

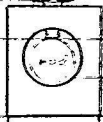
Research In
Droplet Coalescence

This is the last of four research notebooks used by Robert W. Park, a graduate student and postdoctoral fellow under professor C. J. Crosby in the Mechanical Engineering Department of the University of Wisconsin, Sept. 1961 - May 1971.

4/5/68 Crown, Crater, & Spatter with High Vel ~1700, μ Drops, G, R & S photo series

Ap To provide a long dist. for the gravity acceleration of large drops and to provide a long damping dist. for their oscillations, a 3" dia. glass tube $48\frac{1}{2}$ " long was added to the chamber's top port. The glass column rested on a cork washer on the top port's shoulder. As protection against knocking the column over, its top was loosely surrounded by a padded iron ring, as shown in the photo at right.

Driver #10 was removed from its base positioner and suspended from a bolt in the ceiling by a ~ horiz. rod, using the piece shown here →

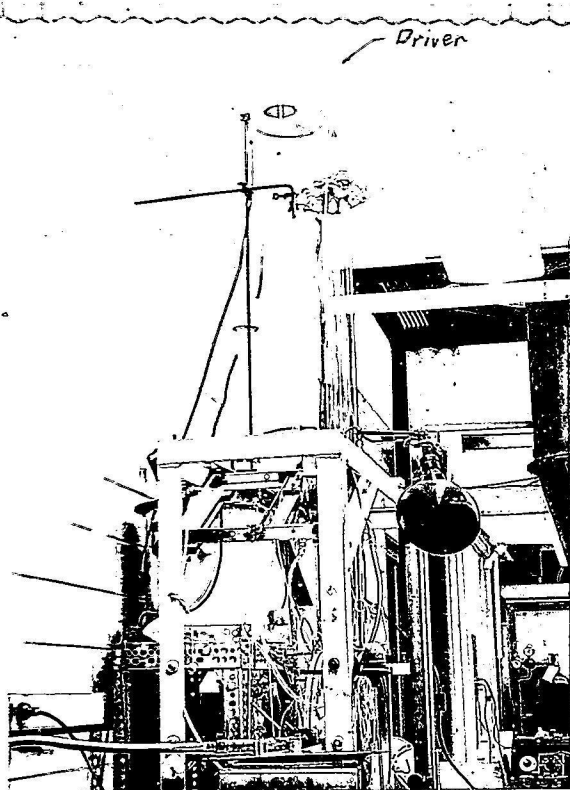


The 2" sphere at the end of the

needle-holding tube, surrounded by the cyl. of plaster foam, ~ closed off the top of the column. Water was fed the driver's cone directly from the left metering valve through a new length of $\frac{1}{8}$ " Nylon tubing which bypassed the water bath. The thermocouple in this cone was removed and replaced with a plug (made from some of the $\frac{1}{8}$ " plaster tubing), since the thermocouple wires could not reach the driver. The at. driver, used only for the S series photos, entered the chamber through the lower port on the rt. side, as pictured on p. 129, but directed upward.

The front chamber window was not used because of splash, which would have coated it and interfered with photography, but the chamber was shielded from drafts by pieces of Al-foil on each side which partially closed the front of the chamber.

The slope to the left of the driver in the photo is the hole in the ceiling in which the feed line from the third floor head tank enters.



Type #2, low exposure at minimum spacing.

The small rectangular container made from microscope slides to provide the flat water surf. for the R series photos can be seen at the bottom of the equip. photo (on top of the electrometer).

The Stroboscopes, set for External Input, Med. Intensity flashes, was run directly from the sine wave output of the Heathkit oscillator. (This is possible only at v. low frequencies). The Stroboscope, set at High Intensity, provided the light for the photos.

Aim The purpose of this work was to investigate the use of drops accelerated to high vel. by a long fall dist. in producing "spatter" collisions between drops, and to illustrate some new possible uses for the equipment.

Graphic View- R + S series

Q series

16 photos
162 mm lens at $f/8.2$ except $f/8$ for Q1 and $f/16$ for Q11 (first 2 photos)
Lens to plate $19\frac{1}{16}$ " (full normal bellows extension, giving magnification of $\times 1.9$ on the photo)
No microscope used!
Shutter speed $\frac{1}{25}$ sec
Strob 25.2 flashes/sec
Lighting by Stroboscope at high intensity setting
Light red. by frosted glass + screen + by 3" O.D. black rubber wacker with $1\frac{1}{8}$ " dia hole.
(90% yellow sheet)
Type 47 Polaroid film

18 R photos, 3 S photos
90 mm lens at $\sim f/16$ except $f/13.2$ for R1 and $\sim f/22$ for R3; $f/14$ for S photos
Lens to plate $18\frac{13}{16}$ " (full extension)
The dist is $\frac{1}{2}$ " less than in Q series because the front edge of the 90 mm lens protrudes $\frac{1}{2}$ " less than the 162 mm lens. Magnification = $\times 3.9$
No microscope used
Shutter speed $\frac{1}{25}$ sec
Strob 26.5 flashes/sec for R series
21.4 flashes/sec for S series
Lighting by slave at high intens.
Light red. same as for Q series
Type 47 Polaroid film

Results Medium sized drops produced in a regular stream at the top of the glass column were found to coalesce with each other before they reached the chamber. Larger drops reached the chamber intact, but control of their position was not good. The best results in controlling the chamber position of drops produced at the top of the column were

Rot. Check Pts

$$\frac{7.30 \text{ cc}}{2 \text{ min}} = 3.65 \frac{\text{cc}}{\text{min}} @ 10.49_{\text{cc}}$$

$$\frac{7.32 \text{ cc}}{2 \text{ min}} = 3.66 @ 10.53_{\text{cc}}$$

Drop Control Data

	Q series	R series	S series	
			Left	Right
			Shortest #18	Long. 22. hand #22
1	Shortest #18	Shortest #18		
2	10.49 _{cc}	10.53 _{cc}	10.70 _{cc}	$\frac{24.2 \text{ cc}}{50.5 \text{ sec}}$ (not used, 50.5 sec. range)
$\frac{\text{cc}}{\text{min}}$	3.65	3.66	3.80	28.7*
f_c , $\frac{\text{cy}}{\text{sec}}$ from counter	25.2 ³ $\frac{10^4}{\text{Qmax hit}}$	26.5 ³ $\frac{10^4}{\text{Qmax hit}}$	21.40 ^{10^4} $\frac{10^4}{\text{hit}}$	857 ⁸ $\frac{10^4}{\text{HP}}$
Drop dia (calc)	1.66 mm	1.64 mm	1.78 mm	1.02 mm
4	#20, 0 bars	#22, 0 bars	#20, 0 bars	#10, 0 bars
5	#10	#10	#10	#8
6	~54"	~52"	~47 $\frac{1}{2}$ "	~6.9 cm
7	~0	~0	~0	4.5 cm
Drop spacing	~20.6 cm	~15.6 cm	~18.5 cm	~4.5 mm
Stk vel, $\frac{\text{cm}}{\text{sec}}$	~520	~425	~396	~386
13	~5 M (fline)	~1 M (fline)	α ~112°	
% R.H.	~20%	~27%	β ~55°	
15	78.7°F (Chic corr'd)	76.8°F (Chic corr'd)	V_r 648 ^{cm} / _{sec}	

~1/2 length of exposed hyp. tubing with the 18 gauge needle was 0.66 cm while the exposed length of the #22 needle was 2.23 cm. The R series f_c was raised a bit (to the value recorded above) after the 2nd photo attempt was black, indicating that the shutter opened & closed between strobe flashes. Drop diameters were calculated from the freq. & flow rate, neglecting the sat. drops which occasionally appeared in the 22 pts (as in Q3 & Q5). Drop spacing for vel. calcs. was measured visually with strobe by holding ruler next to str.

obtained with large drops produced by the ejection mechanism using the shortest #18 needle (as mentioned on p. 103). The v. low freq. at which these drops are produced permits the strob. run from the same oscillator, to be flashed at the same freq. By selecting a freq. near 25 cycles/sec, it was found possible to take photos with the camera shutter set at $\frac{1}{25}$ sec.

