INVESTIGATION OF THE FEASIBILITY OF USING GAMMA RAY ABSORPTION FOR THE DETERMINATION OF THE SPECIFIC GRAVITY OF A FLUID

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PREFACE

This study is the first of a series of investigations using gamma ray absorption methods for the determination of fluid properties under the direction of Professor Harry M. Wyatt, Jr.

The author wishes to acknowledge and express his indebtedness to Professor Harry M. Wyatt, Jr. for his invaluable assistance and constructive criticism in the preparation of this report and for acting as the writer's major adviser. Acknowledgement is due Professors John B. West, C. Fremont Harris, and Ernst M. Hodnett for making facilities of the Oklahoma State University School of Nuclear Engineering available to the author. Lesilie Nave, a graduate student in Civil Engineering, offered many invaluable suggestions. Acknowledgement is due the staff of the School of Civil Engineering for their most valuable instruction and aid during the writer's graduate study.

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CHAPTER I

INTRODUCTION

Part A. - Radioactive Tracer Technique

The use of radioisotopes in the petroleum industry has been well established. Radioactive isotopes are used in pipeline interface marking, leak and corrosion detection, tracing flow in a closed system, flow rates, and residence time. These categories of applications for process control or inspection make use of the radioactive tracer technique.

The radioactive isotope or radioactive liquid is injected quickly into the pipeline in order to obtain sharply defined peaks. Detecting elements are attached externally to the pipeline at any desired station. By connecting two detecting elements it is possible to record the tracer peaks at two points on the same recorder. This is practical in the petroleum industry only with a beta emitter isotope and the use of a G-M portable field instrument as a detector.

The selection of the tracer isotope to be used for a given job can be made after considering a number of conflicting requirements:

1.) The half life - an experimental time limit of 7 to 9 times the half life of the isotope must be rigidly observed for accurate and economical counting. Decay during dormat use requires a longer half life isotope for routine use.

2.) Energy - the isotope must be detectable and efficiency of counting obtainable, using the desired method of detection. The scintillation counter, a high efficiency particle detector, has made available isotopes for tracer use that have a soft beta particle. Decay of the radioisotope to another radioactive element presents another problem to be considered.

3.) Chemical action -a chemical exchange or reaction may cause an undesirable contamination problem. In addition, the injected tracer method may require expensive filtration and waste disposal of the contaminated fluid at the conclusion of the investigation. The contaminated liquor should be stable and not water soluble to prevent concentration in the bottom of tanks or low spots in a pipeline.

4.) Injection of tracer - the storage and handling of large quantities of radioactive liquid requires extensive and costly safety measures. A difference of potential is required for injection of the radioactive liquid into the system, thus requiring additional energy and equipment.

5.) Tracer detector - any gamma ray sensitive detector such as a G-M tube, ionization chamber, or scintillation counter can be used for detection, but the G-M tube would be ideal for any field measurement or permanent installation. Cost, power requirements, and desired accuracy of counting are all items to be considered. The inexpensive G-M tube is rugged enough for field use and efficient enough to obtain a high peak total count. Two or more tubes should be connected to the count rate meter and recorder so that the failure of one tube will not disrupt the measurement. The geometry control of the injected tracer method is at a minimum, an advantage when using radioisotopes in field measurements.

Part B. - Radioactive Tracer Applications

Interface Marking. If the interface of two products in a pipeline is marked with a radioactive liquid, there is no limit to the number or complexity of automatic devices that can be operated by the radioactive liquid operating through an electronic circuit. The interface can be detected accurately with a portable and inexpensive G-M tube, but with a recorder and continuous observation the passing interface can be completely graphed.

A two detector system operated at a receiving station allows the complete picture of the interface to be recorded and studied before the interface reaches the second detection system at the distribution point. Study of the recorded interface lets predetermined count rates at the second detection system operate relay circuits to activate:

1.) Power driven valves
2.) Pump operation for maximum pump system efficiency
3.) Separation of two products
4.) Cutting out the radioactive interface to allow only that amount of contamination permitted by specifications.

The time required for the interface to move from the injected point to the distribution point would give the velocity and then the flow rate could be calculated. Maximum efficiency of pumping could also be checked against calculated values. An isotope selected in regard to half life, could eliminate the necessary disposal of the contaminated liquid at the distribution station.

Leak Testing. The diversion of any fluid stream from one channel to another can be readily detected with a radioactive tracer. A complex setup of a pig, recorder, G-M tube, detector, and a slug of radioactive liquid can pin point a leak in a pipeline. If a radioactive interface is passed through the pipeline any leak will allow a deposit of radioactive solution on the outside of the pipeline. A follow up of a pig equipped with the G-M tube and recorder will register the peak total count. Simple calculations will exactly locate the leak.

Other applications in industry now making use of the radioactive tracer technique are :

1.) catalyst flow rates

2.) dilution

3.) holding time

4.) peak circulation

5.) flow paths

6.) blending.

Part C - Beta Particle Absorption

When a beta particle passes through a material, energy is lost due to collisions with electrons. The total energy lost depends on the number of electrons per unit area in the material traversed. The number of electrons per atom is proportional to its mass; therefore, absorption is a function of mass per unit area. Absorption by different materials becomes independent of their atomic weight.

For measuring a thickness of material with the most accuracy it is desirable to choose a source of beta particles which are 50 % absorbed in the thickness measurements. If this is done, small changes in thickness will result in measurable changes in the number of beta particles passing through the material. Beta particle absorption can be used for measurements from 0.5 to 2 times the half-thickness. Absorption by air between source and detector limits the range of low energy beta particles. Pure beta emitters are preferred for thickness gages, since penetrating gamma rays are little absorbed. The sensitivity of the pure beta particle absorption is increased for small changes in thickness. A long half life of the isotope is desirable so that frequent recalibration of the instrument will not be required.

Part D - Beta Particle Absorption Applications

Level Detector. A simplified form of absorption gage is used as a level detector for liquids or solids in an enclosed system. A collimated radioactive source is fixed at a critical level on one side, and a detector is mounted on the opposite side. The source is chosen so that its radiation can easily penetrate the walls of an empty container, but are absorbed when the container is filled above the critical level. This application could be used for the monitoring of containers on a conveyor belt. Empty or underfilled containers could be automatically rejected.

