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"NEGENTROPY AND THE CONCEPTS OF FREEDOM, DEMOCRACY AND JUSTICE."

by

Frederick B. Wood

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Socio-Engineering Problems Reports are a series of manuscripts on the social relations of engineering and related philosophical questions dealing with the interaction of science and society. Distribution is limited to reviewers and discussion groups for criticism prior to consideration for possible publication.

This issue is a part of Chapter 10 of a proposed book, "Communication Theory in the Cause of Man." A short outline of the book plan is included as Appendix I.

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"Negentropy and the Concepts of Freedom, Democracy and Justice."

I. INTRODUCTION AND DEFINITI[illegible]

A. OBJECTIVES.

This study is an examination of the usefulness of a concept -- negentropy -- from the physical sciences in bridging the gap between the two cultures of "science" and the "humanities." This material is offered as a "theoretic hypothesis" on the usefulness of the concept of entropy from the physical sciences as a tool of [illegible] value to social sciences.

The possibility that entropy [illegible] thermodynamics might belong both to the family of measurable quantities of science and the family of ideas such as beauty and melody was suggested many years ago by Eddington.(1) The development of the mathematical theory of communication by Shannon (2) in 1948 and the partially overlapping concepts of Cybernetics developed by Wiener (3,4) made it possible to move from a rough analogy to the consideration of more specific applications of quantities such as "information" or "negative entropy." In this paper I shall confine my discussion to the relevancy of the concept of negentropy to some important concepts in our civilization, namely "freedom," "democracy," and "justice."

I shall try to avoid the [illegible] that Raimon Lull ran into in the transition from [illegible] 14th centuries when he developed a rudimentary [illegible] was not content to lead mankind on the path of [illegible] machine which would be a very useful tool, but he [illegible] run too far ahead and tried to use his logic mac[illegible] theological arguments. His attempted application of [illegible] to questions of theological faith led to his being stoned [illegible] in Bugia, Morocco, in 1315.(5)

I wish to dedicate this paper to the memory of Simone Weil, a French mathematics teacher and scholar of the human [illegible] who [illegible] to acquire the necessary experiences to bridge the gap between the sciences and the humanities in a way to help reconstruct human [illegible]. He[illegible] untimely death during World War II [illegible] the staff of [illegible] DeGaulle's Free French prevented her from [illegible] having her [illegible] notebooks [illegible] man, and [illegible] concerned with the problems of [illegible] (6, 6A)

2. PLAUSIBILITY ARGUMENT FOR CHOICE OF ANALOGY

Biological systems preserve [illegible] some order [illegible]. The life process represents [illegible] reversal of the degradation processes predicted by the second law of thermodynamics. The units of information are related to both the life process and to negative entropy (or negentropy)* in thermodynamics. Physically entropy can be defined as:

$S = k \ln W$ where k is the Boltzman constant of [illegible] $\times 10^{-16}$ [illegible], "ln" means logarithm of, and W is the number of elementary states the system can be in.

In information theory the negentropy of a message of [illegible] symbols is

$H = -(P_1 \ln P_1 + P_2 \ln P_2 + \ldots + P_k \ln P_k + \ldots + P_n \ln P_n)$

where P_k is the probability of occurrence of symbol k.

If we take the formula for information or negentropy and substitute philosophical systems (or political systems) in place of the symbols of a message, [illegible] the respective philosophies among the population [illegible] analogous to the probabilities of occurrence of the symbols in a message.

* The term "negentropy" was introduced by Leon Brillouin.[illegible]

[illegible]

[illegible] thought are required to [illegible] the official philosophy [illegible] and this philosophy is number (k) [illegible] then

[illegible] = 0.

Thus the requirement that people adhere to an official philosophy is equivalent to a zero contribution to the negative entropy of the political system or the "life process" or the evolution toward a higher order of life. If we go back to our equation to see under what conditions leads to a maximum contribution to the negentropy of [illegible] when P_1 [illegible] P_2 [illegible] P_n [illegible] This corresponds to equal probability for each different philosophy: a condition approximating a democracy. After reviewing the [illegible] of the concepts, we shall make a more detailed [illegible]

c. DEFINITIONS.

Before proceeding with this study it is important to review the dictionary definitions of the principal words we are using. The definitions in Table I are from Webster's Seventh New Collegiate Dictionary.(7) Where a definition uses directly another word, the definition of the second word is also included in Table I.

My plan for this paper is to first review some elementary properties of finite sets of discrete messages that might be sent over a telegraph line. These simple examples will illustrate the the relationship of the probabilities of different messages being sent, the negentropy component of the individual messages, and the negentropy of the set of messages. Then I shall consider a hypothetical world divided into six countries of 100,000 people in each country. These six countries will have a range of social orders from ideal democracy to a dictatorship. I shall assume a set of probability distributions for the chances of an individual having a measure of freedom in these different social orders.

Then I shall make the hypothesis that the negentropy of the set of probabilities of freedom in a country or sub-system is a measure of the "democracy" of the sub-system. The next step is to compare these numerical results with our common sense rating of social systems in order of increasing amount of "democracy." If there is consistency we can assume the relationship between "negentropy" and "democracy" is a useful hypothesis, even though

TABLE I: DEFINITIONS

Definitions from Webster's Seventh Collegiate Dictionary (1963)

ENTROPY.

- 1a: a measure of the unavailable energy in a closed thermodynamic system so related to the state of the system that a change in the measure varies with change in the ratio of the increment of heat taken in to the absolute temperature at which it is absorbed
- 1b: a measure of the disorder of a closed thermodynamic system in terms of a constant multiple of the natural logarithm of the probability of the occurence of a particular molecular arrangement of the the system that by suitable choice of a constant reduces to the measure of unavailable energy
- 2: a measure of the amount of information in a message that is based on the logarithm of the number of possible equivalent messages
- 3: the degradation of the matter and energy in the universe to an ultimate state of inert uniformity

FREEDOM

- 1: the quality or state of being <u>free</u>: as
  - a: the absence of necessity, coercion, or constraint in choice or action
  - b: liberation from slavery or restraint or from the power of another: INDEPENDENCE
  - c: EXEMPTION, RELEASE
  - d: EASE, FACILITY
  - e: FRANKNESS, OUTSPOKENNESS
  - f: improper familiarity
  - g: boldness of conception or execution
  - h: unrestricted use
- 2a: a political right
- 2b: FRANCHISE, PRIVILEGE

FREE

- 1a: having the legal and political rights of a citizen
- 1b: enjoying civil and political liberty

(See also definitions 2 through 15)

P. 2B

TABLE I (continued): DEFINITIONS

DEMOCRACY

1a: a government by the people, esp.: rule of the majority

1b: a government in which the supreme power is vested in the people and exercised by them directly or indirectly through a system of representation usu. involving periodically held free elections

2: a political unit that has a democratic government

3 cap: the principles and policies of the Democratic party in the U.S.

4: the common people esp. when constituting the source of political authority

5: the absence of hereditary or arbitrary class distinctions or privileges.

JUSTICE

1a: the maintenance or administration of what is just esp. by the impartial adjustment of conflicting claims or the assignment of merited rewards or punishments

1b: JUDGE

1c: the administration of law; esp.: the establishment or determination of rights according to the rules of law or equity

2a: the quality of being just, impartial, or fair

2b(1): the principle or ideal of just dealing or right action

2b(2): conformity to this principle or ideal: RIGHTEOUSNESS

2c: the quality of conforming to law

3: conformity to truth, fact, or reason: CORRECTNESS

JUST

1a: having a basis in or conforming to fact or reason: REASONABLE

1b archaic: faithful to an original

1c: conforming to a standard of correctness: PROPER

2a(1): morally right or good: RIGHTEOUS

2a(2): MERITED, DESERVED

2b: legally right

IMPARTIAL: not partial

PARTIAL : 1: inclined to favor one party more than the other: BIASED [illegible] contradictions between the hypothesis and accepted facts. For further discussion of hypotheses in science, refer to either W. K. H. Panofsky (8) or Gerald Holton (9).

The next question is whether the concept of negentropy can also be useful in measuring some longer range variable which might be an extension of the concept of "justice." The static measure of deomcracy at a given time may be overshadowed by other factors such as the degree of organization or stability, if an ideal democracy cannot survive an attack from a dictatotship. It is felt that additional parameters not accessible in this study will be required in order to develop an extended concept of justice* which would include the ability of a more democratic country to defend itself. However we shall include some preliminary remarks on how this problem might attacked, but the study has not reached the stage where it is possible to put numbers on the relative "justice" of the total system including the interaction with time between the six hypothetical countries considered in this paper.

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* At present I shall call this extended concept of justice "dynamic-justice," implying the definitions of "justice" in Table I (items Ia and Ic) represent "static-justice." A possible qualitative test of "dynamic-justice" is discussed in another manuscript in preparation, entitled "Four Philosophical 'Tools' For Improving Our Insights Regarding the Problems of Disarmament," SEPR no. 19.

2. Negentropy.

In this section we shall review briefly the concepts of the entropy of probability distributions. These equations apply to Webster's definition 2 in Table I. The examples in this section apply to sets of messages which might be sent over a telegraph line. For those who want a brief introduction to Information Theory, I recommend the following books:

Colin Cherry, <u>On Human Communication</u> (10)
- Ch. Two: Evolution of Communication Science-- An Historical Review
- Ch. Five: On the Statistical Theory of Communication

R. Duncan Luce, Robert R. Bush, and J. C. R. Licklider, <u>Deveopments in Mathematical Psychology</u> (11)
- Part I: The Theory of Selective Information and Some of Its Behavioral Applications

J. R. Pierce, <u>Symbols, Signals and Noise</u> (12)
- Ch. I. The World and Theories
- Ch. II. The Origins of Information Theory
- Ch. III. A Mathematical Model
- Ch. IV. Endoding and Binary Digits
- Ch. V Entropy

The entropy of the set of messages is defined as:

$$I = \sum_{i=1}^{n} p_i \log_2 p_i \qquad (1)$$

where p_i is the probability that the i-th message will be sent. Since the probability p_i is a positive number between zero and one,

$$\log p_i \leq 0,$$

we can define the negentropy as minus the entropy,

$$H = -I, \qquad (2)$$

or

$$H = -\sum_{i=1}^{n} p_i \log_2 p_i \qquad (3).$$

The choice of the base of the logarithm to the base two is arbitrary. For this study eq. (3) becomes:

$$H = -\sum_{i=1}^{n} p_i \log_2 p_i = \sum_{i=1}^{n} p_i U_i \qquad (4)$$

where $U_i = -\log_2 p_i$ is sometimes called the "uncertainty." (*)

* David Middleton, <u>Statistical Communication Theory</u>. N.Y.:McGraw-Hill(1960), pp. 293-5.