The three S series photos show that these large drops can be used to produce spatter collisions with fast moving somewhat smaller drops. (Spatter occurs when two drops collide with such force that they flatten into a thin sheet which shreds into drops around the edges before it can contract). Since the drops and their collision phenomena are quite large, microscope magnification is not needed, and the camera can be used directly. This permits the lens aperture to be reduced, which provides an important improvement in depth of field.

In photo S1 the remnant of the large drop can still be seen, while S2 & S3 show later stages of spatter. In S2, two of the smaller drops have apparently been hit, with the second one suffering disruption. Smaller drops which were a bit more widely spaced and which were not oscillating so strongly would be better for a photo series on spatter. The position of the falling large drop cannot be controlled so precisely as to keep the collisions in plane. (The angle between the streams, used to calculate V_r , was measured by assuming that the large drops move vertically through the S series photos).

Q Series Results The Q series photos show the large drops striking a heavy piece of plate glass, wetted by previous drops, at a vel. of something over 520 cm/sec. (This vel. is based on the spacing between successive drops just above the plate. Acceleration in this 20.6 cm dist. probably raised the vel. at impact to ~535 cm/sec. or more). The plate glass was tilted away from the camera so that most of the water would run off, and the camera was aimed downward at a still steeper angle of $\sim 12^\circ$ with the horizontal.

The photos are set in order to give an idea of the series of events which occur when a drop hits a wetted flat surf. at high vel. In Q2 the approaching ~ 1.66 mm dia drop is reflected in the plate glass. In Q3 the top of the drop can still be

seen as the drop strikes. Photos Q4 to Q11 show various stages of the crown form which follows. Photos of this form have previously been published with drops falling into a shallow dish of liquid. The one-sided forms in Q7-Q11 are probably due to the tilt of the glass plate. The crown form seemed to be thinnest and widest when excess water had just been wiped from the plate, as in Q7.

After drops have shredded from the upper rim of the crown, the thin cyl. of liq. contracts to forms such as those in Q12-Q14. These protuberances eventually contract into the liq. on the plate, as in Q15.

R Series Results To improve on the Q series magnification, the 162 mm lens was replaced by the 90 mm lens for the R & S photos. The R series photos show stages in the collision of a large drop with an approx. flat liq. surf. The water providing this surf. was held in a rectangular glass container made by gluing microscope slides together. The surf. had the dimensions of a 1" slide. Before each photo the level of the liq. was raised to ~ the edge of the container by a rubber syringe. (The edge of the container and the flat liq. surf. corresp. to the dark horiz. line in each photo). The surf. was never perfectly flat because of surf. waves caused by previous collisions, but the problem was ~ minimized by the v. low frequency of production of the drops. This is only

The collisions start out much like those in the Q series (compare R2 & Q3), but the crown form (R4 & R5) spreads more out than up, and never develops a thin cyl. of liq. ^{seen} in the Q photos. As the colliding drop penetrates deeper, it produces a hollow crater in the flat liq. surf. (R8-R16). About mid-way in the crater's life, its rim gets thick and it stops shedding small drops. As an old crater contracts, it develops a distinctly bumpy outline, as in R14-R16. Eventually, the crater is replaced by a bulge in the liq. surf., as in R1. The irreg. late forms in R17 & R18 could not be fitted into the sequence of events portrayed in the other photos. They may result from collisions less well centered in the narrow vessel than the others.

The R series impact vel. of 425 cm/sec has been corrected

for acceleration during the "15.4 cm fall just above the flat top surf.
by reference to measurements made on 1 drop spacing above & below
the collision pt. in the next run (p. 8).

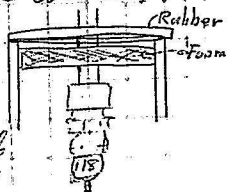
Conclusions Still photos of spatter collisions can readily
be obtained using drops around 1.7 mm in dia produced at
a low frequency at the top of a column giving a fall
distance of around 50". Higher rel. velocities and hence
a longer fall dist or greater initial vel. might be needed for
to produce spatter with smaller drops.

High vel. collisions between large drops with a v. large
size difference would probably start with forms like
those in R2 & R3, with crater formation following.
Forms analogous to the crater formation in a flat surf,
where the smaller drop might be said to turn inside out,
have been recorded in high v_r collisions between drops
with 3:1 dia. ratio. (See, eg., photos 15, 17, & 18 of D83-86).

4/8/68 Spatter and Disruption Collisions between Large Drops, T photo series.

A.p

The 48 $\frac{1}{2}$ " long glass column was used, as in the previous run, but with the 2" sphere & plastic foam cap. replaced by a plaster foam disc (in the column) and a thick rubber disc (on top of the column) closing the top of the column. $\rightarrow$



This permitted the short #18 needle to be raised a bit higher. The 2" sphere was used at the end of the telescoping port extension tubes, which were used in the (lower) rt. side chamber port. As shown in the photo at rt., the rt. driver was moved back from the chamber (to provide a longer damping dist. for the oscillations of the smaller drops) by using the exten. legs which had previously been used on top of that frame.

The Speed Graphic camera, with 135 mm lens and Polaroid back, was used to take the equip. photo above (1 sec exposure at min. opening with type 47 film). The Graphic View camera, used for most of my photographic work, is shown positioned on its side in front of the chamber.

The cardboard box which forms the upper part of the air wall window (which can be opened or closed) in which the electric fan sits can be seen in the background at the extreme left of the photo.

No biasing sleeves or other attempts to control or measure drop charges were made.

Aim

The purpose of the run was to obtain photos illustrating "spatter," the flattening of drops into thin sheets which shed droplets around their edges, which is expected to occur whenever drops collide at a sufficiently high velocity.

Drop Control Data (Sheet 45)

Left Right Left Right

vis. (av) 1.63 mm 1.08 mm

3.52 (ejection mech) 29.6

From counter 25.1 77.7

1 cm/sec 414 356

three streams, $\alpha \sim 92.5^\circ$

colli. pt. of impact all drop stream, $\beta \sim 42^\circ$

vis. rel. vel., $V_r \sim 558 \frac{\text{cm}}{\text{sec}}$

24.9°C

8 cone temp

13 $\sim 1.2 \text{ K}^*$

% rel. humidity

$\sim 100\%$

14 $75.8^\circ\text{F MM} + 5^\circ = 76.3^\circ\text{F (corr'd)}$

15 $77.6^\circ\text{F Chuc} - 0.6^\circ = 77.0^\circ\text{F (corr'd)}$

16 24.8°C

17 $K = 29 \frac{\text{microns}}{\text{cm}} @ 74.9^\circ\text{F (corr'd)}$
 $\sim 30 @ 77^\circ\text{F}$

Barom. press. 744 mm Hg

Not flushed with N_2

* The spacing of the larger drops had to be measured visually (with stick) since it was too large to photograph. Spacing above the colli. pt. measured. 16 cm while spacing below measured. 17 cm, so the av. was taken to represent V_r at the colli. pt. The exposed length of the #18 needle was 1.6 cm (total len. of hypodermic $\sim 1.05 \text{ cm}$) permitting the section in the middle of the photograph. While the exposed length of the #22 needle was 2.23 cm. This #22 needle gave very sharp drops at the max. flow rate over a much wider range of frags. than #22. The front window was removed several times to clear fog & splashes from it which would have interfered with the photographs, but the R.H. built rapidly to values in the neighborhood of 1.2 K. No front screen was used.

Rot. Check Pt.

$$\frac{7.08 \text{ cc}}{2 \text{ min.}} = 3.54 \frac{\text{cc}}{\text{min.}} @ 10.48_{6.6}$$

Results Since the strobe was synchronized with the left driver, the motion of the large drops was "stopped". By turning the dial of the Stroboscopes the position of the large drops above or below the smaller drop stream could be selected at will, giving approx. the stage of collision which I desired to photograph. However, the directness of the collision, how well it was in plane, and whether it was a hit or a miss, could not be controlled, and varied randomly. Photos T2-T20 show various stages of spatter collisions, progressing from early to late. (The colli. impending in T1 is actually a disruption collision. T46 shows drops approaching for a head-on spatter colli.). Photos T21-T40 show disrupt. collisions. T41-T59 failed to record any collision, and T60-T63 are the photos taken through the microscope to provide drop dia. & initial vel. data. Photo T62 shows a colli., indicating how little depth of field is available through the microscope. Field depth is also inadequate in T3-T5, taken at $\sim f/16$, but it is adequate in the rest of the photos. A smaller lens opening giving even better depth of field and sh. better exposure could have been obtained if the screen over the chamber's rear window had been removed.

