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DESIGN PARAMETERS AND TEST RESULTS FOR A FISSION COUNTER INTENDED FOR OPERATION UP TO 750°F AT HIGH GAMMA DOSE RATES*

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Summary

A fission counter was built and successfully tested for operation at 750°F and gamma dose rates up to 6 x 10^6 R/hr. Results from gamma and neutron tests were compared with theoretical predictions and used to optimize the performance of the counters.

Introduction

For low-level flux monitoring and other applications in breeder reactors, neutron sensors will be needed that will retain a high sensitivity at gamma dose rates of 10^5 to 10^7 R/hr and operate reliably under exposure to strong electromagnetic interference and possible high temperature. Since devices with all of these capabilities are not available, we designed, built, and tested a fission counter for this service. The objectives of the test program were to verify that the counter would meet the performance requirements and to develop an understanding of the behavior of neutron pulses and gamma pile-up signals in the counter and electronic system.

In designing the counter, the authors had three goals. The first was to minimize the effect of gamma radiation on the neutron counting sensitivity. It was for this reason that a fission counter was chosen in the first place; furthermore, the electrode spacing, filling gas, and collecting voltage were all selected so as to achieve a small electron collection time without degrading the counter's ability to withstand mechanical shock, radiation damage, and high temperature.

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A second goal was to minimize spurious counts due to electronic noise and external electromagnetic interference. For this reason, a low-noise differential preamplifier was developed, and the counter electrodes were connected to the 50-ohm preamplifier inputs by two copper-shielded mineral-insulated stainless steel coaxial cables.

The third goal was to achieve reliable operation and adequate life at 750°F. The counter is built of type 304L stainless steel with welded, integral cables and alumina electrode insulators and cable end seals.

NUCLEAR AND ELECTRICAL DESIGN

THE COUNTER, CABLES, AND COUNTING CHANNEL WERE CONSIDERED TOGETHER AS A SYSTEM WHICH MUST BE SUBJECTED TO AN OVERALL OPTIMIZATION TO ACHIEVE THE BEST NEUTRON COUNTING PERFORMANCE IN THE PRESENCE OF INTENSE GAMMA RADIATION AND ELECTROMAGNETIC INTERFERENCE.

NEUTRON COUNTING AND GAMMA REJECTION

A COUNTING SENSITIVITY CLOSE TO 1.0 COUNT/SEC-nv_{th} AT 0 R/hr WAS CONSIDERED

DESIRABLE FOR A LOW-LEVEL FLUX MONITOR IN A FAST BREEDER REACTOR. THE COUNTER THUS MUST CONTAIN APPROXIMATELY 2 gm ^{235}U. TO MINIMIZE GAMMA RESPONSE AND ELECTRODE CAPACITANCE, IT IS IMPORTANT TO KEEP THE ELECTRODE AREA AS SMALL AS POSSIBLE. THE ^{235}U COATING THICKNESS WAS MADE 2.0 mg/cm^2; IT HAS BEEN SHOWN THAT THICKER COATINGS THAN THIS GIVE LITTLE ADDITIONAL SENSITIVITY BECAUSE OF THE ENERGY LOSSES INCURRED BY FISSION FRAGMENTS ESCAPING FROM NEAR THE BOTTOM OF THE COATING.[1] THE ELECTRODE AREA IS THUS APPROXIMATELY 1000 cm^2. TO MAKE ALPHA RESPONSE NEGLIGIBLE, URANIUM ENRICHED TO >99.9 % ^{235}U AND CONTAINING LESS THAN 0.03 % ^{234}U WAS USED.

THE GAMMA EFFECT IN A PULSE-MODE ION CHAMBER ARISES FROM FLUCTUATIONS IN THE PILEUP OF VERY SMALL SECONDARY-ELECTRON

PULSES OCCURRING AT A HIGH RATE.[2] THE EFFECT CAN THUS BE MINIMIZED BY MAINTAINING A SMALL PULSE WIDTH. THIS IS ACHIEVED BY DESIGNING THE COUNTER FOR A SHORT ELECTRON COLLECTION TIME AND THE COUNTING CHANNEL FOR ADEQUATELY WIDE BANDWIDTH. THE COLLECTION TIME IS MADE SHORT BY A SMALL ELECTRODE SPACING AND HIGH ELECTRON DRIFT VELOCITY. THE LATTER IS OBTAINED BY APPLYING A HIGH ELECTRIC FIELD AND FILLING THE COUNTER WITH ARGON DOPED WITH A POLYATOMIC GAS. FOR REASONS OF MECHANICAL STABILITY THE SMALLEST FEASIBLE ELECTRODE SPACING WAS CONSIDERED TO BE 0.060 IN. THE APPLIED VOLTAGE WAS LIMITED TO 400 V TO MINIMIZE THE RISK OF BREAKDOWN. AT A GIVEN ELECTRIC FIELD THE COLLECTION TIME CAN BE SHORTENED BY REDUCING THE GAS PRESSURE, BUT THE SIZE OF THE NEUTRON PULSES WOULD ALSO

BE REDUCED. A PRESSURE OF 2.5 ATM WAS CHOSEN AS A COMPROMISE.

ADDITIONAL REDUCTION OF GAMMA RESPONSE IS OBTAINED BY SURROUNDING THE COUNTER WITH A ZIRCONIUM SHIELD, WHICH HAS NEGLIGIBLE NEUTRON ABSORPTION AND HAS A TEMPERATURE CAPABILITY COMPATIBLE WITH THAT OF THE COUNTER. IN THE DEVELOPMENT MODEL THIS SHIELD IS 0.25 IN THICK, GIVING AN OUTSIDE DIAMETER OF 3.0 IN. ITS EFFECTIVENESS COULD BE IMPROVED CONSIDERABLY IF A LARGER THICKNESS COULD BE USED.

ELECTRONICS

TO PRESERVE THE GAMMA REJECTION CAPABILITY OF THE COUNTER AND ACCOMMODATE THE HIGHEST POSSIBLE COUNT RATE, THE COUNTING CHANNEL MUST MAINTAIN A NARROW PULSE WIDTH. THUS

A current-pulse system with a wide-band preamplifier and main amplifiers and a fast discriminator is used. For test purposes it is desirable to be able to vary the frequency response and gain of the system; thus the main amplifiers are fast variable-gain units and the frequency response is controlled by RC filters inserted between stages.

To suppress electromagnetic interference, the counter is built with a guarded arrangement in which the electrodes of different polarity are connected to separate cables and are electrically isolated from the case. When a fission event occurs, current pulses of opposite sign travel on both cables. A differential, current-pulse preamplifier amplifies and adds these two signals and achieves further reduction of electromagnetic interference through its common-mode rejection capability.