Sample values of p_i, $-U_i$, and $U_i p_i$ are tabulated in Table II for a useful range of values. For convenience of the user, these parameters are plotted in Fig. 1. There is a scale change in the center of Fig. 1 where the direction of the log-log paper reverses. The parameters p(x), U(x), and p(x)U(x) are plotted against p(x) on the left half and agianst [1-p(x)] on the right half. This choice of scale makes the curves asymptotic to straight lines for simpler graphical construction and application.

Curve (A) is the simple probability, p(x).

Curve (B) is the uncertainty, $U(x) = -\log_2 p(x)$.

Curve (C) is the product of curves (A) and (B), or the negentropy component H(x) corresponding to p(x).

If we have a set of two messages which can be sent over a telegraph line and their probabilities of being sent are p_1 and p_2, the total probability is $p_1 + p_2 = 1.0$. For example, if $p_1 = 0.1$ and $p_2 = 0.9$, we have from eq. (4):

$$H = -0.1 \log_2 0.1 - 0.9 \log_2 0.9$$

The uncertainty terms can be calculated or read off of Fig. 1,

$$H = 0.332 + 0.137 = 0.469$$ Negentropy of the set of messages.

A curve for the total negentropy is plotted in Fig. 2A for all combinations of p_1 and p_2. The negentropy of the system is maximum for $p_1 = p_2 = 0.5$

For a set of three messages we have the condition

$$p_1 + p_2 + p_3 = 1.0$$

which means there are two independent variables, so we can use a two-dimensional plot to obtain equi-negentropy lines for the case of three messages. Note that the edges of the triangular coordinate plot in Fig 2B are the top projection of Fig. 2A. Equi-negnetropy lines for H= 0, 0.5, 1.0, 1.5, 1.585 are plotted in Fig 2B.

TABLE II: NEGENTROPY COMPONENTS

i	Probability p_i	Uncertainty $-U_i = \log_2 p_i$	Negentropy Component $U_i p_i$
1	0.9999930	-0.0000101	0.0000101
2	0.9999900	-0.0000144	0.0000144
3	0.9999700	-0.0000433	0.0000433
4	0.9999500	-0.0000721	0.0000721
5	0.9999300	-0.0001010	0.0001010
6	0.9999000	-0.0001443	0.0001443
7	0.9997000	-0.0004329	0.0004328
8	0.9995000	-0.0007215	0.0007212
9	0.9993000	-0.0010103	0.0010095
10	0.9990000	-0.0014434	0.0014420
11	0.9970000	-0.0043346	0.0043216
12	0.9950000	-0.0072316	0.0071954
13	0.9930000	-0.0101344	0.0100634
14	0.9900000	-0.0144996	0.0143546
15	0.9700000	-0.0439434	0.0426251
16	0.9500000	-0.0740006	0.0703006
17	0.9300000	-0.1046974	0.0973686
18	0.9000000	-0.1520032	0.1368028
19	0.7000000	-0.5145733	0.3602013
20	0.5000000	-1.0000003	0.5000001
21	0.3000000	-1.7369660	0.5210898
22	0.1000000	-3.3219289	0.3321929
23	0.0700000	-3.8365022	0.2685551
24	0.0500000	-4.3219292	0.2160965
25	0.0300000	-5.0588949	0.1517668
26	0.0100000	-6.6438578	0.0664386
27	0.0070000	-7.1584312	0.0501090
28	0.0050000	-7.6438580	0.0382193
29	0.0030000	-8.3808239	0.0251425
30	0.0010000	-9.9657867	0.0099658
31	0.0007000	-10.4803600	0.0073363
32	0.0005000	-10.9557869	0.0054829
33	0.0003000	-11.7027527	0.0035108
34	0.0001000	-13.2877157	0.0013288
35	0.0000700	-13.8022889	0.0009662
36	0.0000500	-14.2877158	0.0007144
37	0.0000300	-15.0246818	0.0004507
38	0.0000100	-16.6096444	0.0001661
39	0.0000070	-17.1242177	0.0001199

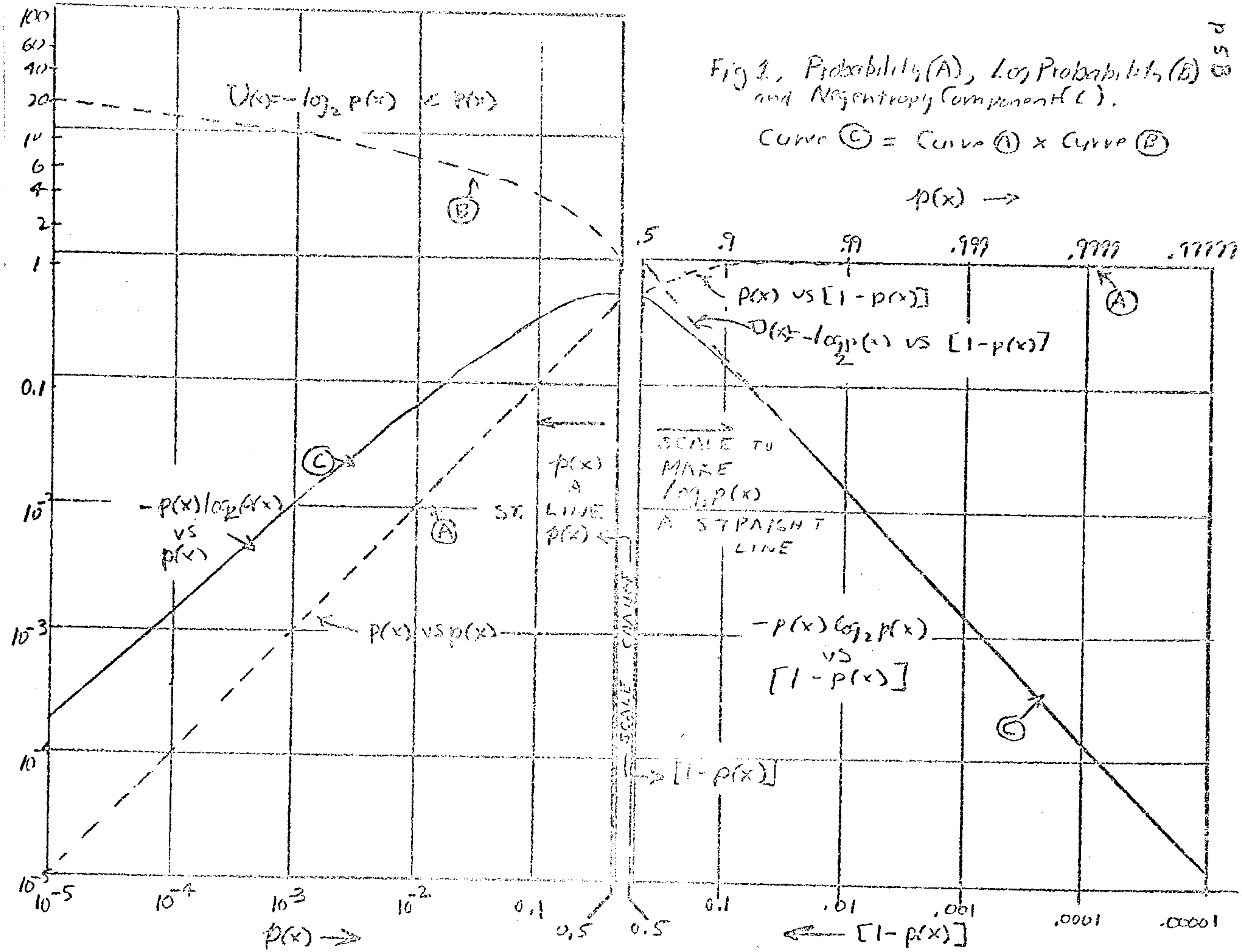
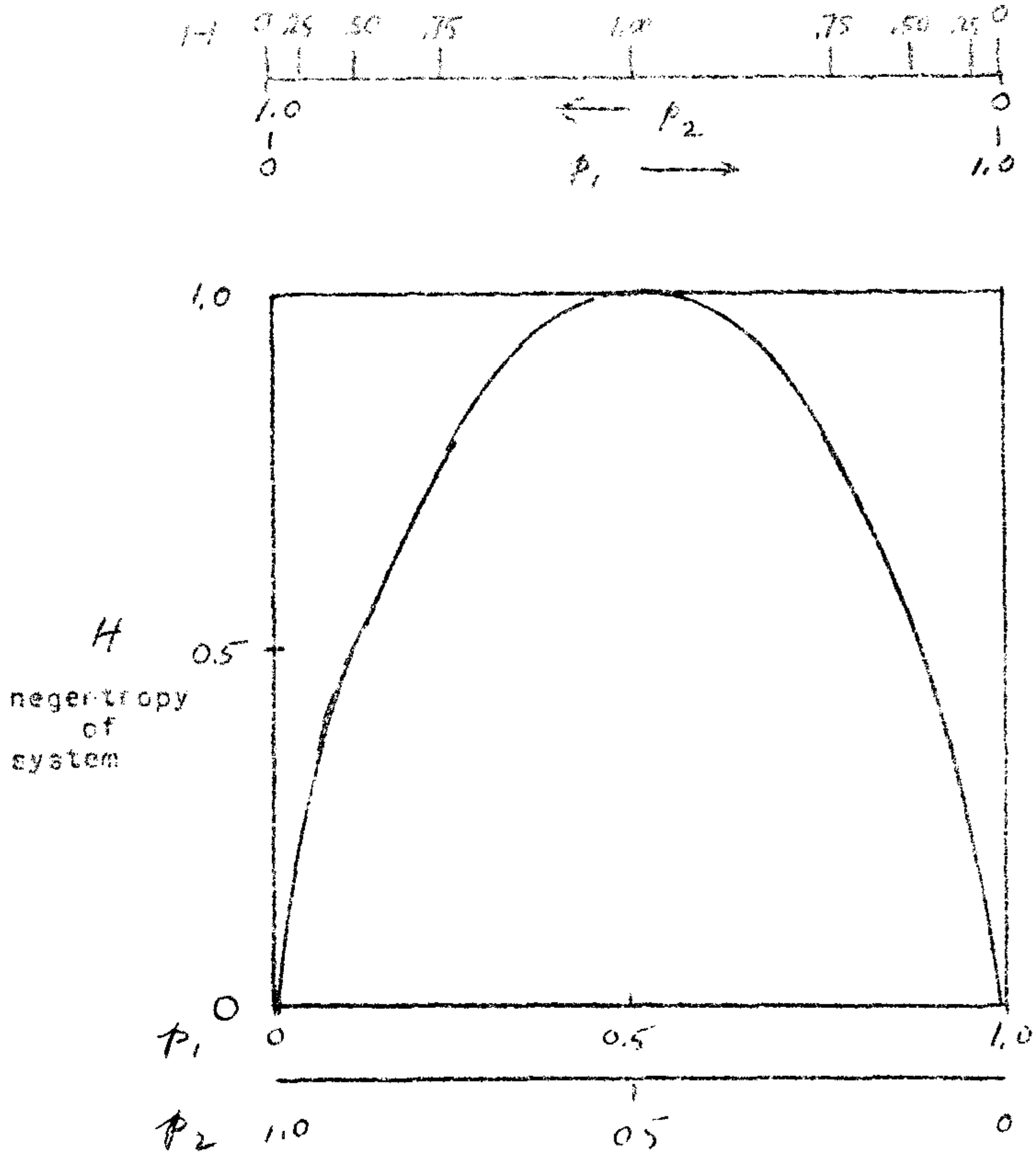


Fig 1, Probability (A), Log Probability (B) and Negentropy Component (C).

