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# EFFECTS OF RADIATION ON A SILICONE FLUID

by

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SUMMARY

~~This~~ Report describes a preliminary investigation into the effects of radiation on a proposed gyroscope damping fluid. The effects of gamma radiation on the viscosity of the fluid are described, together with a quantitative and qualitative analysis of the gases evolved during irradiation. An attempt has also been made to determine the minimum radiation dose necessary to produce bubbles of gas in a sealed container of the fluid.

Departmental Reference: Space 171

CONTENTS

# 1 INTRODUCTION

A satellite which is stabilised in earth axes, using torques caused by a gravity gradient along the vehicle, requires some form of damping to eliminate oscillations in its attitude. This may be achieved by immersing a sealed gyroscope unit in a fluid within the satellite. Any rotation of the satellite relative to the gyroscope then sets up viscous forces which damp the motion. To ensure that this system will operate efficiently for long periods in space, the effects of cosmic radiation on the damping fluid must be evaluated. Two of the more important properties which require investigation are:-

(a) Viscosity: the damping effect of the gyroscope is greatest for a given value of the damping fluid viscosity. Thus, to maintain the viscosity as near as possible to this optimum value, the effects of cosmic radiation on viscosity must be evaluated.

(b) Bubble formation and outgassing: it is undesirable for bubbles to form in the damping fluid, since these may effect the operating characteristics of the gyroscope. If a bubble comes into contact with some solid part of the assembly, surface tension effects may be encountered.

Manufacturers' data regarding phenyl methyl silicone fluid type MS510 indicated that it was suitable for this gyroscope application, since it was non-corrosive under normal conditions and possessed satisfactory thermal properties. The tests described investigated the effects of radiation on the physical properties of this fluid, to determine its suitability for long-term use in space.

# 2 EXPERIMENTAL DETAILS

## 2.1 Preparation and irradiation of samples

### 2.1.1 Samples for mass spectroscopic analysis

Silicone fluid, type MS510, was commercially available with two viscosities only; namely 50 centistokes and 500 centistokes. Quantities of these two fluids were mixed to obtain a fluid with a viscosity of 155 centistokes at 25°C, this being the optimum value for the gyroscope under consideration. The viscosity was determined by timing the rate of flow of the fluid through a capillary tube, at a temperature of 25°C ±0.05°C. Eight glass bottles, of known volume, of the type shown in Fig.1 and described fully elsewhere[1], were each partly filled with 100 ccs of this fluid. They were then outgassed, overnight, at room temperature, at a pressure less than 0.02 torr and sealed while still under vacuum.

The samples were then subjected to various doses of gamma radiation, up to a maximum of 40 megarads, in the spent fuel element facility at Harwell. The gamma ray spectrum was continuous up to 3 MeV with a maximum around 1 MeV. A dose rate of one megarad per hour was employed.

2.1.2 Bubble formation experiment

For this experiment a container consisting of a radiation resistant spectrosil glass and a beryllium-copper bellows assembly, as shown in Fig.2, was completely filled with silicone fluid of 155 centistokes viscosity. Prior to filling, the container had been ultrasonically cleaned and outgassed for two days at a pressure of $10^{-5}$ torr: the fluid had been similarly outgassed for one day. The container was filled under vacuum to prevent the absorption of air, and the filling tubes sealed on removal of the apparatus from the vacuum chamber.

The purpose of the bellows was twofold, it ensured that the pressure of the fluid remained nearly atmospheric, even if bubbles were produced and enabled bubbles which were difficult to see, or were trapped in the bellows, to be detected by measuring the bellows extension when the assembly was placed in a vacuum. The latter technique was also employed before irradiating the sample, to ascertain that no air had been trapped in the apparatus during the sealing process.

The sample was then irradiated in the spent fuel element facility at Harwell, at a dose rate of 0.5 megarad per hour. The total absorbed dose was increased in steps up to 10 megarads, the sample being tested for bubble formation between each step.

