MICROCOPY RESOLUTION TEST CHART

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AD-A143 182

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REP(		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARO 19201.2-EG-H		

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
Two Phase System; Interfacial Turbulence	Technical Report
	6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Winston Khan	DAAG29-82-G-0005

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Puerto Rico	N/A

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
U. S. Army Research Office	Jun 84
Post Office Box 12211	13. NUMBER OF PAGES
Research Triangle Park, NC 27709	14

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Turbulence
Interfaces
Transport Properties

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study of interfacial turbulence is necessary to elucidate the complex nature of transport properties across turbulent interfaces occurring in engineering problems.

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ARO 19201.2-EG-H

20. ABSTRACT CONTINUED:

where the structure of the turbulence in the bulk phase is germane to interfacial conditions, hence transport properties and facilitates a theoretical assessment of the problem as shown by Khan.

The structure in a single phase system, was already assessed, which can be considered as a special case of a two phase dynamic system, where one phase is at rest.

There are obvious similarities in the turbulence structure of both systems, but unlike previous authors where isolated pieces of turbulence (eddies) are envisaged as migrating into the interface from the bulk phase, and, which, is not compatible with the concept of turbulence phenomena, Khan was able to provide a more plausible and realistic explanation of interfacial turbulence, hence surface renewal.

A theoretical assessment of the problem was formulated by Khan, based on this model of turbulence structure.

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ABSTRACT

"TWO PHASE SYSTEM; INTERFACIAL TURBULENCE"

by

DR. WINSTON KHAN
Professor of Physics
U.P.R. - Mayaguez, P. R.

A study of interfacial turbulence is necessary to elucidate the complex nature of transport properties across turbulent interfaces occurring in engineering problems, where the structure of the turbulence in the bulk phase is germane to interfacial conditions hence transport properties and facilitates a theoretical assessment of the problem as shown by Khan.

The structure in a single phase system was already assessed, which can be considered as a special case of a two phase dynamic system, where one phase is at rest.

There are obvious similarities in the turbulence structure of both systems, but unlike previous authors where isolated pieces of turbulence (eddies) are envisaged as migrating into the interface from the bulk phase, and, which, is not compatible with the concept of turbulence phenomena, Khan was able to provide a more plausible and realistic explanation of interfacial turbulence, hence surface renewal.

A theoretical assessment of the problem was formulated by Khan, based on this model of turbulence structure.

INTRODUCTION

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Although surface renewal theories have gained general

acceptance, the mechanism by which transport properties by

eddies are effected was still in doubt.

In most cases, isolated portions of turbulence (eddies)

are considered as impelled into the interface from the bulk

phase, which is most unreasonable and incompatible with the

concept of turbulence phenomena.

The purpose of this work has been to elucidate the

complex nature of turbulence in a fluid in a stirred cell

where the interface is the domain of interest in order to

facilitate a theoretical explanation for the phenomenon of

transport processes at turbulent interfaces.

A possible mechanism by which eddies are propagated into

the interface from the bulk phase can be attributed to the

concept of turbulence, as a mass of eddies which change

their shapes and sizes incessantly and enclosed in an

elastic bag of fluid, which fluctuates and pushes its

corrugated periphery intermittently into the interface,

and much more compatible with turbulent phenomena.

This has been confirmed experimentally in a previous

report entitled "The Structure of Turbulence in a Stirred Cell", prepared by the author and submitted to the Research Office of the U.S. Army during April, 1983.

This report facilitates an adequate theoretical model for transport phenomena at turbulent interfaces of the types, liquid-liquid; liquid-gas.

In this model, the transport of matter from one phase to another, where one phase is in motion is effected by molecular diffusion alone and in agreement with the theories of Danckwerts and Higbie.

In all cases, however, the interpretation of surface renewal and the dependence on turbulent paramters which is synonymous with Reynolds number or the degree of agitation was still in doubt.

