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Computer Modeling of a Liquid Fuel Spray

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COMPUTER MODELING OF A LIQUID FUEL SPRAY

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The initial phase of this project involved manipulation of a lengthy FORTRAN computer code named "Kirwan." The code originated from England many years ago and was transferred to UMR by Dr. Drallmeier. Dr. Drallmeier had the code on a series of 5.25 inch floppy diskettes and the objective of the project was to load the code on to the Apollo computer system and be able to use it. Basically, the code was designed to accept several parameters concerning the liquid fuel type and the injector type and predict what the fuel droplet size and distribution was after a finite period of time and flow distance. The code had previously ran successfully on the University of Illinois Urbana-Champaign campus. It was realized from the onset of the project that once the code was loaded, the FORTRAN compiler used here could possibly be incompatible with the code and compilation would be impossible. The first few weeks of the project involved becoming familiar with the Apollo system. Once this was achieved, the assistance of Michael Johnston was employed in operating the "PC emulator" of the Apollo system. The PC emulator is an integral program of the Apollo system which allows the shell/batch system to be transformed into a personal computer environment. This area allows for transference of code, which is how the Kirwan code was transported. Once the code was contained in account, attempts were made to compile. A lengthy list of errors were reported with compilation attempts. Upon reviewing the code, it was found that these errors stemmed from the numerous data statements throughout the code. The worst case was realized. Obviously, the U of I

compiler had allowed data statements to go unchecked, whereas the Apollo compiler did not. Solving this problem would have involved deleting and adding data, which would be a very tedious project manageable only by a participant who had intricate knowledge of the program's internal workings. Dr. Drallmeier deemed this incompatible with my involvement in the program and this phase was halted.

The second phase of the project was begun in early November 1990 and is currently ongoing. The objective of this project is to predict "Rosin-Rammler" (RR) distribution equations for a fuel spray, given scattered intensity data. The RR distribution is given as:

$$V(D) = \frac{\delta D^{\delta-1}}{D\delta} \text{ Exp } \left\{ - (D/\bar{D})^{\delta} \right\}$$

where $\bar{D}$, the mean droplet diameter, and δ, the distribution width parameter, are constants for a particular fuel spray and are the points of interest here.

The project centers around the experimental setup of Figure 1. In this experiment, a laser beam is directed through a projected fuel spray flow, scattering light. This scattered light is detected by a flat, concentric ring detector (Figure 2) which detects the light as an energy, given by:

$$\text{Energy} = L_{ik} = C \int_0^{\infty} \left\{ \left[J_o^2 + J_1^2 \right]_{\alpha\theta_i} - \left[J_o^2 + J_1^2 \right]_{\alpha\theta_k} \right\} \frac{1}{D} V(D) \, dD$$

This gives the energy incident upon one ring.

The energy given by Equation 2 is measurable and is recorded data. Note, however, the containment of V(D), the size distribution, in the integral of Equation 2. The distribution is unknown and, to be solved for, must be assumed. Several distributions have been suggested by various researchers. As noted, this project assumed the function to be a Rosin-Rammler distribution, given by Equation 1. This is a widely accepted assumption.

Note also in Equation 2 the α term. α is given by:

$$\alpha = \frac{\pi D}{\lambda}$$

The dependence of α upon drop diameter, D, makes Equation 2 all the more complicated (λ is wavelength of the laser light, a known constant). In addition, α is an argument of the Bessel functions, complicating matters further still. Also, note the θ term in Equation 2. $(\theta_i - \theta_k)$ is the angle from the bottom of the ring to the top of the ring.

An iterative procedure has been chosen to solve Equation 2 for for V(D), or more specifically, $\bar{D}$ and δ. To do this, a curve-fit method is to be employed.

Educated guesses will be made for $\bar{D}$ and δ and energies calculated from Equation 2. This will then be compared to energy data from experiment and adjustments made in $\bar{D}$ and δ with repetition until the calculated energies equal the experimental energies. Once the energies are equal, the correct $\bar{D}$ and δ values are known. Although this appears as a cookbook operation, Equation 2 is not a simple equation to solve. The first step in this project has been to write computer code to evaluate this integral equation. To do so, data from a calibration reticle was employed. A calibration

