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PROPOSAL FOR PUTTING NUCLEAR DATA ON PUNCHED CARDS

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PROPOSAL FOR PUTTING NUCLEAR DATA ON PUNCHED CARDS

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PROPOSAL FOR PUTTING NUCLEAR DATA ON PUNCHED CARDS

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Abstract

A plan is proposed for coding certain nuclear properties and numerical values on McBee Keysort cards, so that all nuclei may be quickly searched for any of the coded data. Drawings of two proposed cards, one for a stable nucleus, and one for a radioactive nucleus, together with a detailed explanation of the suggested code are presented. Comments and suggestions are solicited by the authors so that a recommendation can be made to the AEC for the production of sets of cards meeting as many experimental and theoretical needs as possible.

What β emitters, with β energy < 1 mev, have a chemistry similar to Mn? Is the cosmic abundance especially high for certain values of N, the neutron number? What nuclei are known to have more than one level with energy < 600 kev?

Answers to many such questions about nuclear data are difficult to find in a compilation or table arranged by element and isotope without looking through a good many pages. A plan for helping to alleviate this situation is proposed here.

The plan is to code nuclear data in such a way that it can be represented by punches around the edges of a card 6-1/2" x 7-1/2". The cards have rows of holes near their edges. Punching consists of clipping away the edge of the card next to the hole. A punch above a certain hole on a card for a given nucleus

represents the possession of a certain property by that particular nucleus. Cards can be sorted by hand by means of long needles. When the needle is inserted in a bunch of cards in the hole representing the property and the cards are jiggled, the cards for nuclei which possess the property will drop off because of the punch. This batch of cards can then be resorted for some other property.

Two cards, one for stable and one for radioactive nuclei, are shown in Figures (1) and (2) with the proposed arrangement of the various punching fields. The exact meaning to be attached to the various punches is described in detail below.

Before settling on this specific proposal, which involves the use of McBee Keysort cards[1], the authors of this memorandum investigated in detail the possibilities of a number of other systems such as the Zator system[2], IBM systems[3], and edge marking systems[4]. Their conclusion is that the McBee Keysort cards offer at present the cheapest and most readily available method of sorting for combinations of properties. Other systems have distinct advantages for bibliographical work but did not seem adaptable for the purpose of making a large number of statements about a certain nucleus on a single card.

In many cases the punched cards may be viewed as a versatile index to existing compilations. Frequently answers found with cards will not be complete without reference to other sources of data. The collection of cards and the various existing tables would exhibit information in different ways and hence could be used both separately and together.

As Figures (1) and (2) show, the proposal is that the information would be punched on the edges of the cards and only nuclear identification written

on the face of the card. This would leave a lot of room for whatever notes or bits of information the user might wish to write in. Moreover, the choice of simple codes allows visual identification of punching patterns, and hence much of the coded data can be read directly from the card. As much space as possible has been left in the punching field of the card for new information and for whatever special use an individual may find of interest.

The proposed punching scheme makes it possible to include considerable information, though not everything by any means. The basic idea could certainly be elaborated to include more data. However, including too much and attempting to make the system completely versatile increases the sorting difficulty. The coding of all nuclear data would surely necessitate use of expensive sorting machines. This would make the person desiring information dependent on some service group for finding the answers.

The authors would like to receive comments on their proposal and suggestions for improving it. If the general reaction is favorable, they will try to incorporate specific suggestions into their scheme and then make a definite recommendation to the Technical Information Service of the AEC that sets of cards punched in a certain way be made available.

EXPLANATION OF PROPOSED CODE

Two methods of coding, direct and binary, are used in the proposed system. A direct code means that each hole has an unambiguous property or value associated with it, and is either punched or not, according to whether the nucleus has or does not have the property or value. It is used for indicating such

things as whether or not a nucleus decays by β^+ or β^- emission or whether or not it has a γ with energy between 2.5 and 3 mev.

The binary system, is used to code number values of half lives, spins, etc. In this system the holes are labeled with the powers of two, 1, 2, 4, etc., and as many are punched as needed to add up to the number being coded.