In the spatter collisions the smaller drop quickly loses its identity as it spreads into the larger drop, as in T2. More & more of the large drop is then spread into the thin sheet until the only reminder of the larger drop is the trace of curvature in the sheet of liq. as in T11 & T12. By then, small arms protruding from the rim of the sheet (which always appears to be thicker than the sheet) have developed, and droplets begin to rack off. These droplets become larger as the sheet contracts and its rim becomes thicker, as in T13-T16. Eventually all that is left of the sheet

Graphic View

63 photos

90 mm lens at $\sim f/22$ except $f/16$ for first few photos
Lens to plate 20 $\frac{3}{8}$ " for illustr. photos, 9" for

T60-T63 (data photos) (bellows exten.
inserted beyond normal max. by reversing front
holder, giving magnification of $\times 4.2$ in photos)

Microscope (with $\times 7.5$ eyepiece & $\times 8$ mm objective)
used only for data photos (T60-T63)

Shutter $\frac{1}{25}$ sec

Stroboscopes (set. at Ext. Input, Med. Intensity)

run at 25.1 flashes/sec by H-kit oscil.

lighting by Stroboscopes at High Intensity

light red. by frosted glass & screen and

3" O.D. black weaker with $1 \frac{1}{8}$ " dia. hole
(+ sheet yell. for T61-T63)

Type 47 Polaroid film

of water is a number of thick arms and separated droplets of a range of sizes, as in T 20. Deformed drops in the smaller drop stream in T 14, T 16, T 18, T 19, & T 20 show that a second drop has struck the lig sheet formed by the 1st colli., but this has probably not produced a qualitative change in the late spatter forms.

As photos T 21 - T 40 show, the forms resulting from disrupt. are much more elongated, along a diagonal line connecting the masses remaining of the original colliding drops as they move apart. If the disrupt. colli. is fairly dir., as in T 24 & T 25, the main masses of the orig. drops are soon no longer recognizable. Photos T 21 - T 40 have been set in order on the basis of the length of the elongated forms and the string of fragments which follows, without regard to how dir. the colli. was. T 28 shows the results of a large drop colliding with two smaller drops, more directly with the first than with the second.

Forms similar to those in the photos were observed with the strob. as the freq. of drop production on the rht. was increased to ~2000 per sec. as the drops in the str. from the rht. got smaller the lig. sheets produced in the collisions appeared to shrink some in size.

4/19/68

Spontaneous Regular Jet Breakups, U photo series

In preparing for the run on p. 14, low vel. jets at two low flow rates with needle #28g were found to spontaneously break up into v. reg. s.d.-free streams of drops. The flow rates were at the bottom of the reg. breakup region for the needle on Graph 10. The phen. was v. sensitive to changes in flow rate. Even changing the flow through the needle on the ^{opposite} other side disrupted it. It was not caused by vibrations from the Strobolac since changing their frequencies did not effect it. Even changing frequencies on the other side's driver & amplifier did not effect it, though it was immediately disrupted when the driver connected to needle #28g was turned on. The phen. continued when oscillator & both amplifiers were turned off. The driver and needle support system was insulated from the frame by the iron rectangle's felt feet as usual, and the needle holding tube passed into the chamber through one of the plastic foam sandwiches. These facts and the fact that diff. frequencies of breakup were found at diff. flow rates indicate that the phen. is self-perpetuating and not determined by any particular external vibration.

Spontaneous Reg. Breakup
with #28g

Rot.	$\frac{cc}{min.}$	Freq.	Vel.
8.43 ₆₆	2.145	~370	~100 cm/sec
8.31 ₆₆	2.08	~485	~85 cm/sec

Ret. Check Pk.

$$\frac{4.29 cc}{2 min.} = 2.145 \frac{cc}{min.} @ 8.43_{66}$$

Graphic View

7 photos

162 mm lens to plate 9"
x 7.5 eyepiece & 48 mm objective
Shutter speed $\frac{1}{25}$ sec except $\frac{1}{50}$ sec for U1
Strob. ~25 flashes/sec (run from H. kit) except
~550 RPM for U1.

Type 47 Polaroid film
light red. by 1 sheet yell. cellophane
for U1-U4, $\frac{1}{2}$ sheet yell. for U5-U7,
black rubber outliner, 3" dia. with $\frac{1}{8}$ " hole for U1

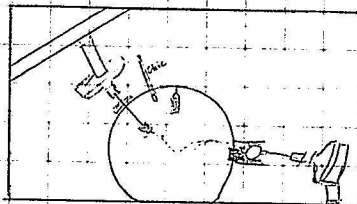
The freq. of spontaneous drop production was determined by noting a number of Strobolac settings which "stopped" the motion. Velocities were calculated from these frequencies and drop spacing measurements on the photos.

Photos V.1-V.4 show stages of the reg. breakup at the higher flow rate. (V.1 is brighter than the other photos because the Strobos have unit, at high intens. setting, apparently gives brighter flashes at the lower (1/2 sec) rate than at the higher (ext. input) rate). In V.1 the first large drop is about to break from the jet. In V.2 it has separated and a connected string of drops is about to separate. In V.3 this string is colliding with the first drop and in V.4 most of the string has coalesced with the first drop, necking off a smaller drop as it did so. This smaller drop is apparently left with an outstanding neck rel. to the larger drop because by the time the stage in V.1 occurs again, it too has collided & coalesced. The small bump on the forward end of the upper drop in V.1 probably resulted from the surf. waves of this coal. As the drops on the rt. in each photo show, no ca. drops are left uncoalesced.

Photos V.5-V.7 indicate that the mech. of the reg. breakup is simpler at the ^{2^d} lower flow rate, where more drops are produced from less water. V.6 & V.7 show that one large and one smaller drop break off from the jet shown in V.5. These coal. to form the more closely spaced drops seen leaving the rt. of each photo. The stage in V.7 is only sl. later than that in V.6, and the nearly identical shapes in the two photos give an indication of the regularity of the spontaneous breakups.

4/20/68 High Medium Vel. Reflex Dissection Collisions of $\sim 450\mu$ & $\sim 900\mu$ Drops, Hycam #6 (Sheet 46)

Ap The upper left & lower rt. chamber ports were used as shown at rt. A plastic foam "sandwich" was used in the left port and the foam cylinder & 2" sphere were used in the brass port exten. tube (which extended the port ~ 12 cm) on the right.



The upward directed rt. needle was withdrawn enough so that it did not protrude into the chamber, but the driver was within the frame (rather than outside it as on p. 8). This was possible because the rt. driver was supported on wood blocks (which rested on a felt pad) instead of being held by the rt. brass positioner.

The tripod and Lo-Hi Unit ordered with the Hycam were used for the first time because the D. Graflex camera stand was in use. The Lo-Hi attachment does not provide as stable a base as the D. Graflex stand, and the camera may tend to overbalance^(tip) if the tripod legs are not well extended.

Aim The purpose of the run was to obtain an illustrative movie of reflex dissection with $\sim 450\mu$ & $\sim 900\mu$ dia drops, and to find the rel. vel. for the onset of R.D.

Hycom #6

Graphic View

103 p.p.s. setting $\rightarrow$ 7900 f/sec max

4" f/2.7 lens set at 9" ft.

3 exten. tubes, 35 mm long

1/2.5 shutter

Positioned upright

100 ft. roll of Tri-X Reversal film

Lighting: 90w RFL2 Photoflood at 120V,

but light was switched off ~ 34 ft. in

lamp. 4 1/2" x 5" back

Light red. by 7 1/2 cm of yell. water

3" O.D. circle of black rubber with 1 1/8" dia hole

15 photos

162 mm lens used until shutter failed, then 90 mm lens (162 mm lens to plate 9)

X 7.5 eyepiece (still set at cond. position for 9" lens pl. with 162 mm lens, reset for 90 mm lens), 48 mm objective.

