THE UNIVERSITY OF MICHIGAN

College of Engineering

Laboratory for Fluid Flow and Heat Transport Phenomena

Report No. 08466-4-I
07738-4-I

DETERMINATION OF GAS AND VAPOR NUCLEI FOR BUBBLE NUCLEATION

(Osman)
O. Ahmed
F. G. Hammitt

Financial Support Provided by:

National Science Foundation

Grant No. GK-730

and

Army Research Office

Contract No. DAHCO4 67 0007

February 1968

Determination of Gas and Vapor Nuclei for Bubble Nucleation

Nucleation in a given liquid depends on many variables, one of the most important of which is the size distribution and concentration of gas vapor nuclei.

These are of importance in providing a free surface or gas-liquid interface within the liquid. This is essential for bubble nucleation at the commonly observed pressures (or superheats) either in the case of boiling or of cavitation. Several techniques have been utilized in the past to obtain some of the required information. The effects upon acoustic and light transmission has been examined by others and also an evaluation of cavitation inception pressures has been used. These techniques provide incomplete information, are complex, and involve human judgment resulting in a substantial error margin which varies with the method and the experimenter. The present work applies a new technique to the investigation of bubble nucleation and the required nuclei.

An electronic Coulter counter together with a 100 channel analyzer are used. After appropriate calibration these will give the gas and vapor nuclei spectrum and population directly. Figure (1) shows the main parts of the counter. The theory of operation is explained in reference 2.

A water sample to be analyzed is introduced carefully and slowly into the beaker, after adding 1 c.c. of pure, deaerated and concentrated NaC. to increase its electrical conductivity. A glass tube with a precisely made sapphire orifice plate (100 micron diameter) fused into its lower end, dips into the beaker and is filled with a similar sample of the same conductivity. The rate of flow can be adjusted through the orifice by a controlled vaccum as shown in figure 1. A constant voltage across the platinum electrodes produces a current through the orifice electrolyte. Any discontinuity through the orifice will cause a voltage pulse proportional the volume displaced by it. These discontinuities in the present work where the water to be analyzed is drawn from a cavitation tunnel will be mostly tiny air bubbles nuclei.

The voltage pulses are amplified and passed through a 100-channel analyzer in the same fashion used to measure nuclear radiation spectrums. The counter and the analyzer can be calibrated using known standard size particles so that the ourput will be the number of particles against their volume in cubic micron.

The presence of small solid particles in the cavitation tunnel water is minimized using an ion exchange column and by-pass filter (100 micron diameter).

Figure (2) shows some nuclei size distributions from the Coulter counter, for various total gas contents as measured by a Van Slyke apparatus.

The numerical integration of such distributions will give the total volume of these nuclei, i.e. the total volume of the entrained gas. Table I gives these values and the corresponding total gas content (dissolved and entrained). The ratio of the entrained to the total is seen to be approximately the same in all cases and of the same order of magnitude. As shown, nearly all the gas is dissolved. However, the very small portion of entrained gas (10^{-6}) is presumably primarily responsible for bubble nucleation.

The distribution is a skewed Gaussian. A very simple, but general approximation for that distribution was found in the form

$$N = \frac{c\,v_g}{V^3} + \frac{a}{V}$$

$N(V)$ =number of nuclei of volume V

V =volume in cm^3

vg =total gas content in cm^3

c, are constants which vary with the ambient pressure in the tunnel.

This fits best small-size portion.

Table I.

Relation between entrained and total gas content in 5 c.c of water sample at ambient pressure 25 psi.

