

QC
879.5
.U4
no. 34

NOAA Technical Memorandum NESS 34



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite Service

Chromium Dioxide Recording— Its Characteristics and Potential for Telemetry

FLORENCE NESH

WASHINGTON, D.C.

March 1972

National Environmental Satellite Service Series

The National Environmental Satellite Service (NESS) is responsible for the establishment and operation of the National Operational Meteorological Satellite System and of the environmental satellite systems of NOAA. The three principal Offices of NESS are Operations, Systems Engineering, and Research.

NOAA Technical Memoranda NESS series facilitate rapid distribution of material that may be preliminary in nature and which may be published formally elsewhere at a later date. Publications 1 to 25 are in the former series, ESSA Technical Memoranda, National Environmental Satellite Center Technical Memoranda (NESCTM). Beginning with 26, publications are now part of the series, NOAA Technical Memoranda, National Environmental Satellite Service (NESS).

Publications listed below are available from the National Technical Information Service, U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, Va. 22151. Price: \$3.00 paper copy; \$0.95 microfiche. Order by accession number shown in parentheses at end of each entry.

ESSA Technical Memoranda

- NESCTM 6 Computer Processing of TOS Attitude Data. J. F. Gross, November 1968. (PB-182 125)
- NESCTM 7 The Improved TIROS Operational Satellite. Edward G. Albert, August 1968. (PB-180 766)
Supplement No. 1. Characteristics of Direct Scanning Radiometer Data. Edward G. Albert, April 1969. (PB-183 965)
- NESCTM 8 Operational Utilization of Upper Tropospheric Wind Estimates Based on Meteorological Satellite Photographs. Gilbert Jager, Walton A. Follansbee, and Vincent J. Oliver, October 1968. (PB-180 293)
- NESCTM 9 Meso-Scale Archive and Products of Digitized Video Data From ESSA Satellites. Arthur L. Booth and V. Ray Taylor, October 1968. (PB-180 294)
- NESCTM 10 Annotated Bibliography of Reports, Studies, and Investigations Relating to Satellite Hydrology. D. R. Baker, A. F. Flanders, and M. Fleming, June 1970. (PB-194 072)
- NESCTM 11 Publications by Staff Members, National Environmental Satellite Center and Final Reports on Contracts and Grants Sponsored by the National Environmental Satellite Center 1968. January 1969. (PB-182 853)
- NESCTM 12 Experimental Large-Scale Snow and Ice Mapping With Composite Minimum Brightness Charts. E. Paul McClain and Donald R. Baker, September 1969. (PB-186 362)
- NESCTM 13 Deriving Upper Tropospheric Winds by Computer From Single Image, Digital Satellite Data. Charles S. Novak, June 1969. (PB-185 086)
- NESCTM 14 Study of the Use of Aerial and Satellite Photogrammetry for Surveys in Hydrology. Everett H. Ramey, March 1970. (PB-191 735)
- NESCTM 15 Some Aspects of the Vorticity Structure Associated With Extratropical Cloud Systems. Harold J. Brodrick, Jr., May 1969. (PB-184 178)
- NESCTM 16 The Improvement of Clear Column Radiance Determination With a Supplementary 3.8μ Window Channel. William L. Smith, July 1969. (PB-185 065)
- NESCTM 17 Vidicon Data Limitations. Arthur Schwalb and James Gross, June 1969. (PB-185 966)
- NESCTM 18 On the Statistical Relation Between Geopotential Height and Temperature-Pressure Profiles. W. L. Smith and S. Fritz, November 1969. (PB-189 276)
- NESCTM 19 Applications of Environmental Satellite Data to Oceanography and Hydrology. E. Paul McClain, January 1970. (PB-190 652)

(Continued inside back cover)

