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thesis entitled

TECHNIQUES FOR MEASURING IN-SITU
OIL DROP DISTRIBUTION AND CONCENTRATION

presented by

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has been accepted towards fulfillment
of the requirements for

MASTERS degree in CIVIL ENGINEERING

Major professor

Date 5/13/88

TECHNIQUES FOR MEASURING IN-SITU OIL DROP DISTRIBUTION AND CONCENTRATION

By

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AN ABSTRACT OF A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Civil and Environmental Engineering

1988

ABSTRACT

TECHNIQUES FOR MEASURING IN-SITU
OIL DROP DISTRIBUTION AND CONCENTRATION

By

Thomas Mark Rushlow

The detrimental impact of oil spills on the environment has led to the performance of numerous investigations to quantify the physical properties of a spill. From these investigations, many oil dispersion models have been developed which estimate the vertical dispersion, horizontal dispersion and aging of the oil. An investigation was performed to further describe the vertical dispersion of oil in water. As part of this investigation, techniques were developed to measure the distribution of oil drops and oil concentration in a modelled ocean environment. Photographic procedures were utilized to collect the oil drop distribution data. This included image processing techniques to analyze the photographs. Oil concentration information was collected and analyzed utilizing an extraction procedure which included measurements with a fluorometer. The methods utilized to collect and analyze data are summarized. In addition, a summary of the results of each measurement is provided.

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A Source Code of Pascal Computer Program for Measuring Oil Drop Diameter.

1.0 INTRODUCTION

The detrimental impact of oil spills on the environment has led to the performance of numerous investigations to quantify the physical properties of a spill. From these investigations, many oil dispersion models have been developed which estimate the vertical dispersion, horizontal dispersion and aging of the oil.

An investigation was performed to describe the vertical dispersion of oil in water. This is known to depend on weather conditions and oil properties. Data describing weather conditions collected for this investigation included; wave breaking, wind velocity, and water turbulence. Oil properties which were described included; oil film thickness, drop size, and concentration. The methods utilized to collect data on the oil drop size and concentration are described herein. This includes a description of the apparatuses and procedures developed to collect and analyze data and a summary of results.

To conduct experiments for the investigation, an artificial environment was constructed in a wind tunnel to model the ocean water surface. Constant parameters utilized in this model included; a wind velocity of 6.6 m/s measured 10 cm above the water surface, a wave period of 0.5 seconds,

and a wave length of 0.39 m. Two oil slick conditions related to oil slick thickness were generated for study. The slick thickness for Conditions 1 and 2 was 0.15mm and 0.55 mm, respectively.

2.0 OIL CONCENTRATION MEASUREMENT

Oil slicks are vertically dispersed into the water column by wave action which breaks the slick into oil drops and forces them down. Once below the water surface, turbulent motions provide an additional mechanism for transporting drops down. The driving forces of the breaking waves and turbulence are counteracted by the bouyant force of the oil which drives the drop back to the surface. However, some fraction of the small particles remains entrained so long as the driving forces exist.

The oil concentration was measured at several locations in the wind tunnel. This data was then correlated with predicted oil concentrations from the dispersion model to evaluate the oil entrainment rate. From this rate, the decrease in slick thickness could be estimated.

2.1 Apparatus

A system was developed to obtain samples of oil and water from the wind tunnel and to measure the oil concentration in each sample. This system was composed of sampling tubes and glass containers to collect samples from the wind tunnel. The measurement equipment consisted of various glassware to extract oil from the water and a Turner fluorometer for measuring oil concentration.

Sampling tubes were located at six positions along the length of the wind tunnel. They were positioned 0, 1.2, 2.4, 4.8, 6.0, and 7.2 m downwind from the point where wave breaking initially occurs. The sampling points were centered in the tunnel and approximately 18 cm below the still water surface. Figure 1 illustrates the location of the sampling points. Pinch clamps were utilized for sealing the sampling tubes until a sample was collected. The clamps were opened by hand so that they would release 250 ml of oil and water during the collection period. Samples were collected in 250 ml glass bottles that were sealed with standard plastic tops.

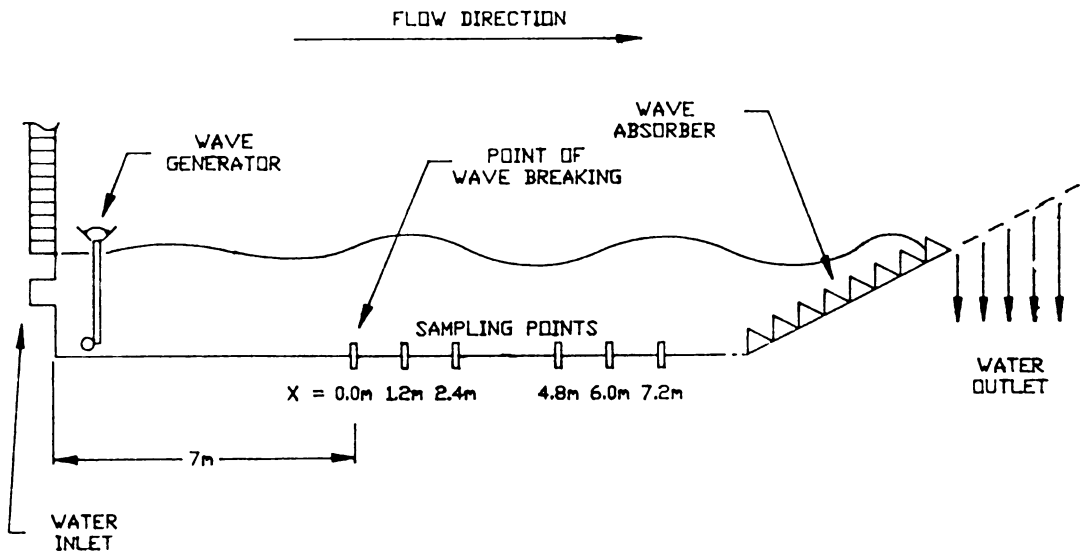

Figure 1: Location of Oil/Water Sampling Points in the Wind Tunnel.

The glassware utilized in the concentration measurements consisted most importantly of a separatory funnel and quartz cuvette. The separatory funnel was used to separate the extracted oil from the oil/water sample. All oil concentration measurements were made in a quartz cuvette due to its low fluorescent properties. These procedures are described further in Section 2.2. A Turner fluorometer was employed to make these measurements. A calibration curve relating oil concentration to fluorescence was utilized to determine oil concentration of the sample.

2.2 Procedure

Several steps were involved to collect and process a sample from the wind tunnel to where its oil concentration could be measured. The steps of the collection procedure included cleaning the sample bottles and sampling the oil/water mixture from the wind tunnel. The sample processing procedure included; preserving the sample, extracting the oil from the sample, and measuring the oil concentration with a fluorometer. The procedure utilized for each step is described below.

2.2.1 Sample Collection

The containers utilized to hold the oil/water samples were thoroughly cleaned before sampling. This minimized the amount of contamination which could contribute to the florescence of the sample. Each bottle and cap was first washed with warm soapy water and then rinsed with warm tap water until all soap residue had been removed. Distilled water was used for the final rinse. The bottles were oven-dryed at a temperature of 103^{o} C for approximately 12 hours. The plastic caps were placed on paper toweling and allowed to dry over the same time period.

At the beginning of each experiment, the tank was washed with warm soapy water and thoroughly rinsed to remove all soap residue. The cleaned tank was filled with filtered water to a depth of approximately 21.5 cm. A wind generator was started after filling the tank. Oil was then released onto the water surface and allowed to travel to the far end of the tank before a wave generator was started. The sampling procedures were begun once wave breaking occurred at $x = 0$ m. A contraction in the wind tunnel which begins at this location induces wave breaking further downstream.

Oil/water samples were withdrawn from the wind tunnel at different time intervals dependent on the sampling location.

Samples from locations 0, 1.2, 4.8, 6.0, and 7.2 m were taken at approximately ten minute intervals over a 40 minute period. At 2.4 m, the sample was obtained at 2 minute intervals over the same time period. The time to withdraw each sample was approximately 14 seconds.

2.2.2 Sample Processing

After the oil/water samples had been collected, they were prepared for storage using a standard preservation technique (References 1 and 2). Each sample was acidified with 0.5 ml of 37% hydrochloric acid and refrigerated in the dark at 6^{o} C. The samples were stored until an extraction process to separate the oil from the water could be performed. This preservation technique stabilized the samples and prevented them from oxidizing. Oxidation could change the florescent properties of the oil. Measurements performed on the same samples approximately 3 months apart indicated only small changes in oil concentration which verified the stability of the samples in storage.

A standard extraction procedure (References 1 and 2) was utilized to separate the oil from the oil/water sample obtained from the wind tunnel. In general, the oil/water sample was combined with a solvent having a greater affinity for oil than water. Hexane was utilized as the solvent because of its low flourescent properties. The oil/solvent

mixture is easily separated from water. The extraction process provides a more concentrated and uniformly mixed sample improving the accuracy of the oil concentration measurement.

The glassware used in the extraction procedure was thoroughly cleaned to minimize contamination of the sample. This involved washing the glassware with warm soapy water and rinsing with tap water until all the visible soap residue was removed. The glassware was then rinsed six times with distilled water and oven-dryed at 103^{o} C for approximately 12 hours. Before each oil/water sample was extracted, the glassware was rinsed with pure hexane to wash all inside surfaces.

The extraction process consisted of three steps. These steps included; mixing the oil/water sample with the hexane, allowing the hexane to combine with the oil, and separating the oil/hexane mixture from the water. The process was begun by pouring the water/oil sample into a separatory funnel. Approximately 10 to 12 ml of hexane was then added to the sample bottle to rinse the inside surface of any excess oil. The hexane in the sample bottle was then added to the sample in the separatory funnel. The funnel was sealed and shaken for 1 minute; pausing every 15 seconds to vent gas build-up. In this way, the hexane could combine with the oil in the water. The mixture was then set aside for approximately 5

minutes. A thin layer of oil and hexane forms at the surface of the mixture as a result of the process. The water was then drained from the funnel back into the sample bottle. The oil/hexane mixture was drained into a 25 ml graduated cylinder. The process was repeated a second time to extract any remaining oil from the water. If the 25 ml graduated cylinder was not filled after the two extractions, pure hexane was added to completely fill the cylinder. The oil/hexane mixture (here after referred to as the extracted sample) was then poured into a 25 ml glass test tube. The test tube was sealed with aluminum foil rinsed in hexane and a teflon lined cap. The oil/hexane mixture was then stored in a dark refrigerator at 6^{o} C.

Measurement of the oil concentration in the extracted samples was performed using a Turner fluorometer. The process involved setting up and calibrating the fluorometer for the range of concentrations being measured and measuring the concentration of each sample.

The fluorometer was adjusted so that the range of concentrations being measured corresponded to the range of the fluorometer scale. Adjustment of the fluorometer included selecting the proper light source, light filters, and sample holder to establish the sensitivity of the instrument. The fluorometer was setup with a far ultra-violet lamp, four standard light filters, and a standard

sample holder. The four light filters utilized in this study included a 254 nm filter on the primary side of the fluorometer and 7-60, 90%, and 10% filters on the secondary side. A window in the fluorometer limited the amount of ultra-violet light passing through the light filters and sample. This window was set at 3X. Several experiments were performed with this setup before actual measurements were made to verify the instrument calibration was in a linear range.