It was also the purpose of this work to demonstrate that the rate of surface renewal depended only on turbulent parameters and not on surface conditions for clean inter- faces. This dependence was determined by Khan and found to be in remarkable agreement with the best experimental correlation.

In any case, the frequency of eddy penetration alone into the interface is not the important factor in surface renewal as claimed by previous authors, but the quantity of area renewed.

The actual theory, based on the quantity of area

renewed is in excellent agreement with experimental results

for both clean and contaminated interfaces as shown by

Khan.

FIGURE 1

Describes the mechanical agitator used in the study of interfacial turbulence in a two phase system. This system is applicable to large scale systems in industry, based on the analogy of geometrical and dynamical similarity for processes of mixing and extraction.

The dimensions of this system are the same on those used in the past for single phase systems, where the stirrers are contra-rotated to maintain a stationary inter-face and can be considered as a special case where the upper phase is at rest. The interface being the domain of interest.

FIGURE 2

Here, the lower phase is agitated while the upper phase is at rest. The structure of turbulence established is that of a turbulent core of fluid with a laminar super-layer, through which eddies penetrate due to the expansions and contractions of bulk fluid.

The diagram describes the from of eddy propagation into the interface due to the expansions and contractions of eddies inside an elastic bag of fluid, which incessantly change its shape and size and pushes its periphery inter-mittently into the interface through the laminar super-layer. This is clearly manifested by the tracer dye and by

the separation of talc particles covering the entire
interface.

Different oils and alcohols can be used in the upper
phase changing the surface tension, densities and viscosity,
but the structure of the turbulence remains the same,
proving that the manifestation of eddies at the interface
is independent of surface conditions for a clean interface.
It is also independent of surface tension for a contaminated
interface, but the theoretical considerations are different
as demonstrated by Khan previously.

FIGURE 3

Here, the upper phase is agitated while the lower phase is
at rest. The structure of the turbulence can be considered
as a mirror image of figure 2 in the interface.

Here, again, manifestations of eddy penetration into
the interface can be observed through the separation of talc
particles and the trajectory of small drops of immisible
tracer dye.

The dye is composed of potassium permanganate dissolved
in water with an approximate density of water.

FIGURE 4

Shows the same situation as in figure 2, but reveals the
talc separation on the surface which are eddy manifestations.

FIGURE 5

This is a mirror image of figure 4 in the interface, showing
clearly eddy manifestations at the interface, this time
from the agitated upper phase where the eddies are impelled
into the interface through a laminar-sublayer.

FIGURE 6

Describes the manifestation of eddies from both phases which
are agitated simultaneously into the interface. The
following cases exist.

1)   If the stirrers are rotated in opposite directions
     maintaining a stationary interface, then we have
     rotating laminar layers on both sides adjacent
     to the interface and, then, the rotating turbulent
     volume of fluid on both sides.

2)   If, however, the stirrers are rotated in the same
     direction, then we generate a rotating interface
     with rotating adjacent laminar layers in both
     phases and, then, the rotating volumes of
     turbulent fluid on both sides.
     In all cases the eddies are impelled into the
     interface from both bulk phases in the same manner
     as before.

COMMENTS

Some aspects of Levich model have been confirmed, that is, the existence of laminar layers at the interface and the eddy velocity, $v_y = \frac{v_o \, y}{\lambda}$, giving $v_y = o$, at the interface implying that the eddies move horizontally into the interface; an interesting analogy for the motion of the eddies is that of a projectile from the turbulent bulk phase where the interface acts as a predetermined maximum height.

However, Levich employed the technique of diffusion layers in deriving an expression for mass transfer across turbulent interfaces which precludes the concept of surface renewal and cannot be modified adequately to explain mass transfer damping at contaminated interfaces.

The theory proposed by Khan is based on surface renewal and molecular diffusion caused by the propagation of eddies into the interface as in the models of Danckwerts and Higbie, but differs in the interpretation of surface renewal and its dependence on surface conditions.