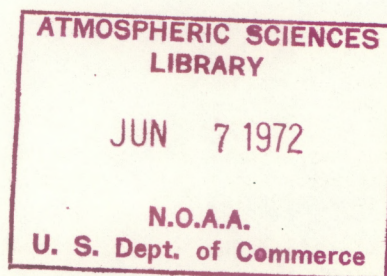
A
QC
879.5
U4
no. 34
c.2

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite Service

NOAA Technical Memorandum NESS 34

CHROMIUM DIOXIDE RECORDING--ITS CHARACTERISTICS AND
// POTENTIAL FOR TELEMETRY

Florence Nesh

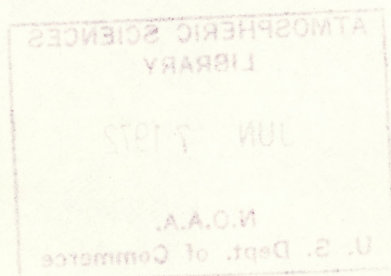


WASHINGTON, D.C.
March 1972

'72 2298

UDC 621.398.625:546.76-31:621.317:621.318.1

546	Inorganic chemistry
.76	Chromium
-31	Oxides
621.3	Electrical engineering
.31	Electrical measurements
.317	Measurement of magnetic properties
.318	Applied magnetism
.318.1	Magnetic materials
.39	Telecommunications
.398	Telemetry
.398.625	Recording apparatus for telemetry



CONTENTS

	Page
Abstract	1
Introduction	2
Experiment	2
Results and discussion	2
Conclusions	5
References	5

LIST OF TABLES

1. Magnetic remanence (in maxwells) at Mag 1, Mag 2, and Sat	6
2. Change in magnetic remanence with variation in h (H is constant at 600 oe)	7
3. Change in magnetic remanence with time	7
4. Variance in peak and end magnetic remanence of chromic oxide tape with varying h at H=600 oe	8
5. Variance of magnetic remanence with variations of temperature of coil and chromic oxide tape	8

LIST OF FIGURES

1. Tape magnetizing unit with magnetizing coil	9
2. Readout unit showing coil from which magnetized sample is propelled, integrating amplifier and fluxmeter	9
3. Readout coil with sample positioned in center of coil before being propelled	10
4. Readout coil with sample in position after being propelled from the coil	10

CHROMIUM DIOXIDE RECORDING-- ITS CHARACTERISTICS AND POTENTIAL FOR TELEMETRY

Florence Nesh
National Environmental Satellite Service

ABSTRACT. A study has been made of the kinetics of the magnetic recording reaction. An expression has been derived for the calculation of an equilibrium constant which holds for all conditions of tape concentration, signal field, and bias field. A preliminary study has been made of the rate processes involved in this reaction and an attempt to apply the rate equations to the experimental results was undertaken.

γ -Ferric oxide and chromium dioxide tapes were studied and compared. The experimental conditions were extended for a further study of the chromium dioxide tapes.

The results indicate some serious problems in using the chromium dioxide tapes with existing recording equipment, such as difficulty in reproducing magnetic remanence readings, excessive sensitivity to slightly increased temperatures, considerable drop in magnetic remanence with lower signals, and decrease in remanence capability with time. However, there are indications of potential improved adaptability to telemetry and communications applications with modification of the circuitry of the recording equipment only. The magnetic remanence per unit amount of oxide is 50 percent greater on chromium dioxide tapes than on ferric oxide tapes. This indicates a greater data storage capacity and the possibility of using thinner tapes with much improved resolution, less usage and storage space, and less tape surface interference with signal reception and retention. In the course of the study it was discovered that a much higher magnetic field is required to reach the equilibrium point of chromium dioxide tape than to reach that of ferric oxide tape. This problem may be attributable to using circuitry designed to bring out the optimum characteristics of ferric oxide tape. A redesign of the circuitry could eliminate or reduce these problems.

INTRODUCTION

A total of 25 γ -ferric oxide and four chromium dioxide tapes were studied in bulk to determine the magnetic remanence incurred under varying conditions. Using the data obtained with the γ -ferric oxide tapes, an expression was derived for an equilibrium constant for the magnetic recording reaction. This equation was subsequently used to explain the behavior of the tapes under varying conditions, and to predict their behavior under future conditions.

EXPERIMENT

The apparatus used in this work was a modification of that described by Daniel and Levine (1960). It consists essentially of a magnetizing coil, a readout coil, and a fluxmeter (see figures 1, 2, 3, and 4). The equipment was redesigned for these studies. Each sample consisted of a packet of 50 strips of tape each 5 inches long one one-quarter inch wide (or the equivalent) in a stoppered glass tube. The tube is inserted into the solenoid (figs. 3 and 4), and the desired field(s) are brought to peak strength in 14 s and reduced to zero in the succeeding 14 s. The total elapsed time is 28 s. The tube is removed, placed into a spring mechanism behind the small coil, then shot through the readout coil. The rate of change flux is measured by the integrated amplifier. The readout is in Maxwells. The recording conditions are referred to as "Mag 1," "Mag 2," and "Saturate."