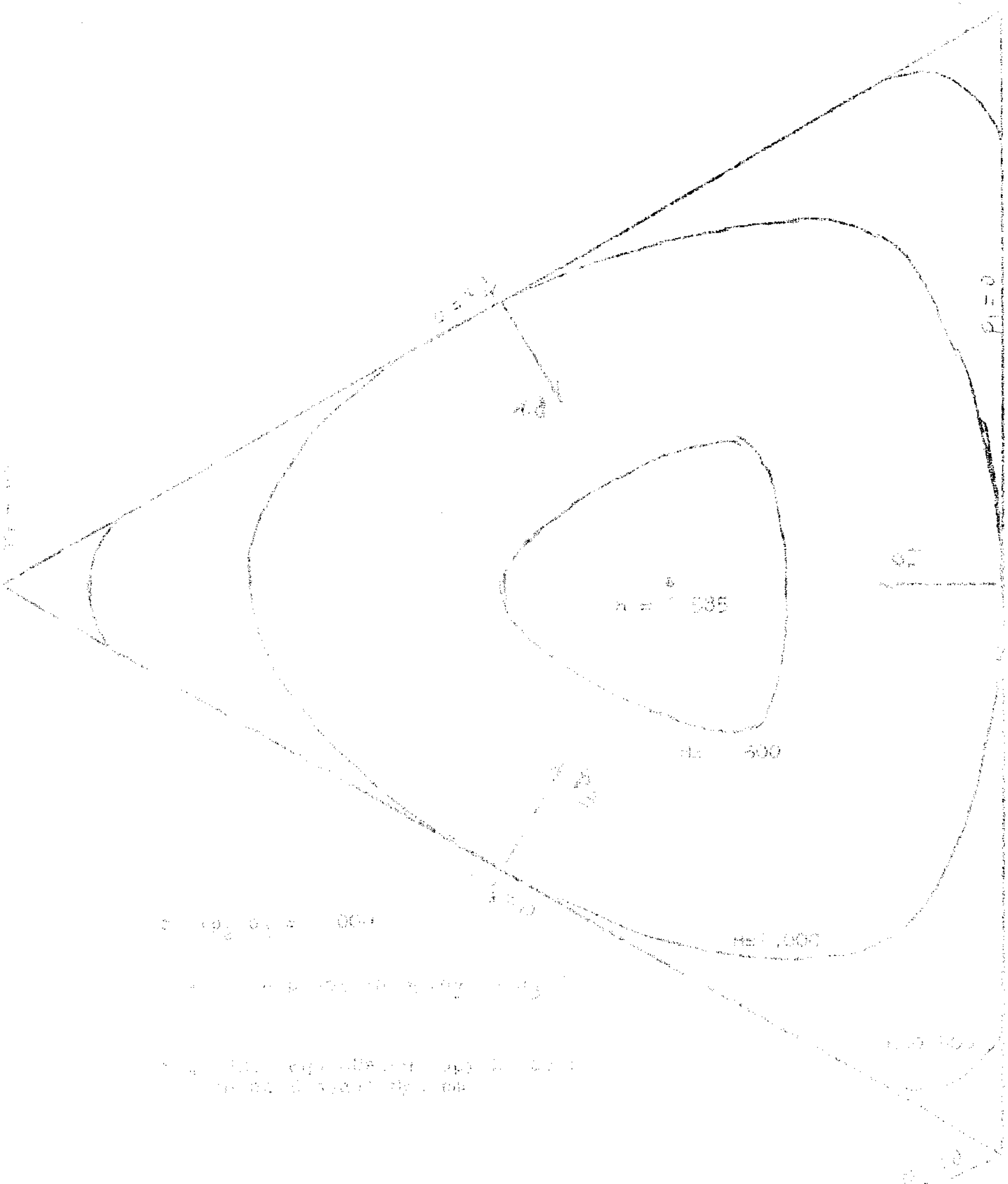
Curve (C) = Curve (A) x Curve (B)



$$H = -[\, p_1 \ln p_1 + p_2 \ln p_2 \,],$$

$$p_1 + p_2 = 1.0$$

Fig. 2A. Negentropy of Two Message System.


n = 535
n = 500
n = 1,000
$p_1 = 0$

In a similar way the triangular coordinate system for the three-message system forms the four faces of the quadrilateral cube with quadrangular coordinates. In this case equi-negentropy surfaces for H = 0, 0.5, 1.0, 1.5 & 2.0 are shown. For larger sets of messages the equi-negentropy surfaces would be in n-coordinate, n-1 space which is hard to visualize for $n > 4$. The conditions for maximum negentropy can be extended to give for the n-message case: $p_1 = p_2 = \ldots\ldots = p_n = \frac{1}{n}$ (7)

and the condition holds that: $\sum_{i=1}^{n} p_i = 1.0$ (6)

Three sample distributions corresponding to maximum negentropy are shown in Fig 3A. The cases for n=2 and n=4 cprrespond to the centers of Figs. 2A and 2C. These distributions will be used for reference when attempting to find an analogy of negentropy to use as a measure of democracy.

Another case of interest in future extensions of the concepts considered in this paper is the continous channel where there is a continous range of analog messages instead of a finite set of discrete messages. In this case eq. (4) becomes

$$H = \int p(x) \log_2 p(x) \, dx \qquad (8)$$

For an electrical signal carrying a message on a telegraph line with an average power of σ^2 and there is random noise on the line, we have a theorem from Information Theory that the negentropy is a maximum when the message distribution is gaussian, i.e.,

$$p(x) = \frac{1}{\sigma\sqrt{2\pi}} \; e^{-(x^2/2\sigma^2)} \qquad (9)$$

The equivalent condition to eq. (6) is

$$\int p(x) \, dx = 1.0 \qquad (10)$$

6A

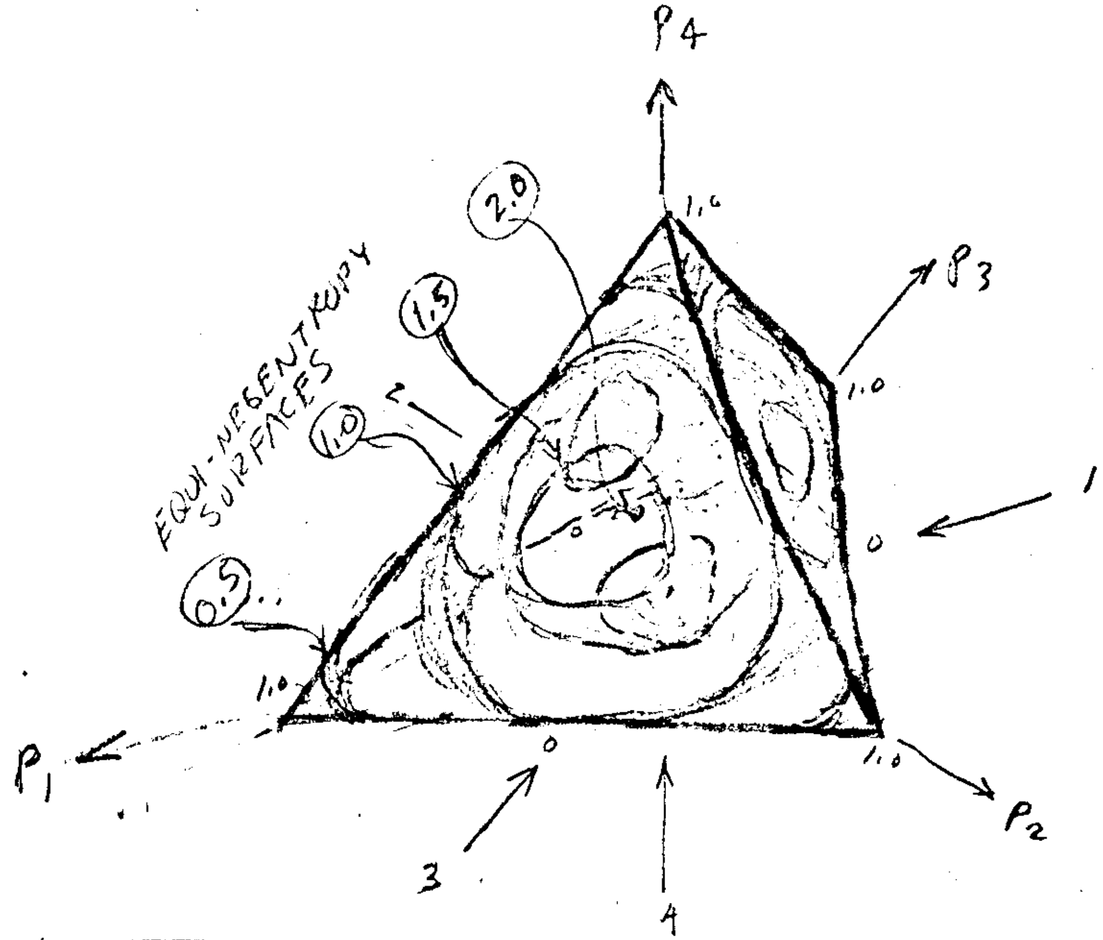


Fig. 2C. Equi-Negentropy Surfaces for Four-Message System.