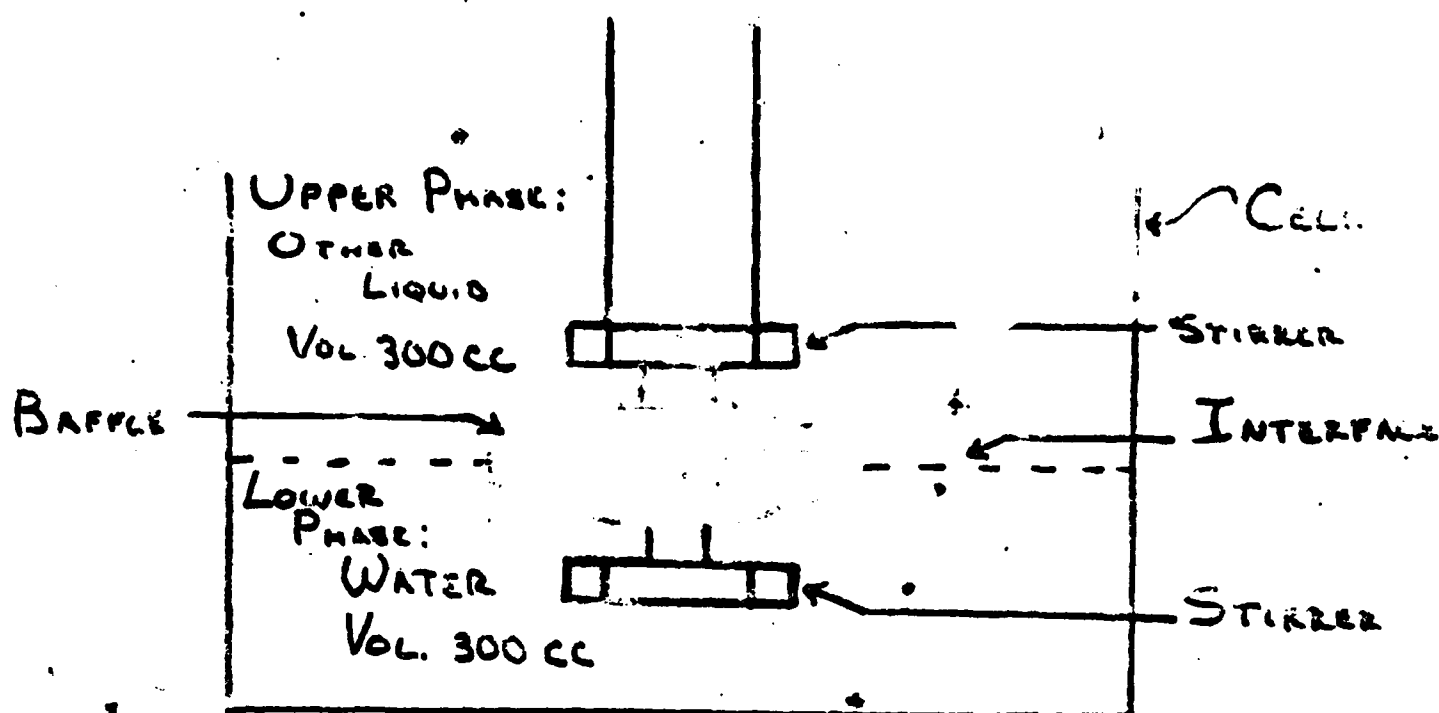Surface renewal depends on turbulent parameters only.