In Mag 1, the DC - signal field is brought to its maximum and held there. Then the 60-cycle AC-bias field is permitted to rise to its peak and decline to zero before the DC signal is brought down again. This represents the ideal anhysteritic situation.

In Mag 2, the bias and signal fields are simultaneously brought to peak strength then reduced to zero. The signal field "h" is induced by a DC signal of 5 oe and the bias field "H" is induced by a 60-cycle AC-field of 600 oe.

In Saturate a DC signal of 500 oe is used.

RESULTS AND DISCUSSION

Tapes A through L are γ -ferric oxide tapes. Tapes M, N, and O are chromium dioxide tapes (see table 1). The equation derived to determine an equilibrium constant (K_{eq}) for the magnetic recording reaction is as follows:

$$K_{eq} = \frac{\phi}{\eta_m (4 \pi n w c X) (h) \left[\frac{H+F(H)}{H} \right]}$$

where $\eta_m = \frac{\phi_1}{4 \pi n w c h_1}$

ϕ_1 = remanent flux under Mag 1 conditions

h_1 = signal field under Mag 1 conditions

($h_1 = 5$ oe)

" η_m " is an individual tape constant derived by Levine and Daniel (1960)

n = number of layers of tape

w = width of tape (cm)

c = coating thickness (cm)

X = specific magnetization. According to Selwood (1965) this is 95 for γ -Fe₂O₃ and Fe₃O₄, though other industrial researchers report figures of 75-80. X for chromium dioxide is 85 (according to industrial researchers).

h = amplitude of signal field (oe). In the equation, $h^*=h$, if $h \leq 72$ oe; $h^*=72$, if $h > 72$ oe. 72 oe is the calculated saturation h .

H = amplitude of bias field (oe)

$F(H) = K_1 H + K_2 H^3 + K_3 H^5$, where

$$K_1 = 1.915 \times 10^{-2}$$

$$K_2 = 1.601 \times 10^{-6}$$

$$K_3 = 7.95 \times 10^{-12}$$

The above constants are not the correct ones for γ -Fe₂O₃ tape; they were taken from Zenner's (1951) paper and had been derived for stainless steel wire. However, they offer corrections sufficiently close to the limits of error of the system to be applied in this initial work.

A study of Table 1 shows that, at saturation, the chromium dioxide tapes have a very high magnetic remanence per amount of magnetic material as compared to the γ -ferric oxide tapes. At lower field strengths, however, they resist magnetization. This would indicate, at this point in the study, a good potential for digital but not for analog recording.

Using the above equation we get:

$$K_{eq}(\text{Sat})(\text{CrO}_2) = 1.8 \times 10^{-2}$$

$$K_{eq}(\text{Mag } 2)(\text{CrO}_2) = 1.2 \times 10^{-2}$$

Using $X = 75$ for $\gamma\text{-Fe}_2\text{O}_3$

$$\left. \begin{array}{l} K_{eq}(\text{Mag } 3) = 1.1 \times 10^{-2} \\ K_{eq}(\text{Mag } 2) = 1.2 \times 10^{-2} \end{array} \right\} \begin{array}{l} 8\% \text{ Difference between } K_{eq}(\text{Mag } 2) \text{ and } K_{eq}(\text{Mag } 3) \end{array}$$

Using $X = 95$ for $\gamma\text{-Fe}_2\text{O}_3$

$$\left. \begin{array}{l} K_{eq}(\text{Mag } 3) = 0.88 \times 10^{-2} \\ K_{eq}(\text{Mag } 2) = 0.94 \times 10^{-2} \end{array} \right\} \begin{array}{l} 6\% \text{ Difference between } K_{eq}(\text{Mag } 2) \text{ and } K_{eq}(\text{Mag } 3) \end{array}$$

Using $X = 85$ for CrO_2

$$\left. \begin{array}{l} K_{eq}(\text{Mag } 3) = 1.8 \times 10^{-2} \\ K_{eq}(\text{Mag } 2) = 1.2 \times 10^{-2} \end{array} \right\} \begin{array}{l} 40\% \text{ Difference between } K_{eq}(\text{Mag } 2) \text{ and } K_{eq}(\text{Mag } 3) \end{array}$$

The direction of change also seems to be the opposite for $\gamma\text{-Fe}_2\text{O}_3$ and CrO_2 .

