# GAMMA IRRADIATION OF PERMANENT MAGNETS:

## EXPERIMENT AND THEORY

By Joe Andrade

A

Only several key sections were scanned and preserved — largely for nostalgia purposes!
JA 15-12-2018

Physics,

Mr. Frazer,

Period 2

WASHINGTON UNION HIGH SCHOOL

MAY 20, 1959

Fig i

Magnetic Domains

PREFACE

An attempt has been made to present the material in this paper in a semi-technical manner. Many photos and diagrams have been included to insure clarity.

The paper is limited to a certain extent because the author was not familair with the calculus. Therefore, many useful and necessary equations, etc., ~~have~~ had to be omitted.

~~It is expected to~~

Special thanks are due to Mr. James Armstrong and Mr. Milton Seibert for their aid in the handling and movement of the radiation source; to Mr. Loren D. Fields of the Calif. Disaster Office for the loan of a cobalt radiation source; to Mr. Howard King of Tektronix, Inc., for his gracious act of allowing me to use his dual beam demonstration oscilloscope; to Mr. Ralph Lovberg of the Los Alamos Laboratory for his information regarding the use of charged particle irradiation of magnets; to Drs. John Russel and Kear, of the General Electric Vallecitos Atomic Laboratory for their helpful aid and discussion of the project; to Mr. Rich Penzotti, Mr. Jules Moritz, Mr. Jerry Greene, Mr. Igor Skaredoff, and Mr. Dave de George, students at Washington High, for their advice and aid; to Mr. Jim Fulmore for teaching me the operation and use of the oscilloscope; to Mr. Beatty of the Veterans' Memorial Hospital for the graph he made for me; and to all the others, far too numerous to mention, who helped in making the completion of the project possible.



PREFACE

A great deal of information was obtained from Sears' Electricity and Magnetism and Glasstone's Sourcebook on Atomic Energy; Ruiter's Modern Oscilloscopes and Their Uses WAs extensively used in the appendix.

An appendix is included to add to the information in the paper. A discussion of the oscilloscope is given and much descriptive sales literature in regards to the oscilloscope is included. Also many of the nearly 100 letters received regarding the project are included to add to the accuracy of the paper.

Finally, the author wishes to apoligize for the many typographical mistakes.

May 14, 1959, J.A.

TABLE OF CONTENTS





III.

THE "BALANCE" METHOD --

A RESEARCH PROBLEM

A. Problem

TO DETERMINE THE EFFECTS OF 45 MILLICURIE COBALT-60 Radiations

ON THE STRENGTH OF A PERMANENT MAGNET.

B. Object

The object of this research project is to determine the effects that neutral (gamma) radiation has on the strength of a permanent horseshoe magnet using a 45 millicurie Cobalt-60 radiation source, and to determine whether said effects are increased strength, decreased strength, or neither.

C. Apparatus

I. Magnet: The first and primary piece of equipment is a common horseshoe magnet. The magnet used was one of weak strength, as too great a strength might damage the balance. (see Fig. III-1).

II. Magnet Adjuster: This is the apparatus that adjusts and holds the magnet. It is a simple gear assembly mounted on a wooden base. An old-type burette clamp is mounted on the gear system and a magnet holder has been attached to the clamp. A dial has been included for recording purposes (see Fig. III-1).

Fig. III-1
"Magnet & Adjuster"

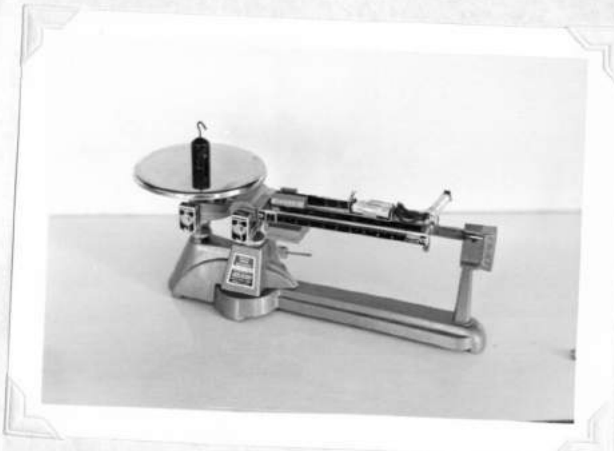


Fig III-2
"Balance & Light Assembly"