SINCE A PREAMPLIFIER OF THIS TYPE WAS NOT COMMERCIALLY AVAILABLE, ONE WAS DEVELOPED AND TESTED AT ORNL.[3] THE UNIT IS SPECIFIED UNDER RDT STANDARD C 15-3T AND AMPLIFIERS MEETING THIS STANDARD ARE NOW COMMERCIALLY AVAILABLE.

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DESIGN FOR HIGH TEMP. OPERATION

AN OPERATING TEMPERATURE OF 750°F WAS CHOSEN AS A DESIGN GOAL FOR THE FIRST DEVELOPMENT MODEL. THIS CAPABILITY WOULD BE SUFFICIENT FOR IN-VESSEL OPERATION IN THE FFTF REACTOR WITHOUT COOLING OF THE DETECTOR, AND CAN BE ATTAINED WITHOUT RISK OF LOSS OF NITROGEN FROM THE COUNTING GAS DUE TO REACTION WITH METAL IN THE COUNTER.

COUNTER STRUCTURE

THE INTERNAL MECHANICAL LAYOUT OF THE COUNTER IS SHOWN IN FIG. 1. CYLINDRICAL ELECTRODES ARE USED BECAUSE OF THEIR SIMPLICITY AND RIGIDITY. THEY ARE MOUNTED ON SMALL ALUMINA INSULATOR BLOCKS WHICH ARE ATTACHED BY PINS TO DISKS CARRIED ON A CENTRAL ROD. BECAUSE THE INSULATORS ARE SMALL, DIFFERENTIAL THERMAL EXPANSION IN THE ASSEMBLY IS ALSO SMALL. ELECTRODES MAINTAINED AT DIFFERENT DC VOLTAGES

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Are mounted on different insulators. The electrodes and all structural parts are made of type 304L stainless steel, fabricated by TIG welding. All electrical connections are spot-welded and the differing lengths of the electrodes allow connections to be made to them without creating narrow gaps at which electrical breakdown might occur.

Fig. 2 is a photograph of the header region of the counter, showing the electrodes, connections, cables, seals, insulators, and mounting disk.

Cables and Seals

In view of the intended operating temperature it is essential to use mineral-insulated cables welded to the counter. These must be fitted with seals at both ends to prevent contamination of either the counter gas or the cable dielectric. A problem often encountered in high-temperature operation of cables is electrical leakage in the form of

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SMALL FAST PULSES, A PHENOMENON KNOWN AS BREAKDOWN PULSE NOISE (BPN). SINCE THE COUNTING CHANNEL RESPONDS TO PULSES FROM FISSION EVENTS IN THE COUNTER THAT HAVE A MAXIMUM CURRENT OF THE ORDER OF 1 μA AND THE SYSTEM MAY HAVE TO OPERATE AT VERY LOW COUNTING RATES, ESSENTIALLY NO BPN CAN BE TOLERATED. THUS CABLES THAT WOULD BE ADEQUATE FOR POWER CIRCUITS OR FOR CARRYING SMALL SIGNALS WITH NO SUPERIMPOSED DC VOLTAGE MAY NOT BE ADEQUATE FOR HIGH TEMPERATURE COUNTERS. FOR THE DESIRED CURRENT-PULSE MODE OF OPERATION THE CABLES MUST FUNCTION AS COAXIAL TRANSMISSION LINES HAVING THE REQUIRED CHARACTERISTIC IMPEDANCE.

AT THE TIME THE COUNTER WAS DESIGNED THE FRENCH SODERN CABLES AND QUARTEX SEALS WERE APPARENTLY THE ONLY COMMERCIALLY AVAILABLE ONES THAT MET THE ABOVE

REQUIREMENTS. THE SODERN CABLE USES MgO DIELECTRIC AND ITS COPPER INNER AND OUTER CONDUCTORS ARE CLAD ON ALL EXPOSED SURFACES WITH TYPE 304 STAINLESS STEEL. IT HAS A 4 mm OUTSIDE DIAMETER AND A CHARACTERISTIC IMPEDANCE OF 50 OHMS. THE QUARTER END SEAL HAS AN Al_2O_3 INSULATOR MADE TO AN ORNL DESIGN THAT PROVIDES A LONG SURFACE CONDUCTION PATH.

THE QUARTER SEAL IS INSTALLED AT THE "HOT" (COUNTER) END; THE CABLE IS WELDED INTO A CUP WHICH, AFTER TESTING OF THE CABLE ASSEMBLY, IS WELDED INTO THE HEADER ON THE COUNTER. AT THE "COLD" (PREAMPLIFIER) END A CERAMIC-INSULATED WELDABLE CONNECTOR IS INSTALLED; IT SERVES ALSO AS AN END SEAL. TO FABRICATE THESE ASSEMBLIES SUCCESSFULLY IT WAS NECESSARY TO DEVELOP SPECIAL WELDING TECHNIQUES, USING A TIG WELDING MACHINE WITH A PROGRAMMED CURRENT CONTROL. BEFORE SEALING, EACH END OF THE CABLE IS EVACUATED AND BACKFILLED WITH NITROGEN.

Environmental Tests

Cable Testing

Since the cable assemblies are not easily repairable once they are installed on the counter, and since they harbor the greatest risk of dielectric breakdown, they were furnace-tested separately. For this purpose the hot end cup of each cable was welded into a small stainless steel can which was filled with the intended counting gas mixture (90%A – 10% N_2), to simulate the counter. The test sequence included 300 hr at 1050 to be sure that the assemblies would withstand not only the intended operating temperature of 750°F but also the counter test temperature of 850°F and the bakeout temperature of 900°F. During the test, DC voltage was applied continuously and DC leakage current was measured. At intervals each cable was connected to a counting channel to check for BPN; none was observed.

COUNTER TESTING

THE COMPLETED COUNTER, WITH CABLES INSTALLED, WAS FURNACE TESTED AT ORNL. THE TEST INCLUDED 720 HR AT 850°F AND SIX CYCLES BETWEEN ROOM TEMPERATURE AND THE TEST TEMPERATURE. CURRENT LEAKAGE AND BPN MEASUREMENTS WERE MADE AS IN THE CABLE TESTS; NO BPN WAS OBSERVED. A NEUTRON SOURCE-MODERATOR ASSEMBLY WAS PLACED NEAR THE FURNACE SO THAT CHANGES IN NEUTRON COUNTING SENSITIVITY COULD BE LOOKED FOR. NO DEGRADATION WAS OBSERVED AS A RESULT OF THE TEST; HOWEVER THE COUNTING SENSITIVITY (AT A FIXED DISCRIMINATOR SETTING) WAS ~ 2% LESS AT THE TEST TEMPERATURE THAN AT ROOM TEMPERATURE. PROBABLY THIS DECREASE RESULTED FROM A REVERSIBLE TEMPERATURE-DEPENDENT CHANGE IN SOME ELECTRICAL PARAMETER AFFECTING PULSE HEIGHT.

The development model counter is now at Argonne National Laboratory being prepared for tests in EBR-II, which are scheduled to begin in January 1975.