Each sample was placed in a quartz cuvette for measurement. The cuvette was used to minimize the amount of fluorescence added to the system from sources other than the sample. It was washed for each set of measurements in the same manner as the glassware and towel dryed with a lint-free tissue and rinsed with pure hexane. The cuvette was marked so that it could be positioned in the fluorometer in approximately the same location each time a sample was read.

The steps required to prepare for measurement included; allowing the fluorometer to stabilize before and after a measurement was made, removing the samples from storage, and diluting the sample to obtain a reading in the calibrated range. The fluorometer was allowed to warm up for approximately 30 minutes before measurements were made. During the measurement of a sample, the fluorometer reading was allowed to stabilize for approximately 1 minute. After

the measurement was taken, the sample was removed from the fluorometer and the door left open until the next sample was ready for measurement. This prevented excess heat build-up in the fluorometer. The extracted samples were removed from refrigeration and allowed to come to room temperature in a dark area before they were measured. It was found that the sample had to be diluted before measurement to obtain readings in the calibrated range. A common dilution was on the order of 1 to 100. Diluting the sample did not present a problem since the range of calibration was linear. After each reading, the sample was disposed of and the cuvette rinsed with pure hexane before the next sample was read. It was found that periodically cleaning the cuvette improved reproducibility of the readings.

A calibration curve for determining the oil concentration of the samples from the fluorometer readings was developed. The curve was constructed by measuring the fluorescence of extracted standard samples with known oil concentrations. The standard samples were made by combining a known volume of oil with hexane and adding the mixture to 250 ml of tank water. Hexane was required to accurately measure and combine the small volumes of oil with water to obtain concentrations within the range of calibration. Zero concentration was established utilizing tank water taken from the line that supplied water to the wind tunnel. The standard samples were extracted using the previously described procedure.

2.3 Results

The results of the oil concentration measurements are illustrated on Figures 2 through 6. These figures present the horizontal variation of oil concentration with the rate of oil release. The data utilized to develop these figures is presented in Tables 1 through 3.

The sampling began when wave breaking initially occurred at the beginning of the channel contraction in the wind tunnel (X = 0.0 m). Samples were collected at approximately 10 minute intervals at all locations except X = 2.4 m. At this point, samples were collected at 2 minute intervals. Each experiment was run for approximately 40 minutes. Figures 2 through 5 indicate low oil concentrations initially at time zero due to either background oil remaining in the tank after cleaning or initial wave breaking in the vicinity of the sample point. After the experiment had run for 2 minutes, the measured oil concentration had increased to a level which remained constant through the remainder of the experiment at each sampling location. Fluctuations in concentration were assumed to be random. These fluctuations about a mean value can be explained by the intermittant nature of wave breaking and could be reduced toward the mean value if the samples were collected over a longer time period.

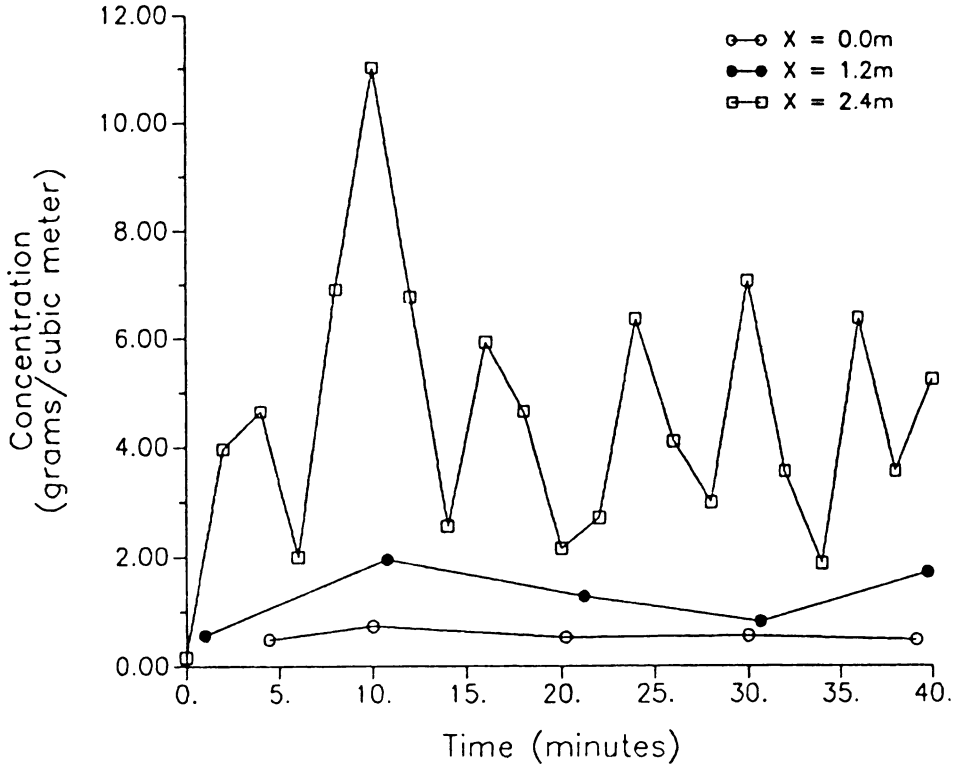

Figure 2: Measured Oil Concentrations; Oil Release Rate = 0.11 l/s; x = 0, 1.2, & 2.4 m.

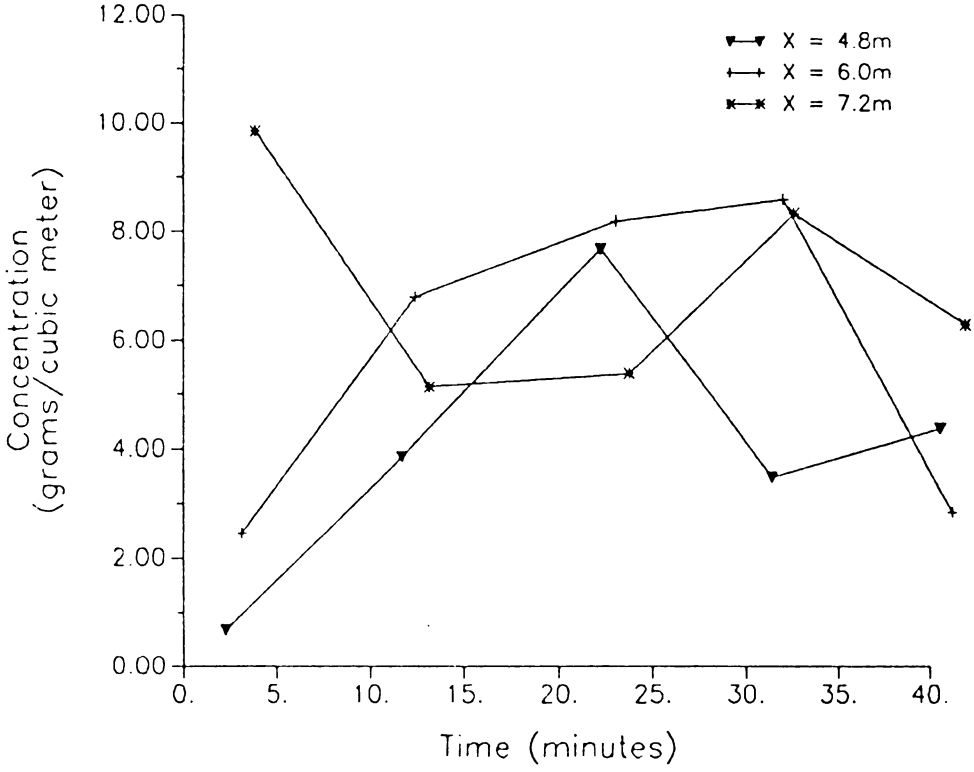

Figure 3: Measured Oil Concentrations; Oil Release Rate = 0.11 l/s; x = 4.8, 6.0, & 7.2 m.

Table 1: Measured Oil Concentrations; Oil Release Rate = 0.11 l/s.

X = 0.0m		X = 1.2m		X = 2.4m		X = 4.8m		X = 6.0m		X = 7.2m	
T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)
4:26	0.49	1:00	0.57	0:00	0.16	2:15	0.68	3:08	2.46	3:50	9.85
10:00	0.73	10:46	1.95	2:00	3.97	11:41	3.86	12:24	6.79	13:10	5.14
20:14	0.53	21:12	1.27	4:00	4.66	22:14	7.68	23:02	8.19	23:44	5.39
30:01	0.55	30:40	0.81	6:00	2.00	31:22	3.48	32:01	8.57	32:37	8.32
39:07	0.48	39:44	1.70	8:00	6.91	40:33	4.37	41:10	2.84	41:54	6.28
				10:00	11.0						
				12:00	6.77						
				14:00	2.56						
				16:00	5.93						
				18:00	4.66						
				20:00	2.15						
				22:00	2.71						
				24:00	6.35						
				26:00	4.10						
				28:00	2.99						
				30:00	7.05						
				32:00	3.55						
				34:00	1.87						
				36:00	6.35						
				38:00	3.55						
				40:00	5.23						

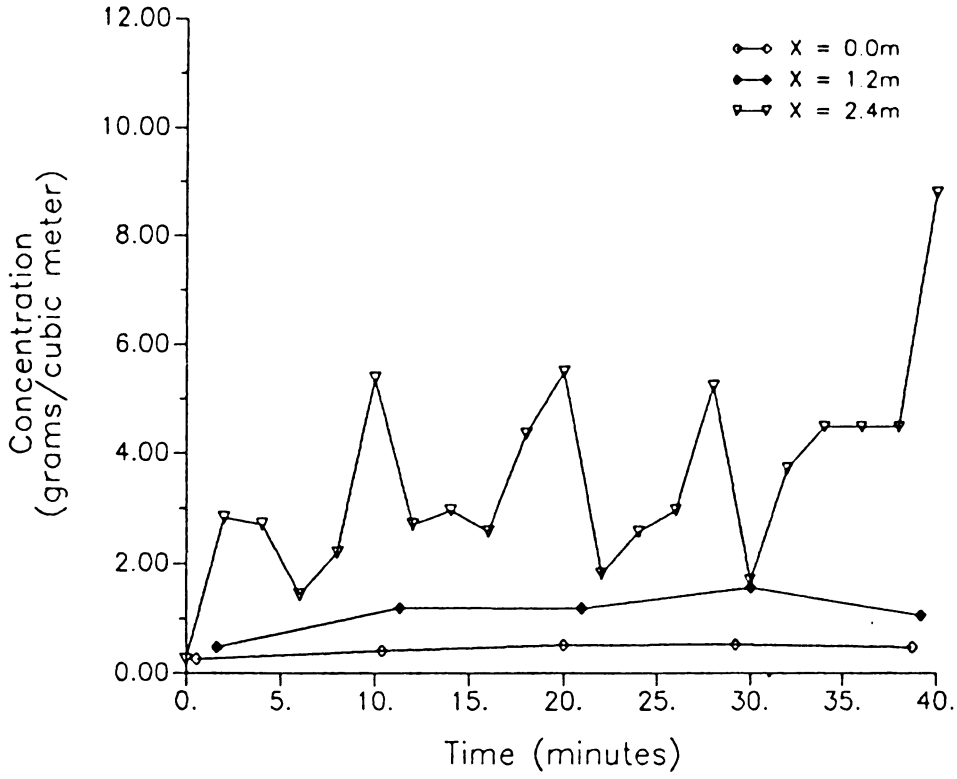

Figure 4: Measured Oil Concentrations; Oil Release Rate = 0.35 l/s; x = 0, 1.2, & 2.4 m.