2.2 Test details

After irradiation, each of the sample bottles described in 2.1.1 was examined as follows:-

2.2.1 Quantity of gas produced

Each sample bottle was first connected to the mass spectrometer inlet system, shown diagrammatically in Fig.3 and described fully elsewhere[1]. The glass seal in the neck of the bottle was then broken, using a ball-bearing and a magnet and the outgassed products allowed to expand into the previously evacuated, known volume, v. From a knowledge of the pressure of this gas, measured by means of the mercury manometer, together with the volume it originally occupied, the pressure of the gas prior to breaking the seal could be found.

2.2.2 Mass analysis

A mass analysis was performed initially on the background gases present in the mass spectrometer. Gas from the sample bottle was then allowed to expand into the volume V (Fig.3), until the flow rate through the calibrated leak was sufficient to raise the equilibrium pressure in the mass spectrometer to about $7\times10^{-6}$ torr. At this pressure, the partial pressure of the residual gases, present in the instrument before the sample was admitted, accounted for less than 2% of the total pressure. A mass analysis of the sample gas was then performed, from which the background spectrum was subtracted.

2.2.3 Viscosity measurements

As soon as the mass analysis had been completed on each sample, it was removed from the mass spectrometer and the viscosity of the fluid measured at 25°C, as described in 2.1.

## 3 EXPERIMENTAL RESULTS

### 3.1 Quantity of gas evolved

A graph of the quantity of gas evolved at 760 mm Hg pressure versus absorbed radiation dose is shown in Fig.4.

When the seal was broken, gas from the bottle expanded into the volume v resulting in an immediate pressure reading on the manometer: it was this pressure which was used as a basis for the curve shown in Fig.4. However, gas was observed to be evolved slowly but continually for a considerable time after this, presumably out of solution in the fluid, as a result of the change in pressure when the seal was broken. No quantitative measurements were made regarding this phenomenon.

### 3.2 Mass analysis

Very similar mass spectra were obtained for all the samples, with the exception of the one which had received a dose of 25 megarads. This spectrum showed abnormally large peaks at mass numbers 18, 28, and 32, and was interpretted as showing the presence of relatively large quantities of water, nitrogen and oxygen. Furthermore, from an inspection of Fig.5, it can be seen that the gas pressure in this bottle was inconsistently high. It was concluded that air had probably leaked into the bottle and that therefore the results from this sample were unreliable.

Fig.6 shows a typical mass spectrum of the remaining seven samples, together with a possible interpretation. The peak heights have been expressed as a percentage of the maximum peak, which occurred at mass number 16.

### 3.3 Viscosity

The change in viscosity with absorbed dose is shown in Fig.5, together with the pressure of the gas in the bottle after irradiation. The viscosity rises slowly from its initial value of 155 centistokes to just over 205 centistokes after a dose of 20 megarads. For doses greater than this the rise is more rapid, reaching about 525 centistokes after 40 megarads.

Fig.5 also indicates how the gas pressure in the particular container used rises steadily with dose, with the exception of the previously mentioned 25 megarad sample which appeared to have leaked. However, this leak did not appear to have affected the viscosity, which lies on the smooth curve through the other points in Fig.5. This might be taken to indicate that the dependence of the viscosity on gas pressure during irradiation is slight.

### 3.4 Bubble formation

For absorbed doses of up to 6 megarads no visible bubbles were formed, and, by measuring the bellows extension with the container in a vacuum chamber, it was confirmed that no bubbles had become trapped in the bellows. However, after the next radiation dose, which brought the total absorbed dose up to 10 megarads, about 3 ccs of gas were visible in the container. The test was terminated at this point.

## 4 CONCLUSIONS

An investigation into the radiation induced changes in phenyl methyl silicone fluid which are likely to affect its use in satellite damping gyroscopes has been described. It has been shown that the viscosity of the fluid rises with increasing absorbed dose, and that the rate of increase is most rapid for higher doses. In addition, this is accompanied by outgassing, the main constituents of which appear to be methane, hydrogen and ethane.

It has also been shown that the silicone fluid is capable of trapping in solution at atmospheric pressure the gases produced by gamma radiation of up to 6 megarads.

