COMMUNICATION THEORY in the CAUSE of MAN

VOL. II NO. 1

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Notes on the application of General Systems Theory, Cybernetics, Information Theory, and related fields of Communication Theory to the strengthening of democratic institutions on our planet.

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CONTENTS OF THIS ISSUE

TABLE: THE THREE ERAS OF HUMAN CIVILIZATION: FORCE, POWER, AND COMMUNICATION.

ERA (time span)	Characteristic of Major Tools of Era	Notes on Social Implications
FORCE 7000 yrs.	Force Amplifying Devices such as levers, pulleys, bows and arrows.	Led to the division of labor into agricultural workers, craftsmen, and standing armies. Also the first large cities at major river deltas.
Transition: First Industrial Revolution.		
POWER 300 years	Power Amplifying Devices such as the steam engine, electric motor, gasoline engine, diesel engine, atomic bomb, nuclear power generation, and hygrogen bomb.	Led to the abolition of slavery on the basis that use of power amplifiers could produce more than slaves and that educated technicians were needed to maintain the power amplifiers.
Transition: Second Industrial Revolution.		
COMMUNICATION* 25 years	Intelligence amplifying devices such as RADAR, SONAR, electronic computers, television, automated factories and chemical refineries, and communication satelites.	When half of the cost of an automobile consists of data processing and expediting of parts orders in connection with production control, it is safe to say that we are well into the Communication Era. This communication era gives us the tools with which we could communicate with the Viet Cong, Cubans, Red Chinese, and many others to give people technical assistance in a constructive way without the need for military action. Force could be restricted to U.N. police action the communication era.

* called "Information Era" or "Cybernetic Era" by some philosophers.

The above table is reprinted from CTCM Jan-Feb 1971, Vol. I, No. 7-8, p. 14.

NOTE ON REVISIONS AND ADDITIONS TO CTCM:

'7' in File No. 100-F-7 indicates updating to August 30, 1970.
'10' in File No. 98-F-10 indicates updating to March 28, 1971.
'14' in File No. 97-F-14 indicates updating to March 5, 1972.
'15' in File No. 97-F-15 indicates updating to June 18, 1972.

Developments Regarding the "Thermodynamic Imperative."

Since I have received a number of inquiries as to what practical use can be made of this material on cybernetics and information theory, I have done some experimental work with the Long Range Planning Committee of the San Jose Unitarian Church. This involved some monitoring of what Unitarian schools for the ministry were doing that might provide a test case. It turned out that the Meadville-Lombard Theological School in Chicago has an affiliated Center for Advanced Study in Theology and the Sciences, in cooperation with which it publishes a magazine, ZYGON - Journal of Religion and Science.*

The June 1971 issue of ZYGON has a series of papers based on the Symposium on Science and Human Values at the 1970 Meetings of the American Association for the Advancement of Science. The paper, "The Larger Cybernetics" by R. B. Lindsay, pp. 126-134, proposes the thermodynamic imperative as an important ethical imperative. Lindsay's emphasis on "order" is challenged by Van Rensslaer Potter in the article, "Disorder as a Built-in Component of Biological Systems The Survival Imperative." Mihaly Csikszentmihalyi in the article, "From Thermodynamics to Values: A Transition Yet to Be Accomplished," questions the usefulness of the debate between Lindsay and Potter.

Our discussions in the local church committee were limited by the failure to find an adequate explanation of the concept of "entropy" for the layman. We concluded that Lindsay's "thermodynamic imperative" is probably a very important principle, but he is devaluing it by using the simplistic translation of "entropy" into "order." The experimental discussions in the local church ended at this point.

At this point the philosophers of science need the cooperation of electrical engineers and computer scientists to resolve this problem. If we modify Lindsay's "Thermodynamic Imperative" as outlined in Section 2.3.2A(CTCM I/3-4, p. 17), we then need a mathematical model to relate the principle to a specific social system. For a first approximation, the probability distribution of a set of messages on a telegraph line is proposed as a trial model.

* Zygon is published by University of Chicago Press , 5801 Ellis Ave., Chicago, Illinois 60637,

A general explanation of how the principle of the "Thermodynamic Imperative" can be used as "A Star To Steer By In A Disconnected Society" is given in Section 1.0.2 of this issue of CTCM. In this discussion the aim is to chose an alternative form of social organization on the basis of decreasing the entropy (or increasing the negentropy or communication entropy).

A calculation of the communication entropy(negative entropy or relative measure of democracy) is tabulated for six hypothetical countries. Then in Section 1.1.1(continued), these results are displayed in graphical form. Also a discussion of the limitations on the validity of these calculations is included. Curves are plotted showing the sensitivity of these entropy calculations to changes in population.

The equations used in the above calculations are described in section 2.3.3, where the gross value of the probability distributions of human freedoms are plotted graphically. The detailed mathematical calculations are outlined in Section 3.2.1(pink pages).