The binary-decimal system is a modification of this. A field of four holes, 8, 4, 2, 1, is assigned to each decimal position, and the digits from 1 to 9 only are coded in each field. For example, to code 85, the 8 hole would be punched in the "tens" field and both the 4 hole and 1 hole in the "units" field.

Three ways of punching the edge of the card are used:

(1) the shallow punch, which covers only the outer row of holes

(2) the deep punch, which covers both the outer and inner row

(3) the inner punch, which leaves the edge of the card intact, but removes the part of the card between the two rows.

When the cards are sorted for a property indicated by an inner punch, the selected cards drop 1/4", instead of dropping completely out of the pack. If a second needle is then inserted in one of the corner holes (not used for coding), the first needle may be withdrawn and the selected cards will drop out. This type of punch has been used as little as possible since it is not very convenient.

DETAILS OF "STABLE" NUCLEUS CARD. FIGURE (1)

(Punches are indicated for the data on Al^{27})

S — Shallow punch indicates stable nucleus.

SR — Deep punch indicates that a card of the type of Figure (1) has been made for a radioactive nucleus. Such cards would be made for K^{40}, Cs^{135}, etc., i.e. radioactive nuclei for which abundances, moments, or levels are known.

Cosmic abundance — Cosmic abundance per 10^7 atoms of silicon is given to the nearest power of 10, coded in the binary system. The cosmic abundance of Al^{27} is 0.882×10^6, or 10^6 rounded, hence 4 and 2 are punched.

Relative abundance — For $<$ 1 per cent the $<$ 1 is punched. Otherwise the upper limit of the interval, 10 per cent, 20 per cent, etc., is punched in binary code. The 80 and 20 holes are punched in Figure (1) to indicate Al^{27} has a relative abundance of 100 per cent.

Thermal σ_s in barns — The value in binary code of the upper limit of the unit interval into which the scattering cross section falls is punched for $0 < \sigma_s \leq 14$. When $\sigma_s > 14$, all holes are punched. For Al^{27}, $\sigma_s = 1.5$ barns, hence 2 is punched.

For elements with more than one stable isotope special cards could be made showing the scattering and absorption cross sections of the isotopic mixture occurring in nature.

Scattering length — A shallow punch here indicates positive sign and a deep punch negative sign. For nuclei with spin dependent scattering lengths such as H^3 an inner punch on the $\pm$ hole is used, along with a deep punch. For Al^{27} the scattering length is positive; hence the shallow punch is used.

Thermal σ_a in barns — The value is indicated by one significant figure and the power of 10, both in binary code. For positive power of 10 the + hole is punched, while for a negative power it is not punched. The zero power of 10 is indicated by a + punch alone. For Al^{27} $\sigma_a = 0.22$, hence 2 is punched in the figure field and 1 is punched in the power field without the plus punch to indicate 2×10^{-1}.

Spin, $\hbar$ — The binary code is used for integral spin values. Half integer values are shown by punching an integer value and the 1/2 hole in such a way that the sum of the values punched is equal to the spin. The zero hole is punched if spin = 0. For Al^{27}, the spin = 5/2, hence the 2 and the 1/2 holes are punched.

Neutron Resonances, E_o, in ev

The value of the upper limit of the interval to which a given resonance belongs is punched in direct code. For Al^{27} resonances occur for 2.3×10^3 ev, $\sim 4 \times 10^4$ ev, and for a number of energies between 10^5 and 10^7 ev. Hence the 10^4, 10^5, 10^6 and $> 10^6$ holes are punched in Figure (1).

Γ in ev

The value of the resonance width at half maximum is indicated by punching the upper limit of the interval to which it belongs. The possible intervals are 0-0. 01, 0.01-0.1, > 0.1 ev. Since the widths are not known for Al^{27} no punches have been made in this field in Figure (1). Other intervals could be added in the inner row.

Γ_n/Γ

The scattering fraction, i.e. the ratio of resonance scattering width to the total width, is indicated as follows:

>50 per cent shallow punch >90 per cent deep punch	Indicates resonance is predominantly scattering.
< 50 per cent shallow punch < 1 per cent deep punch	Indicates resonance is predominantly absorption.