III. Balance: This is a standard triple-beam balance, accurate to better than 1/10 of a gram. The material directly underneath the pan is an alloy containing a ferromagnetic substance, susceptible to magnetic attraction. The magnet "pulls" the pan down. (see Fig. III-2).

IV. Balance Light Assembly: A set of batteries attached to a flashlight bulb in a tube is the basis of this piece of equipment. The tube is completely sealed except for a pinhole poked through the front to provide a fine light beam. If the balance's pan goes down, the balance's pointer and light assembly will rise, etc. The light assembly's weight is compensated for by gram weights and minor adjustments. (see Fig. III-2).

V. Kymograph: The kymograph (or "photograph") is to provide a permanent record of all experiments and to provide a method of observing the experiment without having to be near it. This was necessary due to the high energy of the radiation involved; one could not come within three feet of the exposed source.

The apparatus consists of a one r.p.m. motor onto which is mounted a 35 millimeter cartridge film spool. The motor provides a source of power to move the roll of photographic paper evenly and smoothly from the spool, around the nail (which which serves to keep the paper at the same distance from the light at all times), and around the cartridge. The pressure roller assembly, consisting of part of a wire coat hanger and a piece of glass tubing, suggested by Mr. Jules Moritz, places a pressure on the paper and the cartridge, the friction involved forcing the paper to flow (see Fig. III-3).

VI. Radiation: This piece of apparatus is second in importance only to the magnet. It is a 45 mc. source of Cobalt-60, obtained from Mr. Loren D. Fields, Radiological Defense, Calif. Disaster Office, Walnut Creek, California (see second letter in "Letters" section of Appendix, please), under the supervision of Mr. James Armstrong.

VII. Processing Pans: These are modificed canned ham containers, one with a series of rollers to permit fast and efficient development of the photo paper. The second pan, used for the hypo, is "standard".

VIII. Solutions: Standard developing and fixing solutions for enlarging paper.

Fig: - III - 3

Kymograph or "Photograf"



D.

METHOD OF EXPERIMENTATION:

(For Discussion and Photos of Apparatus used, see Next Chapter)

1.---All apparatus placed in proper positions and checked.

2.---New batteries inserted in light assembly.

3.---Balance is balanced out as accurately as possible.

4.---Magnet adjuster, with magnet, is placed in position.

5.---Magnet is adjusted to proper height by means of adjuster. The magnet now produces a "pull" on the balance, creating an unbalancing force.

6.---Balance is re-balanced as accurately as possible to compensate for magnetic pull.

7.---Photographic paper placed on recording apparatus.

8.---Motor turned on.

9.---Light assembly turned on.

10.--Apparatus observed; if functioning correctly, experiment continues; if not, mal-functioning part must be corrected.

11.--Radiation source opened and placed in position.

12.--After proper time has elapsed (20 to 30 minutes for the author's experiments), the radiation is removed and covered.

13.--Motor and light assembly turned off.

14.--Unused paper put away.

15.-- Used paper processed.

16.--Results observed and studied.

NOTE: The entire experiment is carried out in a darkroom under red safe-lights.

~~VIII~~

~~(Cont.)~~

Explanation:

As has been mentioned before, the magnet creates a pull on the pan of the balance. This is compensated for by scale adjustment, etc.. Now we have a balance affected by magnetic strength, but still balanced. Radiation is then introduced by placing the source underneath the magnet's center. If the result is an increase in magnetic strength, the pan will be attracted downward due to the greater pull, and the opposite end will rise, including the light assembly. If the strength decreases, the opposite results. If there is no change, nothing happens.