## REFERENCE


| No. | Author | Title, etc |
|---|---|---|
| 1 | M.J. Downey | Radiation effects in fluorolube.<br>R.A.E. Tech. Report No. 66024, February 1966 |

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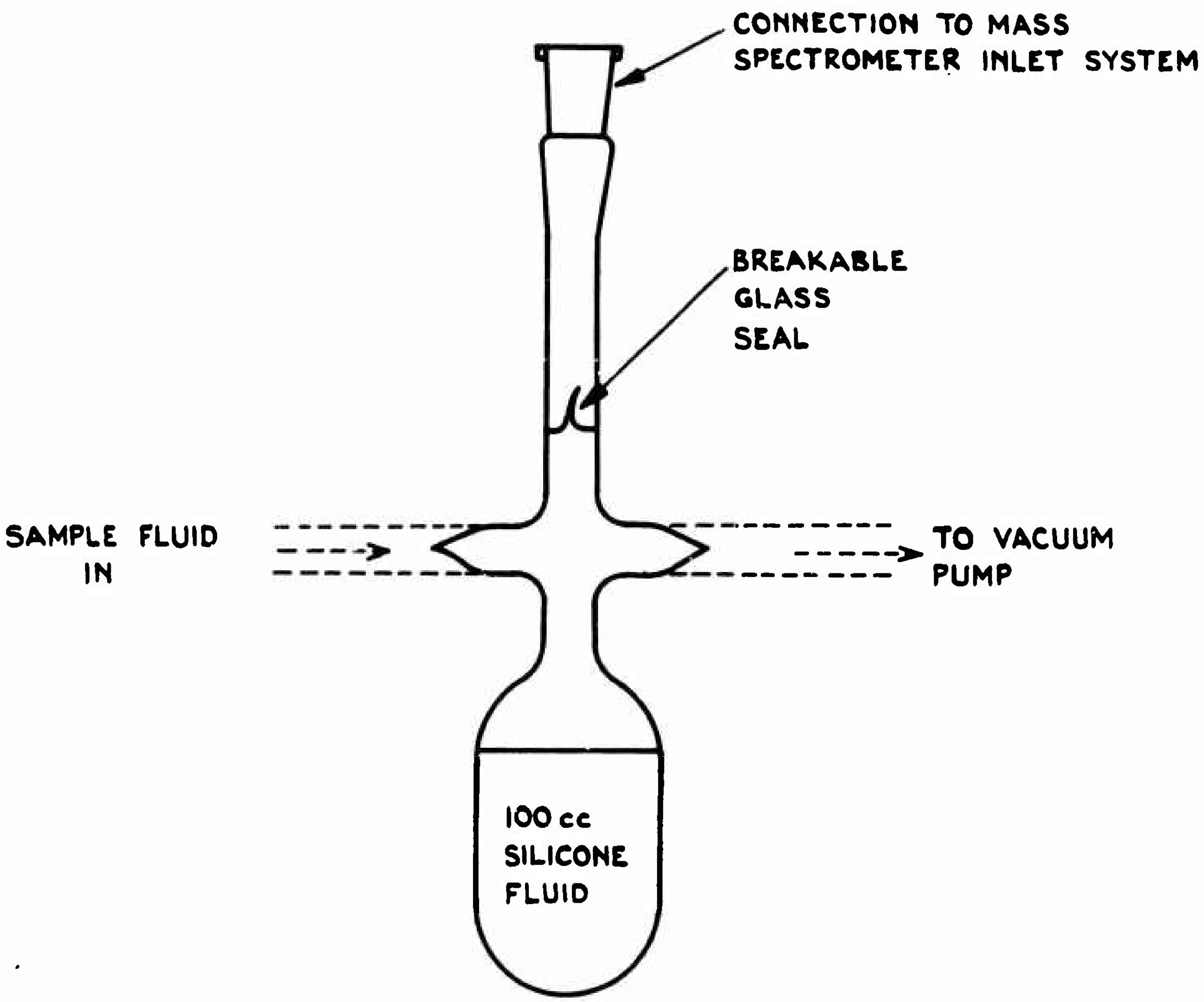