X 7.5 eyepiece without graticule from reg. microscope (see p. 130) used for some of illustr. photos.

Shutter 1/2 sec

Strob ~ 550 RPM with 162 mm lens (photos 1-9, 11 & 12)

570 RPM with 90 mm lens (photos 10, 13-15)

Type 47 Polaroid film

Light red. same as for movie except that black outline was removed

Ret. Check Pts

(Before movie)

$$\frac{2.49 \text{ cc}}{2 \text{ min}} = 1.245 \frac{\text{cc}}{\text{min}} @ 6.42^\circ \pm 0.6$$

$$\frac{10.65 \text{ cc}}{1 \text{ min}} @ 4.23, (204)$$

$$\frac{19.47 \text{ cc}}{2 \text{ min}} = 9.735 \frac{\text{cc}}{\text{min}} @ 3.93$$

Drop Control Data (Sheet 4a)

Left Right

#320 #221 Drop dia. (avg) 45.1 μ 90.9 μ

cc/min 4.103 1.24 10.1

f_c set from counter 431

#10, 0 drop stream rel. sec 193⁺ 12.2

Angle between streams, α 118°

Angle of div. with plane of impact with small drop, ϕ 67°

Air collision rel. vel, v_r 273 $\frac{cm}{sec}$

Cone to target 25.1° 25.2°C

Cond/drop before -2.0 x 10⁻⁵ -7.7 x 10⁻⁵

Cond/drop after -2.6 x 10⁻⁵ -1.2 x 10⁻⁵

1.2 $\frac{10^{-5}}{sec} = +4 \frac{mv}{sec}$ much

1.3 1.3K (1.10K d/c illu. phot)

1.4 7.5.8% $f_{MH} + 5 = 76.3\%$ (cond)

1.5 77.2% $M_{20} - 1.5 = 76.6\%$ (") (Thermom. 3.1. high in column)

1.6 25.0°C

1.7 $K = 24.2 \frac{microns}{drop} @ 74.7\%$ (76.6% f_{MH})

Flushed with M_2 (pressure drops with very over-saturated point)

* Rodding is out a rough estimate made from an approx reconstruction of conditions in the more. One of the smaller leaving leaves was positioned around the dump pt. of the left jet and connected to the D.C. source (with the virus, groundingship clipped to the D.C. source).

The left jet, but the ohm meter assumes so low that no bias was accepted. The above (cond) was used (cond. -2).

The left jet, but a piece of heavy Cu screen was inserted into the 1/8" pipe so that only a small space was left above it. This screen was 3/4" x 1/2" hole was used without opening up.

to compare drops, water on open plate, and opening in column.

Results The last half of the movie was spoiled because the Photoflood lamps were shut off accidentally while the camera was still getting up speed. The film's exposure and contrast are good for the first ~34 ft., but then the light begins to die out until very little can be seen by the time the first 57 ft. has gone through the projector. (After this, only occasional, widely spaced frames were exposed by flashes of the Stroboslane).

About 70% of the collisions recorded resulted in reflex disjection, with the rest resulting in coal. except for an occasional case of disruption. Most of the angle measurements on the film were confined to collisions displaying transition forms. This included R.D. collisions whose fragments remained close together, sometimes colliding, coal collisions where a narrow neck developed (temporarily) as in R.D. collisions, and coal collisions having a "folded" form indicating conditions near those giving disruption. Rough checks were made on a number of other collisions to make sure that they fell within the regions established by the values below, with no precise measurements being made.

θ (#H6)

Reflex Disjection	$0^\circ, 2^\circ, 3^\circ, 3^\circ, 4^\circ, 4^\circ, 5^\circ, 5^\circ, 5^\circ, 5^\circ, \sim 7^\circ$
Coalescence	$5^\circ, 7^\circ, 8.5^\circ, 9^\circ, 13^\circ, 25.5^\circ, 29^\circ$
Disruption	$\sim 31^\circ$

The measurement on the disruption collision is considered approximate because the drops appeared a bit out of plane. (Other measurements on such collisions are omitted above).

The overlap between the R.D. & coal regions may result from the ends of the hourglass form oscillating either towards or away from each other at the crucial moment at which coal or separation is determined. The hourglass form is found both in R.D. collisions and in the most div. coal collisions. Differences in the oscillations of this form could be caused by the still undamped oscillations which the movie shows in the large drop stream combined with the variation in L drop position which is apparent at times (which would change the stage of L drop oscillation at the coll. pt.).



Other variations from standard conditions in the $\theta = \sim 7^\circ$ R.D.

collision (or the $\theta = 5^\circ$ coal collision) could also account for the discrepancy. The S drops following the one involved in the $\theta = \sim 7^\circ$ R.D. colli was out of str., & while the position of the latter was ~ correct, it may have had a sl. higher than av. str. vel., which would incr β and (in this case) decr θ . The forms before separation in the $\theta = \sim 7^\circ$ R.D. colli seemed to indicate that the colli was more dir. than the $\theta = 7^\circ$ coal colli, which had occurred a few frames earlier.

Because of the occasional out-of-str. S drop, the angle formed by the S str. and the top of the frame, was checked for each colli. angle measurement, and reference was made to the line forming the av. angle of 42.5° with the fr. top instead of the S str. when there was significant variation. Occasional sa. drops from each str could be seen in the movie, and the problem got worse later during the illustr. stills. The amplitude of the sq. wave used ~~from~~ ^{to drive} the left driver (since it was found to give more stable elimination of sa's with the small left jet broken up at a low freq.) was sl. changed occasionally to keep the left str. relatively sa. free, and the amplitude of the sine wave driving the rt. driver had to be changed frequently to try to minimize the sa drops and to produce enough regularity in the rt. str. to provide repeated R.D. collisions during the stills.

Photos 9-15 are the illustrative photos taken with the drop streams at movie conditions. Photos 9 & 12 were taken immediately after the movie, before data photos 1-8. Only photos 9 & 10 show (fully) forms resulting from R.D. collisions. The drop second from top in 9 shows the elongated, narrow-waisted form preceding separation in a fairly dir. R.D. collision. The bottom drops in 10 show the fragments resulting from such a collision. The more closely spaced fragments at the bottom of 9 result from a less dir. R.D. collision. The smaller of the two main fragments from an R.D. colli is also visible at the bottom of 12. The top colli in 11 might have produced R.D., but the rest of the collisions recorded in the photos were coal collisions, including (probably) the top forms in 9 & 12. Early forms like the ~~top~~ ^{bottom} drops in 7 and the top drops in 11, 9, & 12 are quite similar for both coal & R.D. collisions. The bottom drops in 7, 6, & 8 show stages of a coal colli somewhat more dir. than the least dir. ($\theta = 27^\circ$) coal colli in the movie. The folded form in the middle of 10 is v. much like a stage recorded for this

least dir. coal colli in the movie. The movie also shows that the upper middle form in 13 results from an out-of-plane coal colli. The lower middle form of 12 results when the two ends of an ~hourglass form from a fairly dir. coal colli (like the form just above it but with thinner waist) pull back together again.

P6 The horiz. microscope support aims it a bit downward when it is pointed toward the chamber. One of the capping needles was found to leak, which has probably permitted air to leak into the needle-holding tubes when the equip. stood unused.

Minimum Rel. Vel. for Reflex Disjection with $\sim 450\mu$ and $\sim 900\mu$ Drops, V & W photo series

Ap The set up was the same as on p. 14 except that the rt. needle protruded into the chamber and was made more nearly horizontal in reducing d. The oscillator freq. was the same and the left rot. reading held at the value on p. 15. The rt. rot. reading had to be restored to ~ 4.12 several times when the rt. valve stems were bumped. The R.H. rose sl. during the photos to give ^{reading} lower than that previously obtained (p. 893) at presumably 100% rel. humidity. Readings 12 & 17 of the p. 15 table were made after these photos. The only other drop control data ^{kept} after these stills were the distances from breakup pts. to colli. pt. after the W series, which were 7.5 cm & 9 cm on the left & rt. respectively.