Depth Gage. Operation for optimum production requires accurate level control of liquids. The radioactive depth gage utilized the absorption of beta radiation in a vertical column of liquid and measures continuously the radiation transmitted through the liquid column. The detector may be located outside and below the container, while the sealed source may float on the liquid. The gage is calibrated by measuring the radiation intensity at known levels. Advantages of such a gage:

1.) Continuous record of depth, therefore the volumn can be computed.

2.) The beta particle absorption is reduced by only one wall thickness.

3.) No provisions for radiological shielding are necessary.

This instrument could easily be adapted to a cut-off level gage. At a given count rate, for the calibrated instrument, a electronic relay could open or close valves to divert and control flow.

Thickness Gages. The beta particle absorption gage is used to measure the thickness of coatings such as paint or corrosion resistance material on a base metal. The source is put on the base metal so that the coating is the only beta particle absorption material between the isotope and the detector. This instrument could be calibrated so that the count rate would be proportional to the thickness.

Product Testing. The deposit forming characteristics of fuel additives can be measured in relatively inaccessible parts of engines by simple methods of radiation detection. Operating variables, influence of lubricant composition, and quality of fuels can all be investigated with the use of radioisotopes. Radioactive engine parts-piston rings, gears, and bearings - can be analyzed for wear without partial or complete engine dismantling. Short time periods of cold engine starting and warm-up wear can be more efficiently and accurately measured by activating engine parts. Oil samples may then be withdrawn from the crankcase and particles that have been worn from engine parts and deposited in the crank case can be counted to determine the wear rate. The radioactive analysis of the wear rate is cheaper, faster, and more sensitive. One engine part can be investigated at a time; whereas a physical analysis would include wear from all engine parts.

Other applications in industry now making use of the beta absorption method are the measurement of snow depths and the measurement of silt movements.

CHAPTER II

STATEMENT OF THE PROBLEM

When a gamma ray passes through a material, radiation absorbed is proportional to the intensity of the incident radiation, thickness of the absorbing material, and the density of the material.

This research investigates the use of a source and counter as a calibrated instrument to determine the density of a fluid in a pipeline under static conditions. The selection of a isotope and counter for the absorption method must be investigated under many of the same conflicting requirements as the tracer isotope technique. (See Chapter I Part A).

The position of the source, detector, and test section must be fixed during all runs of the investigation. The radiation absorbed by the fluid will be the only variable. Absorption by the air and pipe walls will be fixed for each test during the investigation.

For the calibration of an instrument, the radioactive isotope must be of low energy, long half life, and be readily available.

An ideal detector for field measurements would be the G-M tube. This detector is inexpensive and would make a better portable field instrument than the scintillation detector. The G-M tube does not see the different types of radiation and has a low efficiency. The scintillation detector is not a field instrument, but its pulse-height discrimination, and high efficiency is an advantage over the G-M detector.

Of particular interest in this investigation will be: 1.) Geometry, 2.) Source, 3.) Detector, 4.) Time.

CHAPTER III

PROCEDURE AND EQUIPMENT

The test section is a length of 4.5" O.D. schedule 80 steel pipe. Each end has a welded slip on flange with blind flanges bolted on. One end is equipped with a fluid loading apparatus and the other end with a globe valve to discharge the fluid. See Plate I.

The radioisotope source used in the first investigation was a glass sealed 0.28 millicurie Cesium 137 isotope. This isotope has a 26.6 year half life and a maximum Beta energy of 1.17 mev. (8%) and a Beta energy of 0.51 mev. (92%). The daughter activity is a 0.66 mev. Gamma ray with a 2.6 minute half life. The sealed Cesium 137 isotope is used for the gamma ray source. The qualities that make this an ideal isotope for the first investigation are long half life, ready availability and a classification of "moderately dangerous."

A N Wood CounterLab Geiger-Mueller tube with a RCL scaler was first used as a detector, but did not prove satisfactory. A BJ Electronics (Borg-Warner Corporation) scintillation counter with a scaler unit, linear aid amplifier, present time scaler control, and a high voltage supply was used. Sensitivity and the amplified, discriminated, and shaped pulses, made the scintillation probe a much more efficient detector for the gamma ray absorption method.

The scintillation head consists of a chromium plated iron magnetic shield, photomultiplier tube, phosphor holder, and a sodium-iodide crystal. An operating voltage of 900 is recommended. The linear amplifier intensifies small pulses from the scintillation probe to a level where they can be measured and for more efficiency in counting. A pulse height selector is used such that only pulses larger than a selected value will be counted. For a fixed geometry of the radioactive source, test section, and scintillation probe, static measurements of gamma ray transmission through water, kerosene, engine oil, glycerine, and carbon tetrachloride were made. These fluids represent a range of densities from 49.5 lbs per ft^3 to 98.0 lbs per ft^3.

Absorption of gamma rays by air and the steel pipe was kept constant for each run. The different fluid densities were the only means of changing the total gamma ray absorption. See Plate II for the path of total absorption.

Reagent grades of glycerine and carbon tetrachloride were used. City tap water (specific gravity, 1.000) was used as the standard. The kerosene and engine oil were obtained from a service station. The specific gravity of each fluid was computed at room temperature by standard methods.

Each run of gamma ray absorption measurements was made at constant temperature and pressure. For the runs of water, kerosene engine oil, and carbon tetrachloride five sixty minute and five thirty minute counts were made. Five twenty minute and five ten minute counts were made for the runs using glycerine in the test section. All total counts were above 10,000 for the one per cent accuracy in counting. Five counting runs were made using water in the test section at the start of the investigation and five counting runs at the end of the investigation to check for fixed geometry during all gamma ray absorption runs.

CHAPTER IV

EXPERIMENTAL TEST DATA

The experimental test data, shown in Tables I through IV, were obtained from tests performed in the Oklahoma State University Civil Engineering Hydraulic Laboratory. This data was taken with the Cesium 137 source in a collimated position, the 4.5" O.D. steel pipe test section, and the scintillation probe used as a gamma ray absorption instrument for measuring fluid densities.