For Al^{27} Γ_n/Γ = 0.99 hence the > 90 per cent deep punch is indicated.

Graphs

A shallow punch of the hole labeled slow (or fast) indicates graphs are available for slow (or fast) neutron cross sections. A deep punch (see Figure (1)) indicates slow (or fast) graphs are given in the collection of R. K. Adair, Rev. Mod. Phys. 22, 249 (1950). Deep punches are indicated for Al^{27}.

Levels in Mev The value of the upper limit of the interval to which the known levels belong is punched in direct code. For Al^{27} levels are known for 0.84, 1.07, 1.48, 1.79, 2.28, 2.82, 3.07, and > 8.28 mev. Hence the 1.0, 1.2, 1.6, 2.0, 2.5, 3.0, 5.0 and > 5 holes are punched in Figure (1).

Magnetic moment in nuclear magnetons The value in binary code of the upper limit of the interval to which μ belongs is punched, the intervals being taken in steps of one. For negative μ values the < 0 hole is punched. $\mu = 3.6$ for Al^{27}; hence the 4 hole is punched in Figure (1) to show that the moment lies between 3 and 4 nuclear magnetons.

Quadrupole moment in barns This is coded in the same way as μ. For Al^{27}, $q = 0.156$, hence the 1 hole is punched in Figure (1).

N, number of neutrons A modified binary decimal code is used for this number. Numbers up to 15 are coded in the "tens" field and numbers up to 9 in the "units" field. For Al^{27}, $N = 14$; hence 1 is punched in the tens field and 4 is punched in the units field.

Z, number of protons The binary decimal code is used here. $Z = 13$ for Al^{27}; hence 1 is punched in the tens field and 1 and 2 are punched in the units field.

The mass number, A, could be coded in the same way using inner punches.

Chemical group — The chemical groups, 1 through 7 are given in binary code, using shallow punches. Groups 1' through 7' are given in binary code using deep punches. No punch means group zero and an inner punch in the 4 hole means group 8. Al belongs to group 3, hence the 2 and 1 holes are punched.

DETAILS OF RADIOACTIVE NUCLEUS CARD. FIGURE (2)

(Punches are indicated for the data on 5.2^{y} Co^{60})

S, SR — An inner punch indicates that a card of the type of Figure 1 has been made for this radioactive nucleus.

Type of Decay — A punch in any of the holes labeled α, β, etc. means that the nucleus decays with emission of the radiation indicated. The γ hole when deep-punched indicates a delayed γ-ray. The 5.2^{y} Co^{60} emits β^{-} and γ rays, hence these holes are punched. The γ hole is shallow-punched, since neither of the γ rays is delayed. The radiations of the 10.7^{m} isomer would be indicated on another card.

Coincidences — A shallow punch means that the indicated type of coincidence has been found. An inner punch means that the coincidence has been looked for, and not found. For the 5^{y} Cobalt $\beta\gamma$ and $\gamma\gamma$ coincidences have been found, so the holes are shallow punched.

τ, half life — The first four holes show the first significant figure, and the next 3, the power of 10, coded in the binary system. The holes labeled s, m, h, d, and y are punched to indicate the unit. The hole under s is deep punched if $\tau < 1$ sec. and that under y is deep punched if $\tau > 10^6$ years. In Figure (2) the punches for $\tau = 5.2^y$ are shown.

Certainty — Degree of certainty of mass assignment is punched in this field, deep if the mass assignment is sure, shallow if only probable, and not at all if the assignment is highly doubtful. Figure (2) shows a deep punch for Co^{60}, whose mass assignment is well established.

Log_{10} ft — Values of $\log_{10}$ ft are direct-coded in this field for the intervals 4.5-5.5, 5.5-6.5, etc. A deep punch on the left means that log ft $\leq$ 4.5 and on the right > 9.5. For $5^y Co^{60}$, log ft is 7.5 so the hole corresponding to the interval 6.5-7.5 is punched.