Aim The V series data photos were taken to give the $\sim$ minimum rel. vel. for the onset of reflex disjection.

Results After movie #146 and the H.G. still photos were completed, the angle between the (same) drop streams was reduced until all dir. collisions seen with the strob. resulted in coal.

The angle was then increased little by little until reflex disjection reappeared, this pt. again being determined by viewing collisions made as dir. as possible through the microscope with the strob. These are the conditions under which the V series photos were made. Data photos V1-V3 gave the information for the table above (except R.H.). The following conversion factors derived from a photo of the .005" div. scale with the same lens, bellows extension, and microscope eyepiece setting were used in the calculations.

Graphic View

15 photos
90 mm lens used
Lens to plate set at 9" ^{giving .85" with 90 mm lens}
X7.5 eyepiece with graticule for V series,
X7.5 " without " for W series,
48 mm objective
Shutter 1/2 sec
Strob 570 RPM
Type 47 Polaroid film
Right red, by 7 1/2 cm yell. water,
no outliner.

V series Drop Data

	Left	Right
Drop dia. (mi)	454 μ	900 μ
Stream vel. ^{cm} / _{sec}	212	150
Angle between str. d.	83° (av)	
angle of dir. colli. plane of impact with S. stream, β	52.5°	
Dir. colli. rel. vel., V_r	244 ^{cm} / _{sec}	
% rel. humidity	100%	

90 mm lens (Microscope eyepiece set to give sharp lines in H.V. photos). ^{later}

8. $\frac{3}{4}$ " lens to plate 10 graticule units $\longrightarrow$ 396 μ /unit
2 " " $\longrightarrow$ 392.7 μ /unit

The result indicated is that with drops of the size used here, reflex disjection begins in head-on collisions at a rel. vel. just under 244 cm/sec. This v_r has not decreased as much as might be expected with the large change in α from #H 6 conditions because the more vertically downward left str. and the no longer obliquely upward directed rt. str. have larger str. velocities than before due to the acceleration of gravity.

The top drops in V4 & V5 and the bottom drops in V6 show stages of the elongated form to be expected in a ~ mini vel. R.D. collision. Irregularity in the rt. str. foiled attempts to record the actual R.D. separation under these conditions (which had been visually observed), but the lower V6 form seems v. close to separation. The other forms in photos V4-V9 are those of the coal. collisions which seemed to predominate. However, disruption collisions could readily be produced at this vel., as shown in V10 & V11.

After the V series photos the angle between the streams was again increased to produce repeated R.D. collisions. W1 & W2 each show ~ disc, hourglass, and separated forms for these higher V. R.D. collisions. (The line in the drops resulted from their being ~ in front of the bar holding the rear screen securely in place). No further photos were attempted because of irregularity in the drops streams.

Conclusions The movie #446 and the H6 & W series photos provide photographic proof that R.D. occurs between the large drops of 2:1 dia ratio as it does in the other 3 2:1 & 1:1 dia ratio cases. Reflex disjection between colliding 450μ & 900μ dia drops begins at a rel. vel. just below $V_r = 244$ cm/sec, and with an incr. of about 30 cm/sec in the rel. vel. the central R.D. region expands to cover the θ range of 0° to 5° or 7° . This expansion is much less rapid than that found after the onset of R.D. with 700μ dia drop pairs. If the rate of initial expansion of the R.D. region is a function of the size difference between the drops, a

similar slow expansion could be expected with the small 2:1 dia ratio drops. As in the 1:1 dia ratio case, R.D. begins at a much lower V_r with the large 2:1 dia ratio drops than with the small 2:1 drops. The diff. between V_r 's for the onset of disrupt. & R.D. is also smaller for the large drops than for the small ones, as found with the large & small equally sized drops.

The rule that the elongated forms resulting from disc contraction will suffer R.D. separation if they reach over three times the av. of the diameters of the colliding drops was again found to hold. The elongated R.D. forms in the H6 & W series photos reached lengths greater than this, while the elongated coal forms were noticeably shorter. The longest form in the V series photos was the hexaglass form in V6, which was 2.8 times the av. dia. in length. A longer form may have preceded it since elongated forms in other runs have been found to shorten somewhat during the final necking down. This lends additional weight to the reclassification of the $V_r = 4.51$ cm/sec data for $\sim 450\mu$ & $\sim 900\mu$ drops on p. 823, which indicated that the R.D. region at this rel vel. covered the θ range from 0° to at least 10° . This shows that the R.D. region gradually expands as V_r increases for large 2:1 dia ratio drops, and the same is probably also true for small 2:1 drops and possibly for 1:1 dia ratio drops as well.

The results show that reflex dissection plays an important part in fairly high vel. collisions between 450μ & 900μ dia drops, but it occurs under more restricted conditions than with large equally sized drops. As in the 1:1 dia ratio case, low V_r R.D. collisions between 2:1 dia ratio drops produce two main fragments. The fragments are not equal in size as in the 1:1 case, but their size difference is much less than that between the drops which collided.

Preparation of Thesis Photographs

Thesis preparation extended until June 1970. One of the time consuming jobs was preparation of the photographs for the thesis. Over 1000 separate prints were involved. These came from the still photographs and high-speed motion pictures taken under the conditions detailed in this and the preceding volumes of research notes. Since the Dynaflex movie were taken on negative strips of 35 mm film, prints were made directly from the desired portions of the selected frames. In the case of the Polaroid still photos and the 100 ft. reels of reversal (positive) film taken with the Hycam camera, negatives had to be made before the prints could be made. I made these negatives in the Chem. E. Dept. 3rd floor darkroom with the copying cassette provided with the D.urst enlarger. The Polaroid prints were copied (onto 35 mm negative film) by illuminating them on the enlarger platform with fluorescent lights on either side and photographing them through the enlarger. For making negatives from Hycam films the cassette was placed on the enlarger platform on a board with 2 holes drilled in it to allow the cassette to lie flat, facing upward. The 16 mm film was then fed through the enlarger emulsion side up to match the film in the cassette. A cardboard adapter was used to hold the film in the enlarger's 35 mm holder. Images from the 100 ft. reels of film were projected onto the cassette film with all other light sources in the darkroom turned off. Only the portion of each 16 mm frame of interest was copied onto the cassette's 35 mm film. Label frames were provided by projecting light from the enlarger through a piece of cellophane with the desired notation marked on it with a felt-tipped pen (cellophane inverted). The felt-tipped pen was used to mark with arrows the sides of the frame which began a sequence which was to be copied in a Hycam film. A takeup spool with film-length markings gave the approx. number of feet from the beginning of a film at which a sequence began. The copy films made with the D.urst cassette were numbered #C1 to #C5. An additional short strip of copy film

was attached to the end of #C4.

Most of the prints from the copy films and the Dynafax film strips were done at the U.W. Photography Cinema Extension ("photo lab"). Photo lab errors made it necessary to repeat over 1/3 of the prints at least once, which led to problems in matching the repeated prints with ones they had done earlier. I eventually did some of the corrective print work myself.

All the drop photographs used in the thesis "Behavior of Water Drops Colliding in Humid Nitrogen", P.W. Park, 1970, may be traced to their original source using the following tables.

Thesis Photo Source Table

Thesis Fig.	Source	Dynafax Frames Used or Copy Film No.	Ref. Table pgs.
5	J series (stills)	#C3	
6	U series (stills)	#C3	124
7	"	#C3	124
9	M series (stills)	#C3	283
10	"	#C3	283
15	#D52	93, 96, 99, 102, 105, 108, 110-123, 126, 129, 132, 135, 138, 141, 144, 147, 150, 153, 156, 159	
16	D 56-57 (stills)	#C1 & #C4	
17	#D57	107, 110, 113, 117, 121, 125, 129, 133, 137, 143, 149, 155	
18	O series (stills)	#C1	
19	D 58-61 (stills)	#C1	
20	#H5	#C3	
21	#H5	#C4	
22	#H5 (9 ft. in)	#C4	
23	#H5 (39 ft. in)	#C4	
24	D 58-61 (stills)	#C1	
25	"	#C1 & #C4	
26	"	#C1	
27	"	#C1 & #C4	
28	D 67-70 (stills)	#C1 & #C4	
29	"	#C1	
30	"	#C1 & #C4 & #C5	
31	"	#C1 & #C4 & #C5	

* Illustrative pair of photos showing regularly jet back up stages 180 out of phase in each other.