Run No.	Total gas cntent V_t in micron cube	Entr. gas content V_e in micron cube	V_e / V_t
1	1.2585×10^{11}	1.1234×10^{6}	9×10^{-6}
2	1.0375×10^{11}	0.6146×10^{6}	6×10^{-6}
3	0.7740×10^{11}	0.4116×10^{6}	5.3×10^{-6}
4	0.5215×10^{11}	0.3451×10^{6}	6.6×10^{-6}

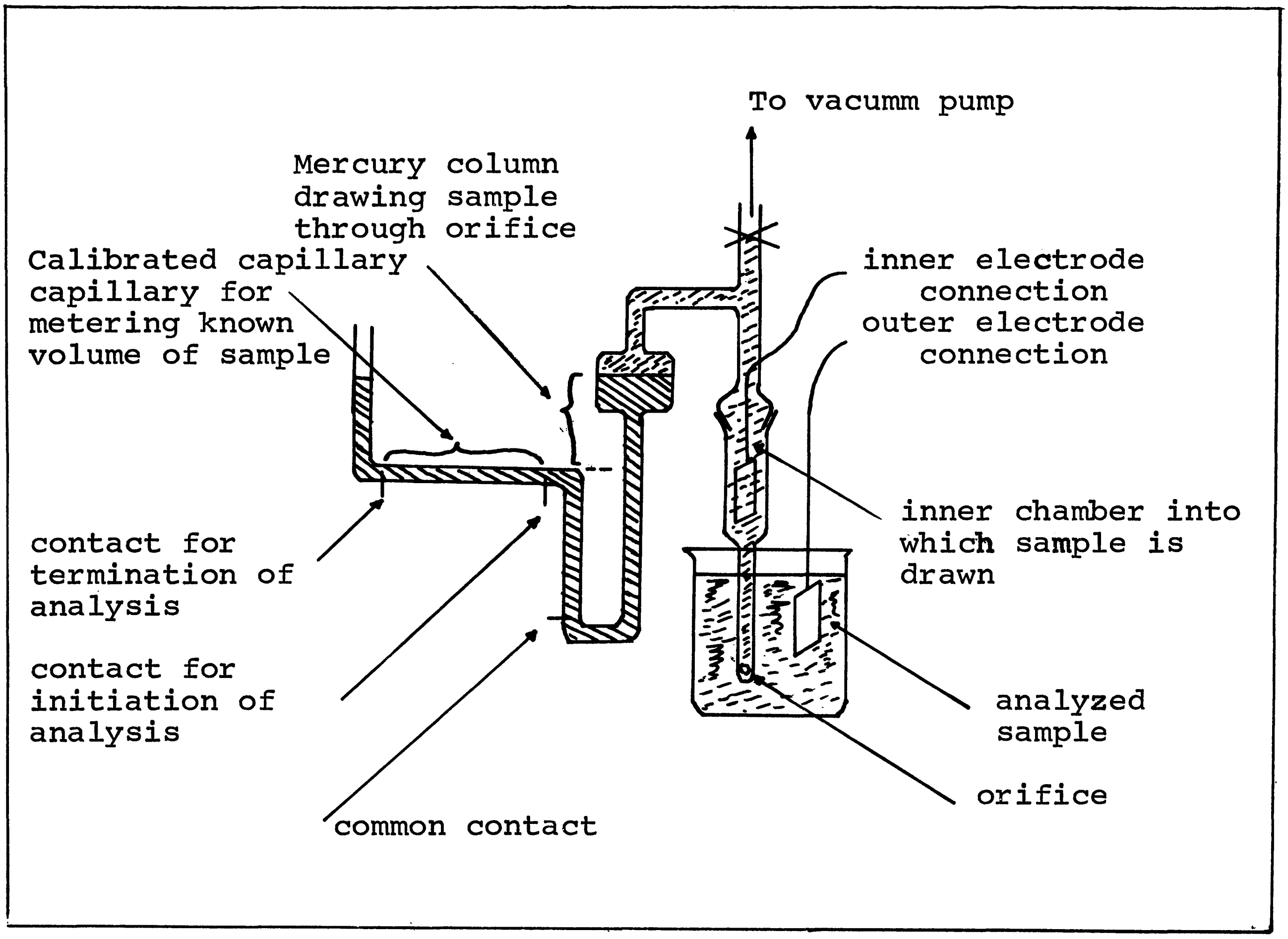

Fig.1. Coulter Counter Schematic.