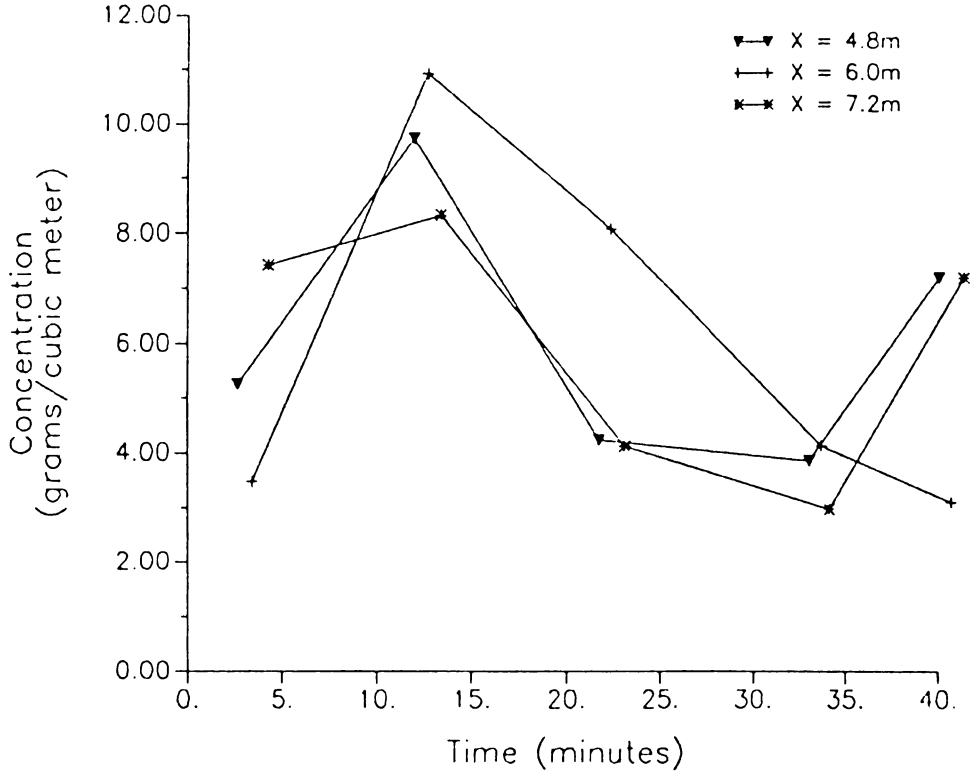

Figure 5: Measured Oil Concentrations; Oil Release Rate = 0.35 l/s; x = 4.8, 6.0, & 7.2 m.

Table 2: Measured Oil Concentrations; Oil Release Rate = 0.35 l/s.

X = 0.0m		X = 1.2m		X = 2.4m		X = 4.8m		X = 6.0m		X = 7.2m	
T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)	T (m:s)	C (g/m^3)
0:33	0.26	1:38	0.48	0:00	0.25	2:39	5.26	3:25	3.48	4:15	7.43
10:23	0.41	11:20	1.20	2:00	2.84	12:00	9.72	12:45	10.9	13:25	8.32
20:00	0.51	20:57	1.19	4:00	2.72	21:44	4.24	22:23	8.07	23:05	4.12
29:14	0.53	30:02	1.57	6:00	1.44	33:02	3.86	33:40	4.12	34:07	2.97
38:43	0.48	39:18	1.06	8:00	2.21	40:03	7.17	40:40	3.10	41:22	7.17
				10:00	5.39						
				12:00	2.72						
				14:00	2.97						
				16:00	2.59						
				18:00	4.37						
				20:00	5.52						
				22:00	1.82						
				24:00	2.59						
				26:00	2.97						
				28:00	5.26						
				30:00	1.70						
				32:00	3.73						
				34:00	4.50						
				36:00	4.50						
				38:00	4.50						
				40:00	8.83						

The variation in oil concentration in the horizontal direction is presented in Figure 6. The time averaged oil concentration for t > 2 minutes at each sampling location is plotted for each oil release rate. The results indicate a tendency for time-averaged concentration to increase with distance in both experiments.

The variation in oil concentration with the oil release rate is also presented on Figure 6. Higher oil concentrations were measured at the lower oil release rate upstream of X = 3 m. This is explained by the thinner layer of oil created by the lower release rate which has a faster entrainment rate for a given wave and wind condition. At locations downstream of X = 3 m, no spatially consistent difference in oil concentration with oil release rate was found.

These results were utilized to predict the entrainment rate of oil into water. The measured oil-in-water concentrations were correlated with the concentrations predicted by a mathematical model describing the oil concentration and buildup in water. The slope of the regression line fit to these data provided an estimate for the actual oil entrainment rate (Reference 3).

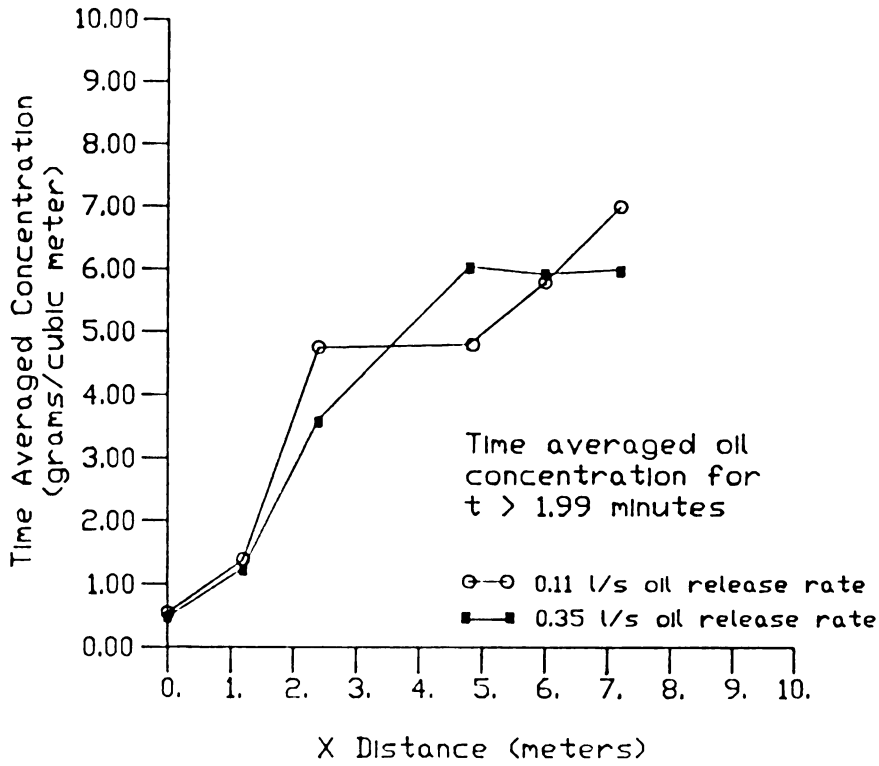

Figure 6: Time Averaged Oil Concentrations; Oil Release Rates = 0.11 & 0.35 l/s.

Table 3: Mean and Standard Deviation of Oil Concentrations (T > 2.25 min.); Oil Release Rate = 0.11 l/s and 0.35 l/s.

	X = 0.0m	X = 1.2m	X = 2.4m	X = 4.8m	X = 6.0m	X = 7.2m
			oil release rate = 0.11 l/s			
Mean (g/m^3)	0.55	1.43	4.72	4.85	5.77	7.00
Std.Dev. (g/m^3)	0.10	0.50	2.28	1.92	2.93	2.03
			oil release rate = 0.35 l/s			
Mean (g/m^3)	0.48	1.25	3.61	6.05	5.93	6.00
Std.Dev. (g/m^3)	0.05	0.22	1.79	2.42	3.41	2.32

3.0 SMALL OIL DROP MEASUREMENT

The distribution of oil drop sizes were measured to better understand the mixing processes which occur in the ocean environment and to clarify the role bouyancy has on the distribution of these particles. A distinction is made between large and small drops because of the two systems developed to measure drop diameters of various sizes. The following system was limited to measuring oil drop diameters in the range of approximately 0.009 mm. to 0.5 mm.

3.1 Apparatus

The major components of this system were a sampling apparatus, a disecting microscope, and a projector. The sampling apparatus was utilized to collect the oil drops for measurement. Once a sample was captured, it was photographed with a disecting microscope. The photographs were analyzed by projecting them onto a screen. Each of these components is described below.

The sampling apparatus consisted of a sampling tube, acrylic chamber, and pressure regulation system as illustrated in Figure 7. The Tygon sampling tube was centered in the wind tunnel and located approximately 18 cm below the still water surface. This tube was 0.318 cm in

diameter. Samples were drawn into an acrylic chamber. The chamber was constructed entirely of a clear acrylic plastic with the exception of the removeable top. The top was made of plate glass for its resistance to scratching and the ability to photograph through it. The acrylic chamber was approximately 3.8 cm high and has an inside diameter of 3.8 cm. Its volume was approximately 43.4 cm^3. The glass top was attached to the chamber by six brass screws. A seal between the glass and acrylic was achieved by means of a rubber "O" ring. The sampling tube and pressure regulation system were connected to the chamber by means of two brass orifices near the bottom and on opposite sides of the chamber. Samples were withdrawn from the wind tunnel into the sample chamber by controlling the pressure in the tank that was part of the pressure regulation system. The pressure in the system was monitored by a gage attached to the pressure tank.

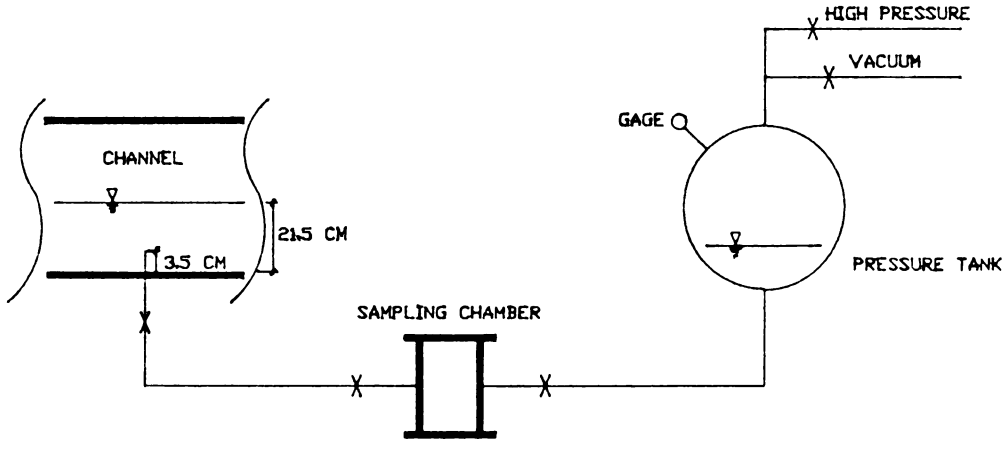

Figure 7: Apparatus for Small Oil Drop Collection.