In any event, any variation could be observed on the processed photographic paper. For example, if the strength increased, the light assembly would move upward and, therefore, the exposed part of the paper would be at a higher elevation. The opposite is true for a decrease.

This method enables one to have an accurate and permanent record of all experiments.



E.

EXPERIMENTATION, DATA, AND OBSERVATIONS:

A total of three experiments were conducted. The first was 30 minutes in length, the others were 20 minutes in lenfth. The observations are reported below:

Experiment 1:

It can be clearly observed from the photo of the original that the line of exposure remains constant; however, the intensity of exposure slowly decreases and then ceases. The batteries used were weak to begin with. The more distinct dots are due to the motor's fairly even "jerky" movement. See photo below, please.

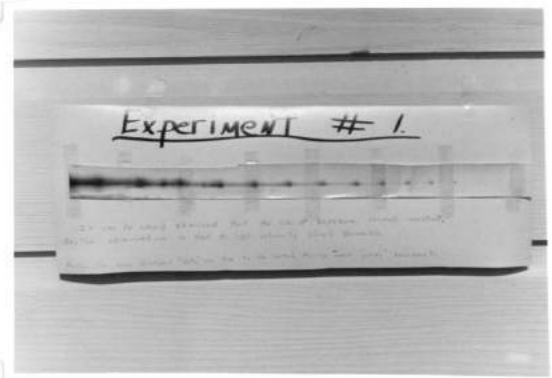



Fig.: III - 4

"Experiment # 1."

X
(Cont.)

Experiment 2:

Although the exposure is very dense at the beginning of this experiment, we can still see that the line of exposure remains straight. Again we find the intensity of exposure decreasing. It decreases from point "X" and slowly ceases. New batteries were used in this experiment. (Note: The background grey in the photo is due to stray light; the white marks to emulsion scratches). See photo below, please.


Fig. 3-5
"Experiment #2"



X
(Cont.)

Experiment 3:

This experiment was somewhat different than the others. Again we find no variance in the line of exposure; however, the variation in intensity is somewhat different. The intensity remains fairly constant and then abruptly drops ("X") to a less intense, but stable exposure ("Y"). It then abruptly ceases, with no fadeout, etc. As in #2, new batteries were used. See photo below, please.

All experiments, except for different sets of batteries, were carried out under nearly identical conditions.

The "dead" batteries were checked several days later and found to be nearly as good as new.


Fig III-6
"Experiment #3"

X

(Cont.)

This is a graph made on an automatic densiometer by Mr. Beaddy of the Veterans' Hospital, Livermore, California. This is not the real graph, but merely a tracing of the original. The instrument recorded the relative densities of the exposure of the photo strip from Exp. 5 on an accurate graph. This graph shows how the exposure varied (density of exposure is directly proportional to the intensity of light, all other factors remaining equal) in terms of accurate density measurement.

It is fairly evenly dense, then suddenly drops to a lesser dense, but still uniform exposure, and then abruptly stops.



IV.

## A MORE ACCURATE METHOD

As has been mentioned before, the method previously described is very inaccurate and impractical. As only one in every 200-300 million atoms are hit, any effect would probably tend to be one of very little increase or decrease in magnetic strength. A 10% or 15% increase would probably be necessary to distort the balance substantially enough to be observable. Therefore, we must develop a method by which very minute changes can be detected.

With the aid of Mr. Rich Penzotti, Mr. Jim Fulmore, and Dr. John Russel of General Electric's Vallecitos Atomic Laboratory, a fairly accurate method was developed.

The phenomenon of magnetic induction is used to induce a current in a coil of wire; the current id then fed to the external vertical input terminal of an oscilloscope. The coil is rapidly rotated by means of an induction motor between the poles of the magnet under experimentation. This induces the current. A microammeter and a micro or milli voltmeter can also be installed somewhere in the circuit and variations in current can be observed by means of these instruments. When a good signal is finally in adjustment on the 'scope, the radiation is placed in its proper position beneath the magnet (the radiation and magnet must be a good distance away from the scope so that they will not directly affect it). Any variation in domain alignment and thus magnetic strength or flux would affect the amount of induced current, which could be seen on the meters and on the 'scope screen. An advantage to this method, in addition to its sensitivity, is the fact that the intensity of variation and also the time interval involved can be determined.