FIG. 1 SAMPLE BOTTLE
FOR IRRADIATION OF SILICONE FLUID

Fig.2



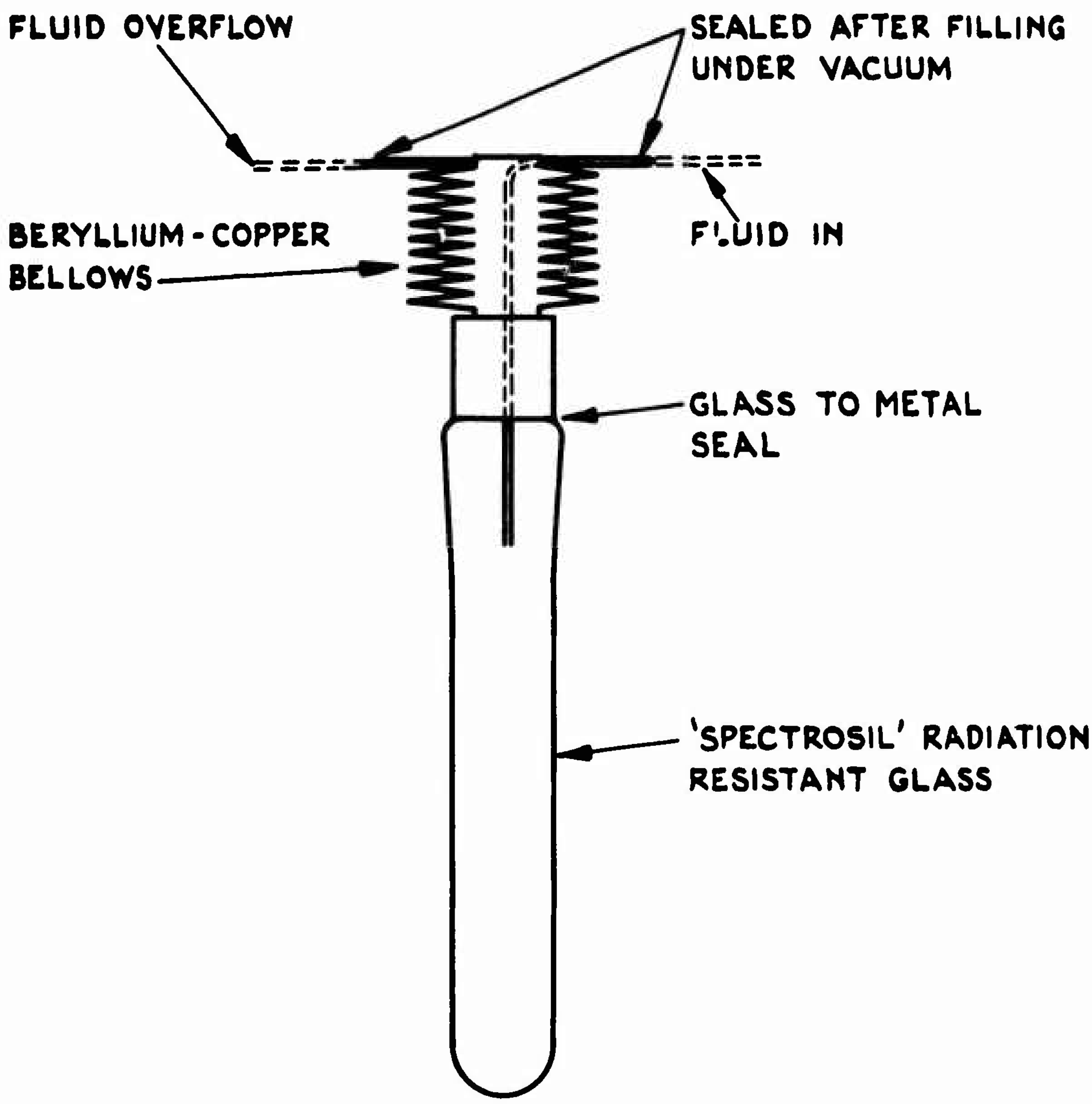


FIG. 2 SAMPLE CONTAINER FOR BUBBLE