Reprint of Table of Force, Power, and Communication Eras.

Since I have received a number of comments that people had difficulty in finding definitions of the Force, Power, and Communication Eras, I am reprinting the table from CTCM Vol. I, No. 7-8, Jan-Feb 1971, p. 14, on page 2W of this issue following the title page for ready reference.

Fig. 102-1

The Long Range Planning Committee of the San Jose Unitarian Church has considered a number of developments in the Unitarian-Universalist denomination that may influence our future. One development reported in the magazine, ZYGON, published by Meadville-Lombard Theological School in Chicago points to a star to steer by through the complex problems of future -- the "thermodynamic imperative". Professor Lindsay in an article, "The Larger Cybernetics," June 1971, pp. 126-134, says: "...we as individuals should endeavor to consume as much entropy as possible to increase the order in our environment. This is the thermodynamic imperative, possibly not unworthy to rank alongside the categorical imperative of Kant or even the Golden Rule."

The diagram on the right indicates how this principle of the "thermodynamic imperative" can be used to help connect decision processes with ethical values in our disconnected society. An example is given on the next page of how the equations for the analysis of the distribution of messages on a telegraph cable can be used to simulate the functions of a political system in an approximate way that permits calculating the 'communication entropy' so one can apply the "thermodynamic imperative to the social system.

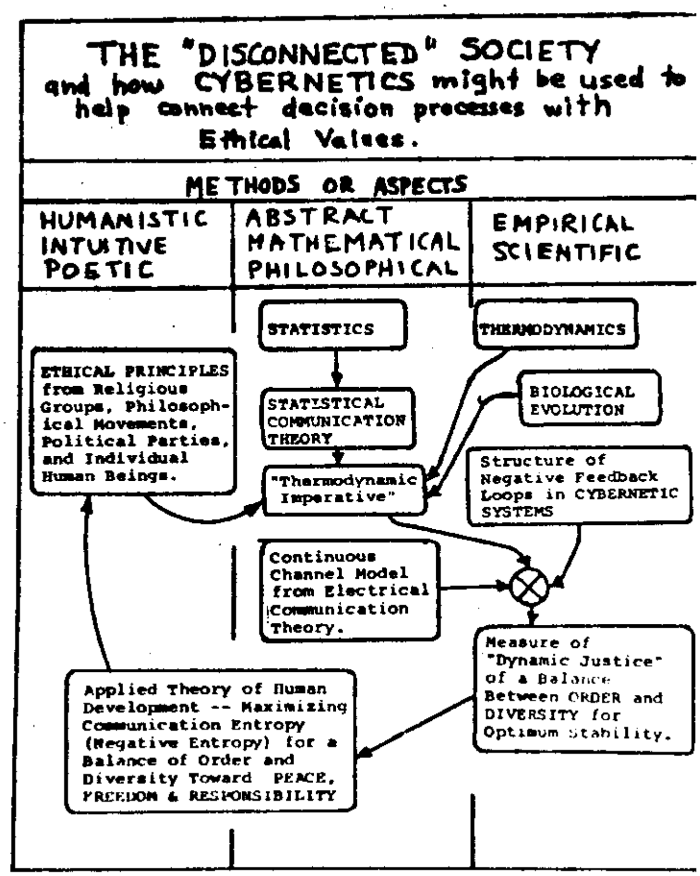


Fig. 102-2

To understand this principle, we need some definitions.

"thermodynamics" is a branch of physics relating to the conversion of heat energy into mechanical energy and vice versa.

"entropy" is a measure of the grade of energy. The lower the entropy, the more accessible the energy is for conversion into useful work.