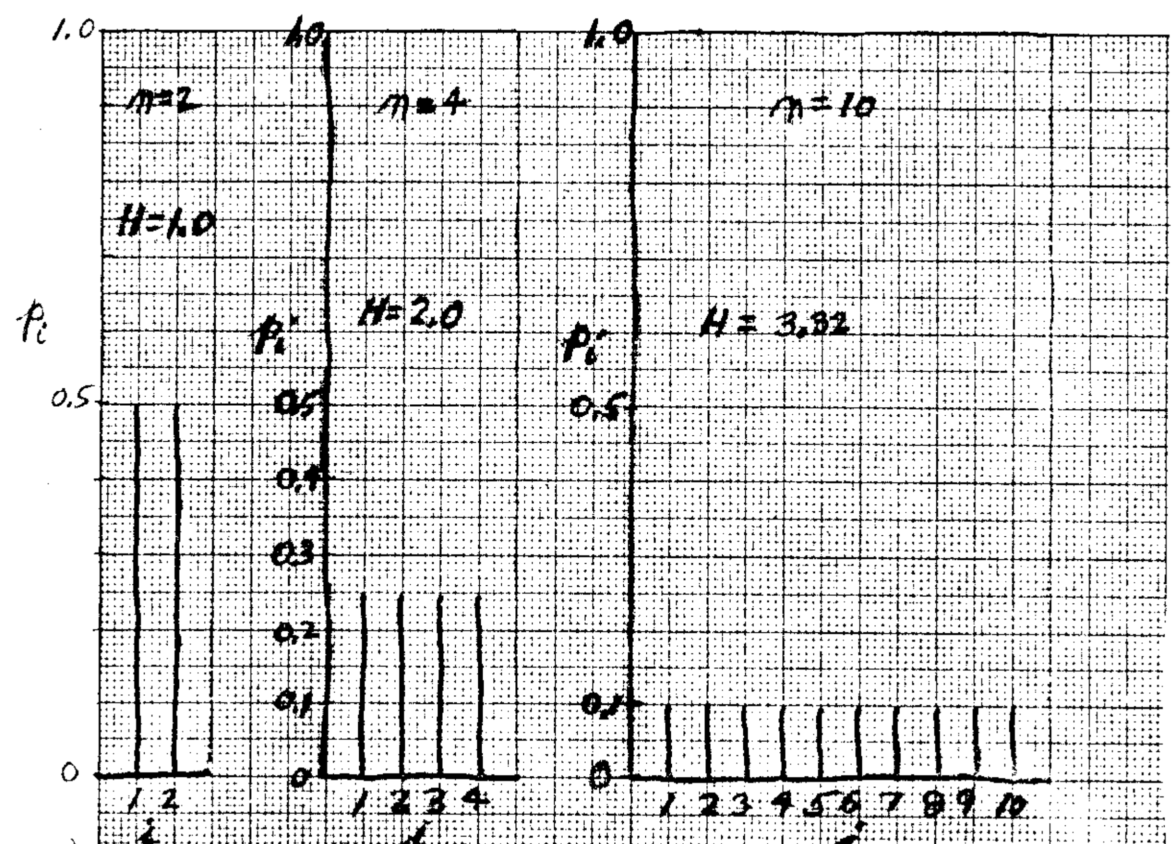


Fig. 3A Sample Distribution of Message Probabilities for n=2,4,10. (Discrete Noiseless Channel) Maximum Negentropy.

Two sets of curves are included in Fig. 3B to show sample continuous probability distributions and also power distributions, i.e., $P(x) = \sigma^2 \cdot p(x)$. The $p(x)$ curves give the probability of messages in the range 0 to 100 occuring and satisfy eq. (10). The power distribution curves satisfy

$$\int P(x)\, dx = \sigma^2 \qquad (11).$$

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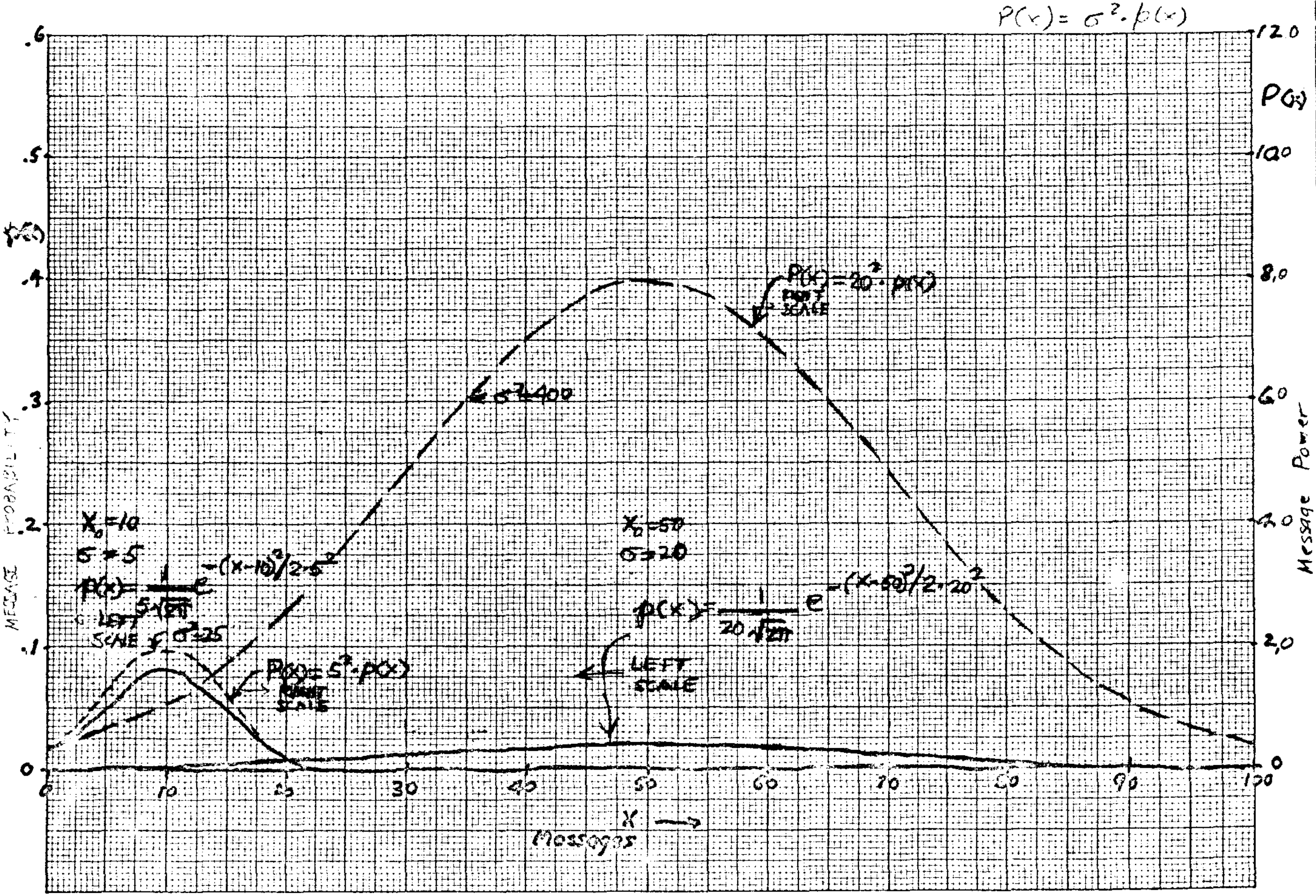

Fig. 3B Sample Distributions of $p(x)$ and $\sigma^2 p(x)$.

3. Freedom.

To assign a numerical value to "freedom" is a difficult task. There are many kinds of freedom, some of which are more valued than others. The ideal way to start this section would be to get some social psychologists to determine the relative weights to different types of freedom. Since such information is not presently accesible to me, I shall assume the following ten kinds of freedom to have equal weight in order to obtain some trial calculations.

I shall assign to each person a unit of "freedom" $F_i=1.0$ If he is deprived of some of his freedom his F_i becomes less than one and the person or persons interfering with his freedom have F_i's greater than one. For example if a dictator reduces the freedom of his subjects to 0.5 and there are 100,000 people under his control then the dictator's freedom is $F_i=50,001$. To obtain a measure of freedom that behaves like a probability function, we define a normalized "freedom" function,

$$G_i = F_i / n \qquad (12)$$

where n is the population of the country or sub-system. In the above case the normalized freedom for each subject becomes $G_i = 0.5 \times 10^{-5}$ and that of the dictator $G_l=0.50001$, i.e. the dictator has 100,000 times the freedom of a subject of his.

In these sample calculations the measure of freedom is arbitrarily between the following components of freedom:

(1) Freedom of speech 0.1

(2) Freedom of religion 0.1

(3) Freedom to print, broadcast, televise and to listen to same 0.1

(4) Freedom to find sexual partner 0.1

(5) Freedom to obtain education 0.1

(6) Freedom from job discrimination on account of race, religion, or national origin 0.1

(7) Freedom to build or buy own home 0.1

(8) Right to vote 0.1

(9) Right to trial by jury 0.1

(10) Freedom to establish small business or farm . 0.1

$$\sum F_{ij} = 1.0$$

Consider Country A, population of 100,000,where everyone has the ideal amount of freedom without infringing upon the rights of tohers, where everyone has an $F_i = 1.0$. In normalized units everyone has $G_i = 1.0 \times 10^{-5}$ units of freedom. A probability distribution curve for this country is plotted in Fig. 4A.

Next consider Country B, 10% of the people have restricted freedom in accordance with the following schedule:

J	Group 1 (10%)	Group 2 (90%)
1	0.05	0.11
2	0.10	0.11
3	0.05	0.11
4	0.05	0.10
5	0.01	0.11
6	0.01	0.11
7	0.01	0.11
8	0.01	0.10
9	0.03	0.10
10	0.02	0.112
	$F_1 = 0.34$	$F_2 = 1.072$
	$G_1 = 0.34 \times 10^{-5}$	$G_2 = 1.072 \times 10^{-5}$
	$0.10 \times 0.34 = 0.034$	$0.90 \times 1.072 = 0.966$

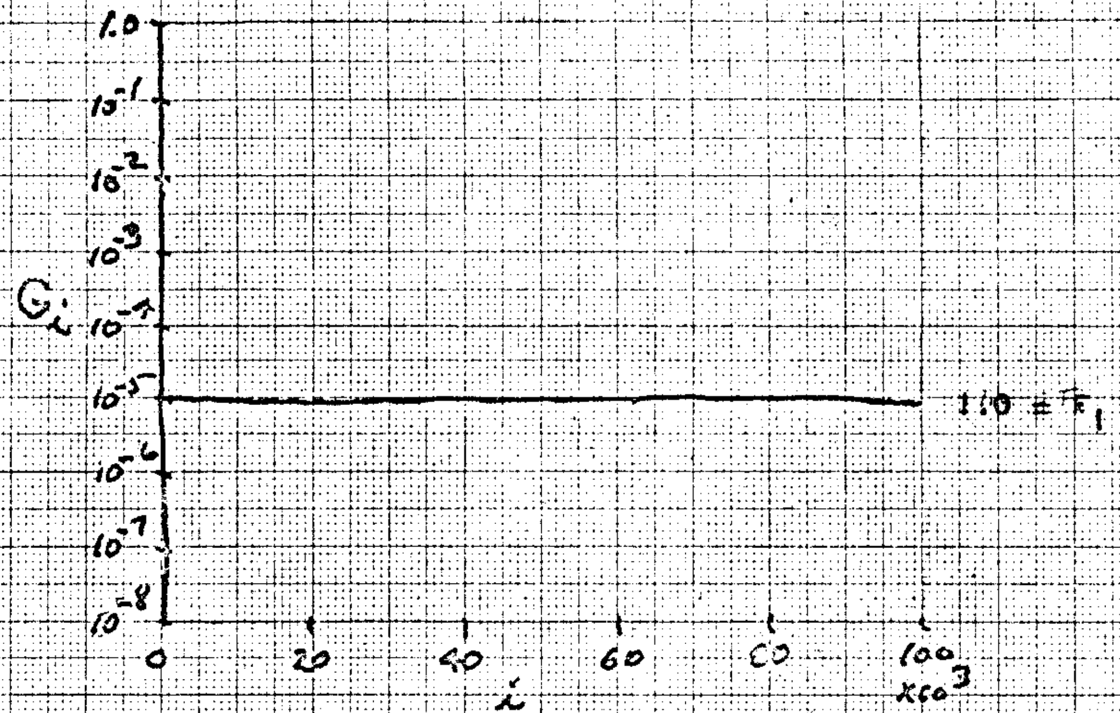

Fig 4A Normalized Freedom Function Distribution for Country A.