Neutron Counting and Gamma Rejection Tests

Tests were made in appropriate radiation facilities to measure the neutron counting sensitivity and gamma rejection capability of the counter. The neutron tests were done in a laboratory source-moderator assembly in which the neutron flux was about 1.3×10^4 nv_{th}. For the gamma rejection tests, a special assembly was built for use in the ORNL underwater gamma facility. The assembly allowed 1 to 12 5000-curie ^{60}Co sources to be positioned around the counter

AND INCLUDED A "DIVING BELL" ARRANGEMENT THAT ALLOWED THE MEASUREMENTS TO BE MADE IN AN AIR — RATHER THAN A WATER — ENVIRONMENT. GAMMA DOSE RATES OF 0.5, 1, 2, AND 6×10^6 R/hr WERE USED.

THE MEASUREMENT DATA FOR EACH TEST CONDITION CONSISTED OF AN INTEGRAL PULSE HEIGHT DISTRIBUTION. PULSE HEIGHT WAS MEASURED IN TERMS OF ARBITRARY BUT REPRODUCIBLE UNITS ESTABLISHED BY CALIBRATING THE GAIN OF THE COUNTING CHANNEL WITH A MERCURY RELAY PULSE GENERATOR. A TYPICAL SET OF NEUTRON, GAMMA, AND ELECTRONIC NOISE PULSE HEIGHT DISTRIBUTIONS IS SHOWN IN FIG. 3.

THE EFFECT ON THE COUNTER OF GAMMA RADIATION

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AT DOSE RATES IN THE VICINITY OF 10^6 R/hr, IS TO GENERATE VERY SMALL PULSES AT A VERY HIGH RATE, SUCH THAT MANY (OF THE ORDER OF 10^3) PULSES OCCUR WITHIN THE 50 msec COLLECTION TIME OF THE COUNTER. THE GAMMA "PULSES" ARE THUS RANDOM FLUCTUATIONS IN AN ESSENTIALLY CONTINUOUS CURRENT. ACCORDING TO THE THEORY OF RICE,[4] THIS CURRENT SHOULD HAVE A GAUSSIAN AMPLITUDE DISTRIBUTION AND FURTHERMORE THE RATE AT WHICH IT TRIGGERS THE DISCRIMINATOR SHOULD BE A GAUSSIAN FUNCTI[ON] OF THE DISCRIMINATOR PULSE HEIGHT SETTING. ON THIS BASIS A COMPUTER WAS USED TO FIT A GAUSSIAN FORMULA, BY A LEAST SQUARE METHOD, TO THE GAMMA PULSE HEIGHT DISTRIBUTIONS AND ALSO TO THE ELECTRONIC NOISE DISTRIBUTIONS. THE CONTINUOUS LINES SHOWN IN FIG. 3 ARE THE FITTED CURVES OBTAINED BY THIS METHOD. VERY GOOD FITS WERE OBTAINED FOR THE GAMMA DATA; THE FITS TO THE ELECTRONIC NOISE DATA

WERE LESS GOOD, PARTLY BECAUSE OF ITS SOMEWHAT POORER PRECISION AND POSSIBLY ALSO BECAUSE IT MAY NOT HAVE A GAUSSIAN AMPLITUDE DISTRIBUTION. No FITTING FORMULA IS AVAILABLE FOR THE NEUTRON DATA; THE CONTINUOUS CURVE SHOWN IN FIG. 3 WAS GENERATED MANUALLY. THE GAMMA CURVES IN FIG. 3 OF COURSE ACTUALLY REPRESENT FLUCTUATIONS OF THE SUM OF THE GAMMA AND ELECTRONIC NOISE CURRENTS; HOWEVER AT THE HIGHER GAMMA DOSE RATES THEY REPRESENT PRIMARILY THE FLUCTUATIONS IN GAMMA CURRENT.

Determination of Effective Neutron Counting Sensitivity

THE PARAMETERS OBTAINED VIA THE LEAST-SQUARES FITS WILL BE USEFUL IN VALIDATING A COMPLETE THEORY OF THE GAMMA PULSE HEIGHT DISTRIBUTION. A MORE IMMEDIATE USE FOR THE FITS, HOWEVER, IS TO FACILITATE OPTIMIZATION OF THE EFFECTIVE NEUTRON COUNTING SENSITIVITY AT HIGH GAMMA DOSE RATES. IN A LOW LEVEL FLUX MONITOR APPLICATION, NEUTRON COUNTING RATES AS LOW AS 10 TO 20 COUNTS/SEC ARE EXPECTED. THUS IT IS REASONABLE

TO REQUIRE THAT THE DISCRIMINATOR BE SET SO THAT THE COUNTING RATE DUE TO GAMMA RADIATION AND ELECTRONIC NOISE IS NOT MORE THAN 1 COUNT/SEC. THE LEAST-SQUARES FITTED CURVES PROVIDE THEORETICALLY SOUND EXTRAPOLATIONS OF THE GAMMA AND NOISE PULSE HEIGHT DISTRIBUTIONS TO THE 1 COUNT/SEC LEVEL AND THUS ENABLE ONE TO OBTAIN AN ACCURATE VALUE FOR THE DISCRIMINATOR SETTING REQUIRED AT EACH GAMMA DOSE RATE. THE EFFECTIVE (ATTAINABLE) NEUTRON COUNTING RATE CAN THEN BE OBTAINED FROM THE NEUTRON INTEGRAL PULSE HEIGHT DISTRIBUTION. THIS PROCEDURE IS ILLUSTRATED GRAPHICALLY IN FIG. 3 FOR GAMMA DOSE RATES OF 1 AND 6×10^6 R/hr. THE CORRESPONDING VALUE OF NEUTRON COUNTING SENSITIVITY CAN THEN BE OBTAINED FROM THE THERMAL NEUTRON FLUX IN THE ASSEMBLY IN WHICH THE NEUTRON DISTRIBUTION WAS OBTAINED.

OPTIMIZATION

SOME OF THE PARAMETERS AFFECTING NEUTRON COUNTING SENSITIVITY AND GAMMA REJECTION ARE OF COURSE FIXED WHEN THE COUNTER IS BUILT. OTHERS, HOWEVER, SUCH AS GAS PRESSURE, GAS COMPOSITION, OPERATING VOLTAGE, AND PULSE-SHAPING TIME CONSTANTS, CAN BE ADJUSTED DURING TESTING. IN OUR EXPERIMENTS THE GAS PRESSURE WAS NOT VARIED (EXCEPT IN SOME OF THE NEUTRON TESTS) SINCE INCREASING IT WOULD HAVE INCREASED THE COLLECTION TIME AND REDUCING IT WOULD HAVE DECREASED THE NEUTRON PULSE HEIGHT IN RELATION TO ELECTRONIC NOISE. THE OPERATING VOLTAGE WAS VARIED THROUGHOUT THE TESTS AND THE COUNTER'S PERFORMANCE WAS FOUND, AS EXPECTED, TO IMPROVE UNIFORMLY WITH INCREASING VOLTAGE. THUS THERE IS NO OPTIMUM VOLTAGE AND 400 V

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WAS CHOSEN AS THE HIGHEST VOLTAGE AT WHICH RISK OF BREAKDOWN IS CONSIDERED NEGLIGIBLE.