Thesis Fig.	Source	Dynafax Frames Used or Copy Film No.	Res. Notebook page
32	#D63	120, 122, 124-138, 140, 143, 148	
33	#D66	72-79	
34	D 71-73 (stills)	# C 1 & # C 5	
35	# D72	5-15, 17, 19, 21, 23, 24, 25, 26, 28, 30, 34, 38, 40, 44	
36	D 71-73 (stills)	# C 1	
37	"	# C 2	
38	"	# C 2	
39	D 87-91 (stills)	# C 2 & # C 4	
40	"	# C 2 & # C 4	
41	# D 89	127-153, 155, 156, 157, 159, 160, 161	
42	# D 87	29-52, 54, 55, 57, 58, 59, 60, 62, 64	
43	"	52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 63, 64	
44	N series (stills)	# C 2	
45	# D 36	80, 82, 84, 86, 88, 91, 93, 95, 98, 101, 106, 111, 115, 119, 127	
46	# D 42	Rebound 16, 19, 20, 22, 25, 28, 31, 34, 39, 52	
47	# D 47	Coalescence 172, 175, 178, 179, 180, 181, 183, 185, 188, 192	
48	D 47-48 (stills)	185-190, 192, 194, 195, 198, 201, 203, 205, 207, 211, 215	
49	"	# C 2	
50	"	# C 2	
51	# D 50	77-82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 118, 122, 126, 130, 134, 144, 156	
52	V series (stills)	# C 2	194
53	# H 6	# C 3	144
54	H 6 (stills)	# C 2	144
55	# H 6 (38 ft. in)	# C 2 & # C 3	144
56	# H 6	# C 3	144
57	H 6 (stills)	# C 2	144
58	D 74-77 (stills)	# C 2	144
59	"	# C 2	
60	# D 77	15-22, 24, 26, 30, 34, 38, 41, 44, 48, 52, 54, 56, 58, 60, 62, 64, 66, 68, 72, 82, 92	
61	D 29 (stills)	# C 2	
62	# D 40	68-74, 76, 78, 80, 82, 84, 87, 90, 94, 99	
63	# D 39	7-17, 19, 21, 22, 24, 26, 28, 34, 40, 46	
64	"	205-219	
65	# D 34	63, 65, 67, 69, 71, 73	
66	# D 30	82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104	
67	D 37-38 (stills)	# C 2	

Thesis fig.	Source	Dynafax Frames Used or Copy Film No.	Res. No. of frames page
68	D78-79(stills)	# C 2 & # C 4	
69	"	# C 2 & # C 5	
70	"	# C 2 & # C 5	
71	"	# C 2 & # C 5	
72	H 3(stills)	# C 3	
73	D18-19(stills)	# C 3	
74	F 8(stills)	# C 3	
75	# D19	138, 142, 146, 148, 150-156, 158, 160, 162, 164, 166, 170, 176	
76	D80-82(stills)	# C 3	
77	"	# C 3	
78	# D17	21-25, 27, 29, 31, 33, 35, 37, 39, 41, 45, 47, 49, 51, 67, 89, 95	
79	"	113, 115, 117, 119, 121, 123, 125, 127, 129, 131, 133, 139, 145, 153, 171	
80	D83-86(stills)	# C 3 & the extra strip which follows # C 4	
81	# D85	141-170, 172, 174, 176, 178, 180	
82	D83-86(stills)	# C 3	
83	"	# C 3 (print. made with negative inverted)	
84	"	# C 3 & # C 4 & the extra strip which follows # C 4	
85	D24-25(stills)	# C 3	
86	# D43	206, 208-214, 216, 218, 220, 222	
87	# D46	126-138, 140, 143	
88	"	54-63	
89	# D21	48-51, 53, 55, 57, 59, 65, 71	
90	"	85-91, 93, 95, 97, 99, 101, 105, 113	
91	H 4(stills)	# C 3	
92	"	# C 3	
93	F 11(stills)	# C 3 & # C 4	
94	H 2(stills)	# C 3	
95	T series(stills)	# C 3	84
96	"	# C 3 & # C 4	84
97	R series(stills)	# C 3	24
98	Q series(stills)	# C 3	24
99	# D64	152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174	

The tables below give the numbers written on the original Polaroid prints which were copied and the impact angles identifying the Hycom collision sequences which were copied in the five copy films and extra strips. Each column identifies the copy film frames in the order in which they appear in the copy films. The heavy lettering shows the label frames that appear between major sequences. Also noted are the accessories used with the Durst M35 enlarger and exposure conditions.

Some of the frames were repeated because of incorrect exposure or other error. Not all of the pictures copied were finally chosen for use in the thesis, and in the case of most of the excluded frames, no prints were made.

The sections of copy film made from $\frac{1}{16}$ in. reversal movie film are identified by a # preceding the letter & number symbols which identify a particular film. All other copy film frames were made from Polaroid prints. Details of the run in which any particular set of prints ^{or movie} was taken can be found by consulting the index at the end of each volume of research notes and looking up the notes on the run. "D56-57" refers to the run in which Dynafax movies #D56 and #D57 were taken and "R series" refers to the R series of still photographs, for example.

The copy films #C1-#C4, because of their length, were developed by the photo lab. The extra strips, ^{and #C5} were short enough for me to develop myself.

Copy Film # C 1

CI

July 1968
Still Photos Copied with Durst M35

Exposures
 $\frac{1}{2}$ sec @ f/16
 unless otherwise noted.

D58-61
 Tube 43 at max
 4" min. variation
 Early stages of R.D.

D56-57
 cont.
 8
 8
 11
 16
 Fig. 15
 17
 19
 20
 22
 23
 26
 27
 15 (note)
 19
 18 (note)
 x2.8 cont.
 Carries
 MITUB dm one
 not in "tube 43"
 turned for max
 magnif.
 1
 3
 4
 5
 Forget to use 1/6
 R.D.
 1
 3
 4
 5
 7
 8
 10 (top)
 4
 7 (note)
 7

D67-70
 Variator at bot
 Tube 43 at max magnif.
 Enlarger raised to
 almost 2.3 (magnif.
 reading) & focus'd.
 MITUB shown in as
 far as possible
 R.D. 22
 28
 28
 units 8
 across 9
 10
 12
 13
 15 (noted 90°)
 17 ("90° deep
 below horizon")
 21 not 90°
 12 "
 16 "
 21 "
 24 "
 13 "
 24 not noted
 10 out of plane
 27 not 90°
 28 "
 29 "
 29 " " " form
 30
 33
 Long diaphragm
 forms 1.5
 magnif. 11"
 40
 41
 42 (1 sec) (light)
 38
 45
 45 diaphragm

Variator at 2.2 mm
 Tube 43 at max
 Enlarger at bot (1/2)
 MITUB at 1/2 sec & 1/10 sec
 Early R.D. stage
 Print at 1/2
 (Fig. 3) 38
 43
 44
 45
 46 (note later)
 46 (1 sec)
 47 (light)
 1 sec
 40
 41
 25 (1/2 sec)
 25 (1 sec) good
 26
 Variator 2.5 mm
 Tube 43 at max
 Enlarger at bot.
 MITUB screwed
 out as far as
 possible
 17
 6
 8
 11
 12
 13
 14
 15

D71-73
 Variator 2.5 mm
 Tube 43 at max
 Enlarger at bot.
 MITUB screwed
 out as far as
 possible
 17
 6
 8
 11
 12
 13
 14
 15

Fig. 36
 22
 23
 22 (5"?)
 18
 Diaphragm
 31 with arrow
 31
 27 Spoiled
 28
 29
 incomplete

Photos on a bit
 overexposed?
 Film a bit grainier
 but with al. higher
 contrast than
 my test film #4?