reticle is a thin gold foil slide which has been precisely etched. The gold is etched away to leave a known number of known diameter particles, simulating fuel drops on a slide. With all numbers of particles and particle diameters known, the $\bar{D}$ and δ parameters of the Rosin-Rammler distribution equation are also known. This data can then be inserted into Equation 2. The second step in creating the simulation code was actually writing the code. The first hurdle overcome was writing from scratch a Bessel function subroutine. This was completed by using polynomial expressions for Bessel functions as displayed in a math CRC handbook. Once the Bessel function subroutines were operable and checked with CRC table values, the integral equation had to be encoded. This was done by using a Simpson Rule approximation from calculus. The function is integrated from a minimum diameter to a maximum diameter in incremental steps of discrete diameter sizes (all of this information for diameter sizes came from the calibration reticle data). Note that Equation 2 computes energy for a finite angle range. To decide upon this range, a radius for the rings must be decided upon. Initial calculations were run using a logarithmic radius for each ring. The calculations were then run again using inner and outer radii of each ring. The inner and outer radii calculations were used since this was the basis for the calibration reticle calculations.

Figure 3 is a plot of calibration reticle energy values and the energy calculations made by the Simpson code discussed here. The trends match very well with the exception of one data point which is suspected to be a data entry error. Once it has been established that this code makes an accurate prediction of ring energies (which

it appears that a little polishing of the code will bring about), it will then be used for the iterative procedure discussed above. It is conceivable that the present code will be integrated into a much larger code which will accept Rosin-Rammler parameters and produce the calculated energies. An extension of this plan is for the code to automatically run through a group of RR parameters and match up the best calculated energy with the inputted experimental energy. This would resemble a linear best fit routine, but would instead be non-linear.

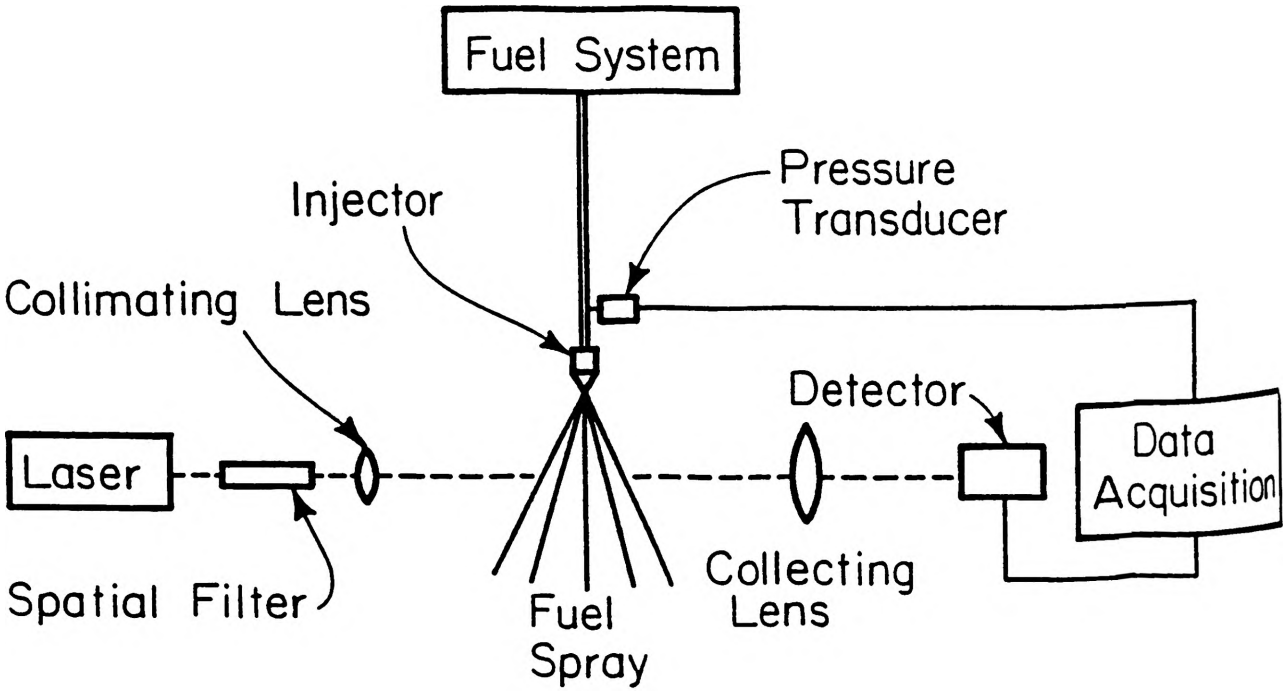
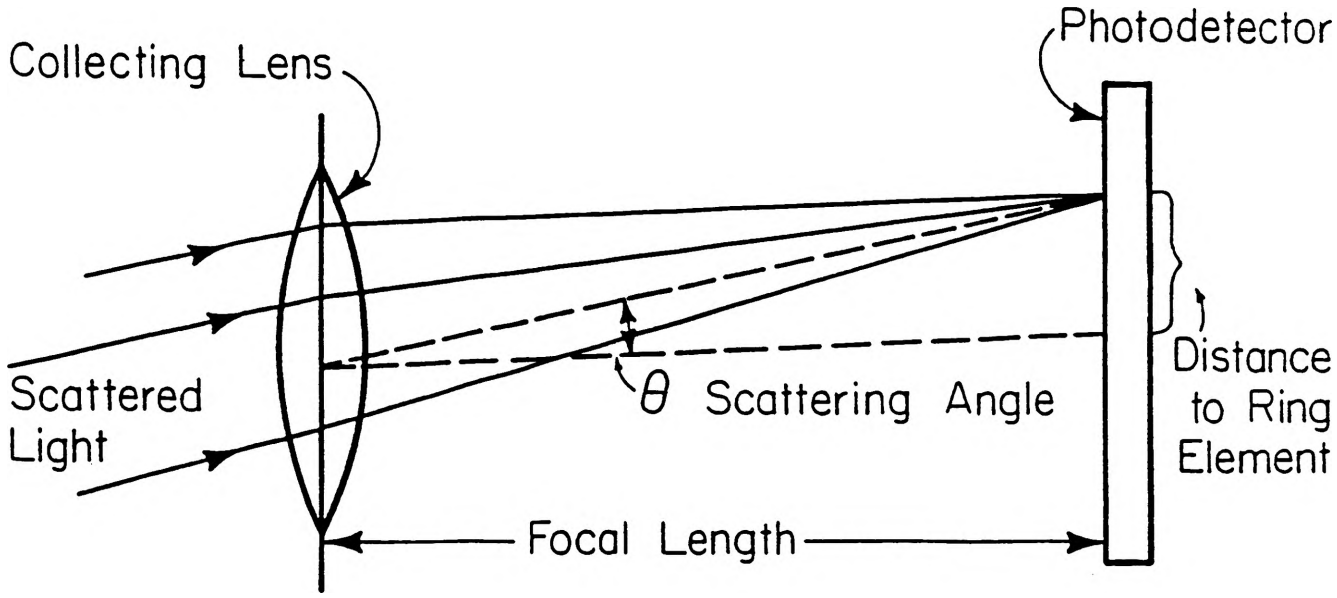