IT WAS POSSIBLE, HOWEVER, TO OBTAIN OPTIMUM VALUES FOR GAS COMPOSITION AND PULSE SHAPING TIME CONSTANTS. THE GAS MIXTURES USED WERE ARGON WITH 1, 2, 4, AND 10 % NITROGEN. THE COUNTING CHANNEL WAS OPERATED WITH EQUAL SINGLE INTEGRATING AND DIFFERENTIATING TIME CONSTANTS. THEIR COMMON VALUE IS REFERRED TO SIMPLY AS THE "TIME CONSTANT". IT SHOULD BE NOTED THAT THE SYSTEM CONTAINS AN ADDITIONAL BUILT-IN INTEGRATING TIME CONSTANT, ARISING FROM THE INTERACTION OF COUNTER ELECTRODE CAPACITANCE WITH CABLE IMPEDANCE. SINCE THE CAPACITANCE IS 350 pF AND THE TW 50-OHM CABLES ARE EFFECTIVELY IN SERIES, THIS TIME CONSTANT IS ~35 nsec.

THE FIRST PART OF THE OPTIMIZATION PROCEDURE IS ILLUSTRATED IN FIG. 4 IN WHICH, FOR EACH GAMMA DOSE RATE, THE EFFECTIVE NEUTRON COUNTING SENSITIVITY (DETERMINED BY THE PROCEDURE ILLUSTRATED IN FIG. 3) IS PLOTTED AS A FUNCTION OF TIME CONSTANT. IT CAN BE SEEN THAT FOR EACH GAMMA DOSE RATE THERE IS (A MAXIMUM EFFECTIVE COUNTING RATE AND THUS) AN OPTIMUM TIME CONSTANT, THOUGH AT 6×10^6 R/hr IT IS NOT WITHIN THE RANGE OF THE DATA. THE OPTIMUM TIME CONSTANT DECREASES WITH INCREASING GAMMA DOSE RATE; PRESUMABLY THIS BEHAVIOR ARISES FROM THE DIFFERENT FREQUENCY SPECTRA OF THE GAMMA AND ELECTRONIC NOISE AND FROM THE VARIATION IN THEIR RELATIVE CONTRIBUTIONS AS THE GAMMA DOSE RATE IS INCREASED.

THE DATA IN FIG. 4 WERE TAKEN WITH 4% NITROGEN IN THE COUNTING GAS;

FOLLOWING THE SAME PROCEDURE AT OTHER COMPOSITIONS YIELDS THE RESULTS SHOWN IN FIGS. 5 AND 6 IN WHICH ARE PLOTTED, RESPECTIVELY, THE OPTIMUM TIME CONSTANT AND THE MAXIMUM EFFECTIVE COUNTING RATE AS A FUNCTION OF NITROGEN CONCENTRATION, FOR THE VARIOUS GAMMA DOSE RATES. TO KEEP THE LENGTH OF THE EXPERIMENT WITHIN REASONABLE LIMITS, THE FULL RANGE OF GAMMA DOSE RATE WAS COVERED ONLY AT 4% N_2.

FIG. 6 SHOWS THAT 2% N_2 IS THE BEST COMPOSITION AT 400V; HOWEVER THE VARIATION OF OPTIMIZED COUNTING RATE WITH N_2 CONCENTRATION IS QUITE SHALLOW AND A 10% COMPOSITION WAS CHOSEN FOR ACTUAL OPERATION. THUS OVER 80% OF THE NITROGEN CAN BE LOST BY REACTION WITH THE COUNTER STRUCTURAL MATERIAL BEFORE THERE IS APPRECIABLE DEGRADATION

OF OPERATING CHARACTERISTICS.

THE TIME CONSTANT CHOSEN FOR ACTUAL OPERATION SHOULD PRESUMABLY BE THE OPTIMUM VALUE AT THE HIGHEST EXPECTED GAMMA DOSE RATE. IF, FOR INSTANCE, THE DOSE RATE WILL BE BETWEEN 1 AND 2×10^6 R/hr, ONE FINDS FROM FIG. 5 THAT THE APPROPRIATE TIME CONSTANT IS 25-30 msec.

DIVIDED-VOLTAGE OPERATION

MOST OF THE ABOVE TESTS WERE MADE WITH THE ENTIRE DC VOLTAGE APPLIED TO THE INTERMEDIATE-DIAMETER ELECTRODE, TO AVOID COLLECTION OF CHARGE FROM GAMMA IONIZATION GENERATED IN THE REGION BETWEEN THE OUTER ELECTRODE AND THE CASE. IN FURTHER TESTS IT WAS FOUND THAT THE GAMMA EFFECT INCREASED

ONLY SLIGHTLY WHEN THE VOLTAGE WAS DIVIDED, WITH +200 V ON THE INTERMEDIATE ELECTRODE AND −200 V ON THE INNER AND OUTER ELECTRODES. THIS CONNECTION WAS ADOPTED FOR FURTHER TESTING AND OPERATION SINCE IT REQUIRES EACH CABLE AND SEAL ASSEMBLY TO CARRY ONLY 200 V. THE RESULT SHOULD BE A REDUCTION IN THE RISK OF BPN AND A SUBSTANTIAL IMPROVEMENT IN THE RELIABILITY AND LIFETIME OF THE COUNTER. IN THE DIVIDED-VOLTAGE MODE THE EFFECTIVE NEUTRON COUNTING SENSITIVITY (COUNT/SEC-nv_{th} VS R/hr) IS 0.92 AT 0, 0.77 AT 1×10^6, AND 0.21 AT 6×10^6.

CONCLUSIONS

LABORATORY TESTS HAVE SHOWN THAT THE ORNL DEVELOPMENT MODEL FISSION COUNTER IS CAPABLE OF USEFUL NEUTRON COUNTING AT GAMMA DOSE RATES AS HIGH AS 6×10^6 R/hr, AND WILL OPERATE AT 750 °F. FORTHCOMING EXPERIMENTS IN THE EBR-II REACTOR WILL TEST ITS ABILITY TO WITHSTAND RADIATION DAMAGE AND TO OPERATE IN A REACTOR ENVIRONMENT. SINCE THE GAMMA AND NEUTRON COUNTING TESTS WERE DESIGNED SO THAT THE COUNTER'S PERFORMANCE COULD BE CORRELATED WITH IMPORTANT DESIGN PARAMETERS, THE RESULTS SHOULD BE USEFUL IN MAKING COMPARISONS WITH THEORY AND IN DESIGNING FUTURE FISSION COUNTERS.