Once a sample was captured in the chamber, the small oil drops were allowed rise to the top inside surface where they were photographed using a 35 mm camera attached to a disecting microscope. The microscope enlarged the drops by 10X. This was necessary to accurately measure drop diameters. The 35 mm camera was mounted directly on the microscope. Each photograph covered an area of approximately 6 mm^2. Approximately 150 photographs were required to cover the entire surface of the sampler. Kodak Ektachrome color slide film was utilized to photograph the small oil drops. Color film distinguished the edges of the drops more clearly than black and white. The film was processed with a standard procedure by a photographic lab.

The small drop diameters were manually measured by projecting their images onto a grid. The spacing on the grid was 10 squares per inch. The drop diameters were measured to the nearest tenth of an inch. The projector was set horizontal and perpindicular to the screen to minimize the distortion of the projection. A scale factor to reduce the measured diameter to the true diameter of the drop was determined by photographing a scale of known length with the disecting microscope.

3.2 Procedure

The data for the small drop diameters was gathered by withdrawing a sample from the wind tunnel into the acrylic chamber, photographing the top surface of the chamber, and measuring the drops on the photographs. A sample was withdrawn from the tunnel under a pressure of -6 in/Hg gage. At this pressure, a velocity of approximately 0.8 m/s was measured in the sampling tube. The velocity corresponds to a Reynold's Number of approximately 2500 which is sufficiently small to insure that drops being withdrawn from the wind tunnel were not torn apart by the sampling system (Reference 4). The sampling time was approximately 40 seconds which allowed approximately 5 chamber volumes to be withdrawn. At no time was gas allowed to enter the system. After a sample had been obtained, the entrance tube to the chamber was clamped. A gage pressure of 5 in/Hg was then placed on the sample. This prevented gas from coming out of solution in the chamber. The tube leading to the tank was clamped and the chamber removed for further analysis.

The top of the sampling chamber was accurately and completely photographed by use of a positioning grid. A circle was drawn on the grid with the exact diameter of the sampling chamber. This circle was sub-divided into 150 rectangles with dimensions of approximately 2 mm by 3 mm. Each rectangle represented a photograph to be taken of a

segment of the chamber surface. Mounted on the bottom of the sampling chamber was a square positioning plate which was carefully moved over the positioning grid to locate the camera for each photograph. Photographs occasionally overlapped but this was easily corrected by noting the position and orientation of the drops when viewing each photograph. A diagram illustrating the equipment is presented on Figure 8.

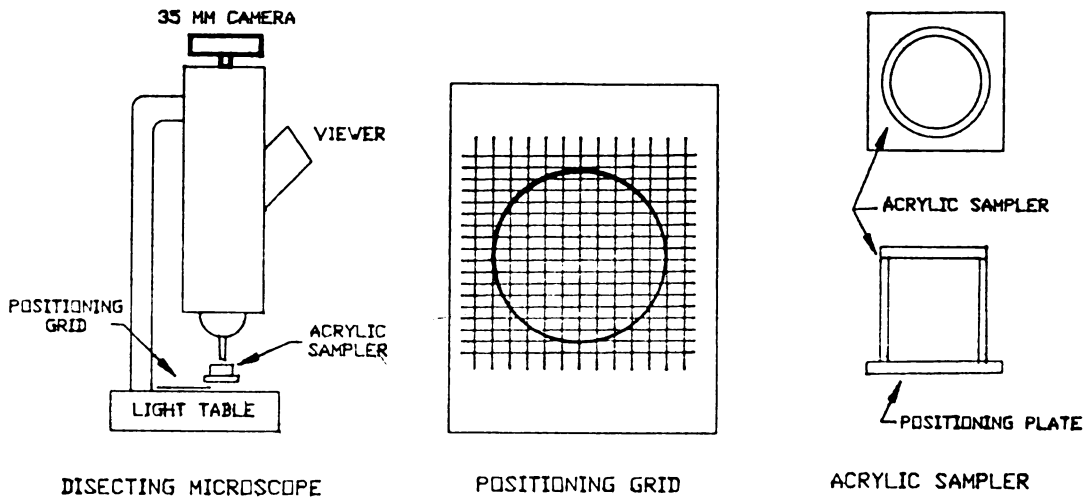

Figure 8: Small Oil Drop Photographic Equipment.

The small oil drops were measured by projecting the image of the oil drops onto a grid. The projector was positioned approximately 8 feet from the grid so that the drops would be enlarged to where they would be easily measured. The smallest drop which could be clearly seen and was counted had a diameter equal to two grid squares or approximately .2 inches on the grid scale. This corresponded

to a true diameter of approximately 0.009 mm. Each photograph was sketched on a paper drawing of the chamber surface. This prevented double counting of drops due to overlapping of the photographs.

3.3 Results

The results of the small drop diameter measurements are presented on Figures 9 and 10 and Tables 4 and 5. The figures indicate the number of drops which were measured in the diameter interval. The number of drops in each interval is given as the percentage of the total number of drops which were counted. A total number of 11,246 drops were counted for an oil release rate of 0.8 PSI and 1,209 drops for an oil release rate of 3.0 PSI. The significant difference in the number of drops counted for each condition can be explained by the higher entrainment rate for a thinner oil slick. Note the major difference in the fraction of each sample occurred in the smallest drop diameter intervals.

The results clearly indicate that the majority of the drop diameters are in the smallest range. A number of oil drops of this size remain permanently entrained in the water column due to turbulence created by the wind and wave action. Larger drops were found, but their small number indicates bouyancy forces drive these particles to the surface or a much smaller number is generated initially.

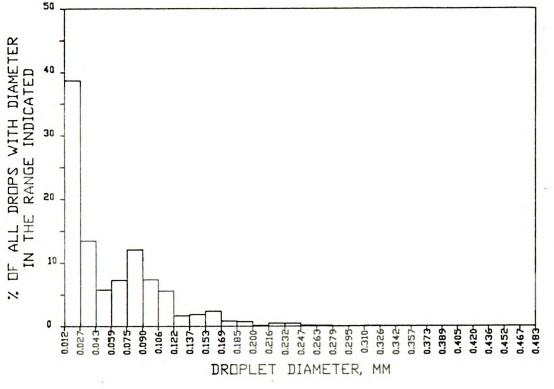

Figure 9: Small Oil Drop Distribution; Oil Release Rate = 0.11 l/s.

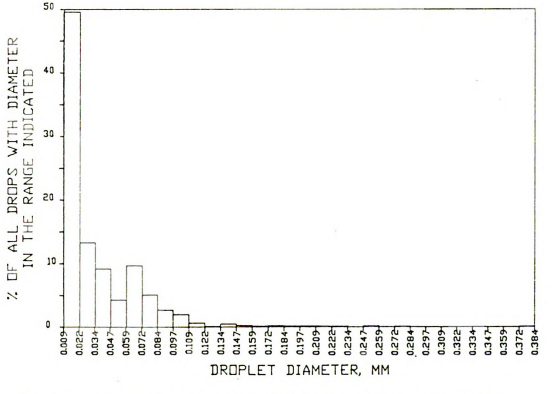

Figure 10: Small Oil Drop Distribution; Oil Release Rate = 0.35 l/s.

Table 4: Small Droplet Diameter Distribution; Oil Release Rate = 0.11 l/s.

Diameter (mm)	Number of Drops	Fraction of Total (%)	Diameter (mm)	Number of Drops	Fraction of Total (%)
0.012			0.247		
	4357	38.74		19	0.17
0.027			0.263		
	1515	13.47		16	0.14
0.043			0.279		
	651	5.79		6	0.05
0.059			0.295		
	826	7.34		9	0.08
0.075			0.310		
	1360	12.09		15	0.13
0.900			0.326		
	831	7.39		4	0.04
0.106			0.342		
	633	5.63		6	0.05
0.122			0.357		
	186	1.65		5	0.04
0.137			0.373		
	217	1.93		2	0.02
0.153			0.389		
	264	2.35		4	0.04
0.169			0.405		
	98	0.87		0	0.00
0.185			0.420		
	86	0.76		1	0.01
0.200			0.436		
	19	0.17		0	0.00
0.216			0.452		
	59	0.52		2	0.02
0.232			0.467		
	56	0.50		2	0.02
0.247			0.483		
			Total	11246	100.00

Table 5: Small Droplet Diameter Distribution; Oil Release Rate = 0.35 l/s.

Diameter (mm)	Number of Drops	Fraction of Total (%)	Diameter (mm)	Number of Drops	Fraction of Total (%)
0.009			0.209		
	600	49.63		2	0.17
0.022			0.222		
	161	13.32		1	0.08
0.034			0.234		
	111	9.18		0	0.00
0.047			0.247		
	52	4.30		2	0.17
0.059			0.259		
	117	9.68		0	0.00
0.072			0.272		
	63	5.21		1	0.08
0.084			0.284		
	33	2.73		0	0.00
0.097			0.297		
	24	1.99		0	0.00
0.109			0.309		
	8	0.66		0	0.00
0.122			0.322		
	15	0.12		0	0.00
0.134			0.334		
	6	0.50		0	0.00
0.147			0.347		
	3	0.25		0	0.00
0.159			0.359		
	2	0.17		0	0.00
0.172			0.372		
	3	0.25		1	0.08
0.184			0.384		
	2	0.17			
0.197			Total	1209	100.00
	2	0.17			
0.209					

4.0 LARGE OIL DROP MEASUREMENT

A separate measurement system was developed to determine the distribution of oil drops with diameters larger than approximately 0.2 mm. This system was comprised of a photographic procedure to capture the drop diameter data in-situ and a computer based measurement technique to analyze the photographs.

4.1 Apparatus

The large oil drops were photographed in the wind tunnel using a laser and a 35 mm camera. Figure 11 illustrates the system. The laser transmitted a concentrated light beam under the wind tunnel where it was reflected and dispersed up through the bottom of the tunnel in a thin sheet of light. The laser emitted a 3 watt multi-mode beam made up of light with most of its power at wave lengths of 488 nm and 514.5 nm. The beam was directed by a small mirror and spread into the thin sheet by a round quartz rod. Oil drops in the tunnel which travelled through this sheet of light were illuminated and photographed. A 35 mm camera with a 50 mm normal lens rigidly mounted to the side of the wind tunnel was used to photograph the drops. The photographs were recorded on black and white panchromatic film.

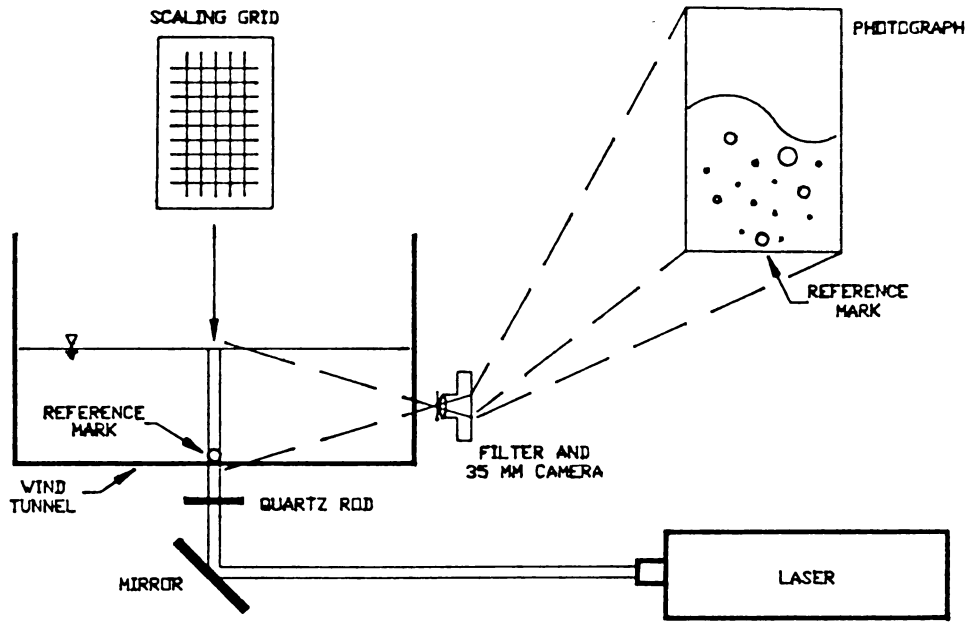

Figure 11: Schematic Diagram of the Large Oil Drop Photographic System.