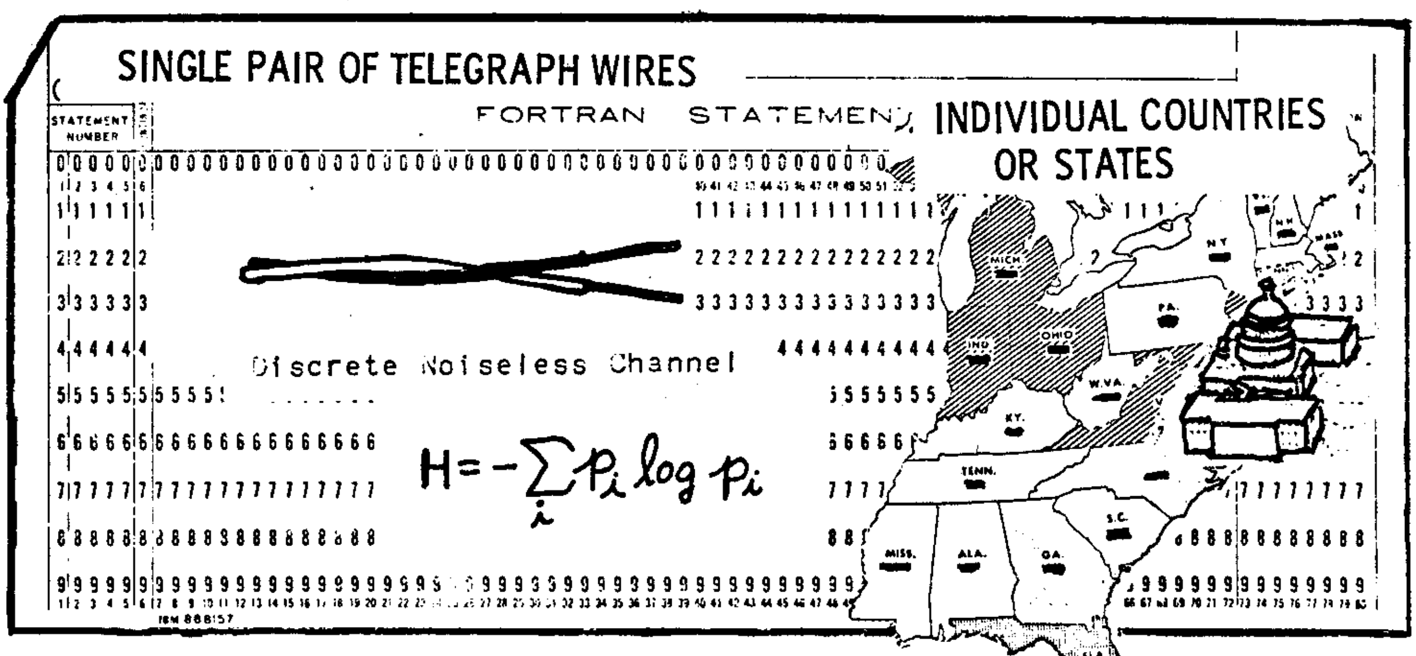
The phrase "consume... entropy" can be interpreted to mean to decrease entropy, or increase "negative entropy," which is sometimes called "negentropy." Professor Fano uses the term "communication entropy" for the negative entropy defined in terms of the probabilities of messages being sent over a telegraph line.

The term "to increase the order in our environment" is confusing to a number of people. Perhaps Lindsay should have said "to increase the communication entropy in our environment." More sophisticated models than the telegraph line model used in this paper correlate increasing the communication entropy with optimizing the balance between order and diversity.

Example of Implimentation of "Thermodynamic Imperative" using an ideal telegraph line:

When a set of human freedoms relating to speech, religion, publication, sex, education, absence of job discrimination, home ownership, voting, trial by jury, and right to establish a small business or farm is treated like a set of telegraph messages such that the corresponding probabilities are substituted into the formula for negative entropy, the relative measure of democracy for six different hypothetical countries come out as follows:

Country A, Ideal Democracy	16.61	Country D, Oligarchy	6.31
Country B, Democracy	16.52	Country E, Caste System	3.25
Country C, Partial Democracy	13.89	Country F, Dictatorship	2.98



Use of the equations for communication entropy of telegraph messages to measure the degree of "democracy" in a country by calculating the negative entropy of a set of human freedoms.

Fig. 102-3

(d) continuation of:
Possible Relationship of Political and Religious Freedom with Maximizing Negentropy.

> Correction: On page 5 of File No. 111(CTCM I/5-6, p. 11) last paragraph should read:
>
> If there is no dominant philosophy, but everyone freely selects a philosophy and each philosophy turns out to have the same probability, then the negentropy of the social system in respect to philosophies would be: $-n(\frac{1}{n}\log(\frac{1}{n})) = \log n$

Since there is possibility of confusion between different entropy-like parameters such as "entropy", "negentropy", and "communication entropy", I plan to plot numerical values graphically with the positive sign for physical entropy in thermodynamics going positive from bottom to top of the paper. The numerical examples of the preceding page(File No. 111-F-10, p. 6) are here plotted using this convention in regard to sign.

There is a certain amount of confusion, even among scientists, as to the proper application of the concept of "entropy" to social systems. I shall carry on further discussions of the validity of the hypotheses involved in Part III of this series. For the present until I find evidence to the contrary, I shall use the convention proposed by Dr. Leon Brillouin in which we define a concept called "negentropy" as the negative of the "entropy" as usually computed by physicists and chemists.(%) A recent article in the Scientific American gives an overview of the concepts of information theory.(¢)

In Fig. 3 on the right, I have plotted entropy increasing from the bottom to the top of the page. Negentropy increases from the top to the bottom of the page. This convention makes it easier to apply the modified thermodynamic imperative. If everything else is equal, we try to work for the system having lower entropy (or greater negentropy).