Please see Fig. IV-1 for a diagram of the circuit.

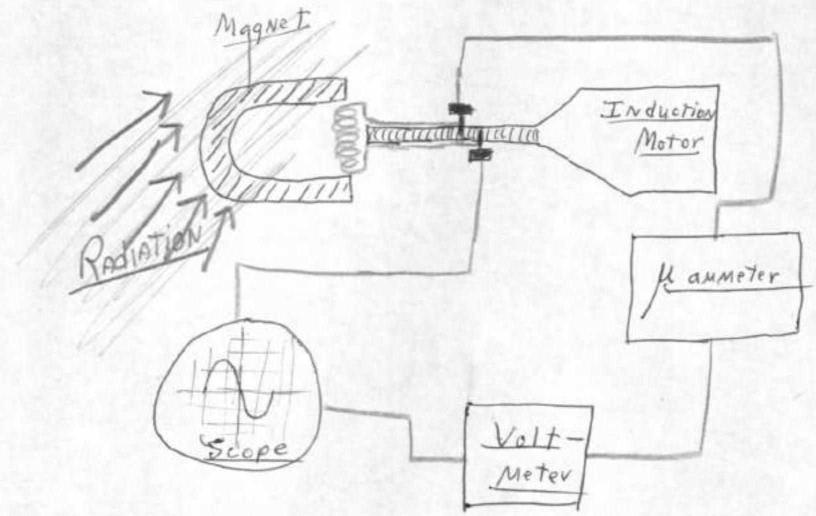



Fig IV-1

Circuit Diagram of "'Scope" Method.
Note: The current is in red.

The main problem in this method is the transferring of the induced current in the coil to the rest of the circuit. This is accomplished by means of copper washers and copper prongs on the "lead-out" wires (see Fig. IV-2 on next page).



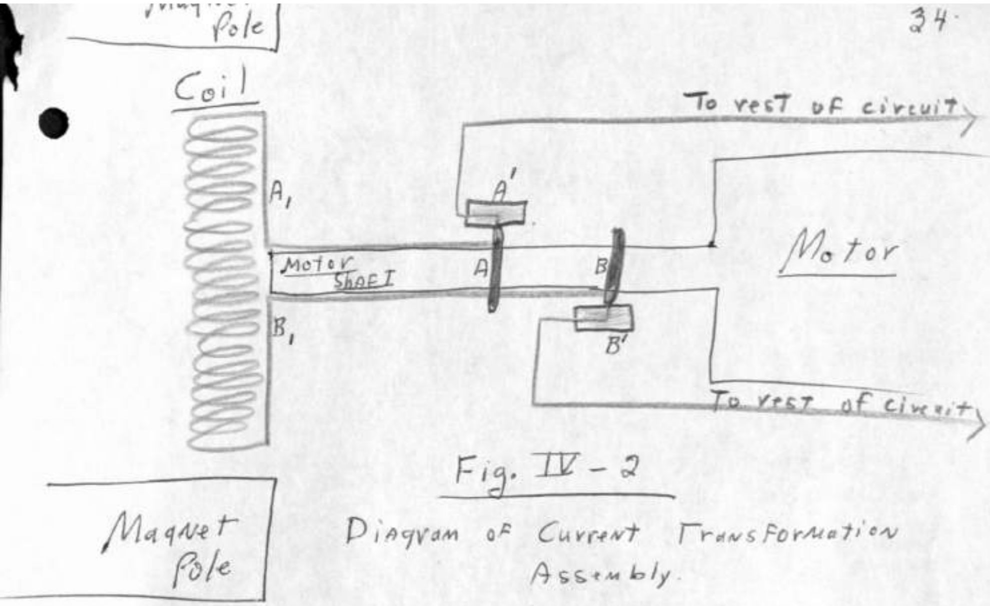



Fig. IV - 2

Diagram of Current Transformation Assembly.