There were many particles in the wind tunnel which would reflect laser light other than oil drops. A few of these particles included air bubbles from wave breaking and small airborne dust particles which became entrained in the water column. To prevent these particles from being recorded on the film, a geletin filter was attached to the camera lens. This filter permitted only light emitted by the fluorescent properties of the oil drops to reach the film. The result was a clear photograph of oil drops essentially free of images produced by reflected light. Therefore dust and other particles in the tunnel did not appear on the image. The photographs of the large oil drops were analyzed with a computer-based image processing system. Figure 12 illustrates the image processing system. Previous analyses were performed by looking at a photographic image through a microscope and measuring the drop diameters by eye. Because

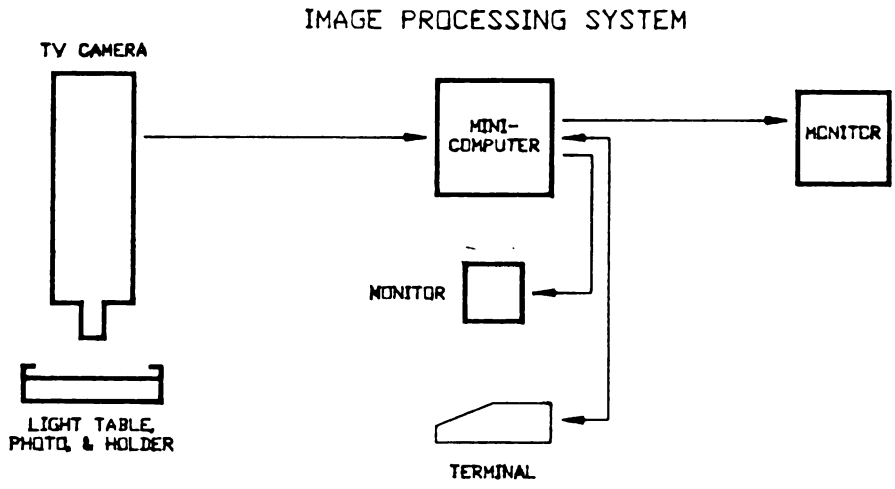

Figure 12: Schematic Diagram of the Image Processing System.

of the large number of drops to be counted, the image processing method was developed in order to simplify and accelerate the analyses.

The image processing system consisted of a specially constructed negative holder, a light table and TV camera, a monitor, and a mini-computer. The aluminum negative holder was constructed so that a negative could be sandwiched between two glass plates. A grid imprinted on one of the glass plates was used to divide the negative into several separate study regions. The light table was used to illuminate the negative for viewing with the TV camera. The TV camera used in the system had a standard 25 mm lens and an extension bellows for focusing the image on a vidicon tube inside of the camera. This lense was reverse mounted which allowed all analyses to be conducted at a magnification of approximately 10X. A mini-computer on line with the video system divided the image into 262,144 separate segments.

Each segment, called a "pixel", was assigned a light intensity value ranging from -1.0 to 1.0. The segments were arranged in a 512 X 512 matrix which made up the image. After processing the image from a buffer, the results were stored in a file for further analysis.

A computer program was developed to interface with the image processing hardware to analyze an image. The basic function of the program was to scan an image for the edge of an oil drop, measure the drop once it had been found, and determine its location. A listing of the program can be found in Appendix A.

4.2 Procedure

The steps of the procedure to obtain the large oil drop distributions included photographing the drops in the wind tunnel and analyzing these photographs using the image processing system. Following is a detailed description of each step.

4.2.1 Photographing Large Oil Drops In-Situ

The light source and referencing system were first set-up to photograph the large oil drops. The laser, quartz rod, and mirrors were positioned such that the laser sheet was near the center of the wind tunnel. A reference point was

then mounted to the bottom of the wind tunnel in the laser sheet. This reference point was utilized in the analysis of the photographs to determine the oil drop locations. An acrylic grid was then placed in the laser light sheet to focus the camera. The acrylic grid is also utilized in the analyses to determine a scale factor for the photographs.

The photographs were taken at random intervals which varied from approximately 1 to 5 seconds over the duration of an experiment which was approximately 40 minutes. A shutter speed of 1/125 seconds was required to adequately freeze the position of the drops. Because of the small amount of time used to photograph the drops and the film's low light sensitivity, a large lens opening (f = 1.4) was required. The width of the laser sheet was kept small in order to have an adequate amount of light for photographing the drops. The width of the sheet was controlled by the diameter and location of the quartz rod used to disperse the laser beam. It is estimated the 10 mm quartz rod utilized in this system adequately lit 1/5 of the total area photographed for analysis. The photographed region was approximately 25 cm wide and 35 cm high.

The total number of drops which appear in any photograph was dependent on the exposure time and the volume lit. The exposure time was kept small so that the motion of a drop was small in comparison to the thickness of the laser sheet. The

laser sheet was approximately 2 mm thick so that no more than 0.02 mm of motion should occur during the time of exposure. This allows errors less than 10% as long as a drop velocity does not exceed 25 mm/s.

The resolution of the system was limited by the normal lens which was capable of resolving 63 lines per mm. Wires as small as 0.03 mm were located and their diameters measured with the photographic system. It was found that if the laser sheet was positioned 150 mm from the tunnel wall, approximately in the center of the tunnel, images large enough for analysis could be photographed. Small drops, with diameters less than approximately 0.2 mm, could not be photographed with this system using either a macro or a normal lens because of the low light intensity produced by the small moving drops.

A typical processing procedure was utilized to develop the Kodak Tech Pan film used to photograph the large oil drops. The developer HC-110 and a 4 minute developing period were used to optimize the contrast of the photographs. Standard wash, fix, and rinse procedures were utilized.

4.2.2 Analysis of Large Oil Drop Photographs

A five step system was developed for analyzing the photographs of the large oil drops. These steps included;

mounting a negative in the negative holder, digitizing a small part of the negative, enhancing the digitized image, analyzing the enhanced image, and calibrating the system. To begin the analysis of a set of photographs, a 35 mm negative was positioned on the negative holder. The reference mark on the negative was positioned such that it corresponded to a corner of the segmenting grid etched on the glass of the holder. The image processing camera was focused on the negative such that one square of the segmenting grid filled the entire 512 X 512 pixel matrix of the monitor. The image was then digitized and displayed in black and white. A computer program which was part of the image processing system was then run which allowed the user to interactively threshold the display to obtain the binary image required for processing. Figure 13 illustrates the light intensity values of a drop before and after thresholding. A flicker command

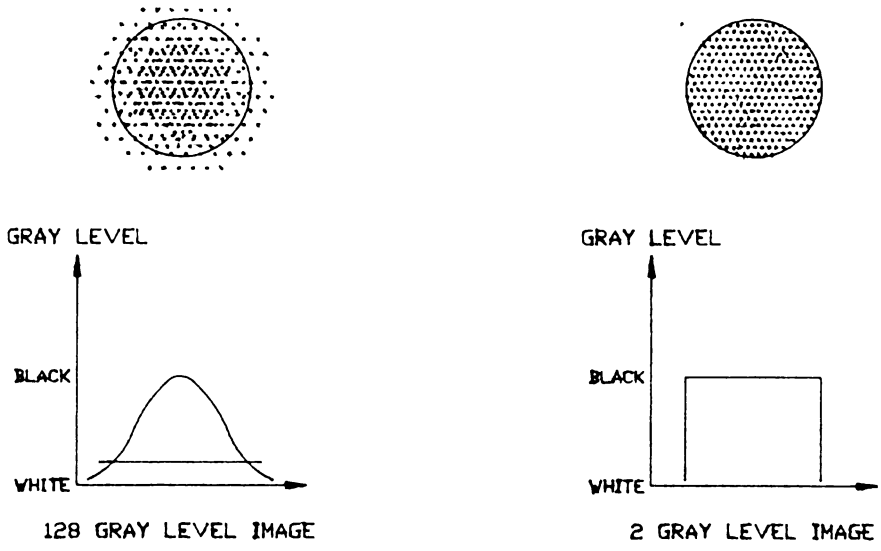

Figure 13: Thresholding the Photograph.

allowed the user to compare each image on the monitor and verify that the thresholded image adequately compared to the digitized real image. After thresholding an image, it was analyzed using a computer program specifically written for this project. This program searched the binary image to locate the position and diameter of the oil drops.

The interactive computer program developed to determine the location and diameter of drops on each digitized binary image prompts for the following information:

- the name of the digitized binary image file
- the name of the output file
- the segmenting grid which was being processed
- the boundary of the image to be processed
- the light intensity value of located drops

The source code for the program is listed in Appendix A.

A search procedure utilized in the program locates drops for processing. This procedure is illustrated in Figure 14. A search begins at the top left corner of an image buffer and scans to the right edge of the boundary for each row. Once the edge of a drop has been found, signified by a specific light intensity value, a search routine is entered which locates the remaining pixels associated with that drop. The search routine examines each pixel on the edge of the first

pixel found. A pixel identified to be part of the drop from its intensity value is stored in a "seed" array. Once the four pixels surrounding the first pixel found have been examined, the search routine advances to the next pixel or "seed" which was found to be part of the drop and examines the four closest pixels to it. Once a pixel had acted as a "seed" for the identification of its neighbors, it is marked by changing its light intensity value so that it will not be counted again. The program proceeds in this fashion until there are no more "seeds", signifying that all the pixels associated with the drop had been found. The total number of "seeds" or pixels associated with a search is stored and utilized to determine the drop diameter. This process is repeated for each drop which is found in the search routine.

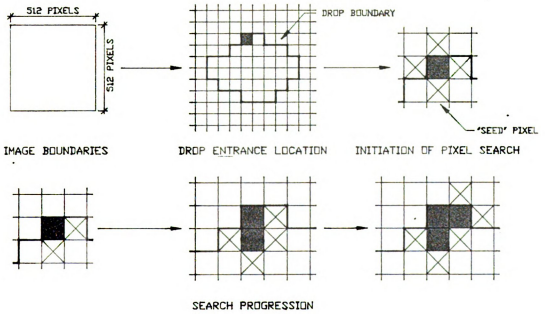

Figure 14: Search of Digital Image for Large Oil Drops.

The drop diameters and locations were found from the information obtained in the search routine. The total number of pixels associated with a drop was known, therefore the total area of the drop could then be determined from the area of the pixels. Knowing the total area of the drop and assuming the drop to be a perfect circle, the diameter is easily calculated. The location of a drop was determined from the location of the maximum and minimum row and column values for pixels associated with a drop. The row location was taken as the midpoint between the maximum and minimum row values and likewise for the column location. Pixel locations are then referenced to the global origin which was the reference mark on each negative.