Copy Film # C 2 (first part)

C2

x 3.5

Condi same

as C1 for

1/1s except

variator raised

to 4" mm (sh.)

above note (f)

the focus (and light) moved back

a bit & tilted

N isrup series in sh. more!

(D71-73 cont.)

31 wide gap

Fig 37

27

28

29

30

33

31

28

32

33

(32)

Fig 38

34 (B)

D87-91

cond 1/5 sec

same cond

in coll R.D.

all tilted

6

7

28

9 (2nd level)

9

10

6

7

11

13

8 1/2 sec

8 1/2 sec

Indir R.D.

Fig 40

14 Photo

22 placed

18 straight

25

22

23

25

22

25

13 other

28 colls

24

Higher magnif needed for 28-43.

No Balphid in 44-51

Vic movie #0 87 + 879 + c=0

V series (no card)

Fig 44

1

2

3

4

5

8

Field 3.2m

wide

1

2

Enlarge raised to 2.1

(with MITUB screw)

all the way in tube

at min magnif. 1 to over

focus + give field with exposed

of 4.0m

Dr.

6

8

7

Two melted

drops out of

picture

3

7

av. out of foc.

D87-91 again

9

9

1 stop

running

(out of foc.)

Dimp

N. 10

2.1 L cords

1/5 sec

D47-48

MITUB screw

out as far as poss.

Tube 83 at min magnif

Variator at 3" mm

Enlarge dr. to tot

av. colls

5L 13

5L 16

5L 11

5L 8 (desp.)

5L 7 (1 sec)

5L 6

5L 5

5L 4

5L 3

5L 2

5L 1

5L 0

5L -1

5L -2

5L -3

5L -4

5L -5

5L -6

5L -7

5L -8

5L -9

5L -10

5L -11

5L -12

5L -13

5L -14

5L -15

5L -16

5L -17

5L -18

5L -19

5L -20

5L -21

5L -22

D74-77

A few P.A. stages

some cond

Fig 58

12

14

15

14

MITUB screw

all the way in

Tube 43 at min

→ no same magnif

Let 7" wide corner

Variator focuses

at 4" mm

Lig. pty moved back

21

19

Dearness

(motion, stagnation)

6

11

5

above 5.5m projected

20

22 (2 out of)

2.1s (1/5)

(D78-79) (2)

24

25

26

27

28

29

30

31

32

33

34

35

36

37

38

39

Copy Films # C2 (concluded) and # C3 (first part)

(C2 cont.)

D78-79 cont.

Diarrup.
condi same)

Minicord D.P. forms

45 1/2
47
49
50
51

Lesser dir. D.

53
54
55 (filled)
58
59
60

MITUB removed

Enlarger at bot.

tube 43 at mini

Varia. at 24 mm. focus

R/C for 1/2 sec. as usual

60

61

62

63 diag

Long forms

of dir. R.D.

28

29

30

34

again

#H6

(movie)

H=5° cond.

colli 38'in

is not on longer

at max height.

Varia. at 0"

3 sec. with 1/2 sec.

black cloth raised

concentric to focus

1/2 sec. at 1/2 sec.

1/2 sec. at 1/2 sec.

1/2 sec. at 1/2 sec.

1/2 sec. at 1/2 sec.

1/2 sec. at 1/2 sec.

1/2 sec. at 1/2 sec.

1/2 sec. at 1/2 sec.

1/2 sec. at 1/2 sec.

The first 7' fr had
to be repeated at f/16

Every frame was copied

hunted film C2 ran

Fig. out as drop was

necking down to mini.

waist.

inc. < 22 frames

(1/2 sec. at 1/2 sec.)

V. overexposed

Repeat

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

13

D83-86 (1/2)

Dir. coal. colli

same condi

17

7

MITUB out as

give 7' dir across

as in photo

17

Varia 2.5 mm

13

17

13

MITUB in all

set may 7' units

across, Varia 5' mm

(tube 43 still max)

14

15 (out of pl)

18

19

20

29

Dir. coal. colli

(same condi)

Hutta 2' (1/2 sec)

26

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

27

3:1s (1/2)

Same condi

D 24-25 (no

2 (1/2 sec) 5' unexposed

2

1

02c

Diarrup?

(same condi)

1 (1/2 sec) 5' unexposed

2

Other

Sizes

F11, PC

HITUB in middle

of 2nd knee

tube 43 at mini

Varia 14' mm

(Should be 14')

11

3

5

4

10

Bounce

MITUB removed

Tube 43 max

Enlarger 2.35

Varia 19' mm

9

H2 (1/2)

HITUB out all

A - neg, tube

43 at mini

Varia. at 3' mm

3

14

5

7

10

12

14

14

14

14

14

14

14

14

14

14

H4 (1/2)

Same condi

15

9

11

14

15

19

21

22

23

24

25

26

27

28

29

30

31

32

33

34

35

36

37

38

39

40

41

42

43

44

45

46

47

48

49

50

51

52

53

54

55

56

57

58

59

60

61

62

63

Copy Films #C3 (concluded) and #C4 (first part)

(C3 cont.)

R series
HIT UB in well
Also may take
43 at mini, Varis
at hot, enlarger
raised to x2.2+
to focus

- Fig 9 1
2 } 20.0 p exposed
4 }
8
12
15

Q series in well
take 43 to max,
enlarger to x2.1
to focus

- 2
3
4
6
7
13

Jet photos
(no card)

No MITUB

Varis 29 in to
focus, take 43
centered,

Enlarger at x2.5
(Fig. 5)

3 photos
of jet
pairs
(10/16 flms)

M series
(no card)

- (Fig. 9) 1
3
4
6
8
13

15 Enlarger
(Fig. 10) 16 @ x2

- 20 } x2.7
18 }
17 }

U series
(no card)

(all x2)
(Fig. 6 & 7)

- 2 = 1/16 in
Light closer
2
3
4
5
6

7/22/68

#H 6 movie

cont., start 19
with narrowed
form with bell
above a wing

(Fig. 55) 35 sec expo @ f/16
#H 6 on white paper
exposed 35 sec @ f/4

Since 7/16 forgotten
Every other frame
after in disc with follow
pulling together.

2nd last for
H center to show
approx top edge
of frame.

Last fr shows
form of a max
extension before
drops down fr.

4 sec #H 6 on all alone
normal

$\theta = 29^\circ$

3 sec. notes etc
selected frames
(only coal.)

R.D. 10 sec

$\theta = 0^\circ$ @ f/16

to supplement
still select
frames

#H 5 (R.D.) 10 sec

$\theta = 1^\circ$ @ f/16

9 sec (copy cassette)

7.4 sec above enlarger

platform, on machine

at f/16

1st fr 30 sec (10/20)

2nd on 40 sec

most early forms stopped

Last fr exposed was

last of film

not used

D at $\theta = 24^\circ$ (19' in)

Diagrams with delay
exp'n (faintly the wall)

20 sec @ f/16

Every fr exposed
until exp'n

2nd last for
H center to show
approx top edge
of frame.

R.D. 10 sec

$\theta = 0^\circ$ @ f/16

to supplement
still select
frames

#H 5 (R.D.) 10 sec

$\theta = 1^\circ$ @ f/16

9 sec (copy cassette)

7.4 sec above enlarger

platform, on machine

at f/16

1st fr 30 sec (10/20)

2nd on 40 sec

most early forms stopped

Last fr exposed was

last of film

not used

D at $\theta = 24^\circ$ (19' in)

Diagrams with delay
exp'n (faintly the wall)

20 sec @ f/16

Every fr exposed
until exp'n

C 4 No prints
ordered for these

#H 4

B, $\theta = 2^\circ$

3:2 dia. ratio

Same work except

Exposure 8 sec @ f/16

Every 2nd or 3rd fr

incl all but last
marked one, copied

three rep'n, + one
marked several frs
later. No prints
for these

C, $\theta = 8^\circ$

cond same

selected frs, incl

frs just before &
after budg.