The above results show that under these experimental conditions, the $\gamma\text{-Fe}_2\text{O}_3$ apparently approaches a state of equilibrium, while the CrO_2 does not. At this point a deduction could be made that the CrO_2 crystals used are not yet stable in their magnetic configuration and therefore are changing. These conditions indicate that there would be difficulty in reproducing results with CrO_2 tape under currently used recording conditions. Instability of magnetic remanence with time is also a factor. To check these assumptions the following studies were undertaken; all three CrO_2 tapes and three $\gamma\text{-Fe}_2\text{O}_3$ tapes were used.

The "h" field was varied and the drop in magnetic remanence from the saturation reading was noted (see table 2). These results would indicate that CrO_2 tape is not suitable for analog recording. There was also difficulty in reproducing readings with the CrO_2 tapes, especially at lower "h" fields, whereas the $\gamma\text{-Fe}_2\text{O}_3$ tapes were reproducible within 2 percent. The magnetic remanence readings of the CrO_2 tapes varied as much as and occasionally more than 10 percent as the field strength went down.

The CrO_2 tapes also were apparently more sensitive than the $\gamma\text{-Fe}_2\text{O}_3$ tapes to small temperature changes in the 24°C to 28°C range. At these temperature changes the $\gamma\text{-Fe}_2\text{O}_3$ tapes showed no noticeable drop in magnetic remanence. The CrO_2 tapes showed drops from three and one-half percent to 10 percent at saturation and 10 percent to 20 percent at $h = 100$.

Table 3 shows the effect of time on the remanent magnetization at saturation of γ -Fe₂O₃ tapes and CrO₂ tapes. The γ -Fe₂O₃ tapes, originally measured in 1962, showed no change between then and 1970. The saturation magnetic remanence of the CrO₂ tapes had dropped 12 percent, 14 percent, and 11.7 percent, indicating an instability with time.

A fourth CrO₂ tape was studied under extended experimental conditions (see tables 4 and 5). The tables show that the peak and end magnetic remanence readings decrease both with increasing time and temperature.

The equilibrium saturation point of CrO₂ tape is about $h = 470$ to $h = 480$ oe for this time cycle. An area of maximum percent increase in end-over-peak reading seems to be between $h = 100$ and $h = 175$ oe. The estimated saturation equilibrium for the CrO₂ tape is about 150 oe, with 475 oe required to saturate at 14 sec. For γ -Fe₂O₃ tapes the calculated saturation is $h = 72$ oe, but 200 oe for γ -FeO₂ tape to reach saturation in 14 sec.

CONCLUSIONS

From the above results one can conclude that the chromium dioxide tapes have a unique potential for use in operational telemetry and communications applications, because the magnetic remanence per unit amount of oxide is 50 percent greater than with the ferric oxide tapes. The results of using CrO₂ tape would be a greater data storage capacity, the ability to use thinner tapes with improved resolution and less usage and storage space, and less tape surface interference with signal reception and retention. However, to realize this potential a redesign of the electronics of the recording system would be required. This should be neither difficult nor expensive. The present circuitry has been designed to bring out the optimum recording characteristics of ferric oxide. What is required now is circuitry optimum for the cited chromium dioxide characteristics. Thus, the problems of non-reproducibility of signal, excessive drop in remanence with drop in signal and slight increase in temperature, and possibly the loss of signal with time might be reduced or eliminated.

REFERENCES

- Daniel, Eric D., and Levine, Irving., "Experimental and Theoretical Investigation of the Magnetic Properties of Iron Oxide Recording Tape," Journal of the Acoustical Society of America, Vol. 32, No. 1, Jan. 1960, pp. 1-15.
- Selwood, Pierce W., Magnetochemistry, (Second Edition), Interscience Publishers, Inc., New York, N.Y., 1956, 435 pp.
- Zenner, R. E., "Magnetic Recording with AC Bias," Proceedings of the Institute of Radio Engineers, Vol. 39, No. 2, Feb. 1951, pp 141-146.