Drops often occurred on an edge or in the corner of a digitized image. A routine in this program examined drops which occurred on an edge and decided whether they should be counted. Only drops that had their center of mass located within the boundaries of the image being processed were counted. The routine compared the length of a side of the drop occurring on the boundary with the perpindicular distance from the boundary to the pixel farthest from the boundary as illustrated in Figure 15. Assuming the drop is a perfect circle, the ratio of these values were used to determine whether the drop's center of mass was located within the image boundaries. The program was limited in its capability to properly interpret drops which occurred in the

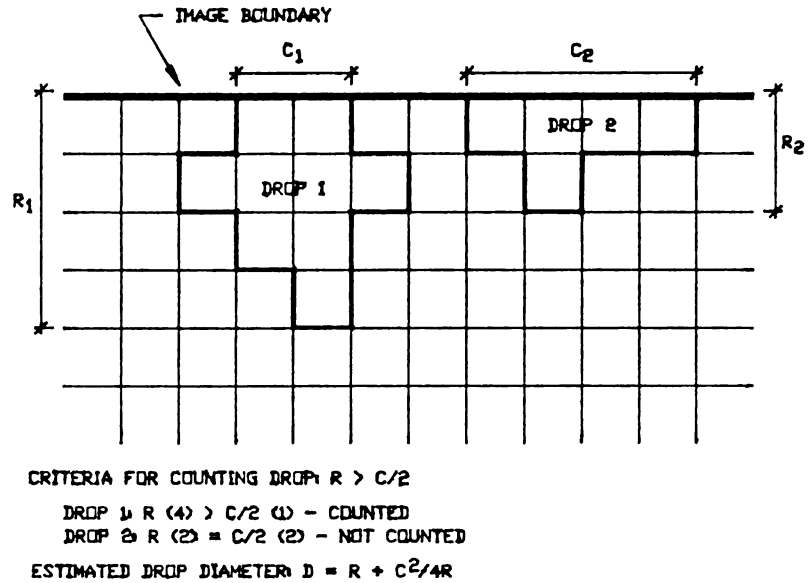

Figure 15: Evaluation of Oil Drop on Image Boundary.

corner of an image or drops which were connected together. When either of these conditions arose, the user was required to make a decision as to whether or not the drop should be counted. If a drop was counted, its diameter was measured with a cursor that could be interactively manipulated on the video screen. When a drop occurred in the corner of an image, it was counted if more than half of its area was within the boundary of the image.

A calibration scheme was necessary in order to determine the true size and location of oil drops measured from digitized images. This was accomplished by calibrating with the scaling grid initially utilized to focus the camera. The

scaling factor was obtained by placing a grid of known dimensions in the plane of the laser sheet (Figure 11). The camera was kept in the same location for photographing the grid and the oil drops. This grid was digitized and the length (B) between grid lines on the scaling grid was measured with the image processing equipment. The actual distance (b) in mm between lines on the scaling grid was known. Then comparing the measured drop diameter (A) with the scaling factor (b/B), the diameter of the oil drops (a) in mm of the full scale dimensions is given by the expression:

$$a = b(A/B)$$

The TV lens position was held constant from one photograph to the next for a given set of measurements to hold the scale factor constant.

The segmenting grid was also used to relate oil drop location to the global origin created by the reference mark as shown in Figure 11.

4.3 Results

The results of the large drop diameter measurement are presented in Figures 15 through 20 and Tables 6 and 7. The figures present the average number of drops which were found

in the indicated range of diameters. The average number of drops is presented as the percentage of the total number of drops which were measured for a particular data set. This information is presented for each oil release rate and position investigated. In addition, the variation of the average number of drops found for each diameter interval is indicated. Tables 6 and 7 present the data utilized to develop these figures.

The large drop measurements were reduced to indicate the average number of drops within a range of diameters found in a specific area of the water column. The measurements were taken for constant wind, wave, and oil release rate conditions. The number of drops of a given measured diameter was tabulated for each photograph and separated into diameter intervals. The average number of drops in each interval was then calculated for a data set. If the number of drops in a diameter interval is given by n and the average number is given as n(avg), then the percentage of the average number of drops for any diameter interval is given by:

$$\%n = [n_{avg} / \sum n_{avg}] \times 100\%$$

The variation of the average number of drops found in each diameter interval was computed from the 68% confidence interval ($\pm$one standard deviation) of the sample. The

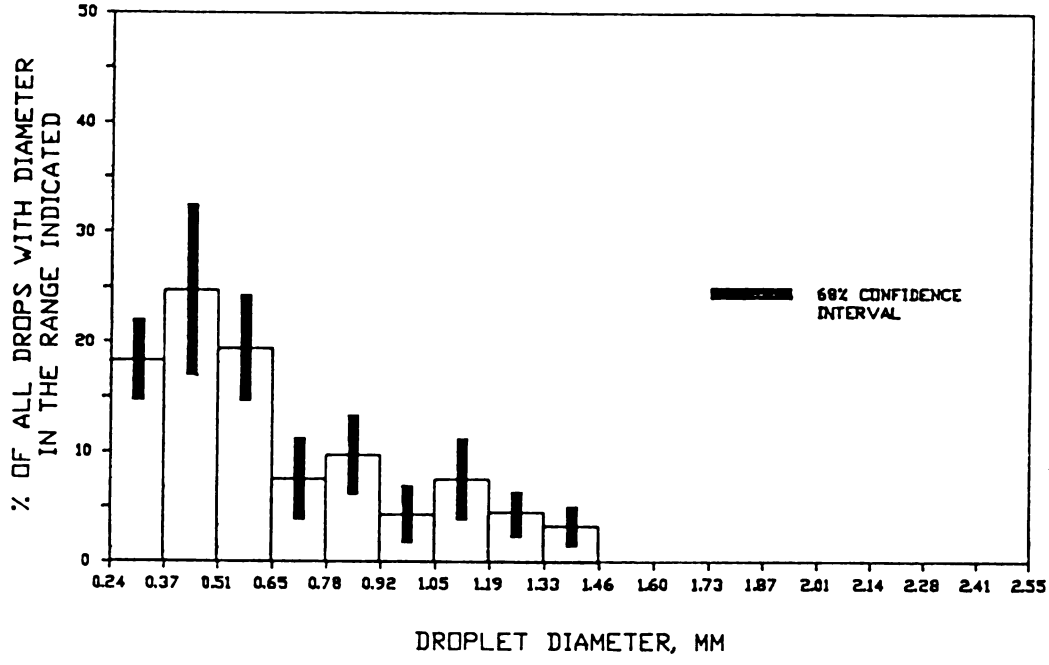

Figure 16: Large Drop Distribution; Oil Release Rate = 0.11 l/s; x = 2.0 m; z = 5.7 cm.

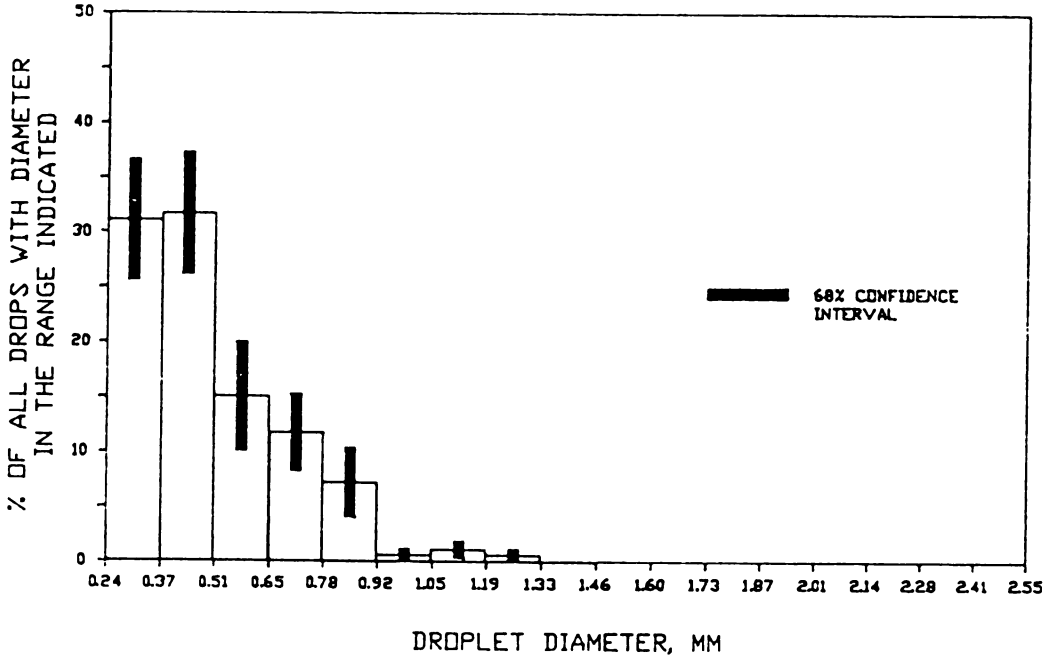

Figure 17: Large Drop Distribution; Oil Release Rate = 0.11 l/s; x = 2.0 m; z = 11.3 cm.

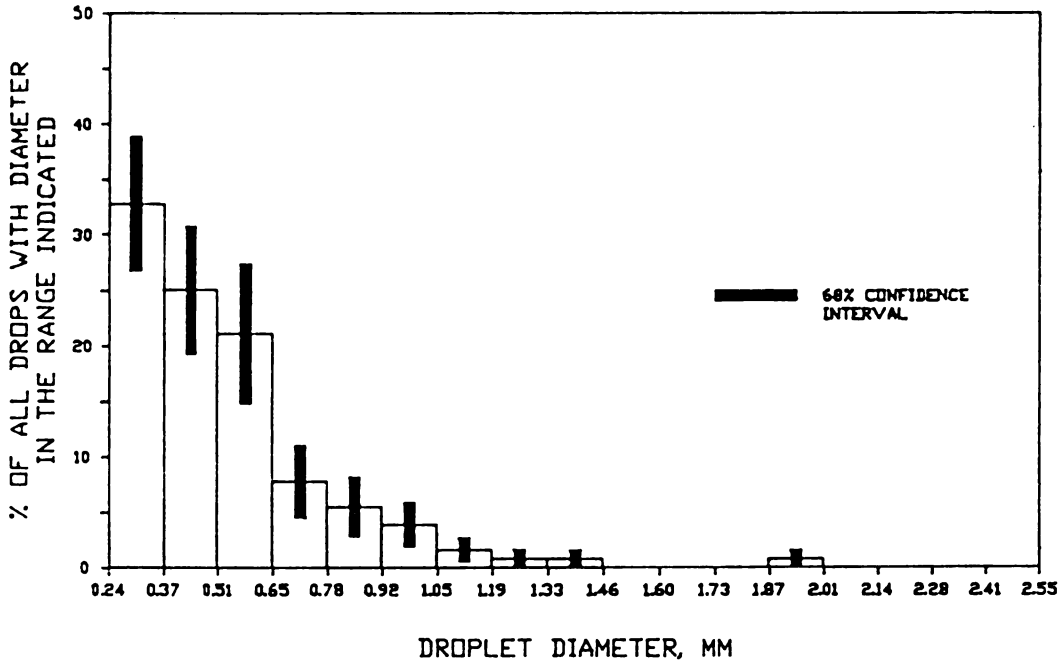

Figure 18: Large Drop Distribution; Oil Release Rate = 0.11 l/s; x = 2.0 m; z = 16.9 cm.