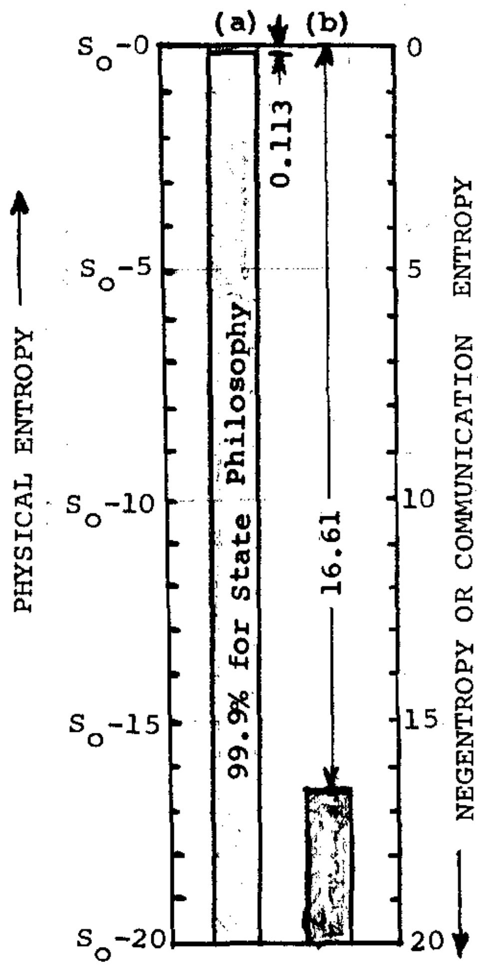


Fig. 3. Comparison of Entropies of City States of 100,000 Population:
(a) Dictator'sPhilosophy
(b) Individual Philosophies

% Leon Brillouin, Scientific Uncertainty, and Information. N.Y.: Academic Press (1964), pp. 8-15.

¢ Myron Tribus and Edward C. McIrvine, "Energy and Information," Scientific American, Vol. 224, No. 3, Sept. 1971, pp. 179--184, 186,188 & bibliog. pp. 244, 246.

The next question is what can we conclude from the relative entropies in Fig. 3? Can we apply Lindsay's "Thermodynamic Imperative" or the "Modified Thermodynamic Imperative" to make a value judgement as to which system is more desirable? For this discussion, see the earlier articles in CTCM on the "thermodynamic imperative." (1,2,3,4,5)

For those who don't have the above back issues of CTCM on hand, I quote Lindsay's Thermodynamic Imperative below:

> "All men should fight as vigorously as possible to increase the degree of order in their environment, i.e., consume as much entropy as possible, in order to combat the natural tendency for entropy to increase and for order in the universe to be transformed into disorder, in accordance with the second law of thermodynamics."

For a preliminary exploration, I am temporarily omitting the problems which lead to the modified thermodynamic imperative, because this simple example can be handled by the original statement satisfactorily. If the only characteristic of significance of the alternative social systems was the entropy, we could quickly refer to the thermodynamic imperative above to see that the one with the lower entropy(or larger negentropy, or larger communication entropy) would be preferred in order to carry out the principle of the thermodynamic imperative.

Now we must remember that our computation of entropy consisted of the representation of a sociological system by a mathematical model. When a mathematician represents a real physical system by a mathematical model, he first asks if there is a completeness theorem which proves that the mathematical model can in fact represent the physical system with less than a specified error. (For a brief discussion of "completeness" see Henry Margenau and George M. Murphy, The Mathe-matics of Physics and Chemistry, N.Y.: D. Van Nostrand(1943) pp. 242-243.)

1. CTCM Section 2.3.2: "Ethics and the Thermodynamic Imperative," Vol. I, No. 1-2, June-July 1970, pp. 23-24(File No. 232, pp. 1-2)
2. CTCM Section 2.3.2A: "Modification of the Thermodynamic Imperative," Vol. I, No. 3-4, Aug-Sept 1970, p. 17(File No. 232, p. 3)
3. CTCM Section 2.3.2B: "Letters on the Thermodynamic Imperative," Vol. I, No. 3-4, Aug-Sept 1970, pp. 17-18(File No. 232, PP. 3-4)
4. CTCM Section 2.3.2C: "An Example of the Modified Thermodynamic Imperative," Vol. I, No. 3-4, Aug-Sept 1970, pp. 19-22(File No. 232, pp. 5-8)
5. CTCM Section 3.3.0: "Status of Entropy, Information and Related Concepts in the Physical, Biological and Social Sciences," Vol. I, No. 1-2, June-July 1970, pp. 27-28(File No. 330, pp. 1-2)

Our next task is to find a completness theorem which would show us whether our mathematical model can accurately represent such sociological systems. My search initially ended in failure. The best authorities I could find said it is practically impossible to prove a completeness theorem in such a case. I quote one authority below: Dwight T. Ingle, Professor of Physiology, University of Chicago, says in an article, "Uncertainty as a Parameter of Ethics," in ZYGON - Journal of Religion and Science, published by University of Chicago Press and Meadville-Lombard Theological School, Vol. 3, No. 3, Sept. 1968, pp. 323-334, says:

> "It is one of the implications of a review of cause-and-effect relationships that it is theoretically as well as practically impossible to prove the completeness of any mathematical or physical model of a living or social system." p. 329

From the above and other similar statements, I concur in the inability to develop a completeness theorem.