Table 1.--Magnetic remanence (in maxwells) at Mag 1, Mag 2, and Sat

Tape *	Thickness (mils)	Rem/mil			Rem 1/ rem 2/			Sat/		
		Mag 1	Mag 2	Sat	Mag 1	Mag 2	Sat	Mag 1	Mag 2	Sat
A	0.35	5.45	2.25	30.2	15.60	6.43	86.2	2.43	13.4	2.42
B	.58	5.20	2.45	42.3	8.96	4.22	72.8	2.13	17.3	2.12
C	.45	4.20	1.88	29.0	9.30	4.18	64.4	2.22	15.4	2.23
D	.45	4.20	1.80	29.0	9.30	4.00	64.4	2.33	16.1	2.33
E	-	3.75	1.60	24.0	-	-	-	-	-	2.34
F	.27	4.00	1.70	25.1	14.80	6.30	92.9	2.35	14.7	2.35
G	.27	3.40	1.40	21.9	12.60	5.19	81.1	2.43	15.6	2.43
H	-	4.80	2.00	36.5	-	-	-	-	-	2.40
I	.45	4.80	2.00	38.5	10.70	4.44	85.6	2.41	19.3	2.40
J	.40	5.60	2.60	34.0	14.00	6.50	85.0	2.16	14.6	2.15
K	.45	6.70	2.80	37.0	14.90	6.22	82.2	2.40	13.2	2.39
L	.45	7.40	3.20	40.0	16.40	7.11	88.9	2.31	12.5	2.31
M	.19	1.75	0.925	19.3	9.20	4.87	101.6	1.91	20.9	1.89
N	.19	1.75	1.150	19.8	9.20	6.05	104.2	1.52	17.2	1.52
O	.19	2.20	1.200	25.0	11.60	6.32	131.6	1.84	20.8	1.83

* Tapes A-L are γ -ferric oxide; tapes M-O are chromic oxide.

Table 2.--Change in magnetic remanence with variation in h
(H is constant at 600 oe)

Tape No.	Magnetic remanence loss from saturation (in percent)					
	h: 240 oe	200 oe	150 oe	100 oe	75 oe	50 oe
chromic oxide:						
#1	16	15.0	30.5	61.0	79.0	86.2
2	19	19.5	36.0	68.0	89.0	94.5
3	22	24.0	39.0	66.0	88.4	93.0
γ -ferric oxide:						
#1	4	3.7	8.7	14.0	28.0	32.8
2	5	4.7	11.5	17.5	34.6	37.2
3	5	4.6	10.8	16.5	33.0	36.0

Table 3.--Change in magnetic remanence with time

Tape No.	Magnetic remanence at saturation (maxwells)	
	August 1966 measurements	August 1970 measurements
γ -ferric oxide:		
#1	30.2	30.0
2	36.5	36.3
3	29.0	29.0
4	21.9	21.8
5	34.0	34.0
6	38.5	38.5
7	37.0	36.5
8	29.0	28.7
9	24.0	24.0
10	40.0	39.5
11	25.1	24.8
chromic oxide		
#1	19.3	17.0
2	25.0	21.5
3	19.8	17.5

Table 4.--Variance in peak and end magnetic remanence of chromic oxide tape with varying h at $H = 600$ oe*

h	Remanence in maxwells		Peak-to-end change		Increase from previous reading (in maxwells)	
	peak (at 18 s)	end (at 28 s)	amount	% change	peak	end
50	0.41	0.43	+0.02	+4.88	-	-
56	0.57	0.60	+0.03	+5.26	0.16	0.17
100	1.90	2.15	+0.25	+13.00	1.33	1.55
150	5.70	6.50	+0.80	+14.00	3.80	4.35
168	7.00	7.95	+0.95	+13.60	1.30	1.45
200	10.95	11.15	+0.25	+2.30	3.95	4.20
224	12.80	13.20	+0.40	+3.12	1.95	2.05
250	13.90	14.20	+0.30	+2.16	1.10	1.00
267	16.50	17.00	+0.50	+3.00	2.60	2.80
300	18.90	19.00	+0.10	+0.53	2.40	2.00
350	19.90	20.00	+0.10	+0.50	1.00	1.00
400	20.85	20.95	+0.10	+0.47	0.95	0.95
450	21.10	21.20	+0.10	+0.47	0.25	0.25
500	21.90	21.75	-0.15	-0.69	0.80	0.55

*Measurements made during November 1970.