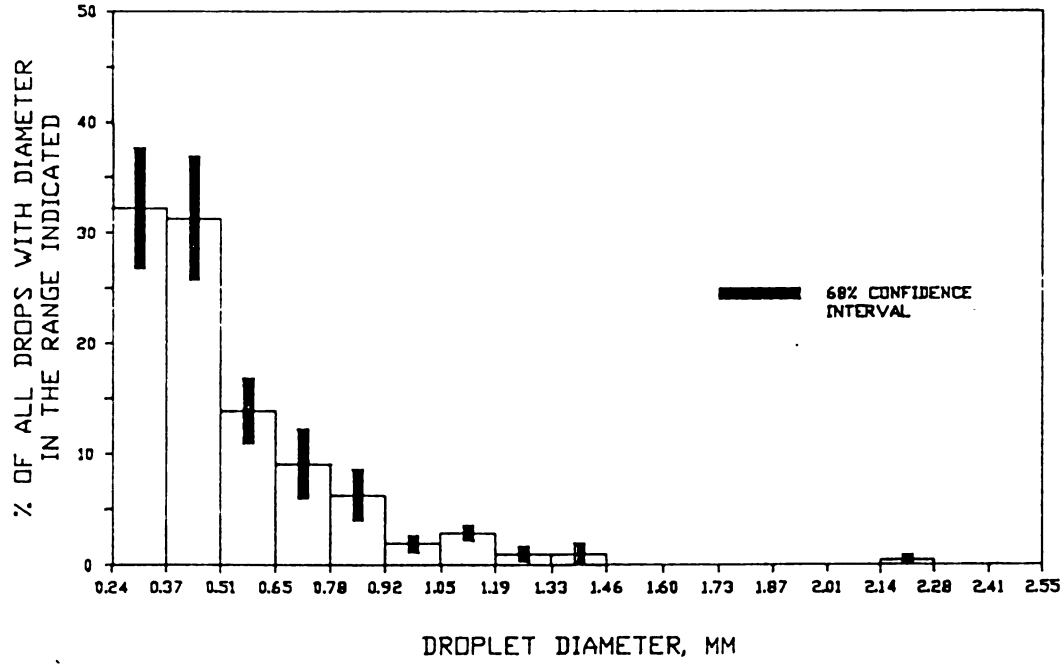

Figure 19: Large Drop Distribution; Oil Release Rate = 0.35 l/s; x = 2.0 m; z = 5.7 cm.

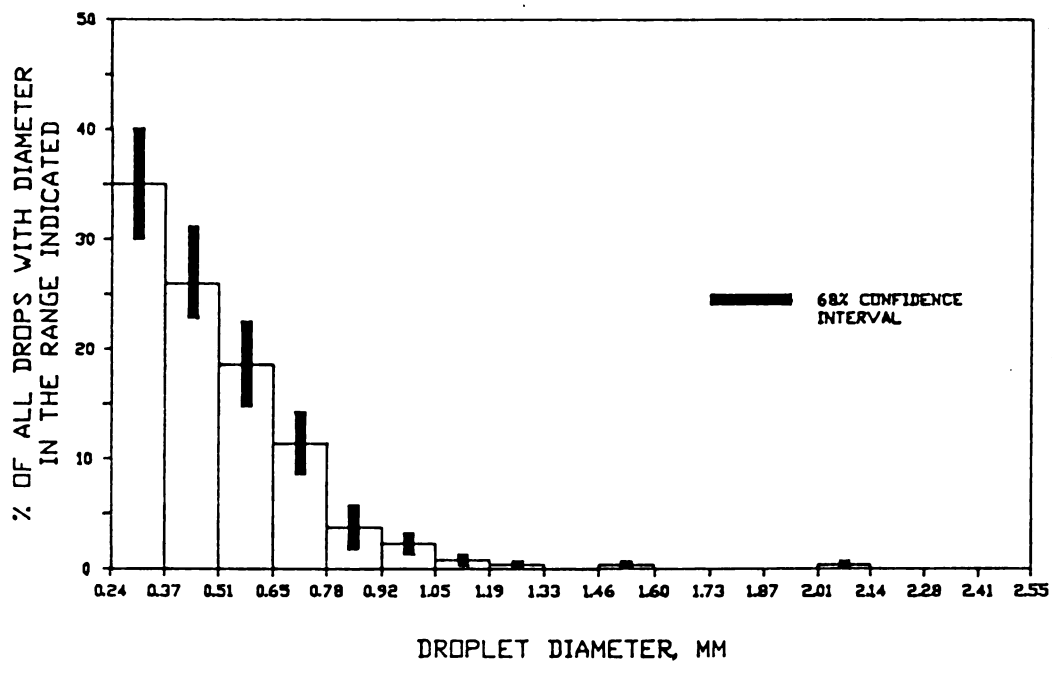

Figure 20: Large Drop Distribution; Oil Release Rate = 0.35 l/s; x = 2.0 m; z = 11.3 cm.

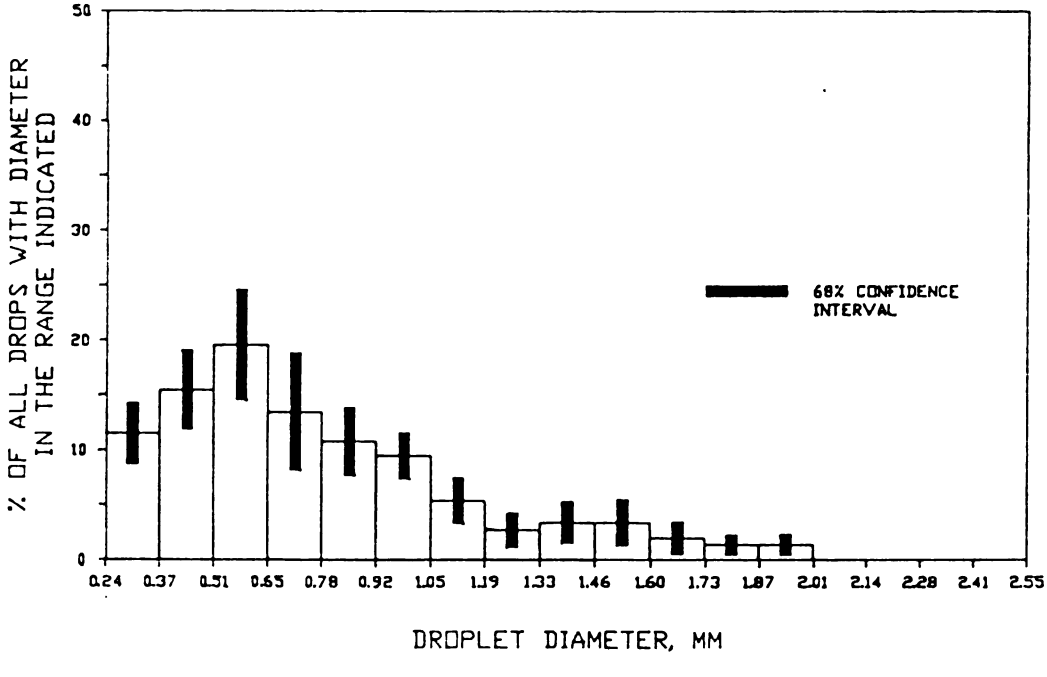

Figure 21: Large Drop Distribution; Oil Release Rate = 0.35 l/s; x = 2.0 m; z = 16.9 cm.

Table 6: Large Drop Diameter Distribution; Oil Release Rate = 0.11 l/s.

	Z = 4.0 cm		Z = 10.4 cm		Z = 16.8 cm	
Diameter (mm)	N_i (%)	S (%)	N_i (%)	S (%)	N_i (%)	S (%)
0.24-0.37	18.3	20.1	31.1	17.3	32.8	18.4
0.37-0.51	24.8	31.3	31.7	17.5	25.0	23.1
0.51-0.65	19.4	24.8	16.1	30.8	21.1	29.7
0.65-0.78	7.5	49.1	11.7	30.1	7.8	41.8
0.78-0.92	9.7	36.8	7.2	44.0	5.5	49.1
0.92-1.05	4.3	59.2	0.6	101.	3.9	51.6
1.05-1.19	7.5	49.5	1.1	69.0	1.6	69.0
1.19-1.33	4.3	47.4	0.6	101.	0.8	101.
1.33-1.46	3.2	55.8	0.0	-	0.8	101.
1.46-1.60	0.0	-	0.0	-	0.0	-
1.60-1.73	0.0	-	0.0	-	0.0	-
1.73-1.87	0.0	-	0.0	-	0.8	101.
1.87-2.01	0.0	-	0.0	-	0.0	-
2.01-2.14	0.0	-	0.0	-	0.0	-
2.14-2.28	0.0	-	0.0	-	0.0	-
2.28-2.41	1.1	101.	0.0	-	0.0	-
TOTAL	100.0	-	100.0	-	100.0	-

Average number of drops of all sizes within window at an instant in time =

2.3223 4.4990 3.1959

Table 7: Large Drop Diameter Distribution; Oil Release Rate = 0.35 l/s.

	Z = 4.0 cm		Z = 10.4 cm		Z = 16.8 cm	
Diameter (mm)	N_i (%)	S (%)	N_i (%)	S (%)	N_i (%)	S (%)
0.24-0.37	11.5	25.1	35.0	13.9	32.3	16.9
0.37-0.51	15.5	24.1	27.0	15.8	31.3	17.8
0.51-0.65	19.6	26.4	18.6	21.2	13.9	21.1
0.65-0.78	13.5	35.0	11.4	25.2	9.1	34.6
0.78-0.92	10.8	27.8	3.8	54.1	6.3	37.0
0.92-1.05	9.5	22.5	2.3	46.9	1.9	38.3
1.05-1.19	5.4	39.1	0.8	70.8	2.9	24.7
1.19-1.33	2.7	58.4	0.4	44.8	1.0	70.8
1.33-1.46	3.4	57.0	0.0	-	1.0	100.
1.46-1.60	3.4	63.8	0.4	90.6	0.0	-
1.60-1.73	2.0	74.0	0.0	-	0.0	-
1.73-1.87	1.4	68.6	0.0	-	0.0	-
1.87-2.01	1.4	71.5	0.0	-	0.0	-
2.01-2.14	0.0	-	0.4	90.6	0.5	90.6
2.14-2.28	0.0	-	0.0	-	0.0	-
2.28-2.41	0.0	-	0.0	-	0.0	-
TOTAL	100.0	-	100.0	-	100.0	-

Average number of drops of all sizes within window at an instant in time =

3.7166 6.5628 5.0713

standard deviation of the average number of drops is given by:

$$S^2_{n_{avg}} = S^2_n / n$$

The standard deviation $S_{n_{avg}}$ may be expressed as a percentage of the total number of drops:

$$\% S_{n_{avg}} = [S_{n_{avg}} / \sum n_{avg}] \times 100\%$$

The variation is presented as plus and minus one standard deviation from the average number of drops.

The large oil drops are characteristic of drops which were not permanently entrained in the water column. Although this data was not used in the final analysis of the study, it might have been used to verify the drop distribution predicted using the small drop data.