Figure 1) Experiment Setup



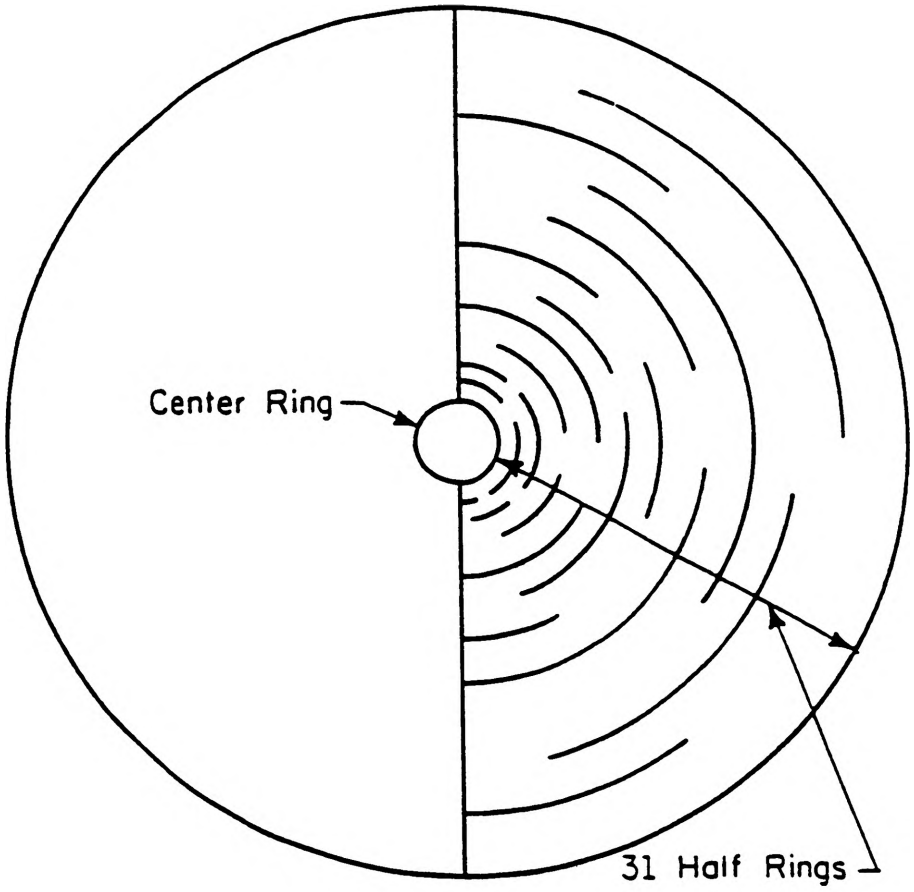


Figure 2) Ring Detector

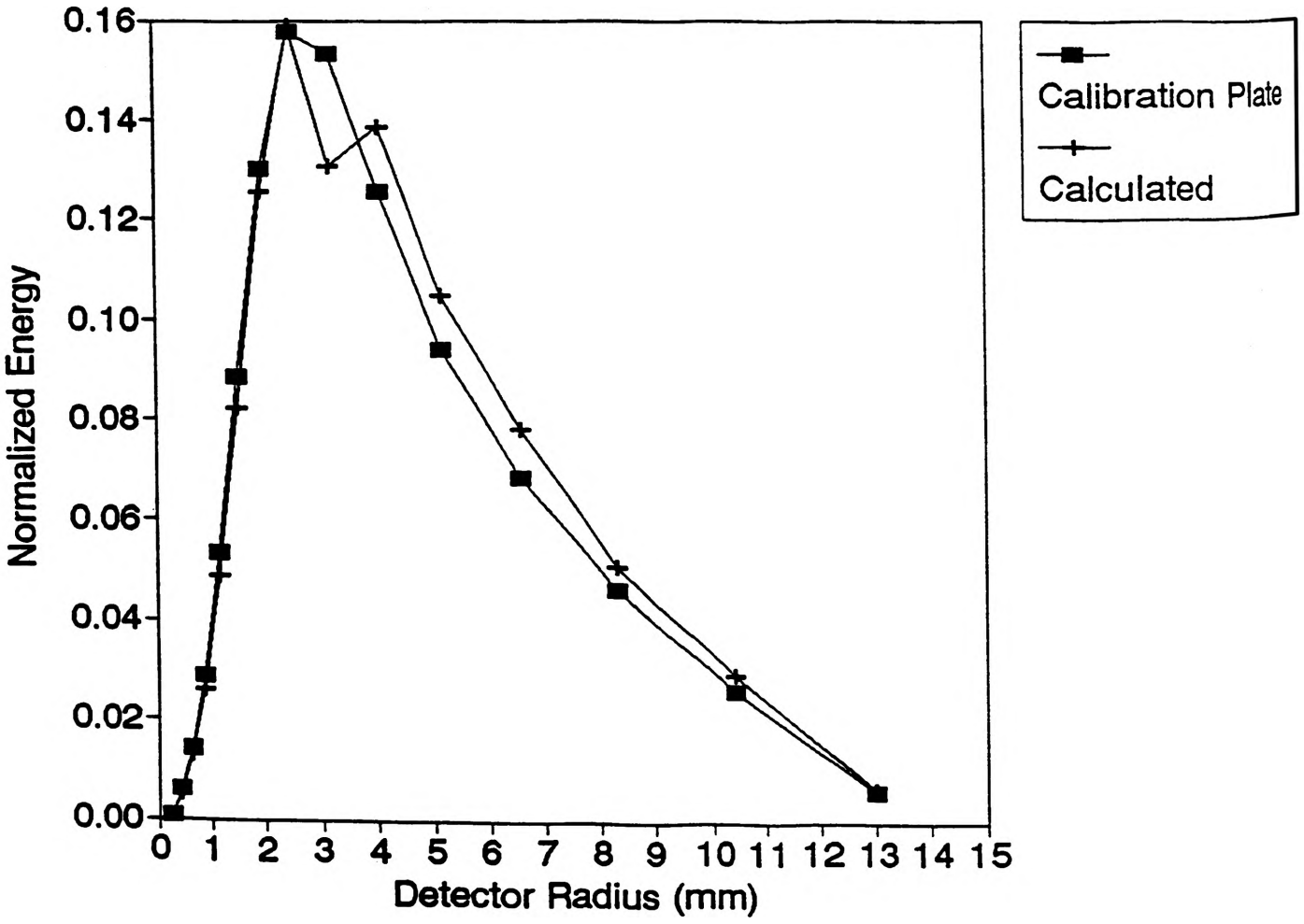


Figure 3) Plot of Results