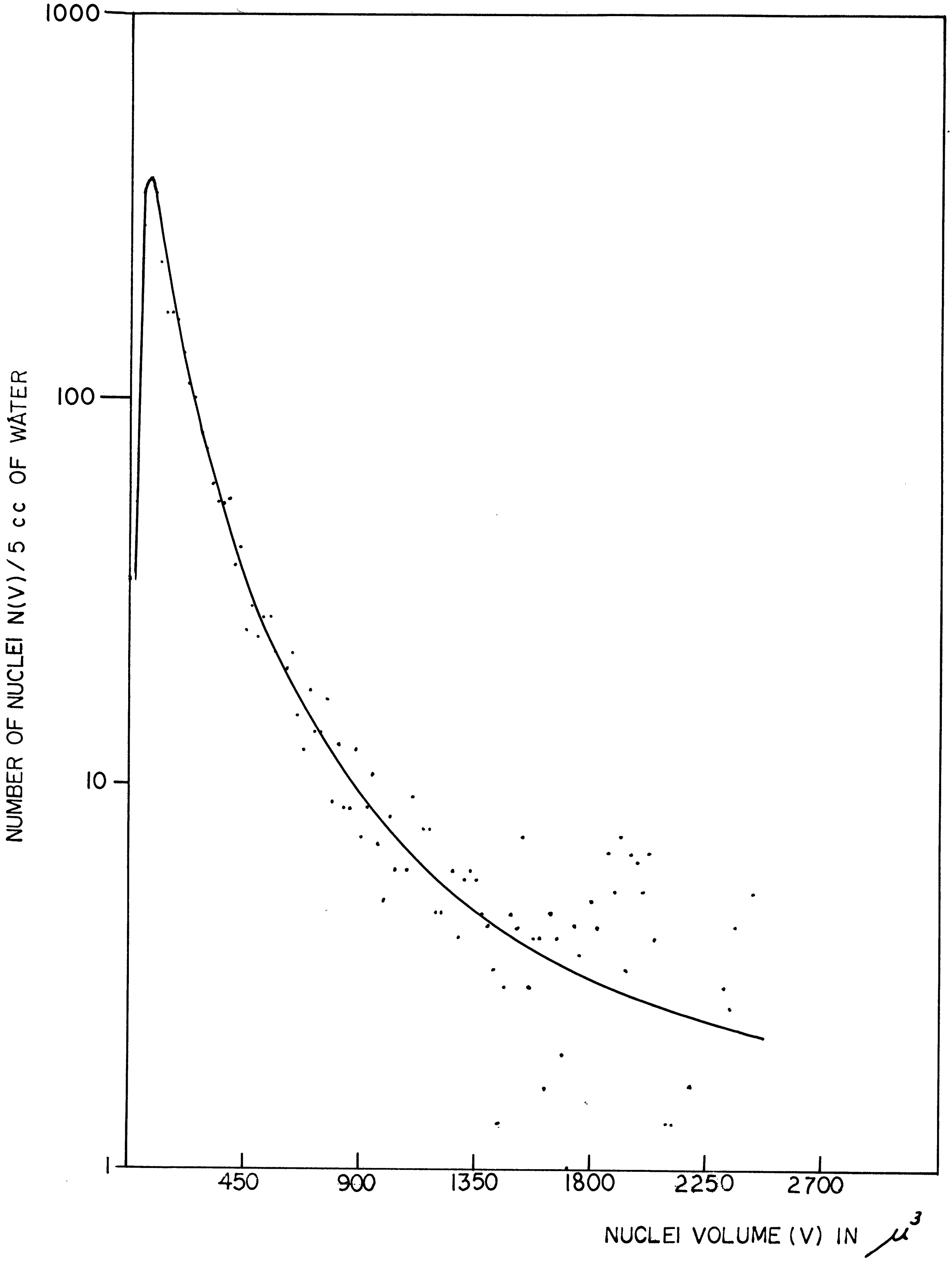

Fig.(2-1). Nuclei size distribuation for 2.517 % gas contents at 25 psi