5.0 OBSERVATION OF OIL DROPS IN SUSPENSION

While performing experiments in the wind tunnel to obtain the data for the large and small oil drop diameter and oil concentration measurements, the following observations were made of the oil drops in the water column. At a breaking wave, an oil jet would form which would drive oil into the water creating an air-oil-water mixture in the water column. Several types of drops were found to occur in this column including oil bubbles, air bubbles, and oil-water bubbles. The oil bubbles were well distributed throughout the vertical water column. Oil droplets approximately 1mm in diameter and smaller could be easily seen in the column. The smaller drops congregated at the bottom of the tunnel and generally rose very slowly. Larger bubbles rose quickly to and remained in the turbulent interface at the water surface.

Air bubbles were also present in the water column. It is estimated that the number of air bubbles was at least equal to the number of oil drops. These bubbles rose very quickly. The remaining bubbles were oil-water bubbles. The oil-water bubbles ranged in size from approximately .5 mm to very large. These bubbles would be non-circular in shape and would remain near the bottom of the tank. They would rise slower than the equivalent oil drop.

6.0 REFERENCES

1. U.S. Environmental Protection Agency, "Total Recoverable Petroleum, Hydrocarbons, Method 418.1," in Methods for Chemical Analysis of Water Wastes, EPA 600/4-79-020, March 1979, Cincinnatti, Ohio.

2. Keizer, P.D. and D.C. Gordon, "Detection of Trace Amounts of Oil in Sea Water by Fluorescence Spectroscopy," Journal of Fisheries, Board of Canada, 30: 1039-1046, 1973.

3. Bouwmeester, R.J.B. and R.B. Wallace, "Dispersion of Oil on a Water Surface Due to Wing and Wave Action," report DOT/OST/P-34/87/060, U.S. Department of Transportation, Washington, D.C., 1986.

4. Brater, E.F. and H.S. King, "Handbook of Hydraulics," McGraw-Hill Book Company, New York, 1976.

```
PROGRAM OILDRP (INPUT, OUTPUT, DROPDATA, NEWFILE, OLDFILE);

CONST
      IMAGE0  = 16#800000;
      IMSPACE = 16#800000;
      ROWSIZE = 1024;
      MAX     = 500;
      MARKED  = 20000;

TYPE
      SEGBLOCK=RECORD
        TASKNAME     :INTEGER;
        SESSION      :INTEGER;
        OPTIONS      :-32768..32767;
        SEGATTR      :-32768..32767;
        SEGNAME      :PACKED ARRAY [1..4] OF CHAR;
        ADDRESS      :INTEGER;
        LENGTH       :INTEGER;
        BUFADDR      :INTEGER
      END;

      PIXELTYPE = -32768..32767;
      LINE      = ARRAY[1..1024] OF PIXELTYPE;

      ADDRTYPE=RECORD
        CASE BOOLEAN OF
           TRUE  : (PTR  :@LINE);
           FALSE : (INT  :INTEGER)
        END;

VAR
      PARAMS                  :SEGBLOCK;
      ADDR                    :ADDRTYPE;
      ROW                     :@LINE;
      X,Y,R,C,RY,CX,
      ROWY,COLX,TR,
      PIXEL,YP,
      RMAX,CMAX,RMIN,CMIN,
      ERR,A0,NUM,N
      LFTBDRY,RHTBDRY,
      TOPBDRY,BOTBDRY         :INTEGER;
      SAVCOL,SAVROW,
      ROWLOC,COLLOC,DIA       :ARRAY [1..MAX] OF INTEGER;
      DETCENTER,
      SIDEBDRY,EDGEDROP       :BOOLEAN;
      NEWFILE,OLDFILE,
      DROPDATA                :TEXT;
      COND                    :CHAR;

PROCEDURE GTSEG(VAR PARAMS:SEGBLOCK;
                VAR A0,ERR:INTEGER);
                FORWARD;

PROCEDURE GTIMAG;
```

```
VAR
     IMIG                    :INTEGER;

BEGIN
{    WRITELN('WHICH BUFFER IS THE IMAGE IN? (1-4)  ');}

{    READLN(IMIG);)}
     IMIG := 2;

     CASE IMIG OF
       1, 3                          :  X := 0;
       2, 4                          :  X := 512
     END;
     CASE IMIG OF
       1, 2                          :  Y := 0;
       3, 4                          :  Y := 512
     END
END;  {OF PROCEDURE GTIMAG}

PROCEDURE GTPIXEL;

BEGIN
     ADDR.INT        := IMAGE0+(R-1+X)*ROWSIZE;
     ROW             := ADDR.PTR;
     PIXEL           := ROW@[C+Y];
     DETCENTER       := FALSE;
     IF (PIXEL = 0)  THEN
       BEGIN
            NUM                          := NUM+1;
            SAVROW[NUM]                  := R;
            SAVCOL[NUM]                  := C;
            DETCENTER                    := TRUE;
            ROW@[C+Y]                    := MARKED;
       END
END;  {OF PROCEDURE GTPIXEL}

PROCEDURE FOUNDDROP;

VAR
    ADV                          :INTEGER;

BEGIN
    RMAX             := 0;
    CMAX             := 0;
    RMIN             := RY;
    CMIN             := CX;
    ADV              := 1;
    SIDEBDRY         := FALSE;
    EDGEDROP         := FALSE;
    WHILE (ADV <= NUM) DO
      BEGIN
           R := RY+1;
           C := CX;
           IF (R  = BOTBDRY) THEN EDGEDROP := TRUE;
```

```
            IF (R <= BOTBDRY) THEN
              BEGIN
                   GTPIXEL;
                   IF (DETCENTER = TRUE) THEN
                     IF (RMAX < R) THEN RMAX := R
              END;
            R := RY;
            C := CX-1;
            IF (C  = LFTBDRY) THEN
              BEGIN
                   EDGEDROP := TRUE;
                   SIDEBDRY := TRUE
              END;
            IF (C >= LFTBDRY) THEN
              BEGIN
                   GTPIXEL;
                   IF (DETCENTER = TRUE) THEN
                     IF (CMIN > C) THEN CMIN := C
              END;
            R := RY-1;
            C := CX;
            IF (R  = TOPBDRY) THEN EDGEDROP := TRUE;
            IF (R >= TOPBDRY) THEN
              BEGIN
                   GTPIXEL;
                   IF  (DETCENTER = TRUE) THEN
                      IF (RMIN > R) THEN RMIN := R
              END;
            R := RY;
            C := CX+1;
            IF (C  = RHTBDRY) THEN
              BEGIN
                   EDGEDROP := TRUE;
                   SIDEBDRY := TRUE
              END;
            IF (C <= RHTBDRY) THEN
              BEGIN
                   GTPIXEL;
                   IF (DETCENTER = TRUE) THEN
                     IF (CMAX < C) THEN CMAX := C
              END;
            ADV := ADV +1;
            RY  := SAVROW[ADV];
            CX  := SAVCOL[ADV]
        END
END;  {OF PROCEDURE FOUNDDROP}

PROCEDURE GTFILE;

VAR
     I,ROW,COLUMN,
     DIAMETER                :INTEGER;

BEGIN
```

```
  REWRITE(DROPDATA)
  FOR I := 1 TO N DO
    BEGIN
      IF (DIA[I] >= 4) THEN
      BEGIN
      ROWLOC[I] := ROWLOC[I]+(YP-1)*464;
      WRITELN(DROPDATA,ROWLOC[I]:4,COLLOC[I]:4,DIA[I]:4,YP:4)
      END
    END;
 RESET(OLDFILE,'DROPDATA.SA');
 RESET(DROPDATA);
 REWRITE(NEWFILE);
 WHILE NOT EOF(OLDFILE) DO
   BEGIN
        READLN(OLDFILE,ROW,COLUMN,DIAMETER,TR);
        WRITELN(NEWFILE,ROW:4,COLUMN:4,DIAMETER:4,TR:4)
   END;
 WHILE NOT EOF(DROPDATA) DO
   BEGIN
        READLN(DROPDATA,ROW,COLUMN,DIAMETER,TR);
        WRITELN(NEWFILE,ROW:4,COLUMN:4;DIAMETER:4,TR:4)
   END;
 RESET(NEWFILE);
 REWRITE(OLDFILE,'DROPDATA.SA');
 WHILE NOT EOF(NEWFILE) DO
   BEGIN
        READLN(NEWFILE,ROW,COLUMN,DIAMETER,TR);
        WRITELN(OLDFILE,ROW:4,COLUMN:4,DIAMETER:4,TR:4)
   END
 END;   {OF PROCEDURE GTFILE}

 PROCEDURE MAINBDRY;

 VAR
    ROWLENGTH,
    COLLENGTH               :INTEGER;

BEGIN
     ROWLENGTH          :=ROUND((RMAX-RMIN+1)*0.78);
     COLLENGTH          := CMAX-CMIN+1;
   CASE SIDEBDRY OF
   TRUE  :DIA[N] := (SQR(ROWLENGTH)DIV(4*COLLENGTH))+COLLENGTH
   FALSE :DIA[N] := (SQR(COLLENGTH)DIV(4*ROWLENGTH))+ROWLENGTH
     END
END;  {OF PROCEDURE MAINBDRY}

{***** MAIN PROGRAM *****}

BEGIN
     N := 0;
     GTIMAG;

{***** SET PARAMETERS TO ADDRESS IMAGE MEMORY ****}
```

```
      WITH PARAMS DO
        BEGIN
             TASKNAME         := 0;
             SESSION          := 0;
             OPTIONS          := 256;
             SEGATTR          := 2048;
             SEGNAME          := 'IMAG';
             ADDRESS          := IMAGE0;
             LENGTH           := IMSPACE;
             GTSEG(PARAMS,A0,ERR);
             IF (ERR <> 0) THEN
               WRITELN('ERROR IN GTSEG CALL: ',ERR)
        END;

WRITELN('INPUT THE GRID HEIGHT OF PICTURE; Y');
READLN(YP);
WRITELN('INPUT THE TOP LEFT CORNER COORDINATES OF GRID; R C')
READLN(TOPBDRY,LFTBDRY);
WRITELN('INPUT THE BOTTOM RIGHT CORNER COORDINATES OF GRID; R C');
READLN(BOTBDRY,RHTBDRY);
COND := 'N';
WRITELN('IS THIS THE FIRST PICTURE IN A SET? (Y/N) ');
READLN(COND);
IF (COND = 'Y') THEN REWRITE(OLDFILE,'DROPDATA.SA');
FOR ROWY := TOPBDRY TO BOTBDRY DO
  BEGIN
       ADDR.INT  := IMAGE0+(ROWY-1+X)*ROWSIZE;
       ROW       := ADDR.PTR;
       FOR COLX := LFTBDRY TO RHTBDRY DO
         BEGIN
              PIXEL := ROW@[COLX+Y];
              IF (PIXEL = 0) THEN
                BEGIN
                     NUM                := 1;
                     RY                 := ROWY;
                     CX                 := COLX;
                     FOUNDDROP,
                     N                  := N+1;
             COLLOC[N]          := CMIN+(CMAX-CMIN+1)DIV(2);
          ROWLOC[N]:= ROUND((RMIN+(RMAX-RMIN+1)DIV(2))*0.78);
          CASE EDGEDROP OF
             TRUE              :MAINBDRY;
             FALSE           :DIA[N] := ROUND(SQRT(4*NUM/3.14))
                     END;
                     IF (DIA[N] > = 4) THEN
                       WRITELN('DROP #',N:3,
                               '   COLUMN',COLLOC[N]:4,
                               '   ROW',ROWLOC[N]:4,
                               '   DIAMETER',DIA[N]:4);
                     WRITELN
                   END
              END
         END;
       GTFILE
END.  {OF MAIN PROGRAM}
```