In Fig. IV-2 (above), two copper washers, A and B are attached to the induction motor shaft. The two wires from the coil, $A_1$ and $B_1$, are run up the sides of the shaft and attached to the copper washers. Wire $A_1$ is attached to washer A; wire $B_1$ is attached to washer B. But before wire $B_1$ can be attached to washer B, it must pass through washer A. We drill a hole in washer A and run wire $B_1$ through it -- there is no loss of current from $B_1$ through A as $B_1$ will be insulated. Now we have current running to both washers. As the entire apparatus -- coil, shaft, and washers,-- is rotating at a constant rate, the current can now be transferred from rotating A and B to stationary $A^1$ and $B^1$ by simple contact. $A^1$ and $B^1$ are attached to the lead-out wires running to the meters and the 'scope. As the shaft rotates, the washers are made to make contact with the prongs $A^1$ and $B^1$. Thus current is transferred to the rest of the circuit.

This method will work very efficiently if care is taken in the construction of the apparatus, especially the attachment of the coil and washers to the shaft. Assembling will have to be performed with the utmost accuracy.

I have been studying the oscilloscope in an attempt to perform some experiments with this method. Mr. Jim Fulmore was very helpful in teaching me the operation and use of the 'scope and allowing me to practice with the various school 'scopes. Mr. Howard King, field engineer for Tektronix, Inc., Palo Alto, provided me with access to a $1600. dual-beam demonstration oscilloscope, but due to the time element I was unable to borrow it (I sure would ~~of~~ have liked to use it!). The experiments were unable to be performed, as I have said, due to the time necessary and also the deadline of this paper.

NOTE: Please see the appendix for a discussion of the theory and operation of the oscilloscope and also various pieces of illustrated sales literature dealing with oscilloscopes.

UNIVERSITY OF CALIFORNIA
LOS ALAMOS SCIENTIFIC LABORATORY
(CONTRACT W-7405-ENG-36)
P. O. BOX 1663
LOS ALAMOS, NEW MEXICO

IN REPLY REFER TO: P-14

October 22, 1958

Mr. Joe Andrade, Jr.
33757 12th Street
Decoto, California

Dear Joe,

Our public relations department has asked me to help you with the questions you asked in your letter of October 19, and I'm very glad to do so.

You ask about the possible effect of radiation upon a magnetic field. Your intuition is well grounded here, since it is indeed possible in principle for certain types of radiation, properly directed, to perturb a magnetic field. In practice, however, we run into serious troubles if we attempt to observe the effect; this trouble arises from the magnitudes of the quantities involved.

First, let us be careful about defining "radiation". The only radiations which are affected by magnetic fields are particles which have an electric charge. This class includes $\alpha$ particles, $\beta$ rays (which are really electrons) and protons, which do not appear as natural radioactivity. Electromagnetic radiation, which includes $\gamma$ rays, x-rays, and light are not affected at all, since they carry no charge. The same is true of neutrons, and for the same reason. I should mention here that the effect of the magnetic field is to exert a force on the charged particle which is exactly perpendicular to the particle's direction of motion. If the particle is at rest, the field does not affect it at all.

Now, how can moving charged particles perturb a magnetic field? To answer this, we must remember that all magnetic fields are set up by electric currents. This is true even for permanent magnets, for while they are not apparently connected to external circuits, there are strong permanent currents flowing in a directed way in the atoms of the magnet. It is also generally true that a magnetic field is warped, i.e., locally changed in magnitude and direction, by the introduction of additional fields which may be in the same direction in one region and the opposite direction in another, thus increasing the total field in the first instance and decreasing it in the second.

There is one remaining fact to observe before we have a complete picture of what happens in our problem; that is, that electric currents are, in fact, moving streams of charged particles.