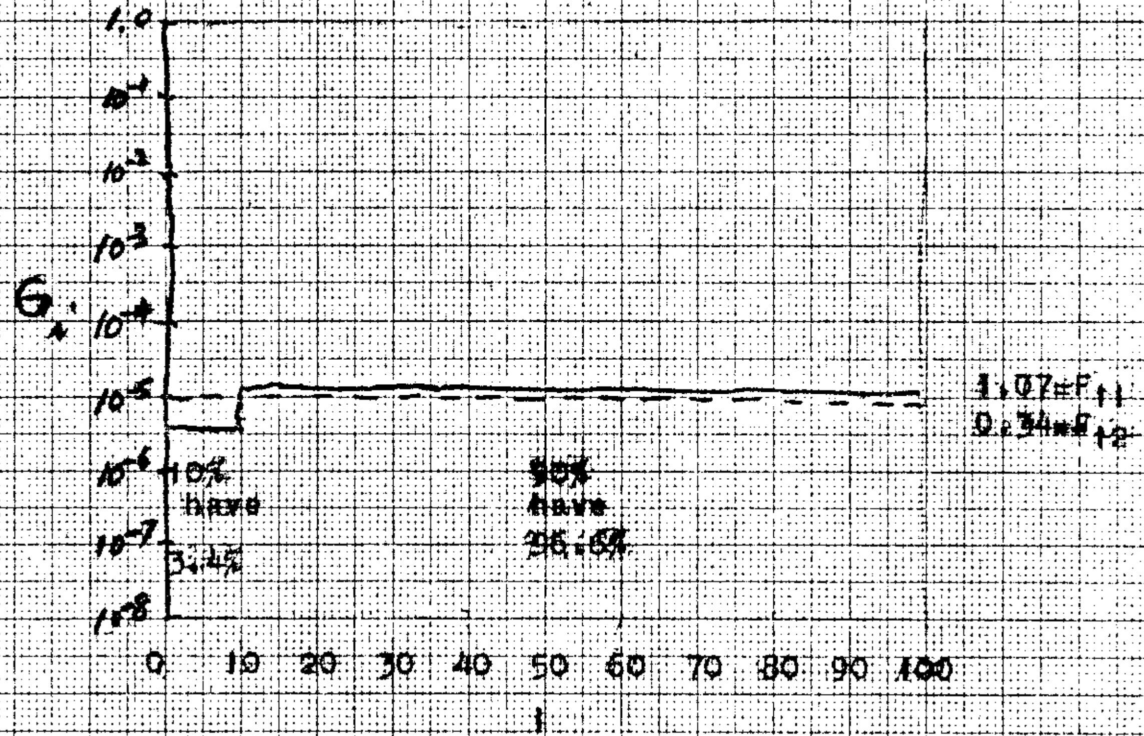

Fig 4B Normalized Freedom Function Distribution for Country B.

In this case it is assumed that the division into classes I & 2 is by individual achievement, not by reason of national origin or other factors determined before birth. In other words this case represents a situation where any loss of freedom is determined by individual consideration with due process of law. This probability distribution is plotted in Fig. 4B.

Next we consider Country C which is asemi-democracy in which 80% of the population have democratic rights, 10% have heriditary rights to strategic jobs, and 10% are grouped as a class by reason of ancestry to restricted jobs.

j	Group I (10%)	Group 2 (80%)	Group 3 (10%)
I	0.05	0.1	0.15
2	0.10	0.1	0.10
3	0.05	0.1	0.15
4	0.05	0.1	0.15
5	0.01	0.1	0.19
6	0.01	0.1	0.19
7	0.01	0.1	0.19
8	0.01	0.1	0.19
9	0.03	0.1	0.17
10	0.02	0.1	0.18
	$F_1=0.34$	$F_2=1.0$	$F_3=1.66$
Class	$G_1=0.034$ (10%)	80,000 out of 100,000	$G_3=0.166$ (10%)
Individual		$G_2=1.0\times10^{-5}$	

Groups I & 3 are considered as classes, not by individuals, while Group 2 is treated by individual case. The corresponding probability distribution is plotted in Fig. 4C.

The cross-hatched sections of Fig. 4C are the shrinkage due to consideration of Groups I & 3 as heriditary classes instead of treating each individual separately.

610A

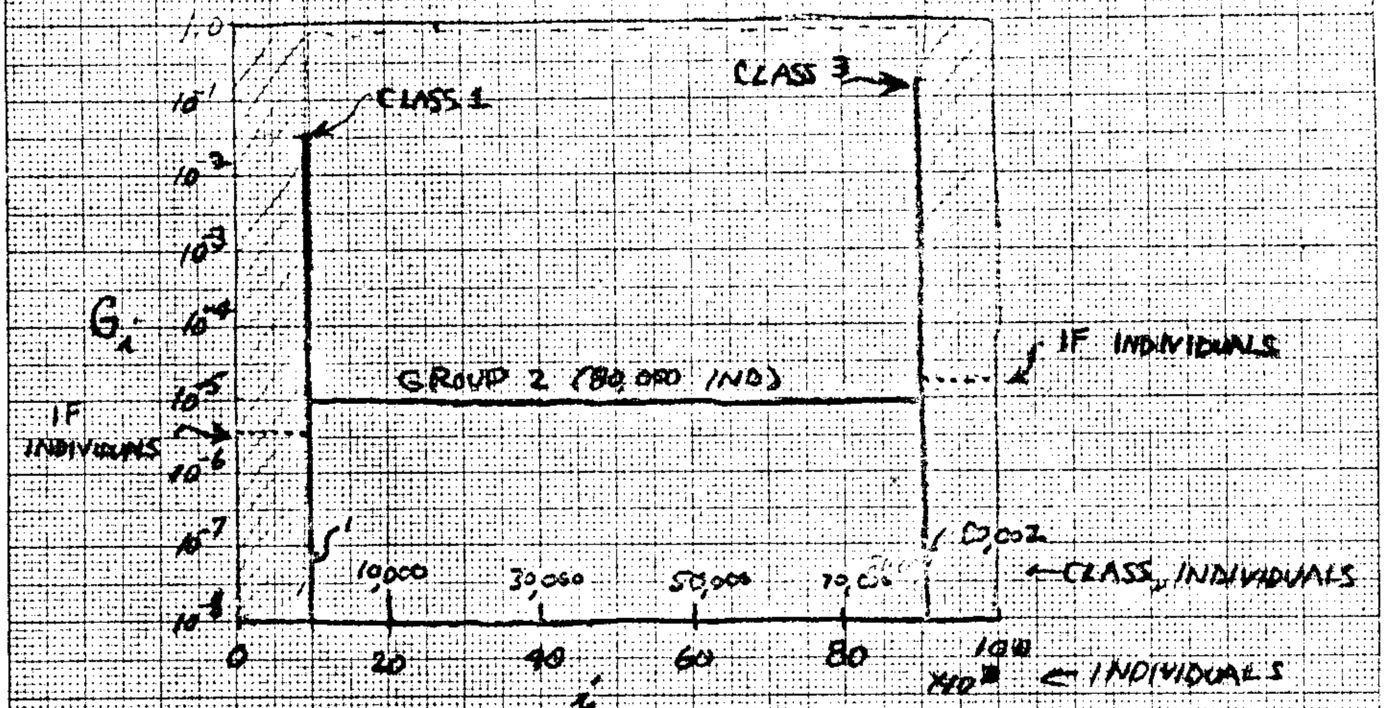

Fig 4C. Country C

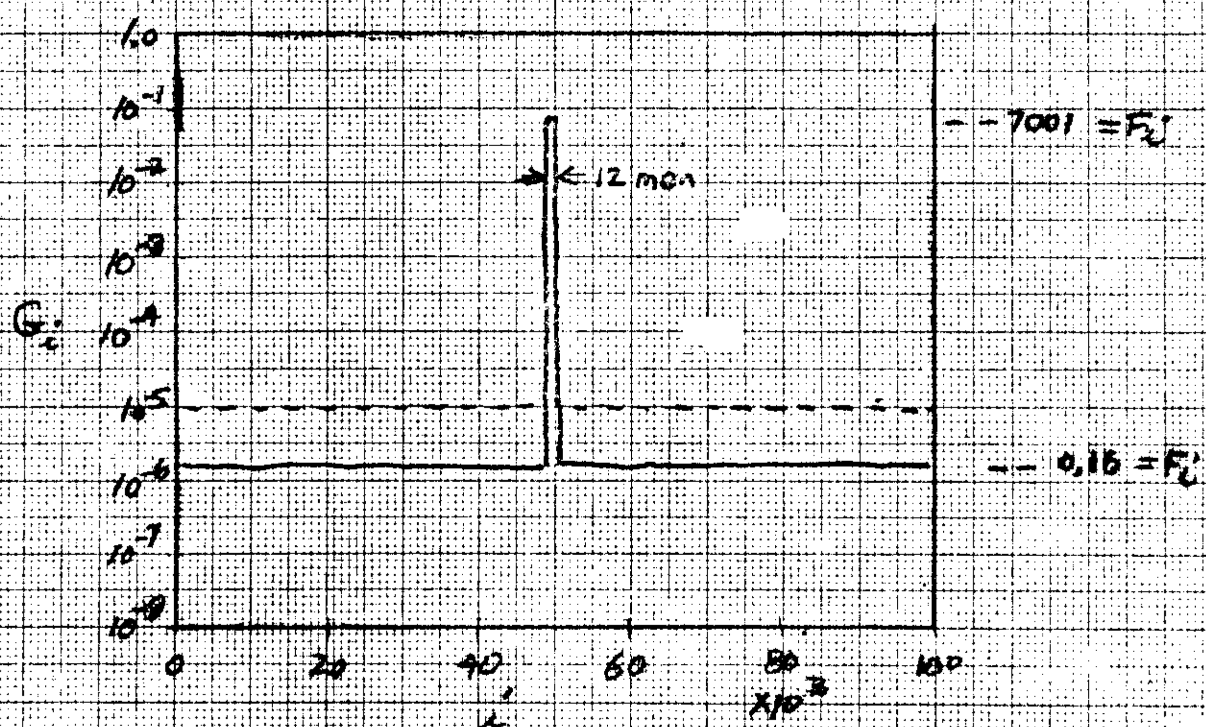

Fig. 4D - Country D

Next we consider Country D, a population of 100.000 controlled by an oligarchy of twelve men.