The experimental average counts per minute (cpm) - specific gravity curve approximates a straight line on a log - log plot and a semi-log plot. Figure 1 is the log-log plot of the experimental average cpm - specific gravity curve for water, engine oil, kerosene, and carbon tetrachloride. Figure 2 is the log-log plot of the experimental average cpm-specific gravity curve for water, engine oil, kerosene, carbon tetrachloride, and glycerine. Figure 3 is a semi-log plot using the experimental data of all five fluids.

Table VI shows the count variation, average transmission ratio of the fluid to water-Ratio "A", and the maximum per cent difference of the average cpm and any one run for each fluid. Figure 4 is the log-log plot of the experimental Ratio "A" - specific gravity curve.

With a given per cent change from the average cpm, Figure 5 shows the corresponding per cent change in the specific gravity.

PLATE I - TEST SECTION

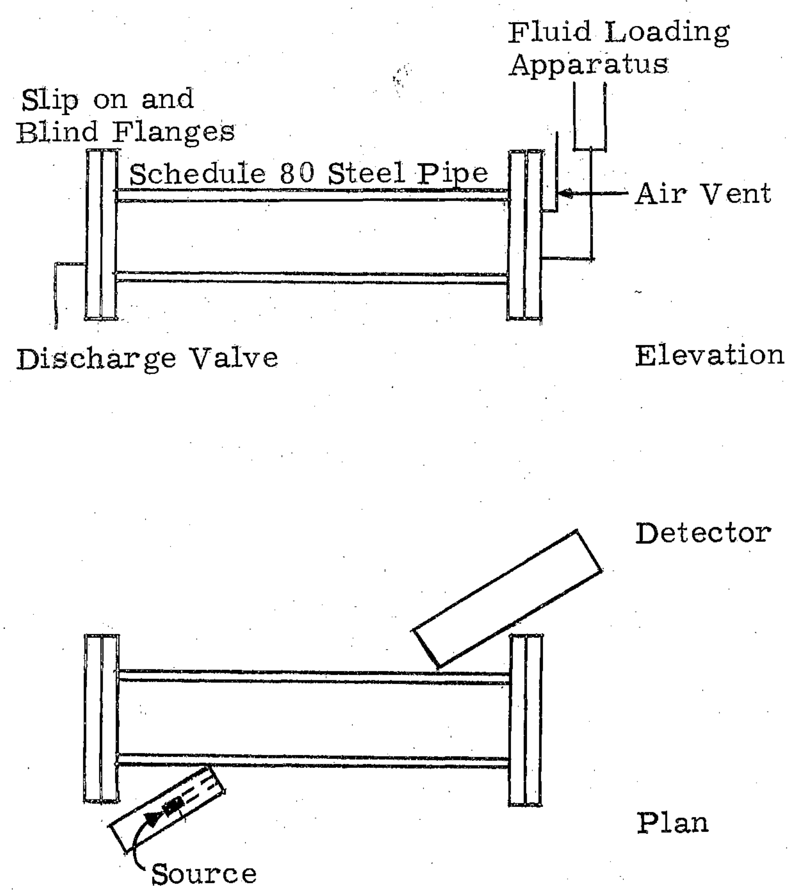

PLATE II - PATH OF TOTAL GAMMA RAY ABSORPTION

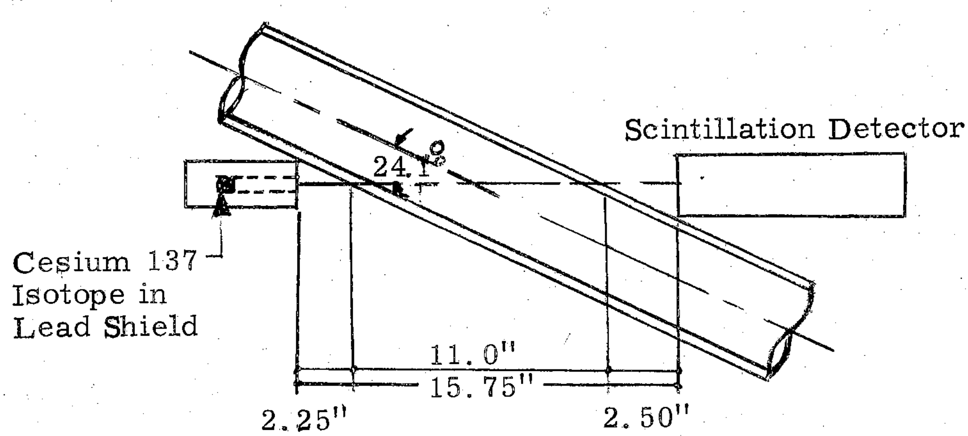

TABLE I

PRELIMINARY TEST DATA

Fluid: Water   Specific Gravity: 1.000   Date: 3-11, 12-59

Run	Total Count	Time Minutes	cpm	
1	152,765	60	2,546	
2	77,671	30	2,589	High Count
3	154,442	60	2,574	
4	75,991	30	2,533	
5	153,003	60	2,550	

Average of five counts: 2558 cpm

TABLE IA   Date : 3-23-59

Run	Total Count	Time Minutes	cpm	
6	76,076	30	2,536	
7	153,297	60	2,555	
8	77,014	30	2,567	
9	154,558	60	2,576	
10	75,935	30	2,531	Low Count

Average of five counts: 2553 cpm

Average of ten counts: 2556 cpm

Source : Cesium 137 (0.28 millicuries)

Detector: Scintillation Probe

Pulse Height : 1.50,

Coarse Gain : 8

Fine Gain : $\frac{13}{16}$

TABLE II

PRELIMINARY TEST DATA

Fluid : Engine Oil Specific Gravity : 0.870 Date: 3-13, 14-59

Run	Total Count	Time Minute	cpm
1	170,582	60	2,843
2	86,914	30	2,897
3	170,277	60	2,838
4	84,965	30	2,832 Low Count
5	171,423	60	2,857
6	86,488	30	2,883
7	170,404	60	2,840
8	85,713	30	2,857
9	174,539	60	2,909 High Count
10	86,911	30	2,897

Average of ten counts: 2865 cpm

Source : Cesium 137, (0.28 millicuries)