D at $\theta = 24^\circ$ (19' in)

repeated

Black board
on wall

MIREX

reads 7.3

on dose

platform

at f/16

1st fr 30 sec (10/20)

2nd on 40 sec

most early forms stopped

Last fr exposed was

last of film

not used

Copy Film # C4 (concluded) and Extra Strip

(C4 cont.) Sept. 12, 1968

O series (5)

MITUB screwed in all the way, "tube 43" at min magnif., enlarger raised to $\times 2.3$ to focus, variator at bot.

O 4 Ship

D58-61 ($\frac{1}{5}$)

MITUB removed, enlarger at $\times 2$ (mini), "Tube 43" at max. magnif., Variator raised to 20 mm to focus (slightly back a bit, still 2 sec)

33 top } Dumps?
33 bot }
37 top } B?

D56-57

15

D58-61 ($\frac{1}{5}$)

(Cont'd above)

33 top } Fig. 25?
33 bot }
37 top Fig. 27?

D56-57 ($\frac{1}{5}$)

some cordi

15 mid Fig. 16
19 (bot) Fig. 16
18 "

D67-70 ($\frac{1}{5}$)

7 top } Fig. 28
8 " }

53 top (not 5) Fig. 30

(Less magnif. in orig photos &)
(D67-70 cont. at same condi)

Fig. 28 25 mid (lanc)
25 " bot (1/5 sec)

Dinrup 38 top

31 47 top

40 mid

41 "

46 (center)

D87-91 ($\frac{1}{5}$)

Fig. 39 9

13

Fig. 40 4 Enter RD.

D78-79 (no card)

Fig. 26 Din RD.

D83-86 ($\frac{1}{5}$)

12 mid

13 bot

Fig. 28 28
37 overposed

F11 (no cord)

Fig. 93 7 (not 90°)

T series (no card)

Fig. 96 T30 (not 90°)

D83-86 pair

MITUB regl'd, screwed

in all the way, tube

43 at mid pt., variator

at 2 mm to focus "x2"

13 mid
17 bot
13 " }

Extra strip to repeat 4 photos of D83-86

D83-86 ($\frac{1}{5}$)

No MITUB etc as for D58-61 at left (Variator at 22 mm)

37 wide open

Fig. 37 1/5 sec at f/16

MITUB in all the way, enlarger x2,

tube 43 at mid pt., Variator at 5 mm

Fig. 80 13 mid

13 bot } 1/5 sec

Fig. 80 17 bot

13 } light back

13 } ~1", 1/5 sec

9/20/68

Development of 5

minidol-X dil A 1:3

for 15 min. (old bulb)

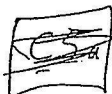
washed 5 min

Fixed 10 min

washed & D.W. rinsed

Copy Film # C5

4/20/69

more Polaroid still photos copied
with Durst M35(Short additional copy film ^{no good.} ~~neg.~~) Exposures $\frac{1}{2}$ sec @ F/16

Tube 43 max
magrif.
Varia @ 22 1/2 fsec
(using ~~the~~ print
holding board)

D 67-70

30
32
32
38
45

D 78-79

45
49

51

51 speck removed

53

56

58

48

all 58

Development with
full strength Microdol
dated (prepared by me)

neg 5, 1468 for 15 min @ 74°F 75°F
washed ~4 min @ 76°F
Fixed 10 min @ 73°F
Washed & sprayed @ 73°F

all w. dark

C5

← same cords

D 67-70

Fig. 30: 30
32
32
38
45

D 78-79

Dinrup

45

49

51

53

56

58

59

60

66

68

Fig. 30: 30

32

32

38

45

Exposures $\frac{1}{2}$ sec @ f/11

Tube 43 at max
MITUB in
Varia at bot

D 71-73
Din. case.

Fig. 34: 13
14
20

Spitter composite
with automatic
focusing settings,
Varia at bot
MITUB out etc.

$\frac{1}{2}$ sec + 115X
 $\frac{1}{10}$ sec " (Printed)

Prints of all
done in FCS
except

T series Dinrup

at $\frac{1}{2}$ sec 115X

wide open

f/11

badly overexposed

Spitter case, 115X

Dinrup

Still 115X

Development

with l. dil. of Microdol
so at 44°

Microdol-X for 9 min @ 74°F 75°F

Washed for 5 min @ " "

Fixed for 10 min @ 73°F 74°F

Washed & sprayed with final D.W. rinse

Thermate 115X

5/18/71 Illustrative Photographs of Collisions Between Immiscible Drops

The chamber was used in an attempt to obtain photographs illustrating the findings of a masters thesis study by Deutsch on the collision behavior of immiscible drops. The liquids in this qualitative work were like those used by Deutsch. Water dyed black was used for the stream on the left. For the drops on the right a ^{clear organic} solvent was used which had a great tendency to spread over the water.

The Keithley 610BR electrometer was used in measuring drop charges. This data are given on the right below. Collision conditions were set to give several different outcomes for the photographs.

f/22 focused first,
then f/16

Camera to see (above)

$f_c = 376$ drops/sec

Heathkit AG-10 oscillator settings @ 1.0V

25W Amplifiers
Left Rt.

⊙ ⊙ ⊙ ⊙ ⊙ ⊙
trans. to trans. to

The front chamber window fogged (making photos dimmer) & was washed 2 or 3 times with distilled water.

Direct rebound

$f_c = 230$ drops/sec

Before { Solv + $9 \times 1 \times 10^{-12}$
Water + $2 \times 1 \times 10^{-12}$
after { Solv + $5 \times 1 \times 10^{-12}$
Water + $30 \times 3 \times 10^{-12}$

Settings
-1X331

after { Solv + $0.7 \times 3 \times 10^{-11}$
(New setting) Water - $1.1 \times 3 \times 10^{-11}$

Direct permanent union

Less direct collisions produce rebound with elongated solvent drop then breaking in two.

A type of off-center partial coalescence may also occur in a narrow range just inside the rebound region (at lower f_c). In less direct rebound collisions the solvent drop remained whole (single). Less direct collisions had approx. the same conditions.

$f_c = 231$ drops/sec

Before each + $0.7 \times 3 \times 10^{-11}$
(Heathkit -1 @ 1.0V)

after { Solv 0.8 x 3 x 10⁻¹¹
Water 0.6 x 3 x 10⁻¹¹

Settings
-1X331

High velocity collisions
 Amplifier for left (water) stream
 generally over ①, Heathkit oscillator
 in range ④ IV

$$f_c = 593 \text{ drops/sec}$$

Conditions varied

Direct reflex dissection with the drop
 sizes used here was characterized by
 an elongated form tapering to a
 fine point which had 2 or 3
 droplets. All drops were black, with a
 coating of the clear solvent evident
 on the middle & left side ones.
 Disruption but not reflex dissection
 produced clear drops on the
 left below the collision point
 under these conditions. See
 the photographs for the relative
 drop sizes. Rotameter flow rate measurements
 were not made in this work. The rotameter float could not
 be seen in the black water.

satellite drops

after Sol's in. ca. $7.8 \times 3 \times 10^{-11}$
 no. only $-.3 \times 3 \times 10^{-11}$
 Water, in. ca. $1.2 \times 3 \times 10^{-11}$

Zero locked $-0.1 \times .3$
 $-0.3 \times .1$

Input capped, unlocks
 zero $\rightarrow -0.1 \times .3$ and
 $-0.2 \times .1$

Keithley 610 B.R. set at
 20.0 g. 10

Robert W. Park

Index to Volume 4

	Page
Crater and Crown forms	2
Disruption collisions between large drops	8
Ejection mechanism of drop production	5, 9
Flat liquid surface struck by large drops	2
Motion Picture, #H6	14
Reflex Dissection - at onset V_r	19
- illustrative movie of	14
- with immiscible colliding drops	36
Spatter collisions between large drops	2, 8
Splash of large drops on wetted glass plate	2
Spontaneous regular jet breakup	12
Still Photographs - immiscible drops	35
- Q, R & S series	2
- T series	8
- U series	12
- V & W series	19
Thesis photograph preparation	23