The next step in our quest is to find how to properly apply entropy calculations to sociological systems without the certainty of a completeness theorem. I propose in lieu of having a completeness theorem, that we make a search for all possible relevant factors over a chart of phenomena-methods-activities, such as is shown in the figure in an earlier article on social responsibility.(6) A careful scan over all three dimensions of the diagram in reference 6 led to a tabel of possible parameters that need to be considered in addition to the entrppy for different levels of social systems. These parameters are listed in reference 5 and in Table II, below:

Table II. List of Relevant Parameters.

Energy/Mass(Population)
Feedback
Structure
Bonds between Elements
Growth/Evolution
Metabolism
Reproduction
Dependence of Species
Learning Processes
Individual Development
Symbols/Language
Organization
Division of Labor

6. CTCM Section 2.3.1: "Social Responsibility of Engineers," Vol. I, No. 9, March 1971, pp. 11-16, esp. Fig. 7 on p. 16(File No. 231, pp. 1-6)

The significance of these parameters in Table II is that we cannot accurately compare two social systems by computing their negentropies, unless we either take into account these thirteen parameters, or know that they are the same for the two social systems being compared. To illustrate how the negentropy of social systems vary with the population base, I have plotted the negentropy of a dictatorship and an ideal democracy for different populations in Fig. 4. These calculations are based on an analysis of the probabilities of people having the ten different freedoms described in Section 2.3.3.