Now we can assemble our picture. A stream of charged particles from a radioactive source passes into a magnetic field. The particles, being an electric current (if they all have the same sign of charge, + or -) set up a magnetic field in the region of their flow. This field, combining with the initial field, increases it on one side of the particle stream and decreases it on the other.

But now, if we calculate how many particles we need we run into trouble. To perturb the initial field significantly, the field of the particle current should be of a comparable magnitude. Let's select the lowest value of magnetic field strength that might be of interest to us, say 1 gauss. This is approximately the strength of the earth's field. How much current sets up a 1 gauss field? This depends on our distance from the current, but if we select 1 centimeter as the distance from the axis of a thin particle beam, we find that a current of 5 amperes is necessary. How many charged particles per second make up 5 amperes? The answer is $3 \times 10^{19}$ $\alpha$ or $\beta$ particles per second. Finally, how strong a source gives of $3 \times 10^{19}$ particles per second. It turns out to be $10^9$ or one thousand million curies! See the trouble? It's all involved with the fact that a very ordinary electric current carries numbers of charged particles which no practical radioactive source could ever produce, and to produce any noticable "bump" in a magnetic field, your source current must be somewhere near the magnet current.

But don't be discouraged by this accident of numbers. Your idea was sound, and that's what counts. As for references on magnetic theory, I can only recommend that you find any good beginning college text. In response to your request for a portable assembly for carrying on radiation experiments, I must point out that the variety of these devices is infinite; I'm sure that you will make the very best device for your purpose by first mastering the few necessary principles which your experiment involves and then designing the gadget yourself.

That's about it. Keep up the good work, Joe; this is an exciting business and I hope you continue in it.

Sincerely,

Ralph H. Lovberg

Ralph H. Lovberg
Staff Member, P-14

RHL:aj

Edmund G. Brown
GOVERNOR OF CALIFORNIA

Harold G. Robinson
DIRECTOR

STATE OF CALIFORNIA

**CALIFORNIA DISASTER OFFICE**

February 11, 1959

Mr. Joseph D. Andrade, Jr.
33757 - 12th Street
Decoto, California

Dear Sir:

In response to your letter of February 4, requesting the use of our training sources.

I have checked our course schedules and find that I can deliver one of our four source pigs to Mr. Armstrong the morning of January 17th. I can leave this pig in his possession until the first week in March. Mr. Armstrong can then supervise your use of these sources. Due caution should be observed as these are approximately 45 millicurie sources and a relatively short exposure period will give a dosage in excess of the Industrial Safety limits.

I hope this arrangement will be satisfactory.

Sincerely

Loren Fields

Loren D. Fields
RADEF Rep., Region 2

cc. Mr. James Armstrong

**BELL TELEPHONE LABORATORIES**
INCORPORATED
MURRAY HILL, NEW JERSEY
CRESTVIEW 3-6000

February 18, 1959

MR. JOSEPH D. ANDRADE, Jr.
33757 Twelfth Street
Decoto, California

Dear Mr. Andrade:

This is in response to your letter of February 4, 1959 relative to your project "The Effects of Low Level Neutral Radiations on the Strengths of Permanent Magnets."

It is possible you have been misinformed, as at the present time we have not attempted any research into neutron irradiation on domain patterns in permanent magnets, nor do we have any published material available on this subject.

In addition we have discussed your letter with several members of our Physical Research Staff, but in view of the fact they have not made any investigations in this field, they are unable to state whether your theories are logical or illogical.

As to mathematical formulas for calculating the strength of permanent magnets, there are no acceptable formulas for this subject and industry's present method is by measurement only.

It is the general feeling here that you may obtain some assistance from the publication entitled "Ferromagnetism" by R. M. Bozorth published by Van Nostrand Co. No doubt your library has a copy of this work.

We are sorry we have not been able to be of more assistance to you.