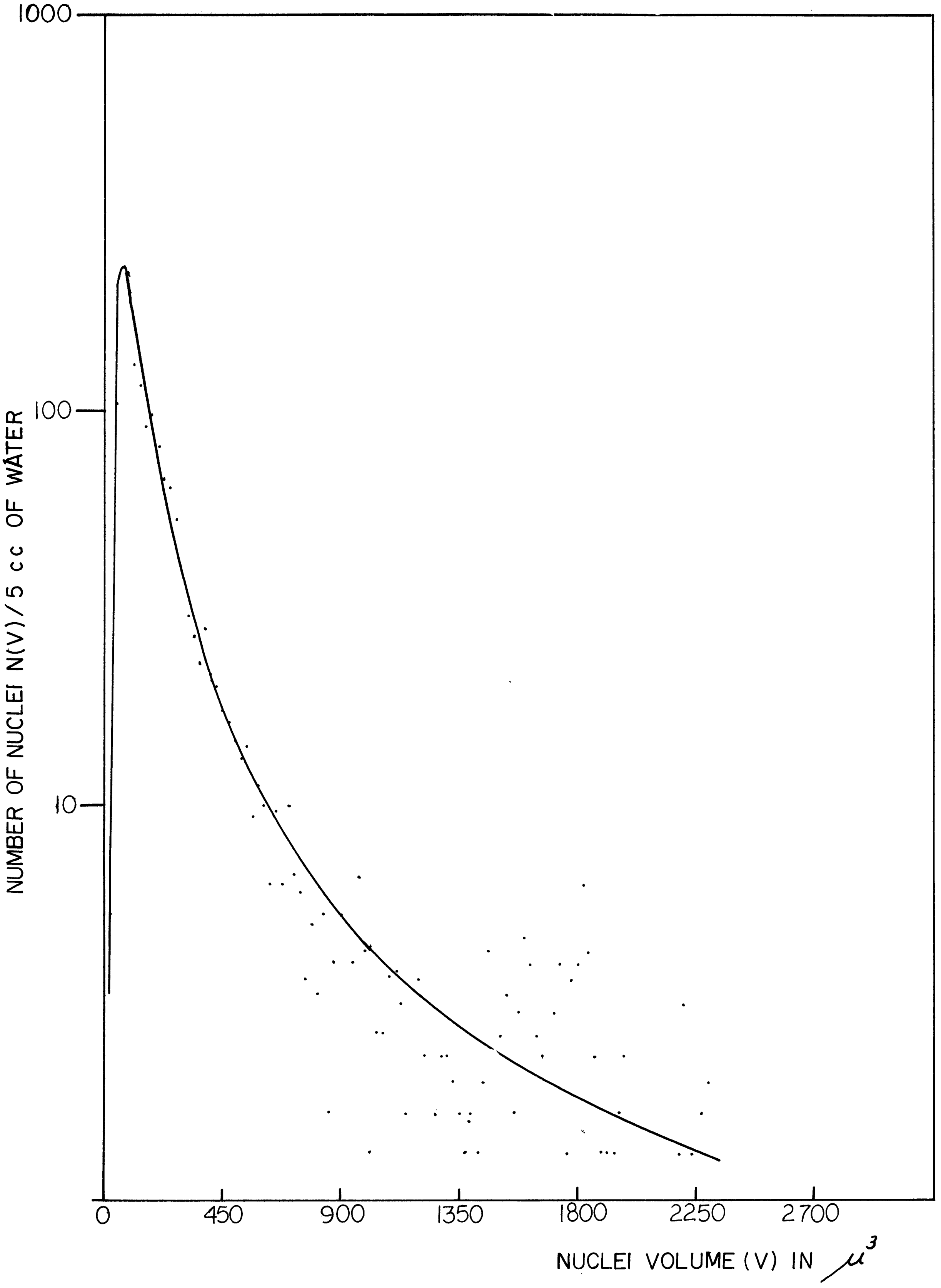

Fig.(2-2). Nuclei size distribuation for 2.075, gas contents at 25 psi.