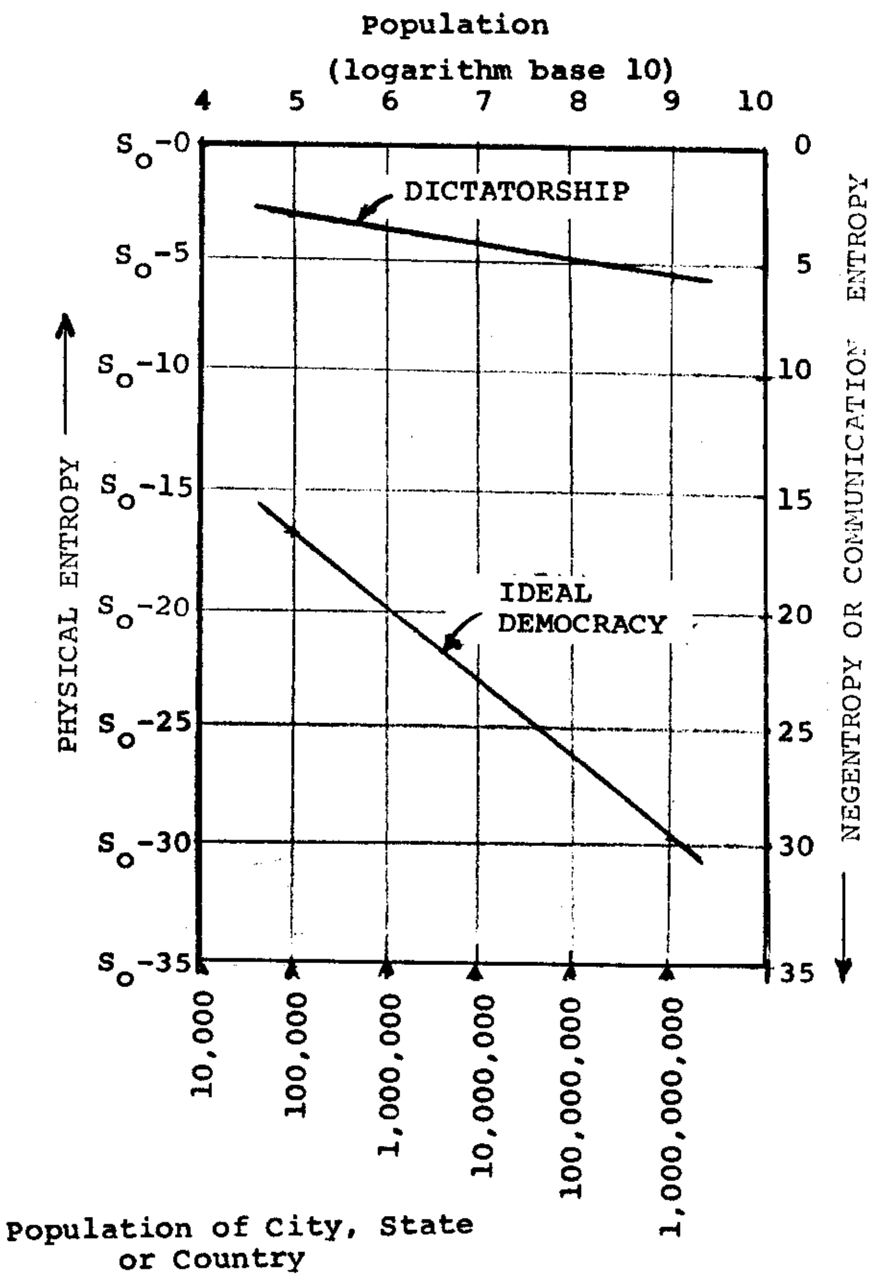
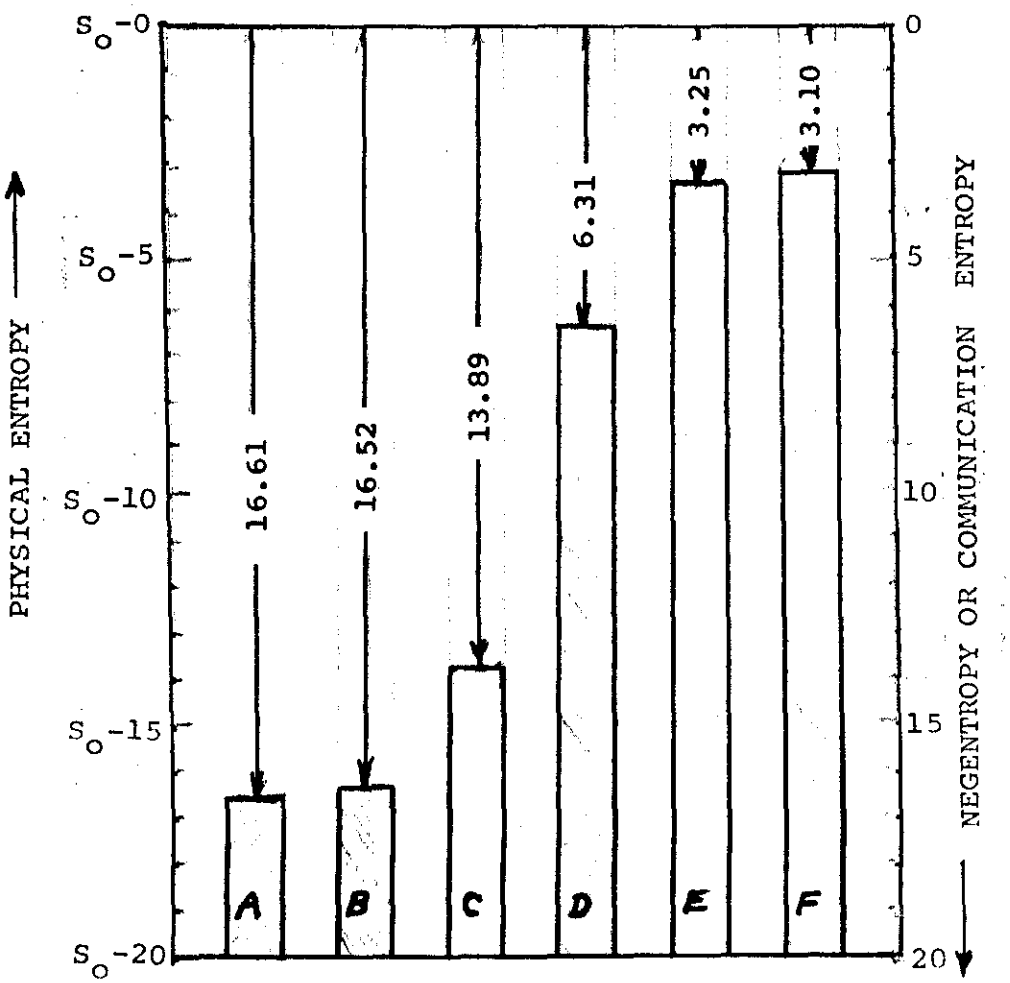


Fig. 4 - Variation of the Negentropy of a Dictatorship and an Ideal Democracy for fixed distributions of human freedom with large changes in population.

Subject to the limitations imposed by the state of our knowledge of the parameters listed in Table II, we can apply the modified (*) thermodynamic imperative to make a relative value judgement between a dictatorship and a democratic country of the same population. This particular model doesn't tell us about the stability of the country. The democratic country might be an ideal democracy, but not have the strength to defend itself against attack from a dictatorship. As we develop this method of analysis, we will have to include more details, so that we can balance the degree of democracy with the ability to survive. A more sophisticated model will be developed in a future issue CTCM.