Table 5.--Variance of magnetic remanence with variations of temperature of coil and chromic oxide tape*

h	Remanence in maxwells		Variance	
	Temperature	Room temperature	change in rem	% change in rem
	cool ($\sim 23^{\circ}\text{C}$)	25°C	change in rem	% change in rem
478	20.75	20.75	0	0
500	20.67	20.55	-0.13	-0.63
	warm ($\sim 27^{\circ}$ to 28°L)			
350	19.90	20.05	+0.15	+0.75
400	20.00	20.13	+0.13	+0.65
450	20.25	20.38	+0.13	+0.64
475	20.75	20.75	0	0
	hot ($\geq 30^{\circ}\text{C}$)			
500	20.00	20.10	+0.10	+0.5
500	19.90	19.90	0	0

*Measurements on August 24, 1971.



Figure 1.--Tape magnetizing unit with magnetizing coil.



Figure 2.--Readout unit showing coil from which magnetized sample is propelled, integrating amplifier and fluxmeter.

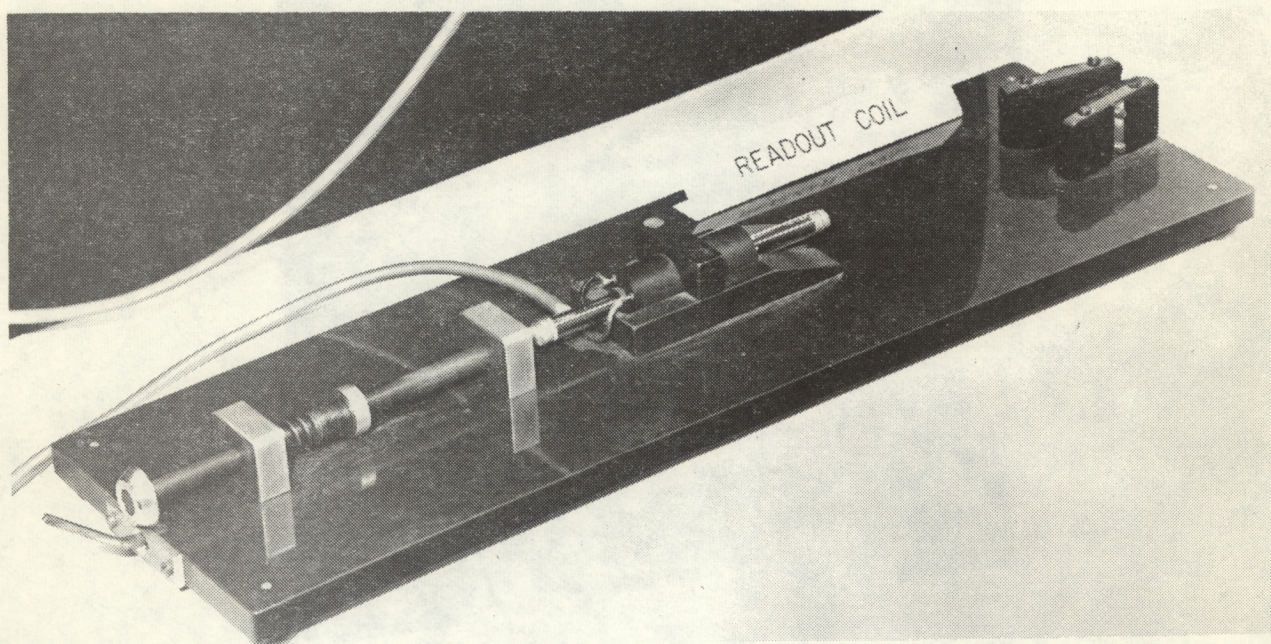


Figure 3.--Readout coil with sample positioned in center of coil before being propelled.