FORMATION EXPERIMENT

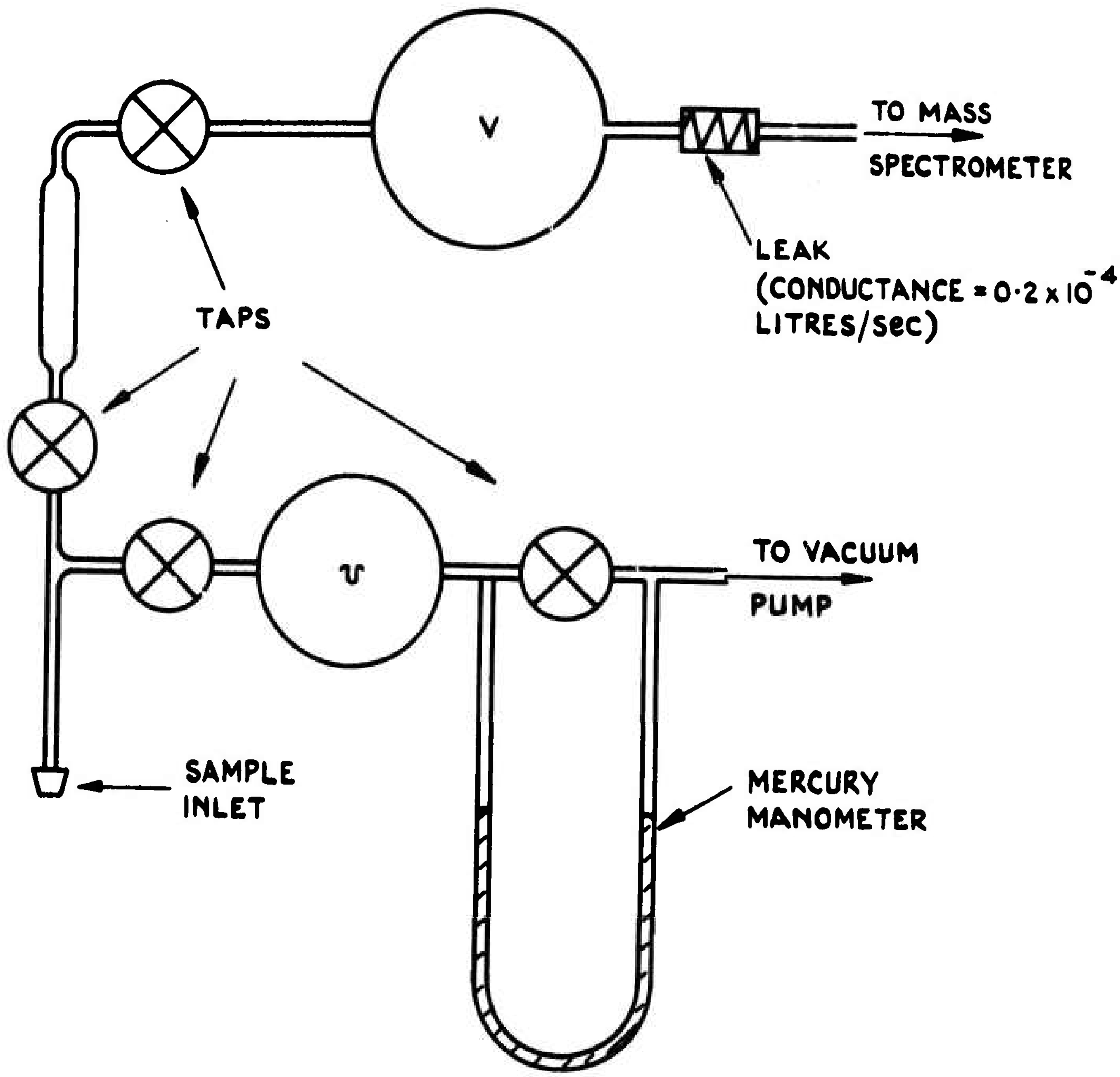


FIG. 3 MASS SPECTROMETER INLET SYSTEM

Fig.4

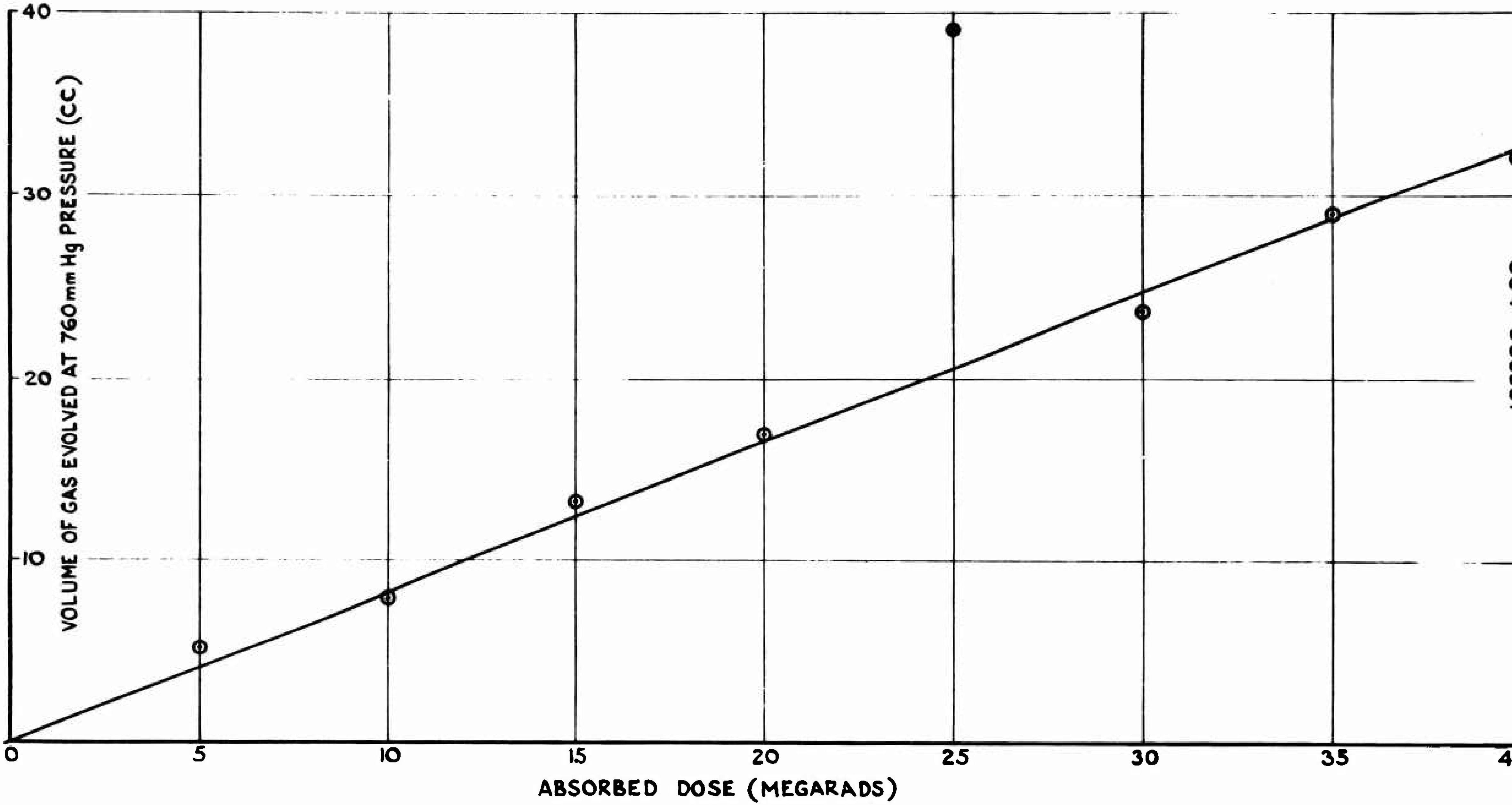