Upper Phase: Other Liquid Vol. 300 cc

Cell

Stirrer

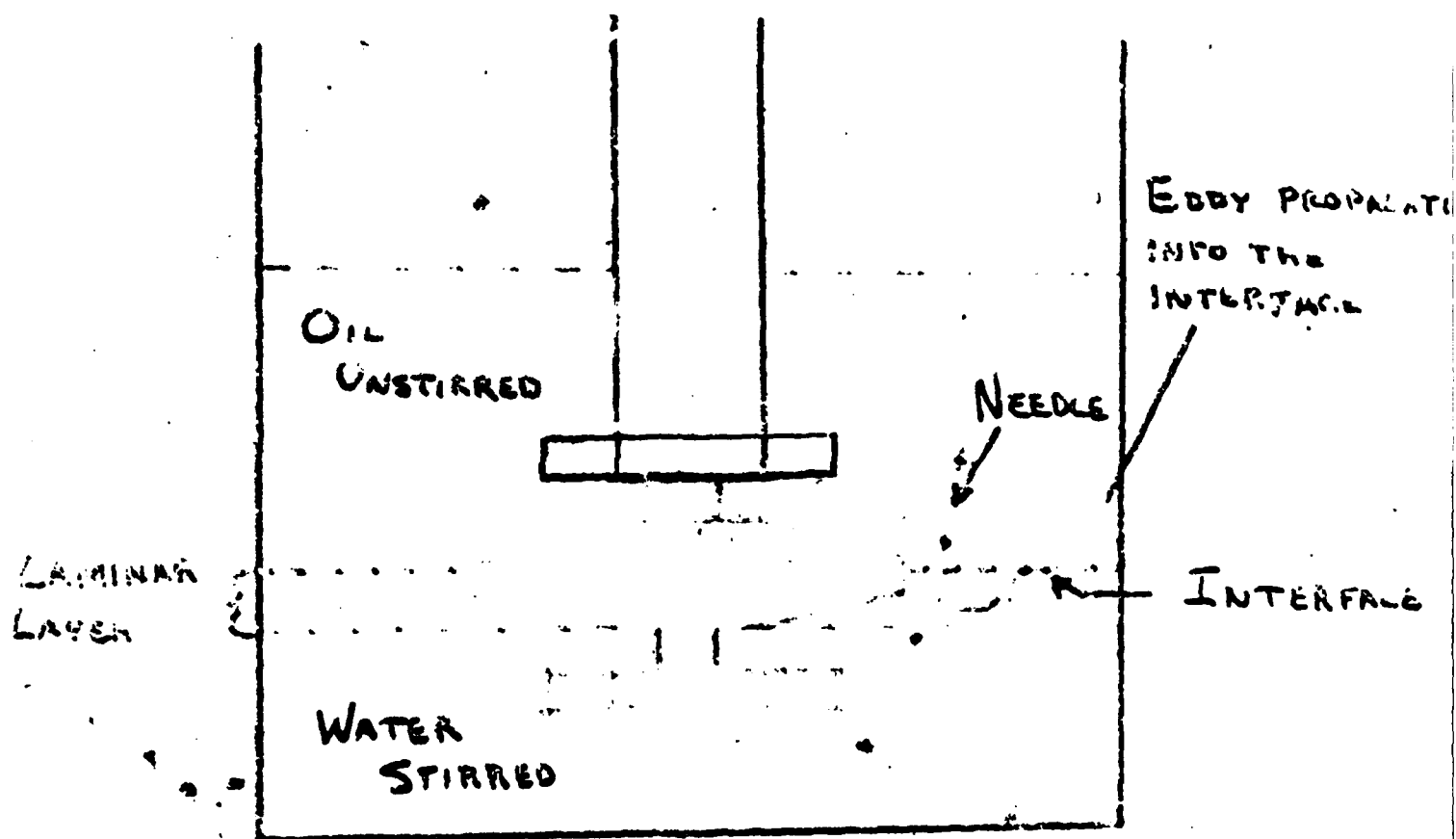