Very truly yours,

R. P. Jutson

R. P. JUTSON
Publication Department

MH-853-RPJ-JO

---

**GENERAL ELECTRIC**
COMPANY

MAGNETIC MATERIALS SECTION

EDMORE, MICHIGAN . . . TELEPHONE HAMILTON 7-5151 . . . TELETYPE 280

October 21, 1958

Mr. Joe Andrade, Jr.
33757 Twelfth Street
Decoto, California

Dear Mr. Andrade:

Producing a suitable visual display of magnetic fields has been attempted many times with disappointing results. Probably the most simple (and oldest) method is the use of iron filings. This technique can be found in first year physics text books.

Another method of visual inspection is explained in an article entitled "An Electron Tube for Viewing Magnetic Fields" by Lutz-Tetenbaum, A.I.E.E., December 1948, pages 1143-1146. The basic idea of an electron in a magnetic field may be extended, for example, to the deflection of the spot on an oscilloscope tube.

We are enclosing our design manual and a bibliography sheet on manufacturing methods for your use. There is a wealth of material on this subject in Bozorth's book entitled Ferromagnetism, McGraw-Hill.

The effects of nuclear irradiation on magnetic materials are under the wraps of government security; but in general, the problem is made acute from a servicing standpoint due to the cobalt content in the material.

For further information on general topics, we are enclosing a "General" bibliography of articles. If we may be of further assistance, please contact us again.

Very truly yours,

R. P. Smith

R. P. Smith
Product Engineering

RPS:mh

Enclosures

# CRUCIBLE STEEL COMPANY OF AMERICA

MELLON SQUARE, PITTSBURGH 22, PA.

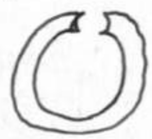
MAY 11, 1959

MR. JOE ANDRADE, JR.
33757 - 12TH STREET
DECOTO, CALIFORNIA

DEAR MR. ANDRADE:

WE HOPE THAT OUR NEGLECT IN FAILING TO REPLY TO YOUR LETTER OF MARCH 25, HAS NOT CAUSED YOU ANY PROBLEMS. THE LETTER WAS ACCIDENTLY MISLAID. WE APOLOGIZE FOR THIS FAILURE IN HANDLING YOUR REQUEST PROMPTLY.

WE HOPE OUR REPLY MAY STILL BE OF SOME VALUE TO YOU. MEASUREMENTS ON A MAGNET WOULD BE FACILATED IF YOU HAD A CIRCULAR OR HORSESHOE MAGNET WITH A GAP, SUCH AS THE FOLLOWING:



THE GEOMETRY WOULD BE MORE AMENABLE TO AN ACCURATE MEASUREMENT OF FLUX BEFORE AND AFTER IRRADIATION WITH A FLUXMETER OR GAUSSMETER. THESE INSTRUMENTS ARE NOT EXPENSIVE. AS A MATTER OF FACT, YOU MAY BE ABLE TO RENT ONE FROM GENERAL ELECTRIC COMPANY. THE MAY 1ST ISSUE OF AUTOMOTIVE INDUSTRIES MAGAZINE (P. 21) ANNOUNCES THAT G. E. IS STARTING A NATIONWIDE RENTAL SERVICE FOR MORE THAN 70 DIFFERENT KINDS OF MEASUREMENTS. PRESUMABLY THEY WILL HAVE GAUSSMETERS OF SOME KIND TO RENT. YOU MIGHT CONTACT YOUR LOCAL G. E. REPRESENTATIVE.

THE GENERAL ELECTRIC CO. MIGHT ALSO BE ABLE TO GIVE YOU SOME CIRCULAR MAGNETS FOR YOUR EXPERIMENTATION.

BEST OF LUCK IN YOUR SCIENTIFIC PURSUITS. IF WE CAN BE OF ANY OTHER HELP, DO NOT HESITATE TO CORRESPOND WITH US.

SINCERELY YOURS,

James K Stanley

JAMES K. STANLEY
TECHNICAL DEVELOPMENT
TECHNOLOGY DEPARTMENT

JKS:ERS