Shape — A shallow punch indicates that the Fermi plot of one or more β-rays is not linear. An inner punch is used to indicate that the Fermi plot may or may not be linear. There is no punch on the card since the Fermi plot of the 0.31 β seems to be straight.

β or α Energy, Mev — Energies of α and β rays are direct-coded in mev. The number under each hole is the upper limit of the interval associated with the hole, i.e., the first hole in the E_β field is punched if

$0 < E_\beta \leq .05$, the second, if $.05 < E_\beta \leq .1$, etc. A deep punch means that the intensity exceeds 10 per cent. The 0.31 β is shown by a deep punch in the hole for the range 0.3-0.4 mev.

The energies of α particles are to be coded in the same field as energies of β's. This will be ambiguous only for those nuclei which emit both α's and β's. The user will, however, be forewarned, since in that case both α and β holes will be punched in the field which shows type of decay. If it seems desirable two separate cards could be made.

Δ I for β's A direct code is used for $\Delta I = 0, 1, 2, 3, 4, 5$. A deep punch indicates parity change, and shallow punch no parity change. Punches here are perhaps best left to individual players of the shell game.

Production The fp (fission product) hole is punched if the nucleus is a product of the fission of U-235 with yield > 1 per cent.

The nγ hole is punched if the nucleus can be produced from a stable isotope by the n,γ reaction.

Figure (2) shows that Co^{60} is not a fission product, but can be produced by the reaction Co^{59}-n-γ.

The two reactions chosen are the ones which can be used for quantity production in a pile. Other reactions will always produce a given end-product if bombarding particles of sufficient energy are

available so there does not seem much point to including them from the production point of view. Knowledge that a given reaction takes place often makes a contribution to the certainty of the mass assignment. However, it does not seem possible to assess such a contribution by means of punched cards.

γ Energy Mev

This field is similar to the β and α field. For the 5^y Co the 1.0-1.2 and 1.2-1.6 holes are deep punched for the 1.17 mev and 1.33 mev γ's. The 1.6-2.0 hole is shallow punched to show the observation of a weak γ with energy somewhere between 1.6 and 2.2 mev.

$\text{Log}_{10}\ \alpha_K$

α_K denotes the K conversion coefficient of a γ ray, N_{e_K}/N_α. $\text{Log}_{10}\ \alpha_K$ is direct coded. In Figure (2) -3 is punched since the α of both γ's of Co^{60} lies between 10^{-3} and 10^{-4}. Actually conversion in the different shells could not be resolved. α_K is here taken to be of the same order of magnitude as α. This field could be shortened by use of the binary code.

A recognized limitation of this system is that, when two γ's are punched, and two α_K's, the card does not show which α_K belongs to which γ ray. It is felt, however, that sorts will generally be made for γ's of a certain energy and α_K's of a certain magnitude and that ambiguities can be quickly resolved by reference to a table.

α_K / α_L This field is direct-coded in the inner row, an inner punch being used in this case. The indicated values are the upper limits of the intervals. (K/L is not known for Co^{60} as mentioned above.)

Λ, Order of γ transitions The order of a γ transition, Λ, is direct coded for $\Lambda = 1, 2, 3, 4, \geq 5$. $\Lambda = 1$ for electric dipole radiation, 2 for electric quadrupole or magnetic dipole, etc. Shallow punches indicate electric multipole and deep punches magnetic multipole radiations. Both γ's of Co^{60} are electric quadrupole hence one shallow punch is made for $\Lambda = 2$.

N The neutron number, N, is indicated as on the "stable" card in a modified binary-decimal code. 33 is shown punched for Co^{60}.

Z The standard binary-decimal code is used for Z, again as on the "stable" card. The punches for 27 are shown on Figure (2).

The mass number, A, could be coded in the same way using inner punches.

Chemical group The chemical groups, 1 through 7 are given in binary code, using shallow punches. Groups 1' through 7' are given in binary code using deep punches. No punch means group zero and an inner punch in the 4 hole means group 8. Co is in group 8, hence the 4 hole is inner punched in Figure 2.