REFERENCES

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3. J. T. DeLorenzo, W. T. Clay, and G. C. Guerrant, "Common-Mode and Integral Bias Tests with a Differential Current-Pulse Preamplifier, ORNL-TM-4316, September 1973.

4. Rice, S. O., "Mathematical Analysis of Random Noise," from selected papers on *Noise and Stochastic Processes*, pp. 133-294; Dover Publications, 1954.

2. D. P. Roux et al, "Neutron Sensor Development for Extreme Environments," ORNL-TM-3959, December 1972.

← FIGURE CAPTIONS:

FIG. 1 INTERNAL STRUCTURE OF FISSION COUNTER.

FIG. 2. VIEW OF HEADER REGION OF COUNTER BEFORE INSTALLATION OF CASE.

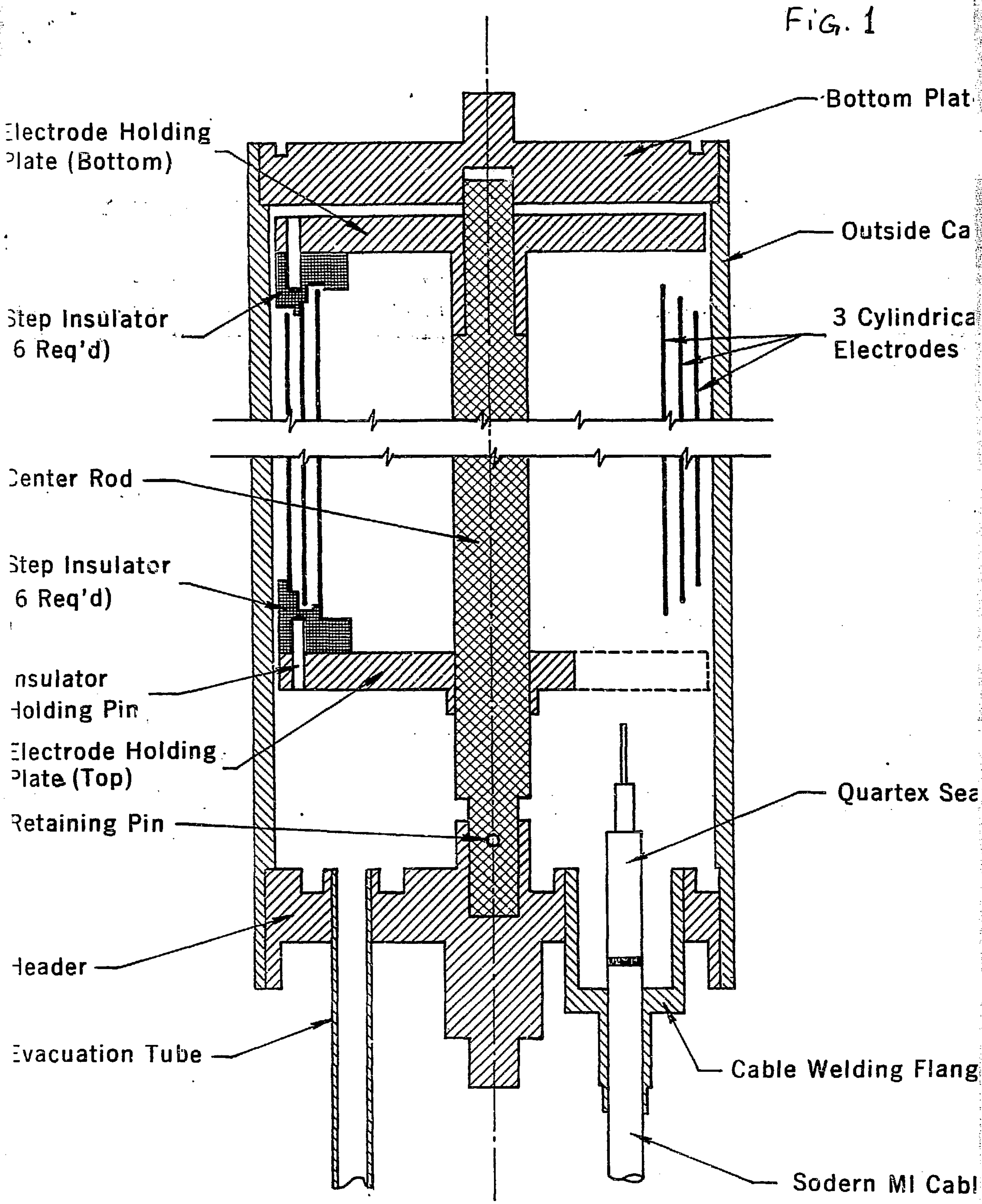
FIG. 3. TYPICAL INTEGRAL PULSE HEIGHT DISTRIBUTIONS FOR NEUTRONS, ELECTRONIC NOISE, AND FOR GAMMA PILEUP AT VARIOUS DOSE RATES.

FIG. 4. EFFECTIVE NEUTRON COUNTING RATE AS A FUNCTION OF COUNTING CHANNEL INTEGRATING AND DIFFERENTIATING TIME CONSTANT, AT VARIOUS GAMMA DOSE RATES. DISCRIMINATOR SET TO GIVE 1.0 COUNT/SEC FROM GAMMA PILEUP AND ELECTRONIC NOISE.

FIG 5. OPTIMUM TIME CONSTANT AS A FUNCTION OF NITROGEN CONCENTRATION IN FILLING GAS.