Baffle

Interface

Lower Phase: Water Vol. 300 cc

Stirrer

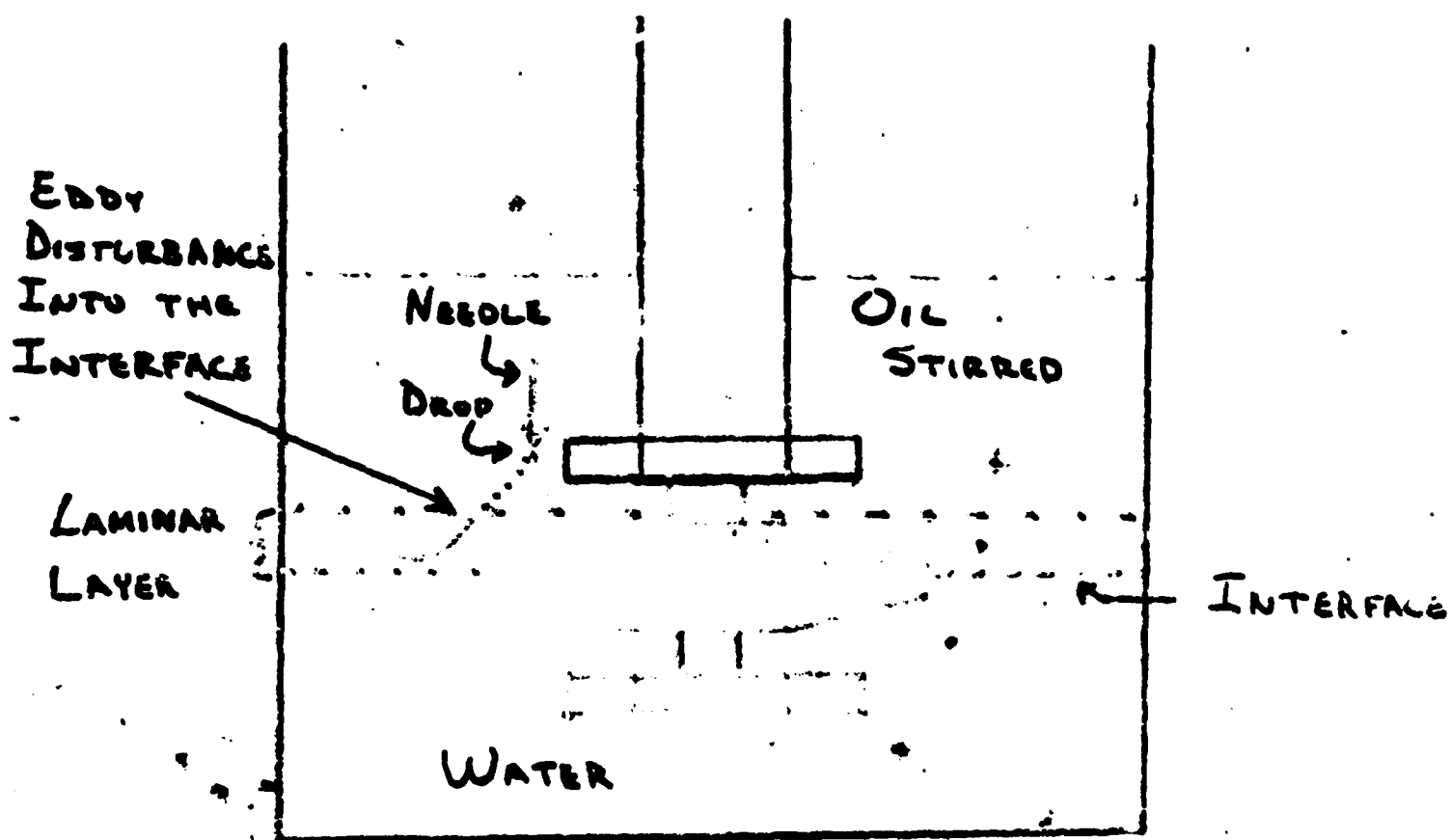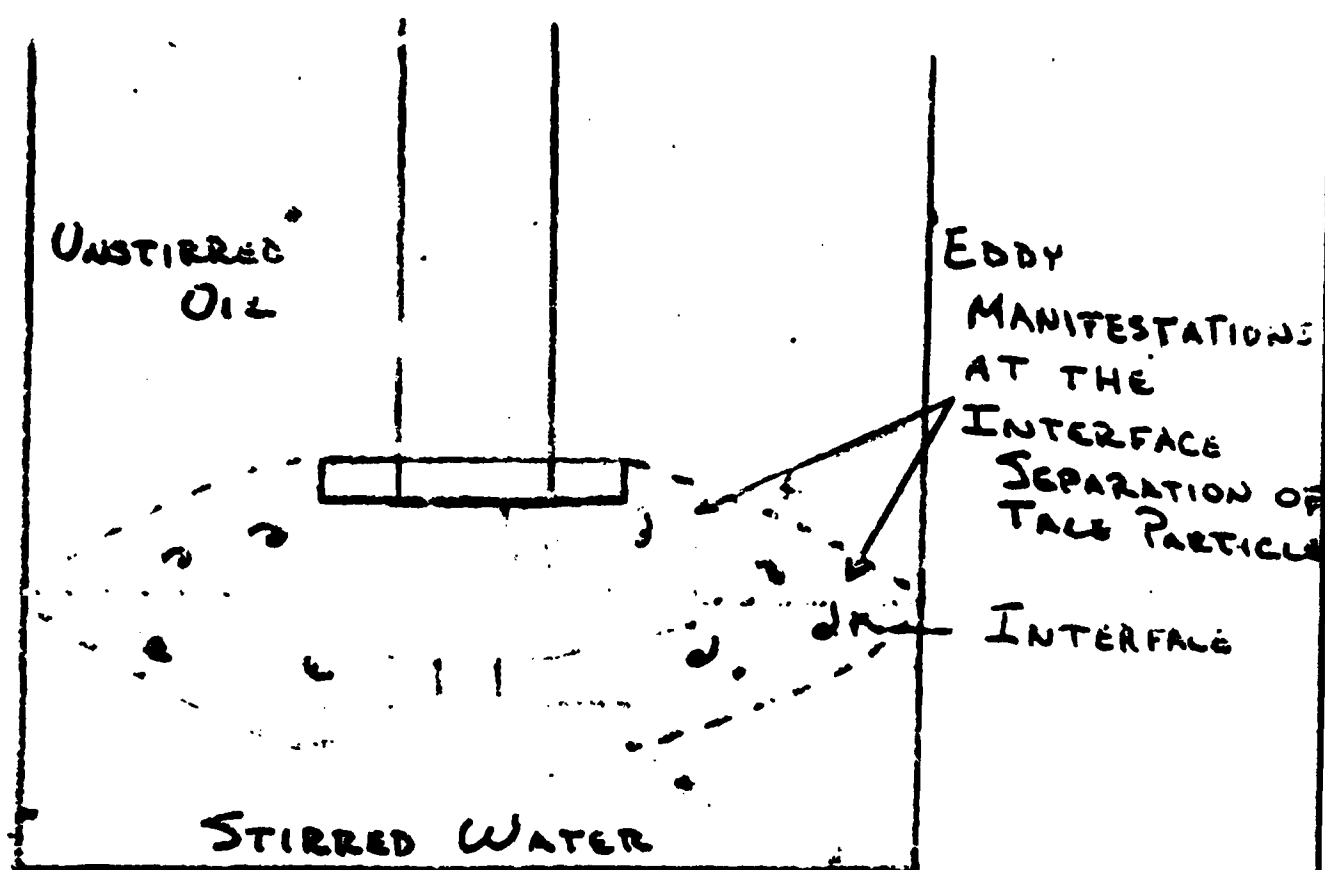