Angular correlation

Shallow punches in this field indicate that $\beta\gamma$ angular correlation, $\gamma\gamma$ angular correlation, or $\gamma\gamma$ polarization direction (p-d) correlations have been observed in the decay of the nucleus in question. Inner punches denote that correlations have been specifically looked for and not found. The punches in Figure 2 show that $\gamma\gamma$ but not $\beta\gamma$ correlation has been observed for the 5^y Co^{60}.

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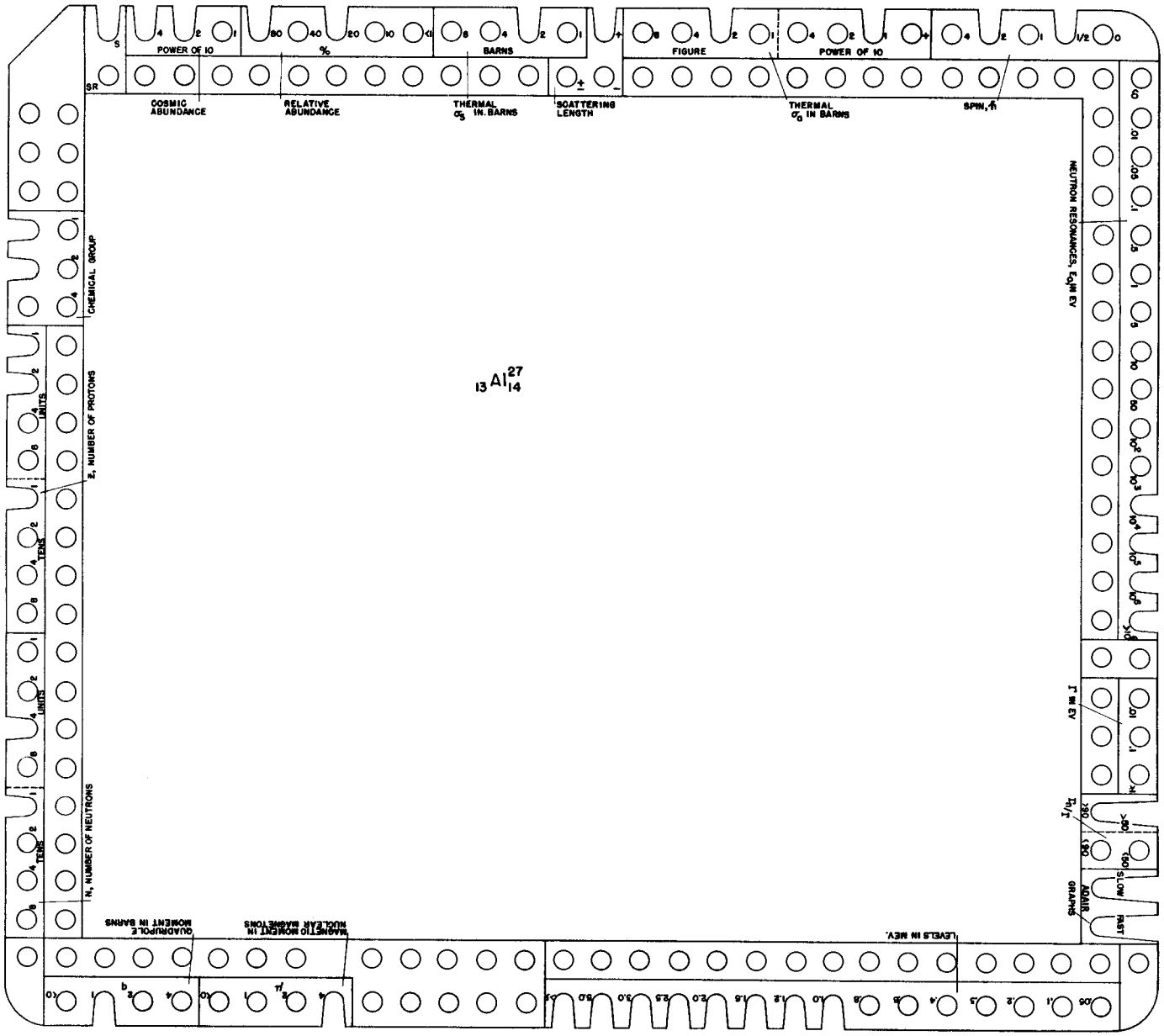