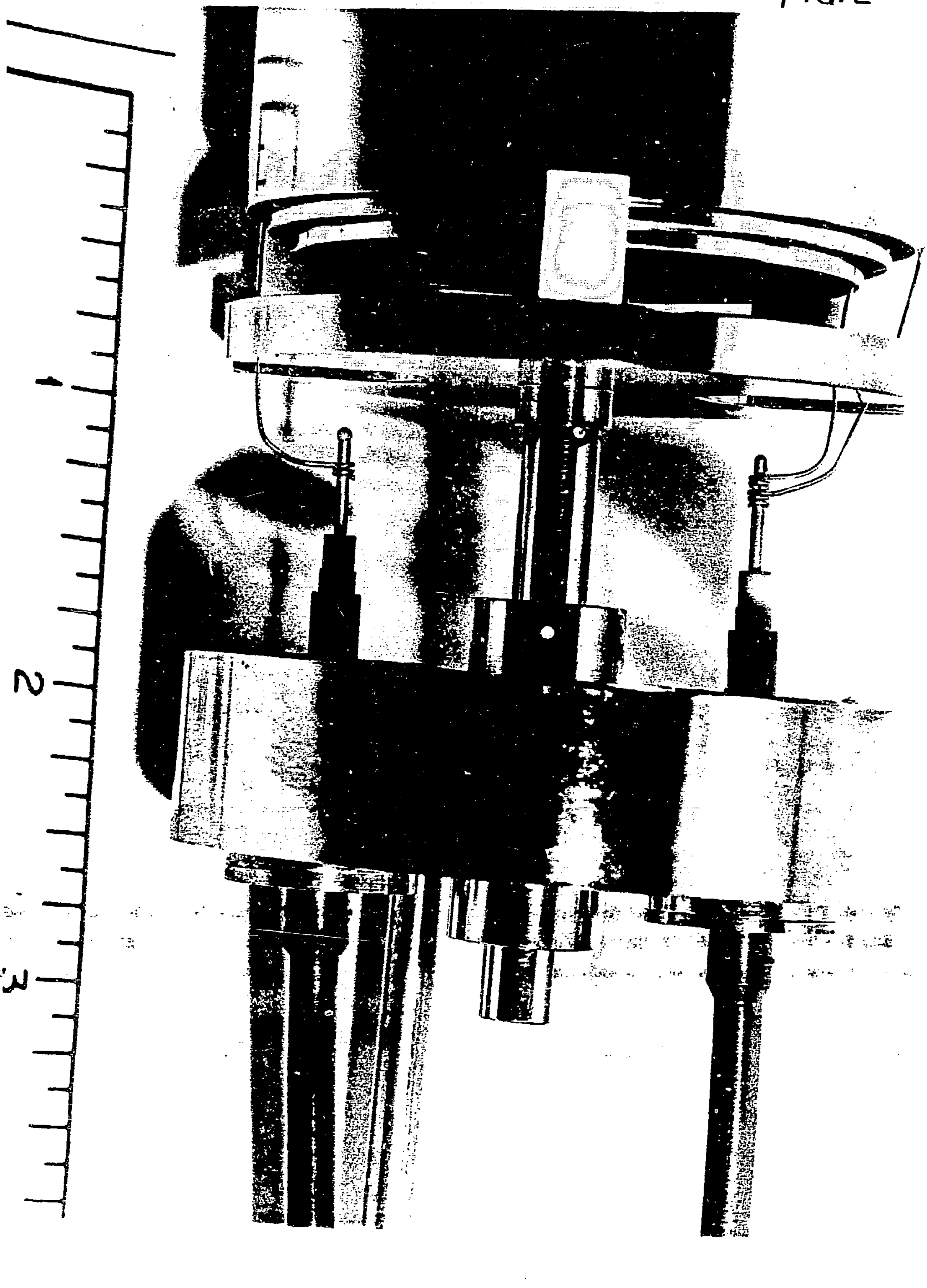
FIG. 6. EFFECTIVE NEUTRON COUNTING RATE WITH OPTIMUM TIME CONSTANT, AS A FUNCTION OF NITROGEN CONCENTRATION IN FILLING GAS.

FiG. 1



Bottom Plat
Electrode Holding
Plate (Bottom)
Outside Ca
Step Insulator
6 Req'd)
3 Cylindrica
Electrodes
Center Rod
Step Insulator
6 Req'd)
nsulator
Holding Pin
Electrode Holding
Plate (Top)
Quartex Sea
Retaining Pin
Header
Evacuation Tube
Cable Welding Flang
Sodern MI Cabl

FIG. 2



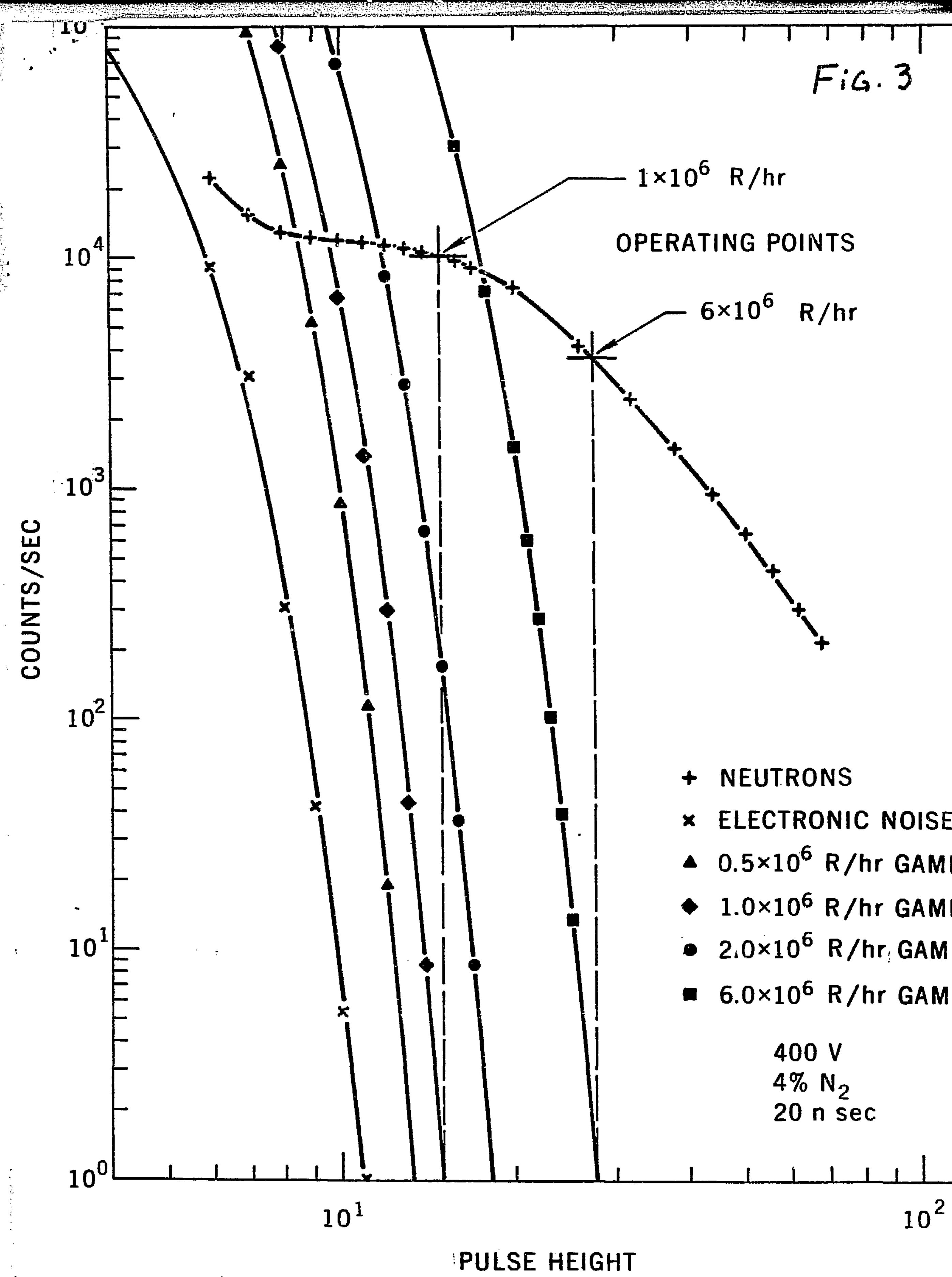


FiG. 3
1×10^6 R/hr
OPERATING POINTS
6×10^6 R/hr
+ NEUTRONS
× ELECTRONIC NOISE
▲ 0.5×10^6 R/hr GAM
◆ 1.0×10^6 R/hr GAM
● 2.0×10^6 R/hr GAM
■ 6.0×10^6 R/hr GAM
400 V
4% N2
20 n sec
COUNTS/SEC
PULSE HEIGHT
10^0
10^1
10^2
10^3
10^4
10^1
10^2