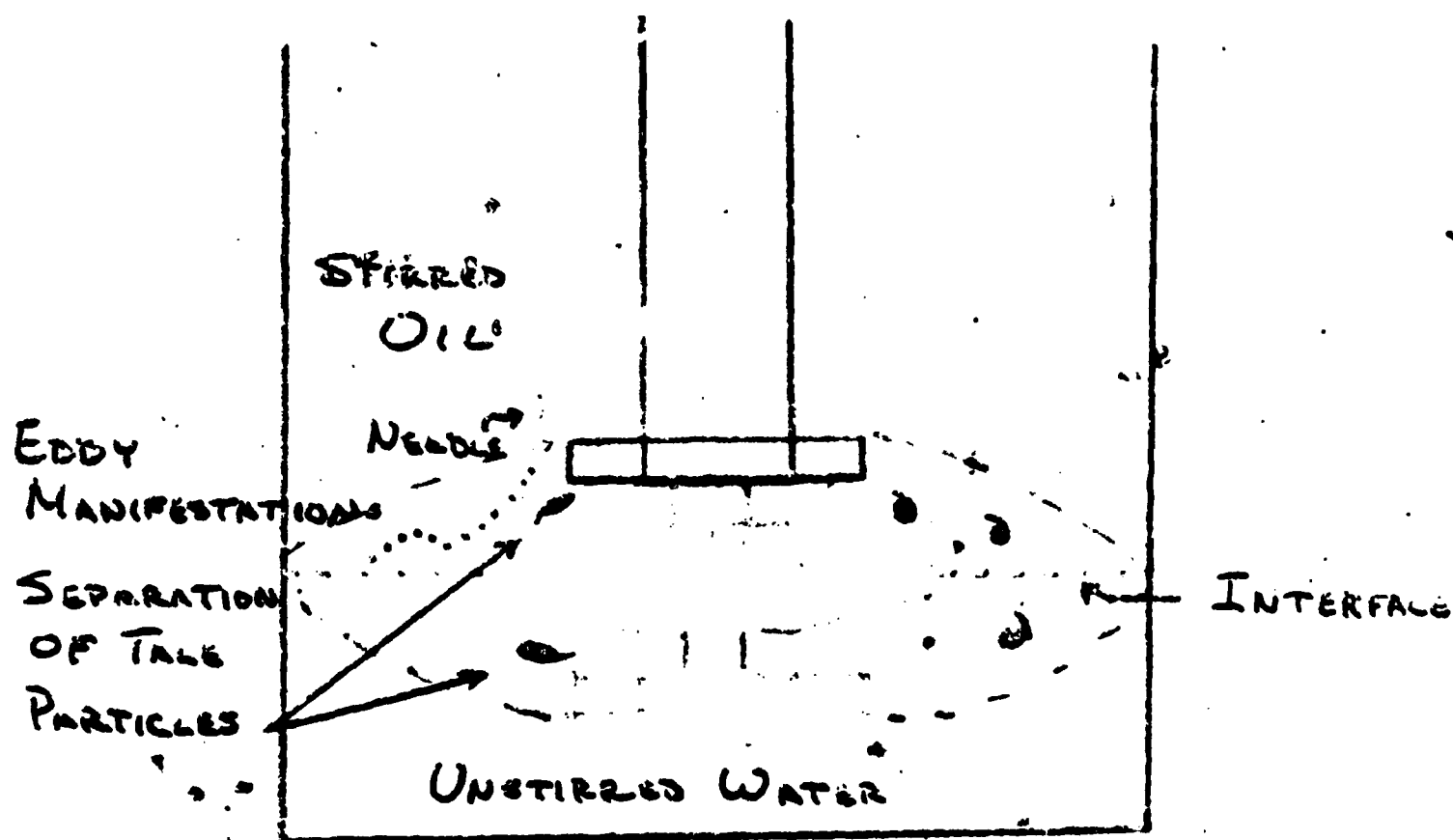Fig. 1. Stirrer Assembly.