j	Oligarchy (12 men)	People (99,988)
1	700.0	0.01
2	1.0	0.01
3	700.0	0.01
4	1400.0	0.05
5	700.0	0.02
6	700.0	0.01
7	700.0	0.03
8	700.0	0.00
9	0.0	0.00
10	1400.0	0.02
	$F_0=7001.0$	$F_p=0.16$
	$G_0=0.07001$	$G_p=0.16\times10^{-5}$
	$12\times0.07=0.84$	$10^5\times0.16\times10^{-5}=0.16$

This distribution is plotted in Fig. 4D. People are all treated as individuals in this calculation.

The next case is Country E, a country where there ten castes into which people ar born. The caste into which one is born determines one's education, job opportunities, and many other restrictions. Although within each caste there undoubtably is individual consideration on merit, to get a limiting value we shall assume people are treated as members of a particular caste, not as individuals. For this limiting case we shall divide the people into eight equal castes, with one privileged caste, and one menial caste.

Caste 1 $F_1=0.34$ $G_1(\text{class})=0.034$ 10%

Castes 2 - 9 $F_i=1.0$ $G_i(\text{class})=0.10$ 10% each

Caste 10 $F_{10}=1.66$ $G_{10}(\text{class})=0.166$ 10%

This distribution is plotted in Fig. 4E. It should be noted that this is a worst case. In practice the consideration of individual merit in each caste would introduce some democracy on a limited scale.

IIA

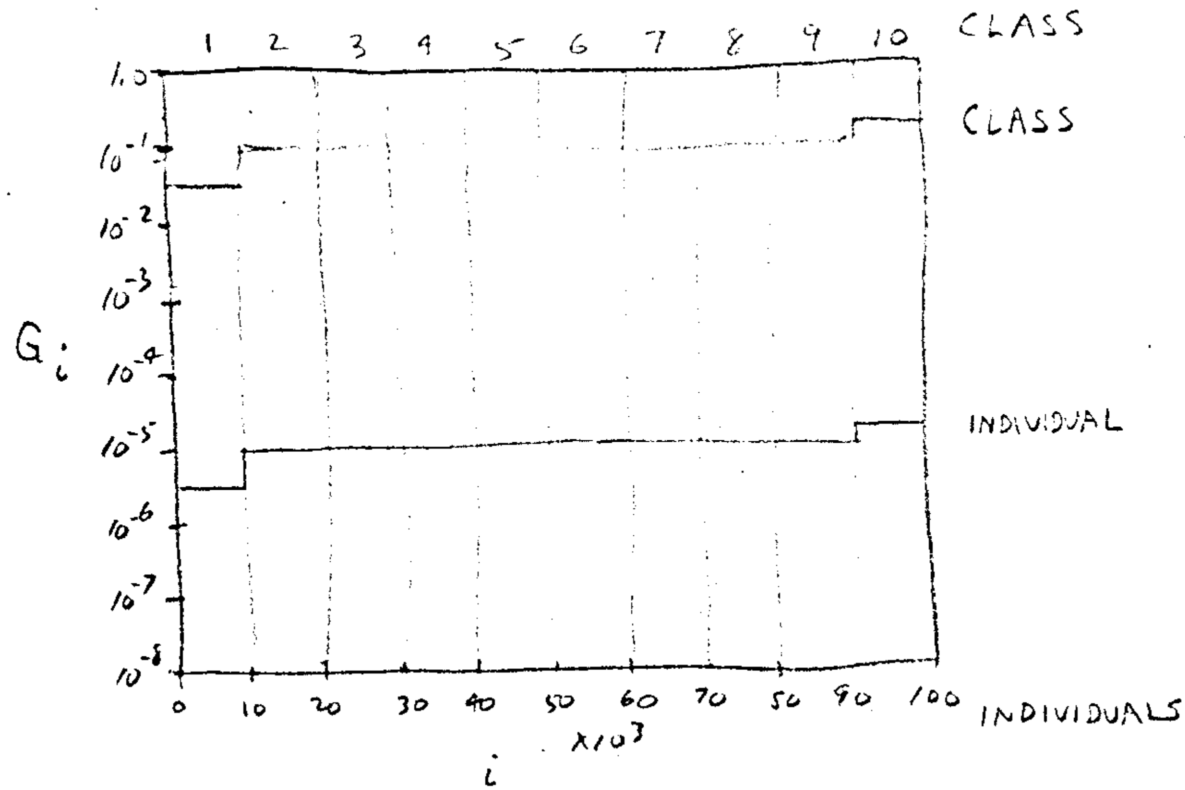

Fig 4E. Country E (Caste System)

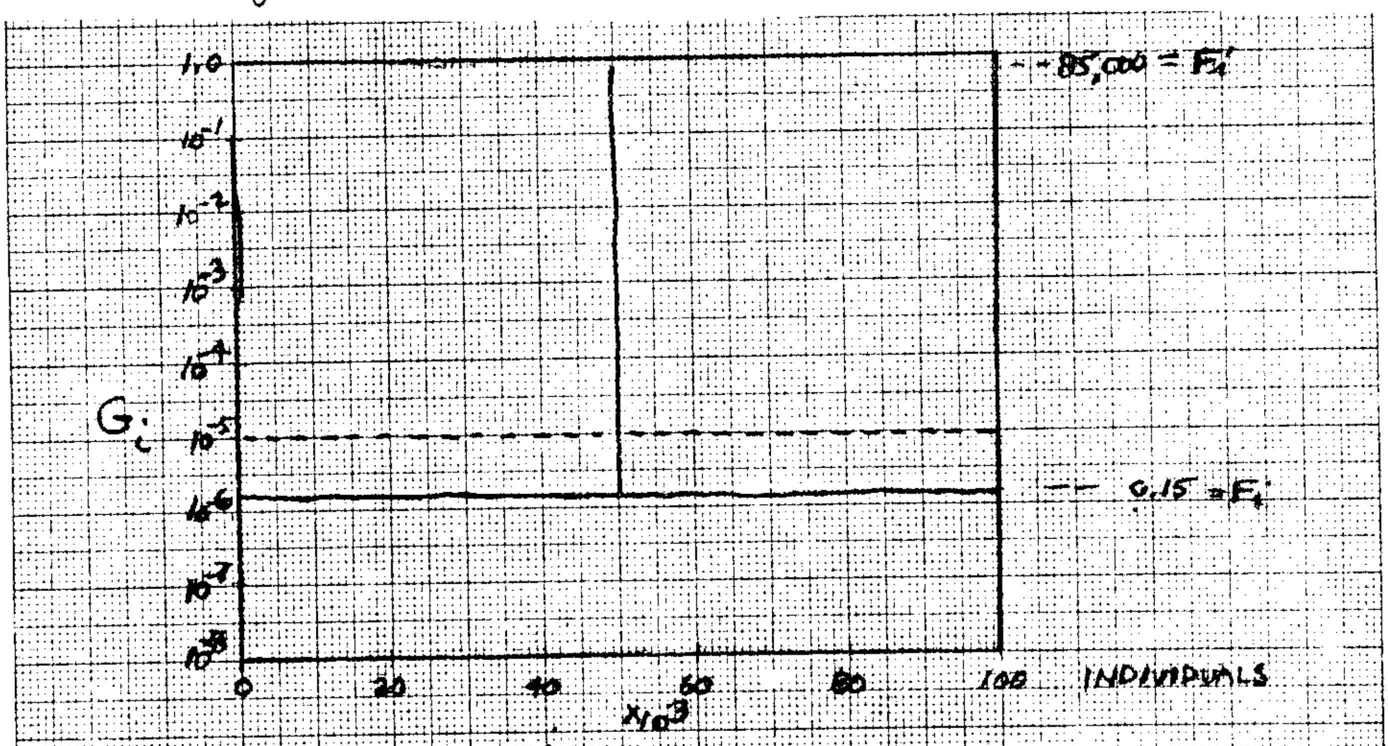

Fig 4F. Country F (Dictatorship)

No. 359-14. Millimeter, .5 mm lines accented, cm lines heavy. MADE IN U.S.A.

Next we consider Country F, a dictatorship. The freedom of the dictator and his subjects are tabulated as follows:

j	Dictator (one)	People (99,999)
1	8500	0
2	8500	0
3	8500	0
4	8500	0.10
5	8500	0.01
6	8500	0.01
7	8500	0.02
8	8500	0
9	8500	0
10	8500	0.01
	F_i=85,000	F_i=0.15
	G_i=0.85	$G_i=0.15\times10^{-5}$

This distribution is plotted in Fig. 4F.

4. Democracy.

This analysis is a test of an hypothesis as to the analogy between "negentropy"and "democracy." We wish to see, if replacing the probabilities of a set of messages by the normalized measure of freedom of the individuals in a social system will give a value of negentropy for the system which is a reasonable measure of the amount of democracy in the social system. If such a procedure gives a higher measure of democracy to a dictatorship than to an obviously democratic society, the hypothesis will have to be rejected. If however the resultant measures of democracy fall into relative positions consistent with common sense concepts and with the more sophistocated analysės of political scientists and sociologists we can accept the hypothesis until another hypothesis is found that gives better agreement with the available facts. In developing this section I wish to acknowledge the valuable assistance of correspondence and discussions with Dr. Stuart C. Dodd, University of Washington, and with Mr. Milton Rubin, MITRE Corp., Bedford, Mass.

Using eq. (4), replacing p_i by G_i, and H by D, we have:

$$D = -\sum_{i=1}^{n} G_i \log_2 G_i \qquad (13)$$

with the restraint that:

$$\sum_{i=1}^{n} G_i = 1.0 \qquad (14)$$

The subscript stands for a single individual unless otherwise noted. When a group of individuals are treated as a class without regard to individual performance, such as job discrimination on account of color, the subscript will refer to the group or class as a unit instead of to an individual.