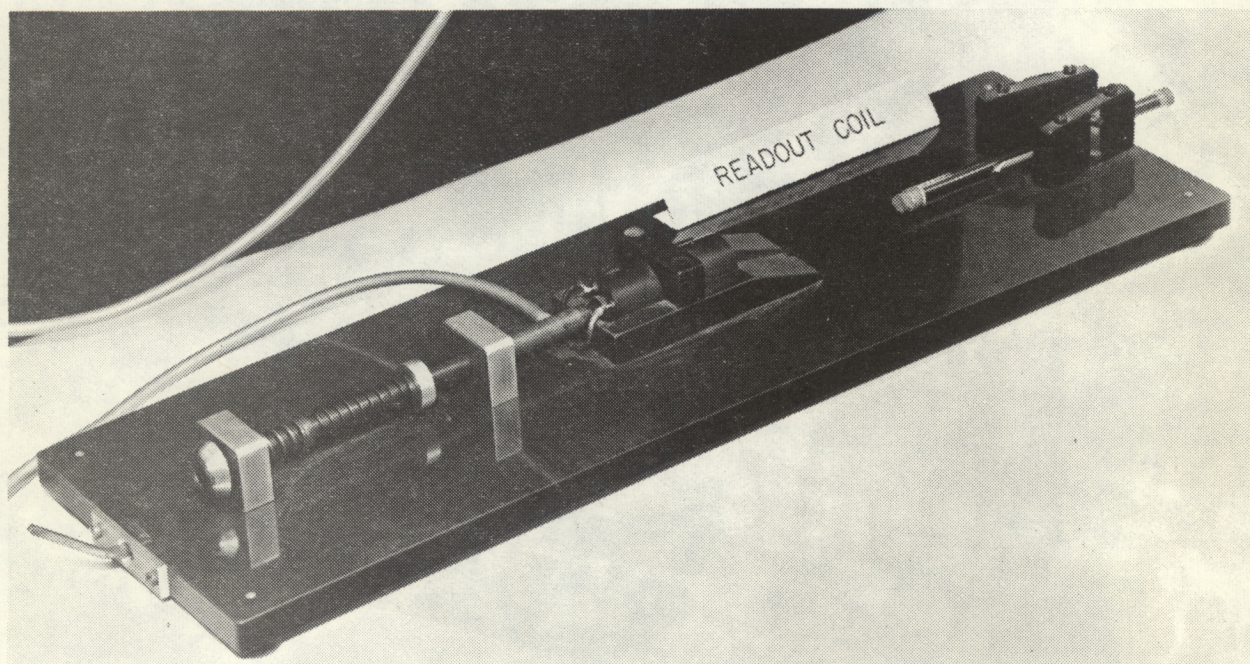


Figure 4.--Readout coil with sample in position after being propelled from the coil.

(Continued from inside front cover)

- NESCTM 20 Mapping of Geostationary Satellite Pictures - An Operational Experiment. R. C. Doolittle, C. L. Bristor and L. Lauritson, March 1970. (PB-191 189)
- NESCTM 21 Reserved.
- NESCTM 22 Publications and Final Reports on Contracts and Grants, 1969--NESC. Staff Members, January 1970. (PB-190 632)
- NESCTM 23 Estimating Mean Relative Humidity From the Surface to 500 Millibars by Use of Satellite Pictures. Frank J. Smigielski and Lee M. Mace, March 1970. (PB-191 741)
- NESCTM 24 Operational Brightness Normalization of ATS-1 Cloud Pictures. V. Ray Taylor, August 1970. (PB-194 638)
- NESCTM 25 Aircraft Microwave Measurements of the Arctic Ice Pack. Alan E. Strong and Michael H. Fleming, August 1970. (PB-194 588)

NOAA Technical Memoranda

- NESS 26 Potential of Satellite Microwave Sensing for Hydrology and Oceanography Measurements. John C. Alishouse, Donald R. Baker, E. Paul McClain, and Harold W. Yates, March 1971. (COM-71-00544)
- NESS 27 A Review of Passive Microwave Remote Sensing. James J. Whalen, March 1971.
- NESS 28 Calculation of Clear-Column Radiances Using Airborne Infrared Temperature Profile Radiometer Measurements Over Partly Cloudy Areas. William L. Smith, March 1971. (COM-71-00556)
- NESS 29 The Operational Processing of Solar Proton Monitor and Flat Plate Radiometer Data. Henry L. Phillips and Louis Rubin, (in preparation).
- NESS 30 Limits on the Accuracy of Infrared Radiation Measurements of Sea-Surface Temperature From a Satellite. Charles Braun, December 1971.
- NESS 31 Publications and Final Reports on Contracts and Grants, 1970--NESS. December 1971.
- NESS 32 On Reference Levels for Determining Height Profiles From Satellite-Measured Temperature Profiles. Christopher M. Hayden, December 1971.
- NESS 33 Use of Satellite Data in East Coast Snowstorm Forecasting. Frances C. Parmenter, February 1972.