will not exercise any measurable influence until oxygen concentration is very low, based on equilibrium criteria.

An attempt to run the computer simulation at a step size of 1/5 engine cycle with continuous nonpulsed input led to an unacceptable error. Without going to large step sizes the simulation cannot be run to cover the entire period of reactor warmup without incurring very high costs.

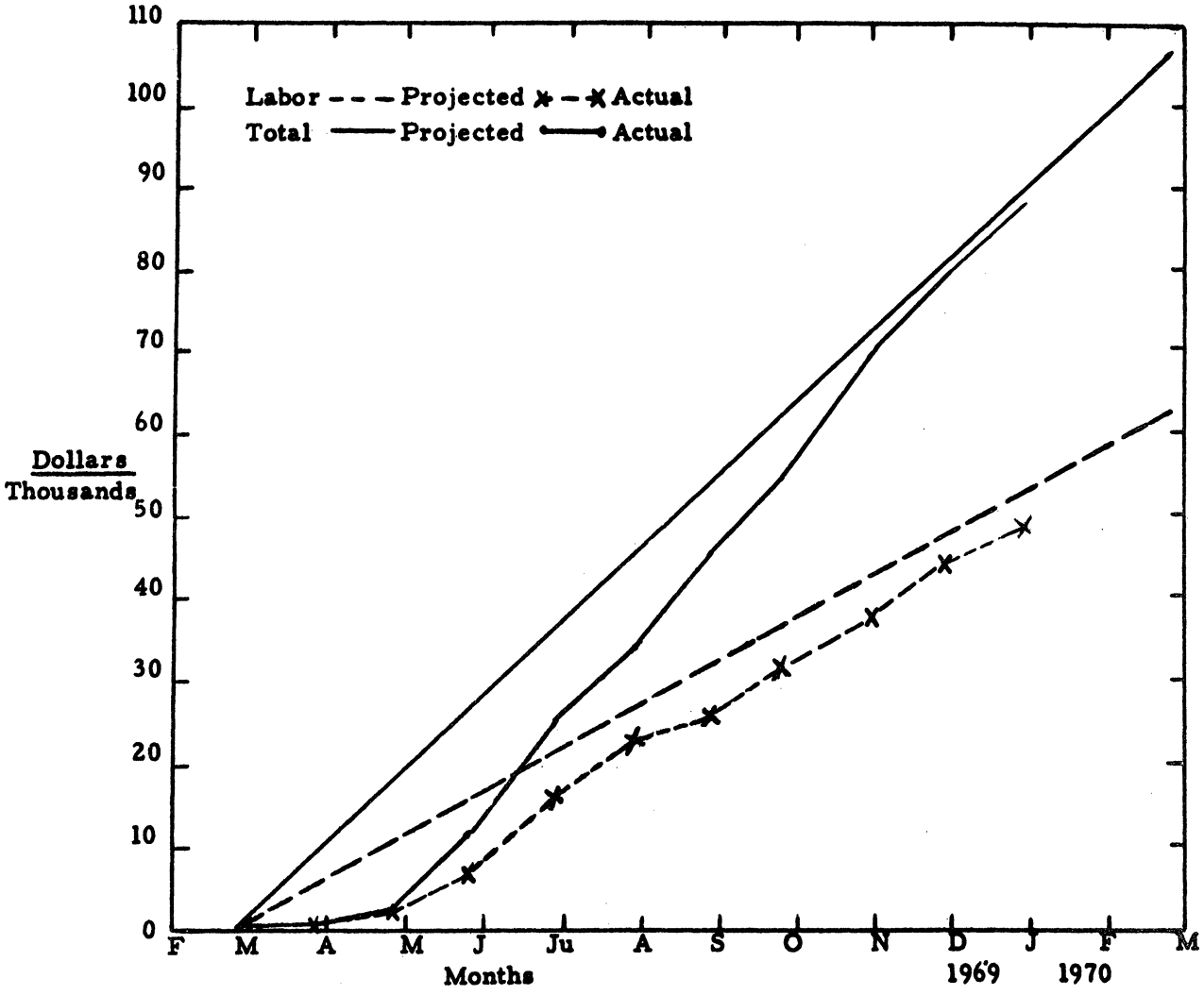
Calculations giving bounds on the rate of warmup for the reactor wall with 3-1/2 in. of ceramic fiber insulation demonstrated that the wall temperature changes too slowly to affect results for a few engine cycles. Therefore, the effect of reactor temperature during warmup is being investigated by running simulations of 3 cycles' duration each at different wall temperatures between 100° and 1200°F. This range of wall temperature affects outlet temperature by about 200°F and changes the level of methane concentration by a factor of ten.

PHASE III PROGRESS

Our gas chromatograph work has temporarily been disrupted because the man doing the work has withdrawn from the University. This event came as a complete surprise to us for we had received assurances for the continuity of this work late in December 1969. We are now looking for a new man who can continue this work.

OVERALL FINANCIAL SUMMARY

Program Total: February 24, 1969 - February 23, 1970		$106,455
Cumulative Expenditures through December 24, 1969		87,568
	Balance	$ 18,887



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