In the following examples the probability distributions for "freedom" from Figs. 4A through 4F will be used in the calculations. For Country A, the ideal democracy, we have by eq.(13):

$$D_A = -100,000\times10^{-5}(\log_2 10^{-5}) = 16.61 \text{ entropy units}$$

In this case the $\log_2 10^{-5}$ was obtained from Table II. Both the "uncertainty" and the "negentropy components" can be read off the curves of Fig. 1 for the problems considered in this paper. If in the above calculation, we were still dealing with a set of messages for a telegraph line, the result would be $D_A=16.61$ bits of information. Where we have tranferred by analogy to another field, without deriving any scale factor, we shall simply call the results "entropy units." We further note that pending further analysis of the effect of normalizing the measure of freedom, we must only make comparisions for populations of the same numbers of people. In this study all hypothetical countries have 100,000 population. It may turn out that the effect of normalizing does agree with the sociological phenomena. To explore this question it is felt that some of the work of N. Rashevsky in the Bulletin of Mathematical Biophysics will shed some light on this question.

For Country B, a democracy with some underprivilged groups, we have:

$$D_B = -10,000(0.34\times10^{-5})\log_2 0.34\times10^{-5}$$
$$-90,000(1.072\times10^{-5})\log_2 1.072\times10^{-5} =$$
$$= 0.34(18.17) + 0.966(16.51) = 0.61+15.92$$

$$D_B = 16.52 \text{ entropy units}$$

For Country C we have Groups 1 and 3 treated as classes and Group 2 treated by individuals:

$$D_C = -0.034 \log_2 0.034 - 80,000(10^{-5})\log_2 10^{-5} - 0.166 \log_2 0.166 =$$
$$= 0.034(4.88)+0.8(16.61)+0.166(2.59) = 0.166+13.3+0.431=$$

$$D_C = 13.90 \text{ entropy units}$$

For Country D, the oligarchy, we have:

$$D_D = -12(0.07)\log_2 0.07 - 99{,}988(0.16\times10^{-5})\log_2 0.16\times10^{-5} =$$
$$= 0.84(3.84) + 0.16(19.255) = 3.23 + 3.08 =$$
$$D_D = 6.31 \quad \text{entropy units}$$

We observe that so far the measure of "democracy" in decreasing as the system becomes less democratic in common sense terms.

For Country E, the caste system, we treat each cast as a group not by individuals:

$$D_E = -0.034 \log_2 0.034 - 8(0.1)\log_2 0.1 - 0.166 \log_2 0.166 =$$
$$= 0.034(4.88) + 0.8(3.32) + 0.166(2.59) = 0.166 + 2.65 + 0.431 =$$
$$D_E = 3.25 \quad \text{entropy units}$$

For Country F, the dictatorship we have:

$$D_F = -0.85 \log_2 0.85 - 99{,}999(0.15\times10^{-5})\log_2 0.15\times10^{-5} =$$
$$= 0.85(0.236) + 0.15(18.506) \doteq 0.200 + 2.78 =$$
$$D_F = 2.98 \quad \text{entropy units}$$

The negentropy measures of "democracy" for each of the six hypothetical countries have been plotted as a bar graph in Fig. 5 for comparison.

Examination of Fig. 5 indicates a general agreement between our theoretical calculations of negentropy with the relative degree of democracy one would ascribe by common sense to the different types of social organization. This means that we can seriously consider using the calculation of negentropy to evaluate social systems where we do not have good common sense references. However we would have to check more rigorously the method of computing the normalized "freedom" G_i.

Another feature is that a democratic country like country B can have an appreciable portion of its population with seriously curtailed freedom, provided restrictions are based on an

5A

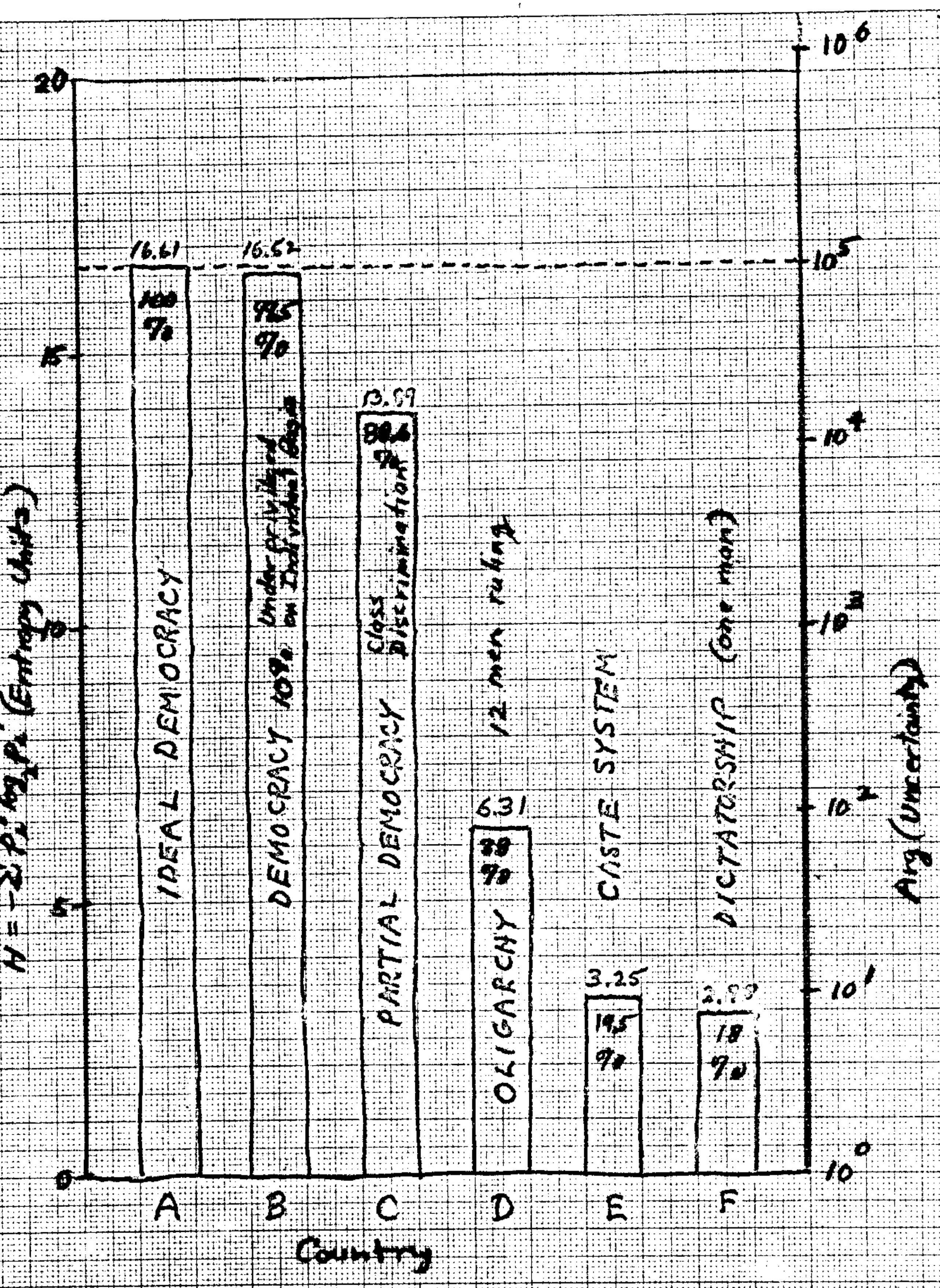

Fig 5. Comparison of Six Countries.

individual basis related to individual performance and are determined by due process of law. For example having 10% of the population restricted in this way reduces the negentropy by 0.5%, while an equivalent amount of restrictions based on classification of people by race or national orign instead of individual performance reduces the negentropy by 16.4%.

Comparision of Countrys E and F indicates that a rigid caste system or a one man dictatorship knock the negentropy down to one-fifth the ideal value. Another feature of interest is that a society run by a rigid set of rules can be almost as bad as a one-man dictatorship. Another feature is that a substantial increase in negentropy results when a one-man dictatorship changes to a twelve-man oligarchy. This indicates the possibility of developing a more detailed measure of "freedom" to put into the negentropy formula to monitor changes in non-democratic systems to determine whether they are becoming more or less democratic.

[illegible] calculations in this paper were made p16A

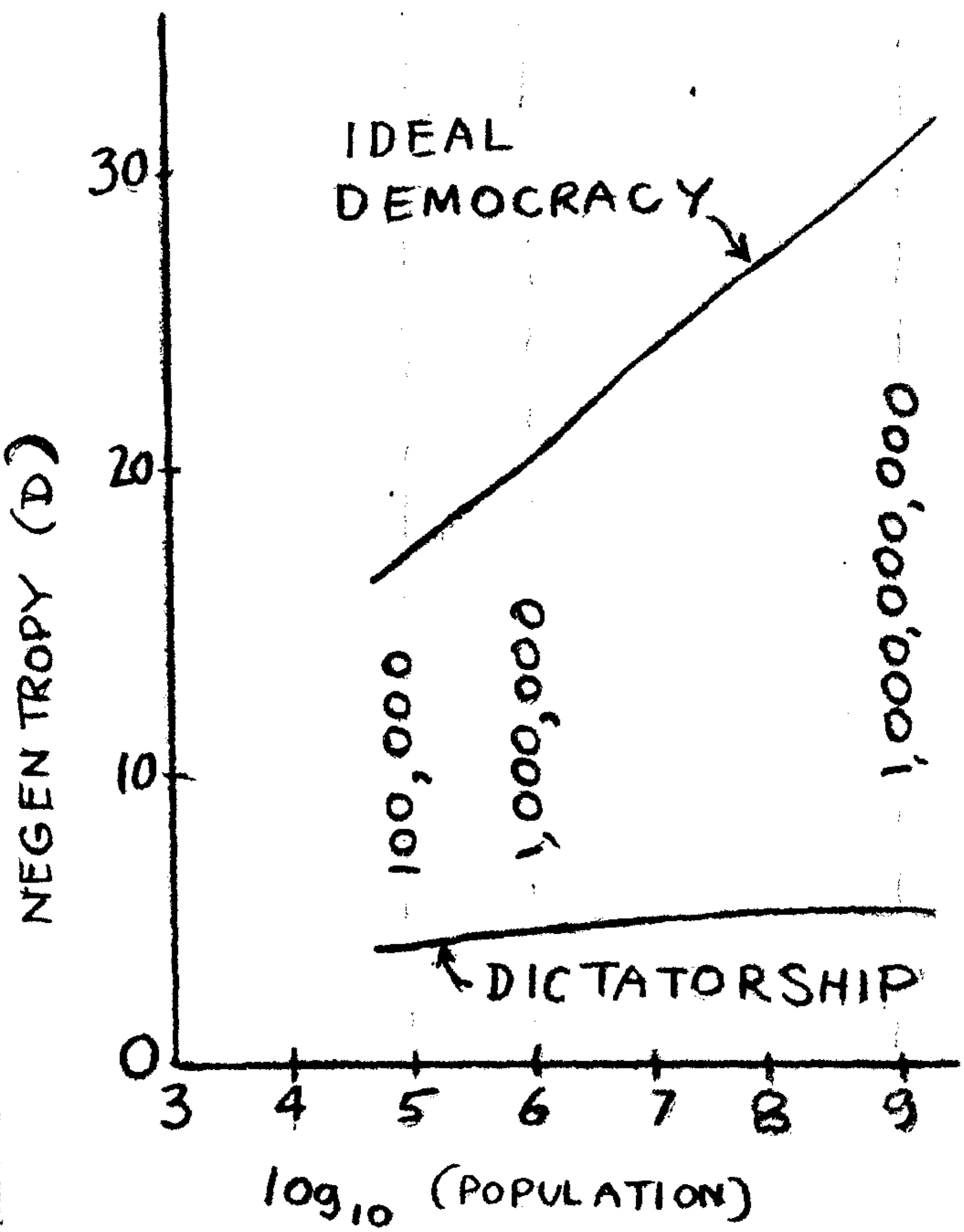

Fig. 6. Variation of Negentropy with Population for Ideal Democracy and for Dictatorship.