FIG. 4 QUANTITY OF GAS EVOLVED AT ATMOSPHERIC PRESSURE

Fig. 5

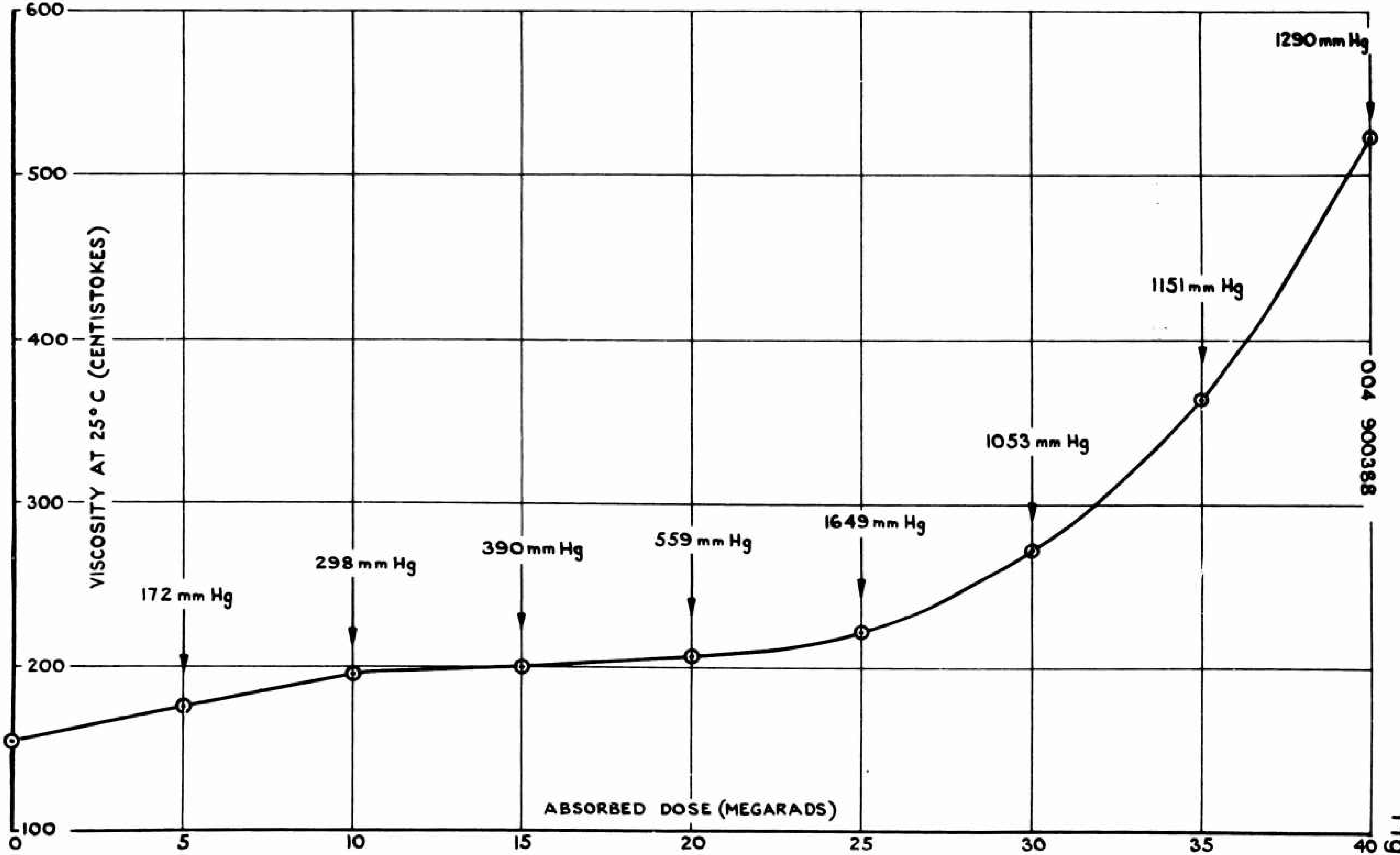