For the next step, we examine what we can do with this model in the way of calculating the negentropy of various types of governments between the dictatorship and the ideal democracy. In section 2.3.3 of this issue of CTCM six different distributions of the average probabilities of a set of human freedoms for a dictatorship, caste system society, oligarchy, a partial democracy with severe discrimination, a partial democracy with limited discrimination, and an ideal democracy. The negentropy of each system is calculated and the results are summarized in Fig. 5 below.



* See note at bottom of next page.

Fig. 5 - Comparision of Entropies of City States of 100,000 Population for Cases A through F.

(A) Ideal Democracy
(B) Democracy
(C) Partial Democracy
(D) Oligarchy
(E) Caste System
(F) Dictatorship

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 it may be possible to use the calculation of negentropy for cases where we do not have reliable common sense references.

Another significant feature visible in Fig. 5 is that a democratic country (Case B) can have an appreciable portion of its population with seriously curtailed freedom, provided the restrictions are based on an individual basis related to individual performance and are determined by due process of law. For example, comparing Case A and Case B, restricting 10% of the population on the basis of individual tests or individual trials under due process increases the entropy by 0.5%(decreases negentropy by 0.5%), while the placing of similar restrictions on people as a group(not as individuals) on the basis of race, color, or national origin instead of individual performance increases the entropy16.4%(decreases negentropy by 16.4%).

* The modified thermodynamic imperative(from CTCM I/3-4 p. 19) is:

> All men should fight always as vigorously as possible to optimize the order-diversity balance in their environment, i.e., consume as much entropy as possible, in order to combat the natural tendency for entropy to increase and for order in the universe to be transformed into disorder, accordance with the second law of thermodynamics.

This section is adapted from part of a paper presented at The First International Congress of Social Psychiatry, London, United Kingdom, August 17-22, 1964, "A General Systems Theoretic Model for the Estimation of the Negentropy of Sociological Systems Through the Application of Two Isomorphic Electrical Communication Networks." If I were presenting the same material now, I would change the title to indicate the relationship to two communication channel models, namely the discrete channel and the continuous channel.

More detailed calculations for these examples were given in a paper presented at the Society for General Systems Research Annual Meeting in cooperation with the American Association for the Advancement of Science, Section L, History and Philosophy of Science, Cleveland, Ohio, December 27, 1963, "Negentropy and the Concepts of Freedom, Democracy and Justice."

Sample numerical calculations of these cases are included in Section 3.2.1.

Objective: Develop a static measure of democracy in a set of countries using the negentropy of the probability distributions of human freedoms in the countries.

The possibility that entropy from thermodynamics might belong both to the family of measurable quantities of science and the family of values such as beauty and melody was suggested in 1928 by Eddington. (1) At the same time Leo Szilard was thinking about the quantitive relationship between the entropy lost by a gas and information gained by a hypothetical "Maxwell's demon," (2) opening and shutting the door between two compartments to separate the high- and low-energy particles of a gas. (3) Dr. Szilard's paper was relatively unnoticed until the development of the mathematical theory of communication by Shannon (4) in 1948, which became known as Information Theory, and the partially overlapping concepts of Cybernetics developed by Norbert Wiener. (5-6)

Biological systems preserve or increase order, decreasing entropy in a limited domain (7), even though over a larger domain entropy is increased in accordance with the Second Law of Thermodynamics. The units of information are related to both the life process and to negative entropy in thermodynamics. (8) Physically entropy can be defined as:

$$S = k \ln P, \quad [1]$$

where k is the Boltzman constant, "ln" means logarithm of, and P is the number of elementary states of the system.

Negentropy in Information Theory, a branch of electrical engineering and mathematics, in respect to a set of n messages is:

$$H = -(P_1 \ln P_1 + P_2 \ln P_2 + \ldots\ldots\ldots + P_k \ln P_k + \ldots\ldots + P_n \ln P_n) \qquad [2]$$

where P_k is the probability of occurrence of message K. For a basic discussion of these concepts see Colin Cherry, On Human Communication (9) or J. R. Pierce, Symbols, Signals and Noise. (10)

If we take the formula for information or negentropy of a set of telegraph messages or computer instructions and substitute a set of n philosophical systems (or political systems) in place of the n messages or instructions, the probabilities of occurrence of the respective philosophies among the population of a country assumes a role analogous to the probabilities of occurrence of the n messages.

If one philosophy is required as the official philosophy by order of a dictator and this philosophy is number "k," then:

$$H = -(Oxl + Oxl + \ldots\ldots\ldots + lxO + \ldots\ldots + Oxl) =). \qquad [3]$$

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" of the evolution toward a higher order of life. If we go back to equation [2] to see under what conditions there is a maximum contribution to the negentropy or "life process," we find when all P_i's are equal such that $P_i = 1/n$ is the condition for maximum H. A curve for a sample case is included in Appendix I. Under these conditions $H = \ln n$. This corresponds to equal probability for each different philosophy, a condition approximating a democracy, provided that n is not so high that no decisions can be made by the country.