Detector : Scintillation Probe

Pulse Height : 1.50

Coarse Gain : 8

Fine Gain : $\frac{13}{16}$

TABLE III

PRELIMINARY TEST DATA

Fluid: Kerosene Specific Gravity : 0.791 Date : 3-17, 18-59

Run	Total Count	Time Minutes	cpm
1	171,184	60	2,853
2	84,181	30	2,806 Low Count
3	172,736	60	2,879
4	87,149	30	2,905
5	174,779	60	2,913
6	86,071	30	2,869
7	174,183	60	2,903
8	87,721	30	2,924
9	178,257	60	2,971
10	89,822	30	2,994 High Count

Average of ten counts : 2902 cpm

Source : Cesium 137 (0.28 millicuries)

Detector : Scintillation Probe

Pulse Height : 1.50

Coarse Gain : 8

Fine Gain : $\frac{13}{16}$

TABLE IV

PRELIMINARY TEST DATA

Fluid: Carbon Tetrachloride Specific Gravity: 1.569 Date: 3-18, 19-59

Run	Total Count	Time Minutes	cpm
1	112,442	60	1,874
2	56,757	30	1,892
3	112,923	60	1,882
4	56,576	30	1,886
5	115,558	60	1,926
6	58,172	30	1,939 High Count
7	111,841	60	1,864 Low Count
8	58,077	30	1,936
9	113,279	60	1,888
10	56,343	30	1,878

Average of ten counts: 1897 cpm

Source: Cesium 137, (0.28 millicuries)

Detector: Scintillation Probe

Pulse Height: 1.50

Coarse Gain: 8

Fine Gain: $\frac{13}{16}$

TABLE V

PRELIMINARY TEST DATA

Fluid: Glycerine Specific Gravity : 1245 Date : 3-21, 22-59

Run	Total Count	Time Minutes	Cpm	
1	43, 041	20	2, 152	
2	21, 190	10	2, 119	
3	43, 138	20	2, 157	
4	21, 351	10	2, 135	
5	43, 560	20	2, 178	High Count
6	21, 165	10	2, 117	
7	43, 182	20	2, 159	
8	21, 469	10	2, 147	
9	42, 323	20	2, 116	Low Count
10	21, 403	10	2, 140	

Average of ten counts : 2, 142 cpm

Source: Cesium 137, (0. 28 millicuries)

Detector: Scintillation Probe

Pulse Height: 1. 50

Coarse Gain: 8

Fine Gain : $\frac{13}{16}$

TABLE VI

PRELIMINARY TEST DATA

	Kerosene S. G. = 0. 791	Engine Oil S. G. = 0. 870	Glycerine S. G. = 1.245	Carbon Tet. S . G. = 1.569	Water S. G. = 1.000
A. Average Transmission Ratio Ratio "A" = $\frac{\text{Fluid-cpm}}{\text{Water-cpm}}$	1. 135	1. 121	0. 838	0. 742	1. 000
B. Difference in high and low cpm	188	77	62	75	58
C. Difference in average cpm (fluid-water)	346	309	-414	-659	0
D. Maximum Difference average, any one run (per cent)	3. 0%	1. 5%	2. 0%	2. 0%	1. 5%