FIG. 5 VISCOSITY OF SILICONE FLUID AFTER IRRADIATION

Fig.6

| POSSIBLE INTERPRETATION | |
|---|---|
| METHANE ($CH_4$) | 61% |
| HYDROGEN ($H_2$) | 34% |
| ETHANE ($C_2H_6$) | 5% |

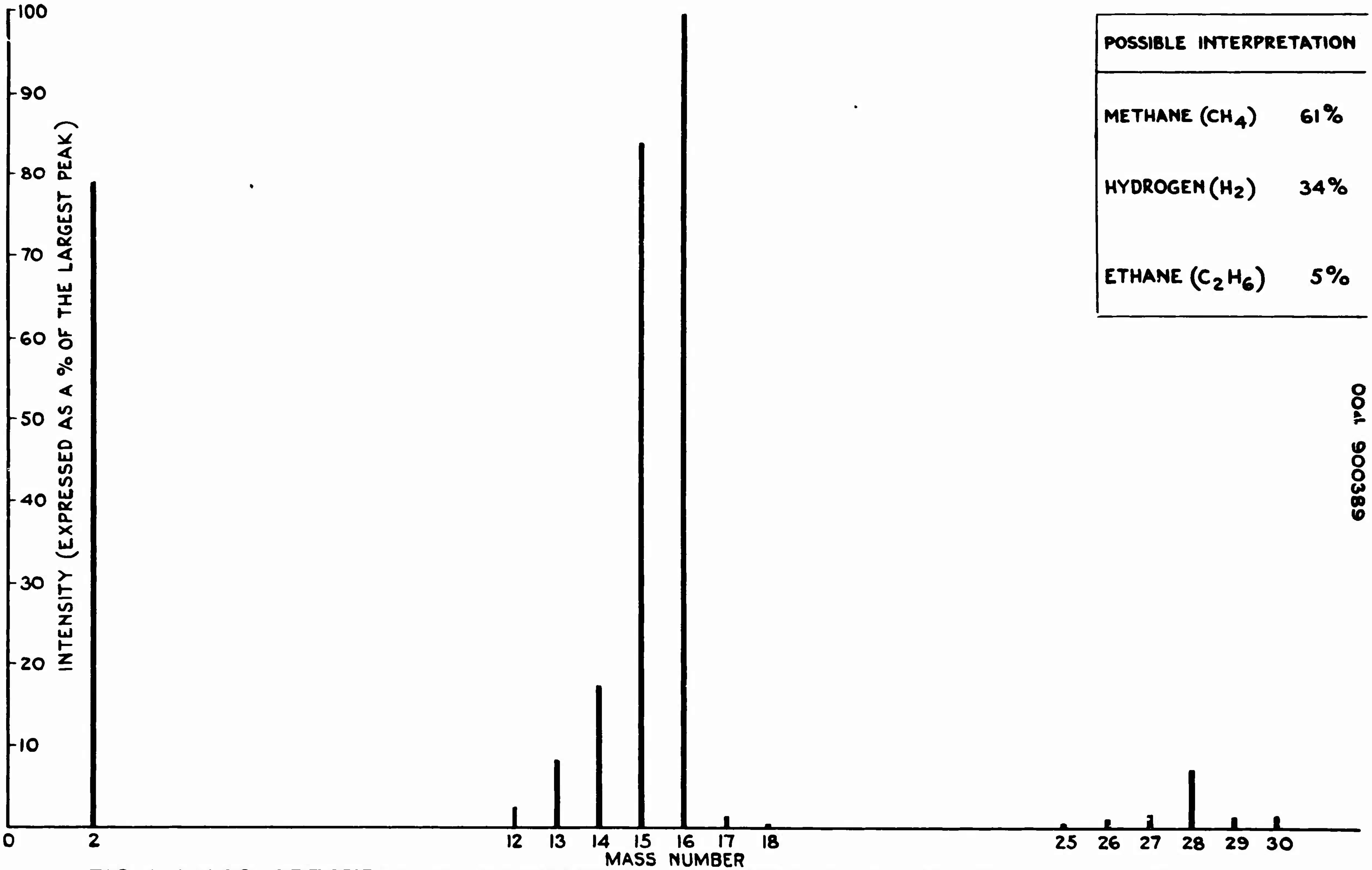


FIG. 6 MASS SPECTRUM OF OUTGASSED PRODUCTS OF IRRADIATED SILICONE FLUID