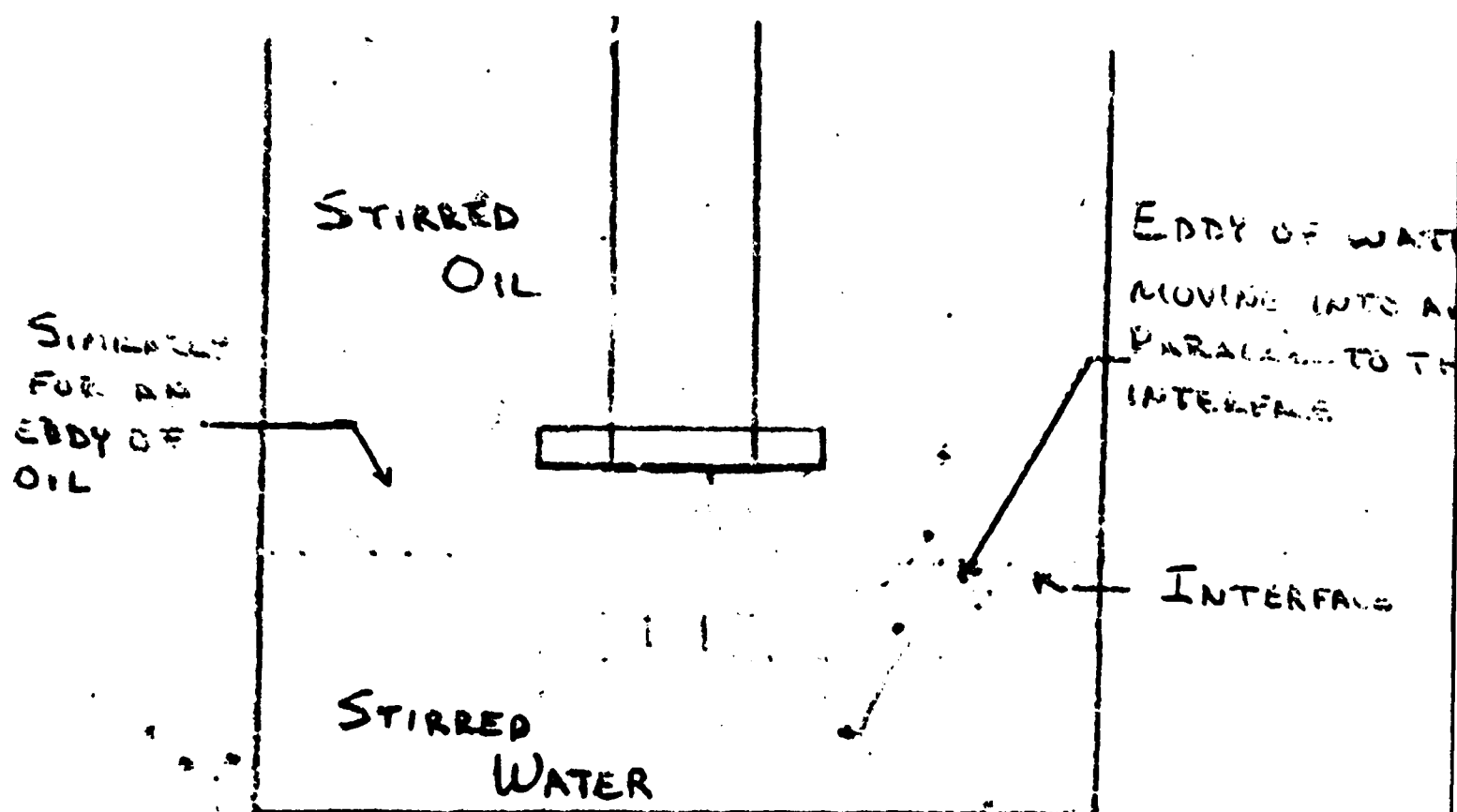Fig. 2

FIG. 3

FIG. 4

Fig. 5

FIG. 6

THE ABOVE IS TRUE WHETHER THE LIQUIDS ARE STIRRED IN THE SAME DIRECTION OR OPPOSITE DIRECTIONS. IF STIRRED IN OPPOSITE DIRECTION WE HAVE A STATIONARY INTERFACE, IF STIRRED IN THE SAME DIRECTION WE HAVE A ROTATIONAL INTERFACE IN LAMINAR MOTION.

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