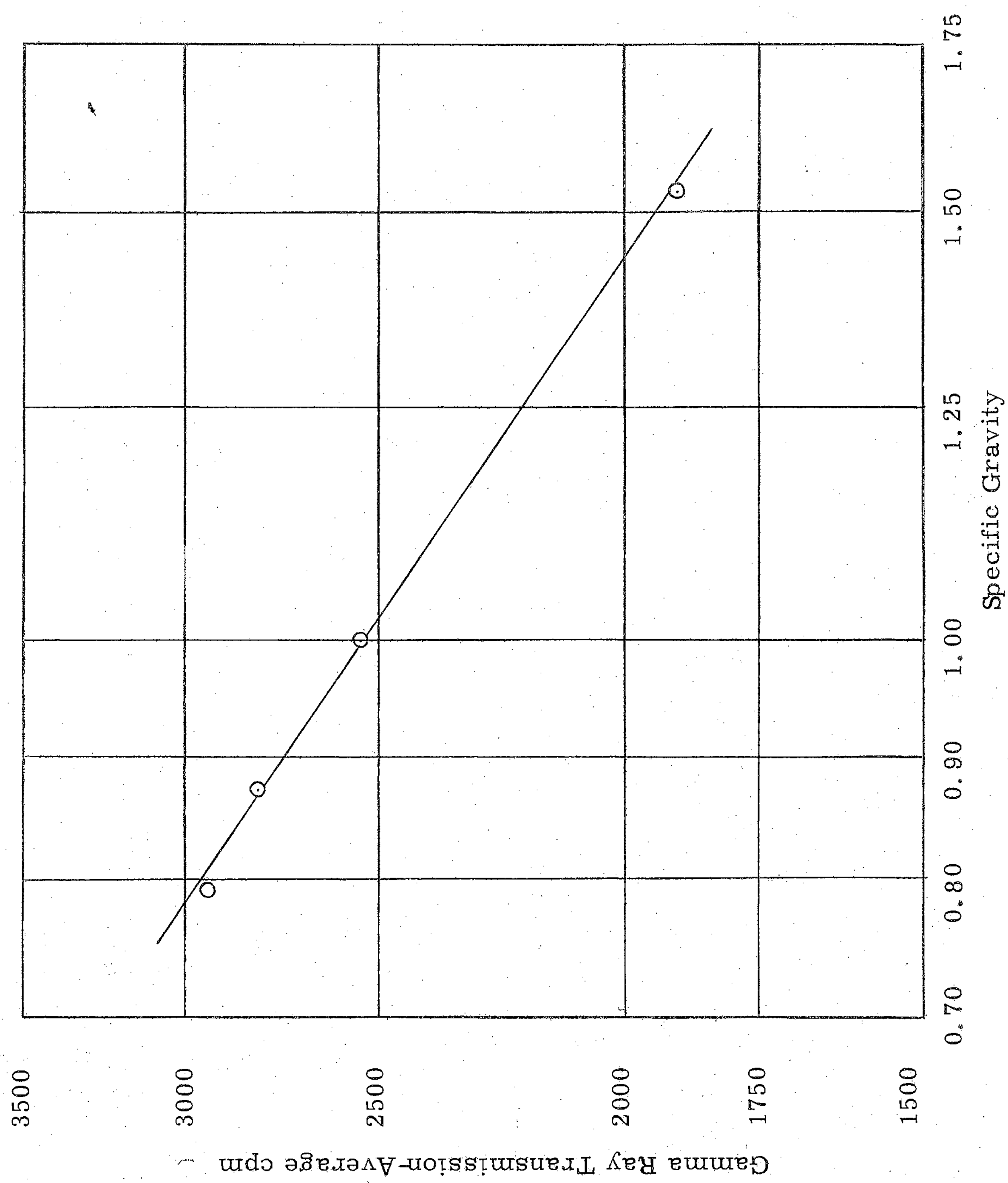

Fig. 1

Variation of Gamma Ray Transmission with Specific Gravity

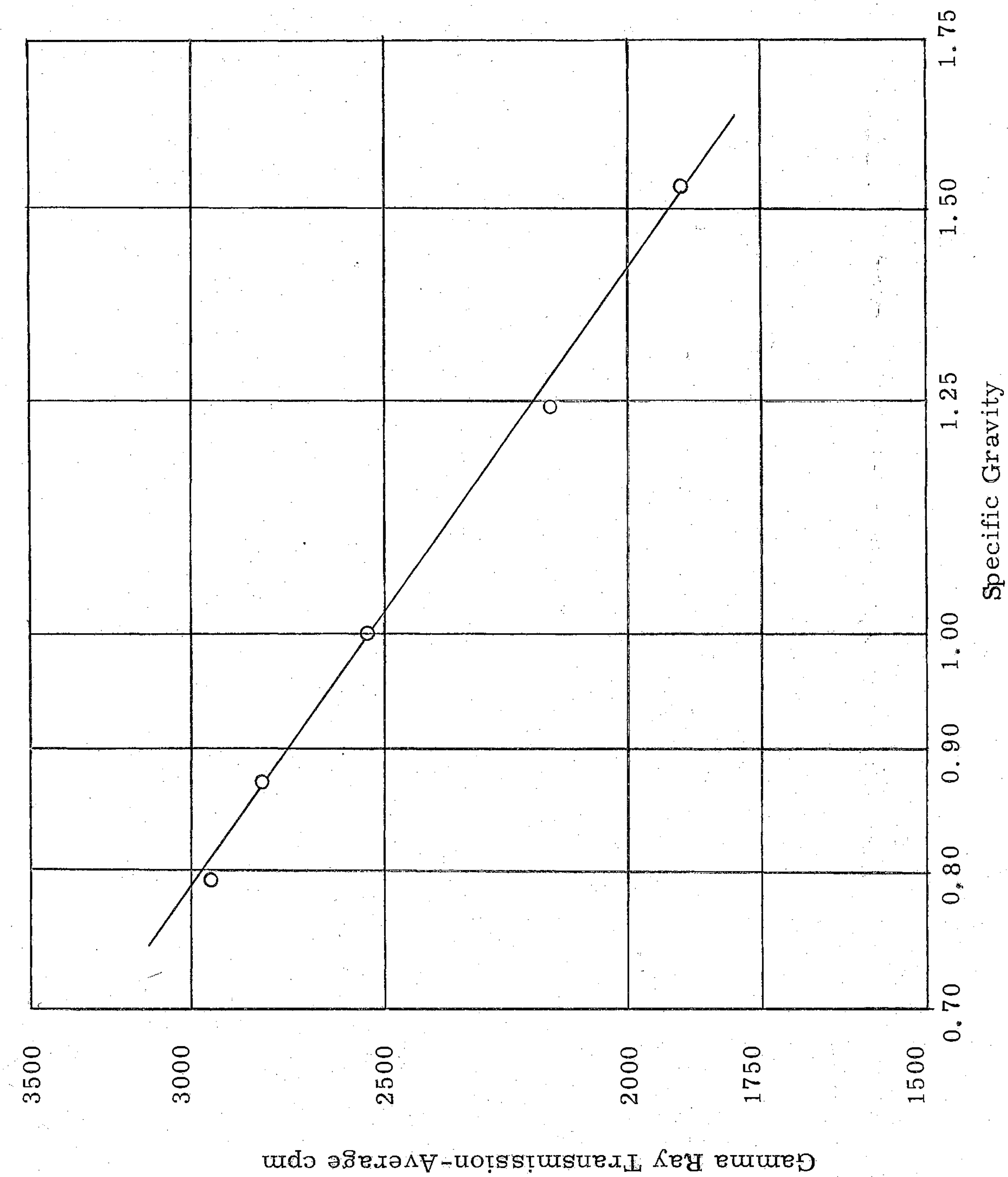

Fig. 2

Variation of Gamma Ray Transmission with Specific Gravity

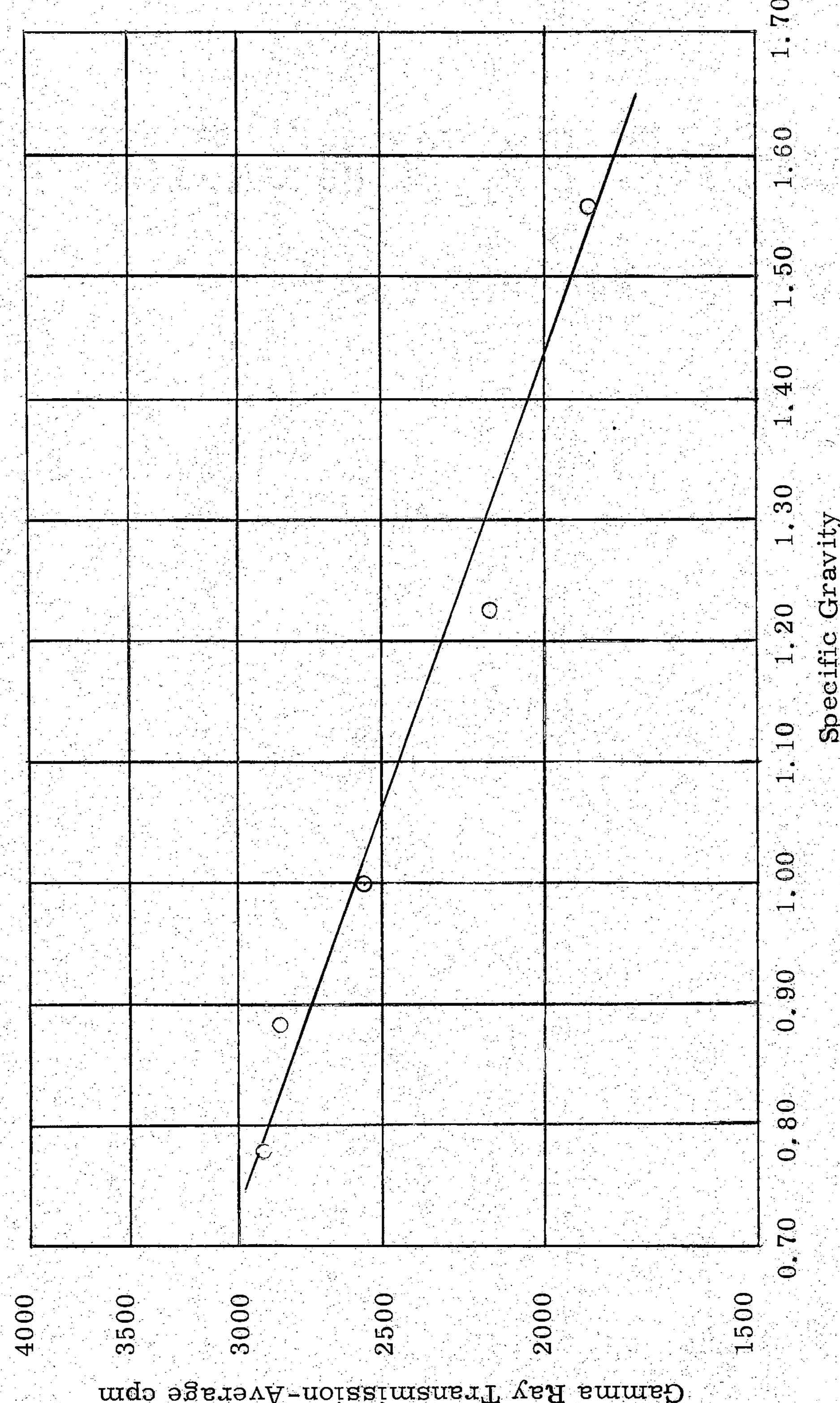

Fig. 3

Variation of Gamma Ray Transmission with Specific Gravity

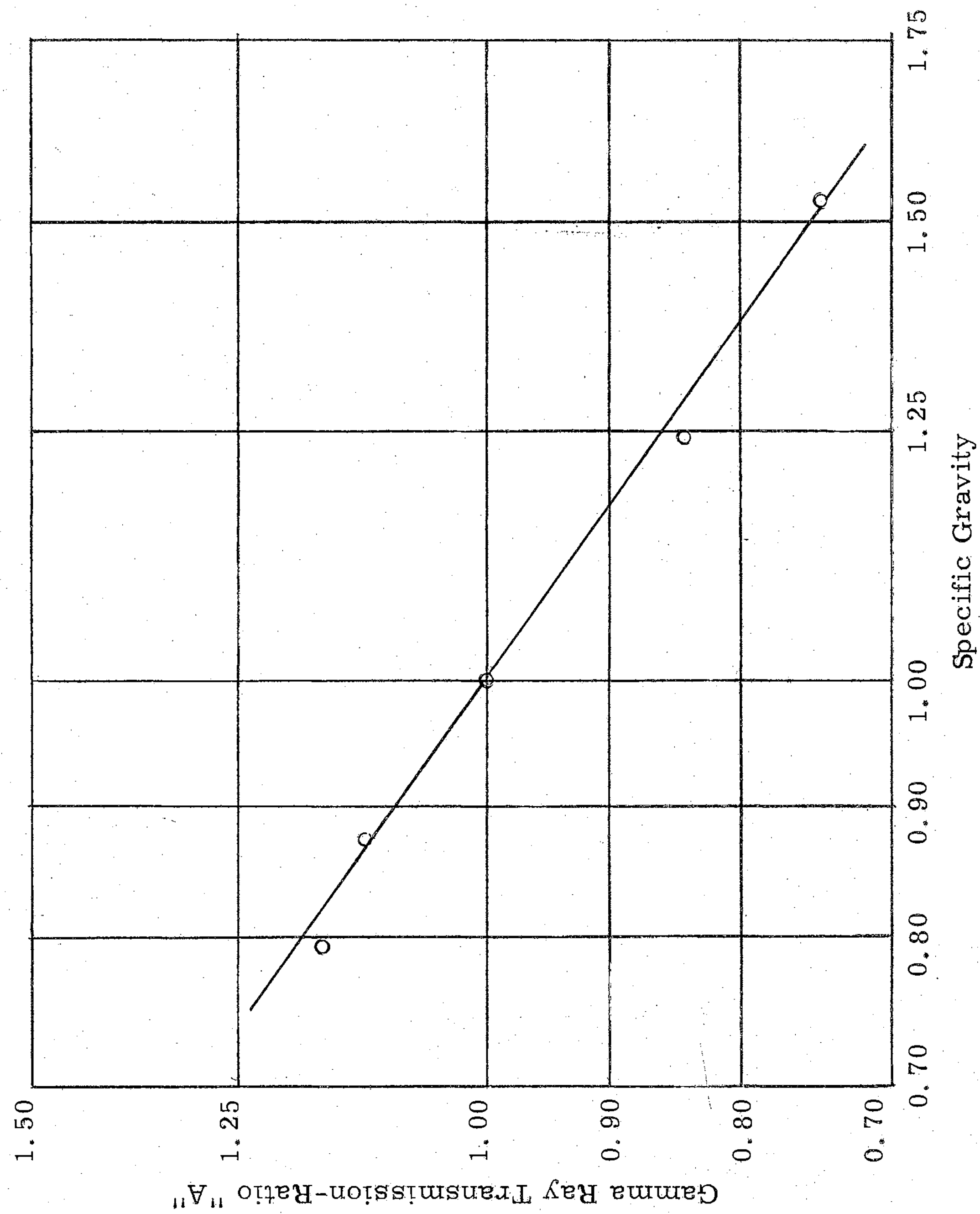

Fig. 4

Variation of Gamma Ray Transmission (Ratio "A") with Specific Gravity

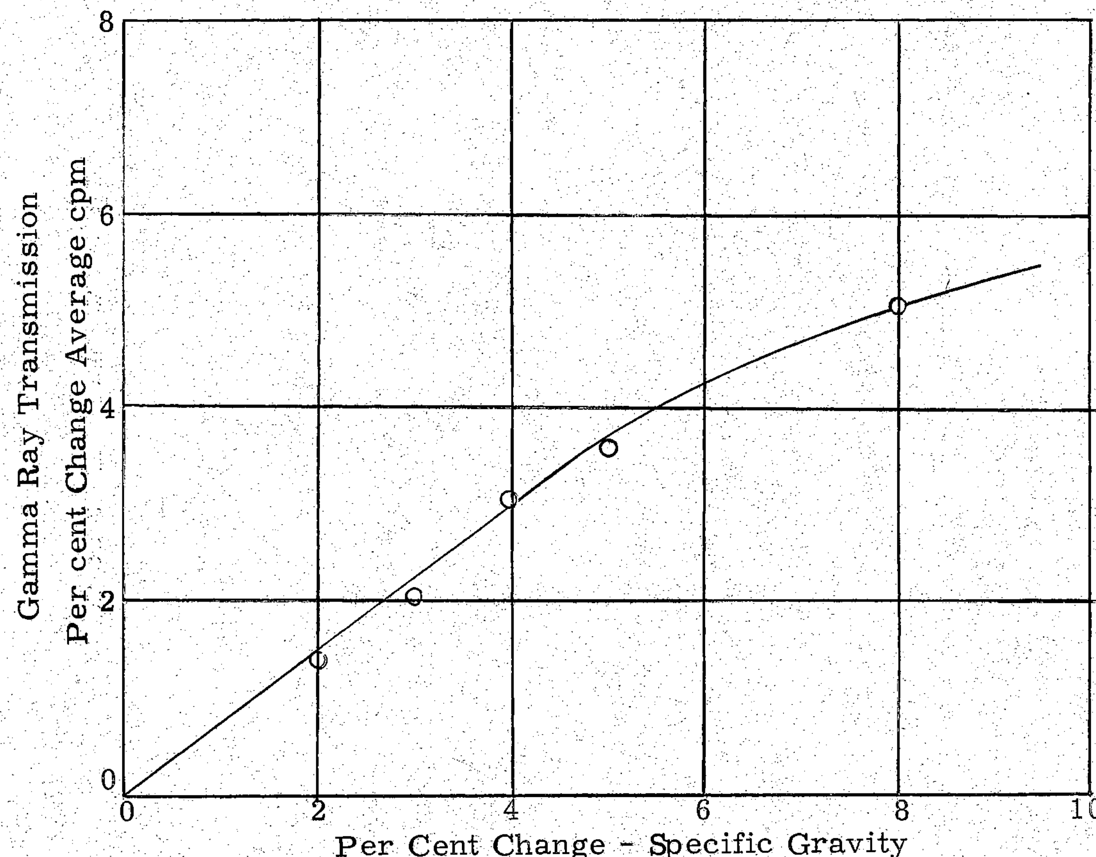

Fig. 5

Variation of Per cent Change of
Average cpm with Specific Gravity

CHAPTER V

DISCUSSION

The experimental average cpm - specific gravity curve followed the calculated curve on a log-log plot. The gamma ray absorption is a exponential function with an increase in fluid density.

Since the fluid density is the only variable in the fixed geometry of the gamma ray absorption instrument, the counting rate and the fluid density relationship can be expressed mathematically. From Figure 1, the general equation is:

$$C_2 = C_1 S_2^{-0.674} .$$

Where:

S_2 = Specific gravity of unknown fluid in the test section

C_2 = Counting rate with unknown fluid in the test section using the source and scintillation probe as a fixed geometry instrument. (See plate II)