8. STATIC VERSUS DYNAMIC ANALYSIS OF DEMOCRACY

We have shown by analogy and by testing the hypothesis developed from the analogy that defining a measure of "freedom" as a normalized probability function, when put into the formula for negentropy of a probability distribution, results in a plausible static measure of the degree of "democracy" in the social system. This in itself is an important step in bridging the gap between mathematical science and the study of human values. However such a test must be repeated as separate analyses at different times to obtain a dynamic trend indicating whether the more democratic countries can survive the interaction with the more dictatorial countries.

For example Country A with its maximum negentropy making it an ideal democracy, might be inadequately organized to deal with aggression by the dictatorial Country F. I propose as a future research problem, the search for a measure of "justice" which might balance maximizing democracy with organization so that the more democratic country could defend itself without losing its "democratic" properties. I propose that the concept of "dynamic-justice" be used for a dynamic measure of democracy related by analogy to the capabilities of the total system to maximize negentropy over a period of time. This would involve the time derivative of the negentropy of a system including sub-systems of different types of social structure. Such a concept of "dynamic-justice" would be closely related to the concept of "reverence for life."

To develop such a dynamic model would require [illegible] time in more [illegible] than is available for this study. To proceed from this static measure to a dynamic measure requires the addition of [illegible] interconnected. The interaction of Countries B, C, D, E and F upon Country A could be interpreted as noise in the communication channe corresponding to Country A. To obtain a noise probability distribution we would need some knowledge of the signal power level in each sub-system and the extent of coupling between them.

To procede to this next step is beyond the scope of this study.* However one can conjecture that the direction of further reseerch might be to investigate the possibility that "dynamic-justice" might be measured by a correlation function between the actual probability distribution of freedom in Country A with the optimum freedom distribution computed from an analysis of the analogous communication channel with noise derived from the other countries in the system. It is premature to attempt a specific model of "dynamic-justice" on this basis. However two curves of message probability distributions for maximum negentropy for given power levels (or signal-to-noise ratios) are given in Fig. 3B. To develop this measure of [illegible] it is necessary to determine some measure of the scientific, educational, and economic levels of the sub-system countries.

* [illegible]

6. Conclusions(or Summary)

The dictionary definitions of a property of physical systems namely "entropy" , and a group of properties of social systems namely "freedom, democracy, and justice" have been reviewed. The examination of the English word definitions does not yield any precise relationship. Therefore the comparision of these physical and social parameters must be done in some mathematical or geometrical way.

First the equations of "entropy" or "negentropy", i.e., entropy with a minus sign, which conform to "information" in the analysis of communication systems are reviewed and plotted as curves and graphs. Graphs are plotted of the parameters: probability, uncertainty, and negentropy component for the probability of occurence of a message in a set of n messages. One-, two-, and three-dimension equi-negentropy points, lines, and surfaces are drawn to develop a feeling for the geometry of "negentropy" in n-dimensional spaces representing sets of n messages.

Then an attempt is made to define a numerical scale for individual freedom. Lacking any recognized weighting of different components such as freedom of speech, freedom of religion, etc., ten principal freedoms are arbitrarily given a value of one-tenth, such that an independent individual has a freedom of $F_i = 1.0$, or a normalized freedom of $G_i = F_i / n$, where n is the population of the group, country, or system being considered. Using this approximate definition of normalized freedom, a set of graphs of probability distributions of freedom are made for six hypothetical countries of 100,000 population each: an ideal democracy; an imperfect democracy; a partial democracy with an upper class, a large democratic middle class, and a lower class; an oligarchy ruled by a committee of twelve; a country structured by a caste systems and a dictatorship.

Next a measure of "democracy" is developed by analogy with the calculation of the average entropy of a set of messages in Information Theory. Normalized freedom corresponds to the probability of a message being sent, and the measure of democracy is taken as the negentropy of the probability distribution. The calculated values of negentropy for the different social systems are:

Ideal democracy	16.61
Approximate democracy.	16.52
Partial democracy with upper & lower classes.	**13.90**
Oligarchy.	6.31
Caste system	3.25
Dictatorship	2.98

Even though the definition of freedom is weak, the numerical measure of "democracy" for the above systems are reasonable and do not conflict with common-sense values.

A more fundamental limitation on the above procedure is that the measure of democracy is a static measure. It does not give a direct measure of the ability of the democratic state to maintain itself with time, i.e., to be able to protect itself against attack by a dictatorship. It is proposed that the present dictionary definition of "justice" be extended to form a concept of "dynamic justice" which would include a measure of the ability of the people to preserve and improve [illegible] over a period of time, say one generation.

[illegible] definition of "dynamic justice" [illegible] single [illegible] static definitions of "freedom" and "democracy." For example Countries A through F could be considered as six communication channels in which each channel would have a noise signal derived from the other five channels. This would require the analysis of a complex network of feedback loops which are beyond the scope of this study. If the number of countries in the system were large and represented a random distribution of social organization, it might be possible to formulate the approximate effect with a gaussian noise model. A possible path to try to get a measure of "dynamic-justice" would be to investigate the correlation function of the normalized freedom function and the optimum freedom function predicted for maximum negnetropy of the channel under the given noise distribution.

7. POTENTIAL APPLICATIONS.

When these concepts are tested against more complete data by sociologists and political scientists, the use of negentropy as a measure of democracy could lead to a useful measure in dealing with domestic problems like civil rights, job discrimination, freedom of religion, and freedom of speech.

When developed further to the proposed concept of "dynamic-justice," the conditions of maximizing negentropy could lead to a useful measure in analysing international problems and in particular disarmament problems.

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[illegible]

Fig. 7 is an attempt to tabulate the extent to which the hypotheses of this paper agree or disagree with known empirical values and other known conditions of variables. Potential future developments are also listed in the table, even though not much can be said about them yet. The references noted in Fig. 7 are:

15. Jerome Rothstein, _Communication, Organization, and Science_, Indian Hills, Colorado: Falcon's Wing Press ([illegible])

16. Mihajlo D. Mesarovic, _The Control of Multivariable Systems_, [illegible] Technology Press (1960)

17. W. Ross Ashby, "The Set Theory of Mechanism and Homeostasis," University of Illinois, NSF Grant [illegible], Tech. Report No. 7, Sept. 1962.

TESTS / HYPOTHESIS	Do Hypotheses Give Reasonable Values For:					[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
Analogue "Inventory" & Migration (Present Law)	Yes	Yes (2)		Yes	Yes	Yes	Yes	(3)	(1)
Analogue "Dynamic Justice"/ Correlation (Comp. Channel with Filter)			Incomplete						
Analogue (4) Cybernetic Specifications give Analysis of Freedom in Organization			Not Yet Performed						

(1) Only in regard to definitions and weighting of freedom.
(2) Refer to ?CPR? ?II.? ?I? for preliminary development.
(3) See Rubstein (?15?) for definitions of "organization," and ?Masarovic? (?16?) for forms of feedback loops and corresponding matrices.
(4) A more rigorous approach would be to reformulate freedoms of individuals and groups using set theory as defined by Ashby(17).

Fig. 7. Checking of Hypotheses.

Appendix I: Short Outline for Book, "Communication Theory in the Cause of Man."

BOOK OUTLINE

Part I: Introduction (SEP No. 81)

1. Introduction. Diagrams based upon checking chart
2. State of Western Civilization.
   Wisdom of Confucius, Ten Commandments of Moses, Teachings of Jesus
   Philosophy and Sociology of Auguste Comte
   Philosophical and Economic Theories of Karl Marx
   Sociology of Lester Ward
   Freud, Jung, and Adler
   'Out of Revolution' E. Rosenstock-Huessy (6[illegible])
   Notebooks of Simone Weil
   Alienation of Modern Man F. Pappenheim (60)
   The Noosphere of Teilhard de Chardin (70)
   Biogeochemistry of Vernadsky (58)
   Accent on Form, L.L. Whyte (71)
   May Man Prevail, E. Fromm (72)

Part II: Problems of Specialization and [illegible]bility (SEP No. 82)

3. The Dilemma of Specialization
4. A Checking Chart.
5. Partial Derivatives of History.
6. Example of Checking Chart.
7. Special Responsibility of Engineers.

Part III: Information Theory and Engineering (Sociology (SEP No. 83)

8. Channel Capacity.
9. Ideology as a Coding Problem.
10. Distribution of Negentropy in Political Organization.
11. Balance of Obligation and Rights--Organization and Freedom (69)

Part IV: Cybernetics and General Systems Theory (SEP No. 84)

12. Feedback Loops.
13. Capitalist and Socialist Systems.
14. Social Planetaria.
15. Computing as a Tool for Democracy.
16. Computer-Data Communication Systems and Economic Systems.

Part V: Human Values and Analogies of Communication Theory (SEP No. 85)

17. Potentials of fruitful contact between competing economic and political systems. (74)
18. Conservation of Human Values: Information Theory provides principles and bounds; Cybernetics the form of institution to carry out the goals.
19. Summary: The Unitary Principle--The Next Development of Man.

Note: Consideration is being given to splitting the above material into two sections or volumes, the first non-technical directed for the layman, and the second technical with more precise information on the status of definitions and "thematic hypotheses."