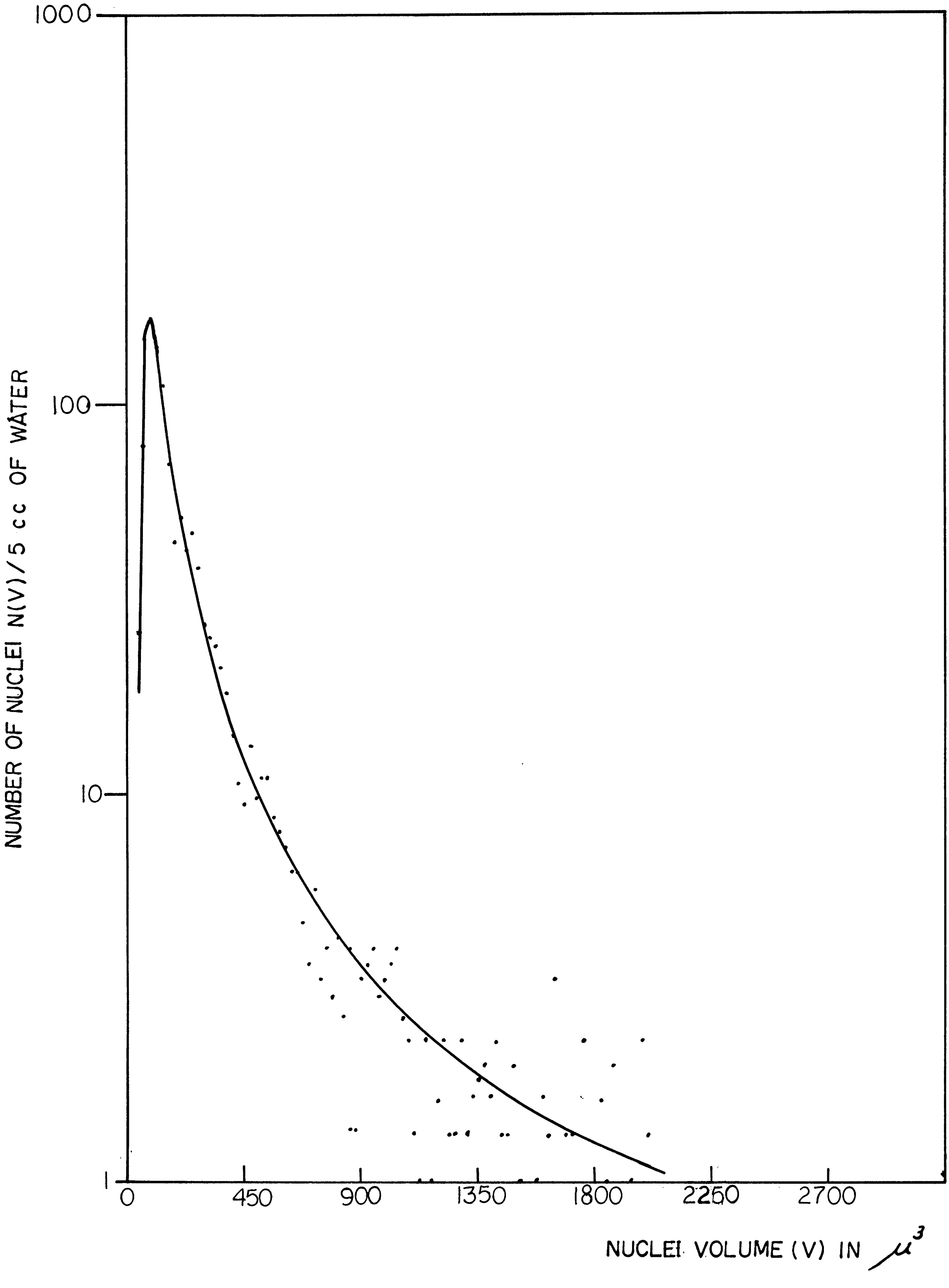

Fig.(2-3). Nuclei size distribuation for 1.548% gas contents at 25 psi.