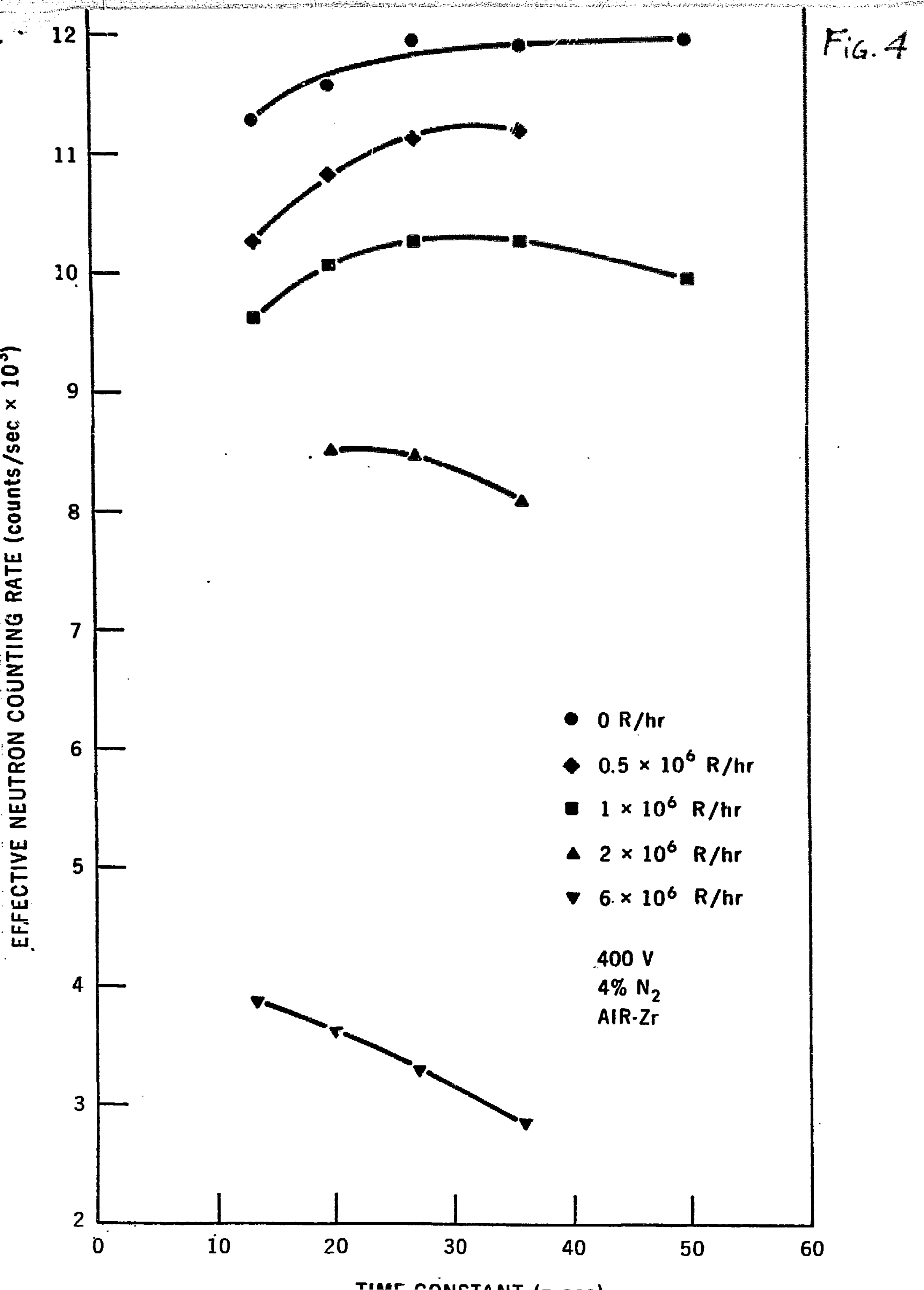
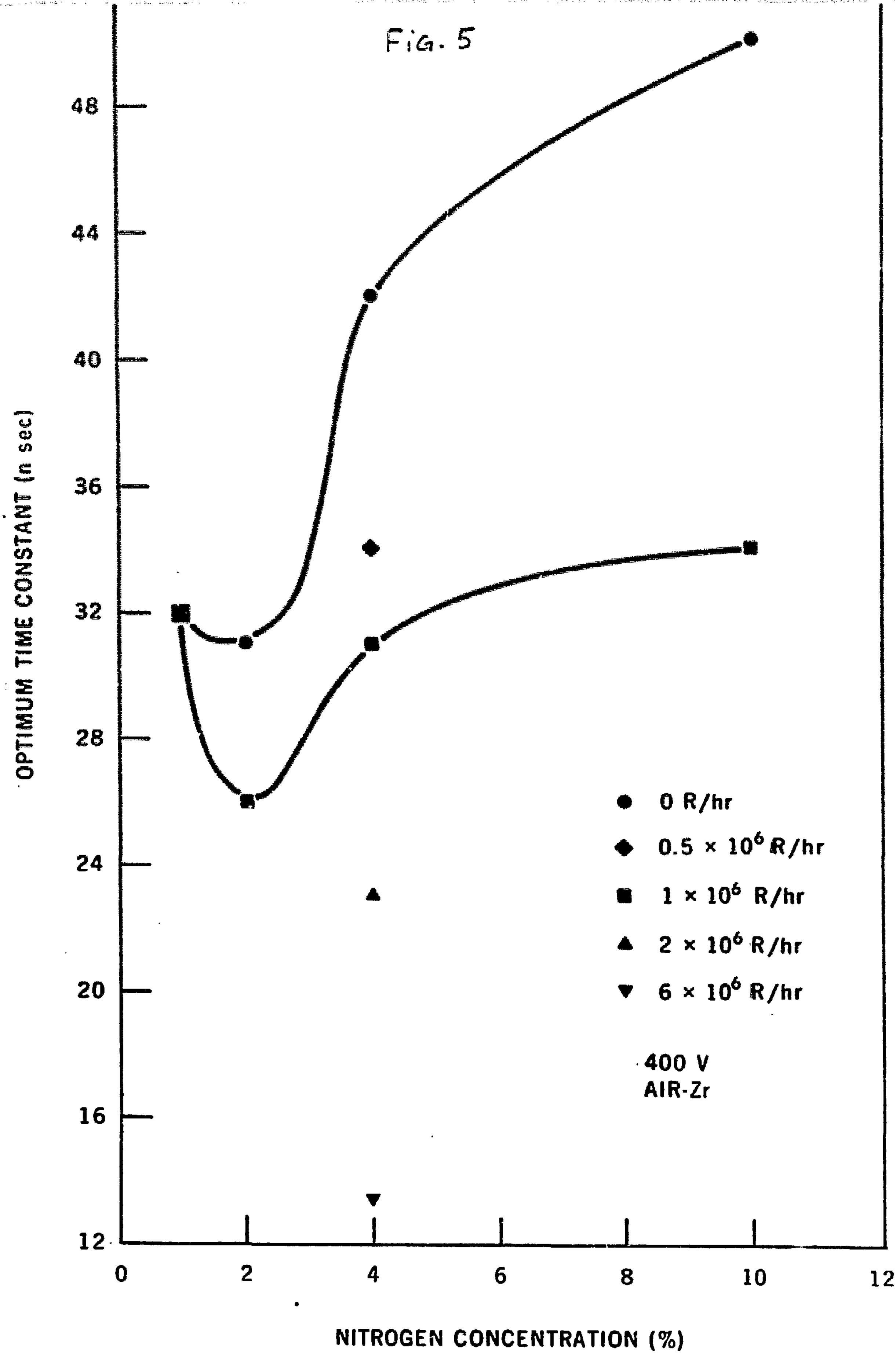