C_1 = Counting rate with water, specific gravity 1.000, in the test section using the source and scintillation probe as a fixed geometry instrument.

Therefore $$C_2 = 2550 \ S_2^{-0.674} \tag{1}$$

or $$S_2 = \left(\frac{2550}{C_2}\right)^{1.480}$$

From Figure II, the equation is:

$$C_2 = 2550 \ S_2^{-0.700} \tag{2}$$

or $$S_2 = \left(\frac{2550}{C_2}\right)^{1.425} .$$

The slope of the cpm - specific gravity from Figure 1 is -0.674. This curve is obtained using four fluids in the test section. A 55% increase in the fluid density from the water standard leaves a large break in the log-log plot of the experimental data. At this point, a straight line or an infinite number of curves could be drawn through the four points.

Using all five points of the experimental data on a log-log plot the straight line relationship of cpm and specific gravity is established. There is little difference in the slope of Figure 1 and Figure 2. This substantiates the straight line log-log plot of cpm-specific gravity curve.

Figure 3 is a semi-log plot of the average cpm - specific gravity curve. Although this approximates a straight line curve, the log-log plot of Figure 2 of the experimental data is better represented by a straight line.

As indicated in Table I, five counting runs were made using water in the test section at the start of the experiment and five counting runs at the completion of the experimental runs. The average cpm difference between the two is five. This indicates that the geometry of the source, test section, and detector probe remained fixed during the series of runs.

Figure 4 is a log-log plot of the Ratio "A" - specific gravity curve. As expected, this has the same slope as the curve of Figure 2. This would be an alternate method of writing the equation for a source-detector instrument for the determination of fluid density.

The difference in the high and low cpm and the maximum difference between the average cpm and any one run can be used to estimate the per cent error in the determination of the specific gravity.

Using Table VI-D and equation 2 a per cent change in average cpm-per cent change in specific gravity curve can be drawn, Figure 5. This approximates a straight line curve for 0 to 3.5% change in average cpm. At a higher counting rate the counting error would be considerably reduced. There would be a smaller per cent error in the determination of the specific gravity using such a source-detector instrument.