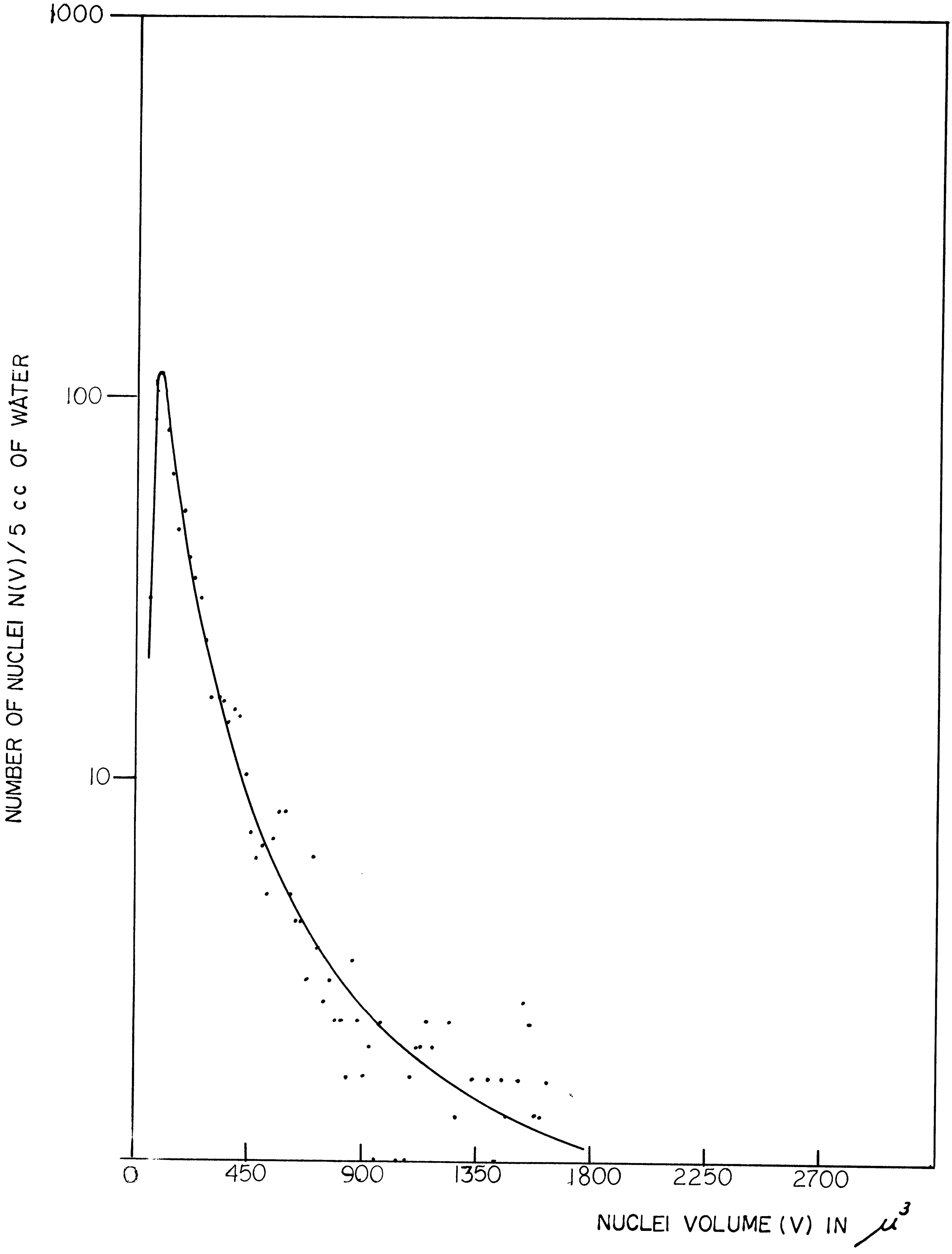

Fig.(2-4). Nuclei size distribuation for 1.043% gas contents at 25 psi

REFERENCES

1. Mason, Physical Accoustics, I, Part B, New York, Academic Press (1964).

2. Advances in Pharmaceautical Sciences, 2, New York, Academic Press (1967).

3. Irani and Callis, Partical Size: Measurements, Interpretation and Application, John Wiley and Sons Inc., (1963).