Fig. 4
EFFECTIVE NEUTRON COUNTING RATE (counts/sec × 10³)
12
11
10
9
8
7
6
5
4
3
2
0 R/hr
0.5 × 10⁶ R/hr
1 × 10⁶ R/hr
2 × 10⁶ R/hr
6 × 10⁶ R/hr
400 V
4% N₂
AIR-Zr
0
10
20
30
40
50
60

Fig. 5



OPTIMUM TIME CONSTANT (n sec)
48
44
40
36
32
28
24
20
16
12
0
2
4
6
8
10
12
NITROGEN CONCENTRATION (%)
0 R/hr
0.5 × 10⁶ R/hr
1 × 10⁶ R/hr
2 × 10⁶ R/hr
6 × 10⁶ R/hr
400 V
AIR-Zr

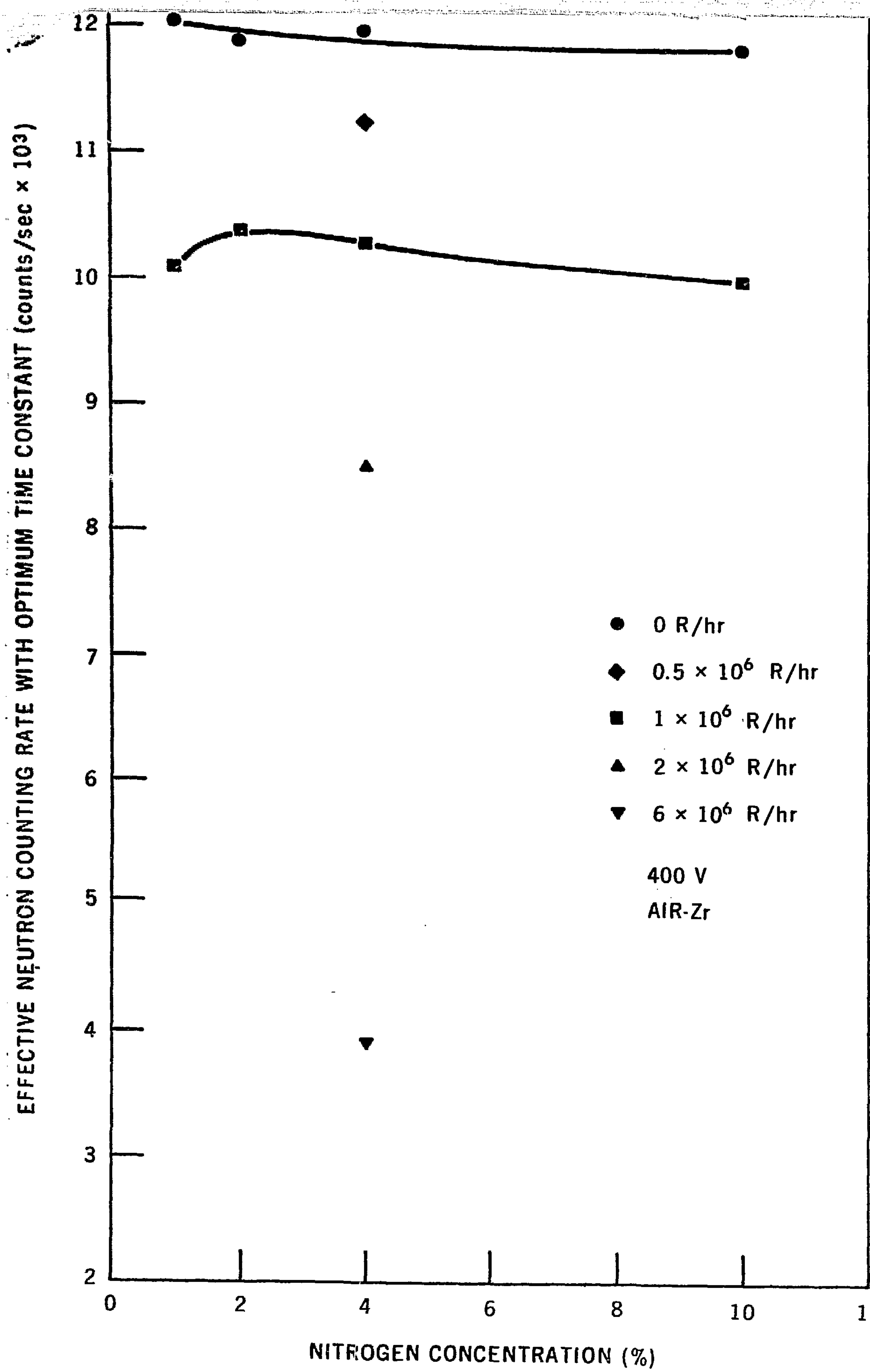

EFFECTIVE NEUTRON COUNTING RATE WITH OPTIMUM TIME CONSTANT (counts/sec × 103)
NITROGEN CONCENTRATION (%)
12
11
10
9
8
7
6
5
4
3
2
0
2
4
6
8
10
12
0 R/hr
0.5 × 10⁶ R/hr
1 × 10⁶ R/hr
2 × 10⁶ R/hr
6 × 10⁶ R/hr
400 V
AIR-Zr

FIG. 6