The slope of the line,(-0.700 from Figure 2) is a relationship of the strength of the radioisotope source, type of radiation detector, and the geometry of the equipment. The average cpm spread, therefore the slope of the cpm-specific gravity curve, could be increased for better accuracy by:

1.) An increase in the strength of the source to increase the counting rate, and decrease the counting error during short time periods. An increase in millicuries of the source would cause a handling problem for use as a field instrument. At a high counting rate the back ground count could be neglected in the calibration and use of the source-detector instrument.

2.) A scintillation probe, amplifier, and discriminator, although not suitable as a portable field instrument, would increase the counting rate and decrease the counting error. A Geiger-Mueller tube would be a desirable field instrument, but at the lower counting rate the counting error would be greater.

3.) When the source and detector are used as an instrument for the determination of fluid density, the only variable for gamma ray absorption is the fluid density. To increase the average cpm spread a diagional cross-section absorption path should be used.

The spread of the C_1 per C_2 ratio at different fluid densities would also increase with a change in any three of the above factors. An increased spread of the C_1 per C_2 ratio would make slide rule field calculations more accurate.

CHAPTER VI

CONCLUSION

It was observed that on a log-log plot the gamma ray absorption is directly related to the fluid density. For a given source-detector instrument, gamma ray absorption measurements can be made to determine the specific gravity of a fluid in a pipeline under static conditions. Experimental measurements indicate that the specific gravity of a fluid can be determined within plus or minus two per cent.

The selection of the radioactive isotope can best be made after the type of detector has been selected. For accurate measurements of specific gravity, plus or minus 0.5 per cent, it would be required to have a gamma ray counting rate greater than 100,000 cpm. This counting rate could be obtained in two minutes with a strong radiation source and a G-M tube detector. If a scintillation probe is used for a detector, the strength of the isotope could be less. The G-M tube would be an ideal portable field detector, but a radiation source of moderate strength (50 millicuries or less) would present a radiation hazard. To prevent recalibration of the source-detector instrument, the isotope should have a half life of greater than twenty years. The source-detector instrument must have fixed geometry so that calculated curves and equations can be used with gamma ray absorption measurements that are obtained in field operations.

CHAPTER VII

RECOMMENDATIONS

Part A - Interface Location

A fixed source detector instrument could be used in field operations as an external means of locating the interface between two fluids of different densities flowing in a pipeline. The detector could be a count rate meter and the source a gamma ray emitter. Using the same apparatus arrangement as Plate I, the results could be represented as in Figure 6.

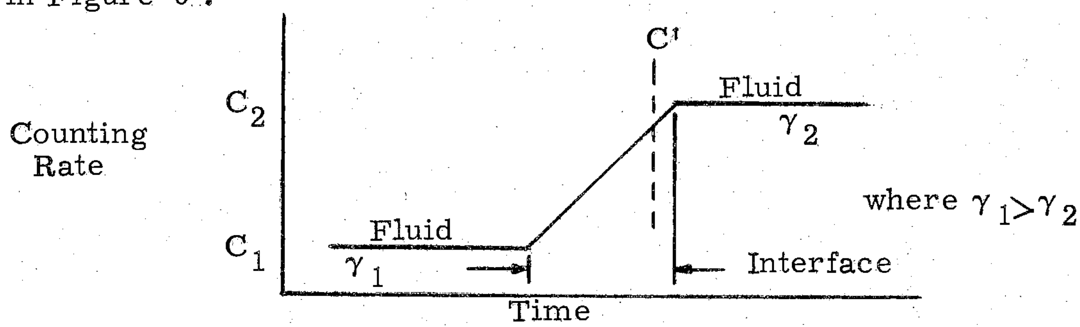

Figure 6

From this plot, the length of the interface or volume of the mixture could be computed. At a gasoline tank farm, two different octanes or densities could be separated or dispatched by such an instrument. At a counting rate C' of a continuously monitoring instrument, an electronic circuit could operate automatic valves for density separation. Using such an instrument for automatic separation, fluid number one would be upgraded and fluid number two would not be down graded.

Part B - Dimensionless Analysis

A dimensionless analysis of radioactivity and the fluid flow problem involves two different types of variables. The American system of force, F; length, L; time, T; and mass, M; must be combined with atomic units, nuclear units and the metric system of units. Variables of atomic number, Z; mass number, A; neutron number, N; linear absorption coefficient, μ_{abs}; intensity, I; electron density would all have to be investigated with the American system of units for a practical set of dimensionless numbers.

Using one set of variables; density, ρ; dynamic viscosity, μ; pressure, P; velocity, V; length, D; kinematic viscosity, ν; linear absorption coefficient, μ_{abs}; and intensity, I, the following dimensionless numbers were found.

1.) $\frac{P^3}{\rho I^2}$

2.) $D\mu_{abs}$.

3.) $\frac{\rho \nu}{D^3 I}$

4.) $\frac{\rho V^3}{I}$

One disadvantage would be the changing from the nuclear system of units to the American system of units.

For the dynamic condition of fluid flow and radioactivity, several investigations of a dimensionless plot are possible, these are:

$$\frac{P^3}{\rho I^2} \text{ vs } \frac{\rho V D}{\mu} \qquad \frac{\rho \nu}{D^3 I} \text{ vs } \frac{\rho V D}{\mu} \qquad \frac{\rho V^3}{I} \text{ vs } \frac{\rho V D}{\mu}$$

The linear absorption coefficient, for investigation and calibration of a given isotope-detector instrument, should be the total linear absorption coefficient. A break down of the gamma ray absorption by pipe walls and air would be cumbersome. The intensity could best be used as the relative per cent intensity. These two nuclear units could be converted to the American system of units for field calculations.

Suggested further study for the use of a radioactive isotope and radiation detector as an instrument for the determination of the specific gravity of a fluid would be:

1.) The testing of a number of fluids with a range in specific gravity from 0.1 to 2.5.

2.) The use of a number of isotopes (gamma ray emitters) with moderatly dangerous strengths. The half life of the isotope should be greater than twenty years.

3.) The scintillation probe should be used as the radiation detector.

The straight line log-log plot of counting rate-specific gravity could be established for a given source-detector instrument for the determination of the specific gravity of a fluid. This instrument could be used in field operations.

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