FIG. 1

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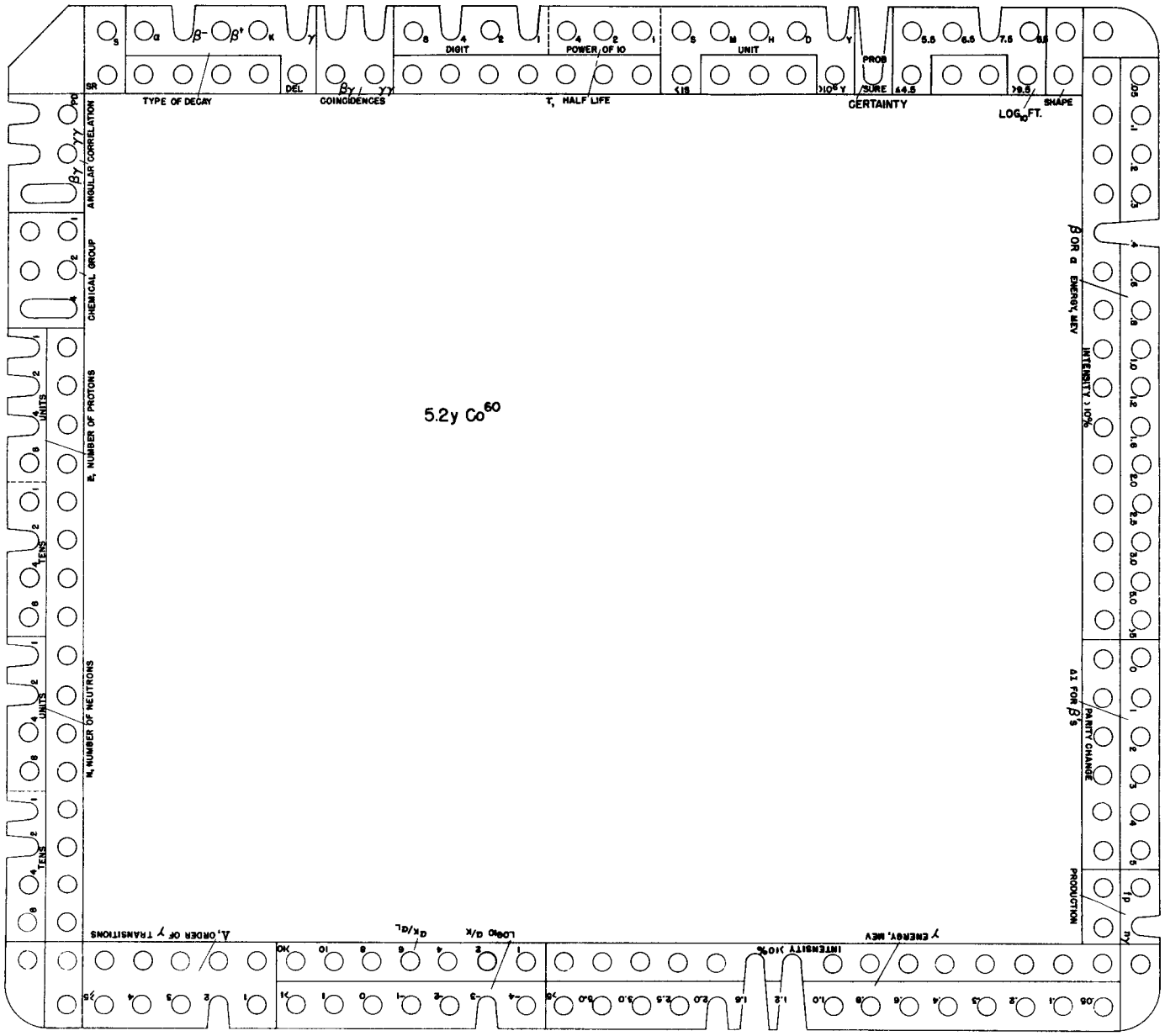

FIG. 2