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 and the range of values to be expected in different political systems. Since such information is not presently accessible to me, I shall assume the following ten kinds of human freedom to have equal weight in order to obtain some trial calculations. See Table I for the list of freedoms.

This analysis is a test of an hypothesis as to the analogy between "negentropy" and "democracy." At this stage it is incomplete, because of the lack of independent data. Our objective is 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 a 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 sophisticated analyses of political scientists and sociologists, we can accept the hypothesis until another hypothesis is found that gives better agreement with the available facts.

TABLE I.

ASSUMED COMPONENTS OF HUMAN FREEDOM

Number (j)	Description
(1)	Freedom of speech
(2)	Freedom of religion
(3)	Freedom to print, broadcast, televise and listen
(4)	Freedom to find sexual partner
(5)	Freedom to obtain education
(6)	Freedom from job discrimination on account of race, religion, or origin
(7)	Freedom to build or buy own home
(8)	Right to vote
(9)	Right to trial by jury
(10)	Freedom to establish small business or farm

Hypothesis One: The negentropy of a sociological system can be approximated by calculating the negentropy of a set of messages that might be sent over equivalent pair of wires such that the sociological system corresponds to the discrete communication channel in Information Theory, in which case the set of human freedoms in the sociological system correspond to the set of messages sent over the isomorphic electrical communication network.

The mathematical formula is obtained by replacing H in equation [2] by D and P_i by G_i, so we have:

$$D = -\left[G_1 \ln_2 G_1 + G_2 \ln_2 G_2 + \ldots\ldots + G_k \ln_2 G_k + \ldots + G_n \ln_2 G_n\right]. \qquad [4]$$

with the restraint that:

$$G_1 + G_2 + G_3 + \ldots\ldots + G_k + \ldots\ldots + G_n = 1.000 \qquad [5]$$

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. The negentropy measures of "democracy" for each of six hypothetical countries of 100,000 population each have been calculated and are listed in Table II.

The probability of individuals having a specified set of freedoms is plotted in Figures 4-A, ... through 4-F for the types of governments indicated.

The parameter, "probability*", is the averaged probability that an individual or class of individuals have a set of human freedoms, divided by the number of individuals in the city state, in Figs. 4-A and 4-B.

In Figure 4-C, the term "probability*", is the probability that an individual or class of individuals have a given set of freedoms divided by the number of individuals or the number of classes, as the case may be.

The numerical calculations for these curves are summarized in Section 3.3.1.

There are two scales for number of people in Fig. 4-C. The scale of one to 80,002 is a combination of 80,000 individuals plus 2 classes of 20,000 individuals each. Within these two discriminated classes the solid line is the probability divided by the class, and the dotted lines are the probabilities divided by the number of people in the class.

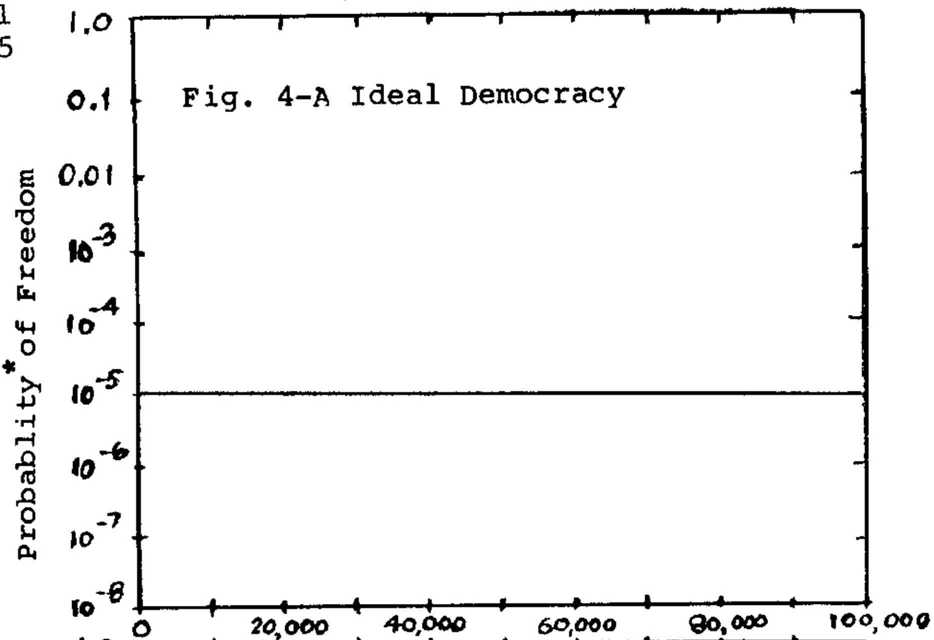


Fig. 4-A Ideal Democracy

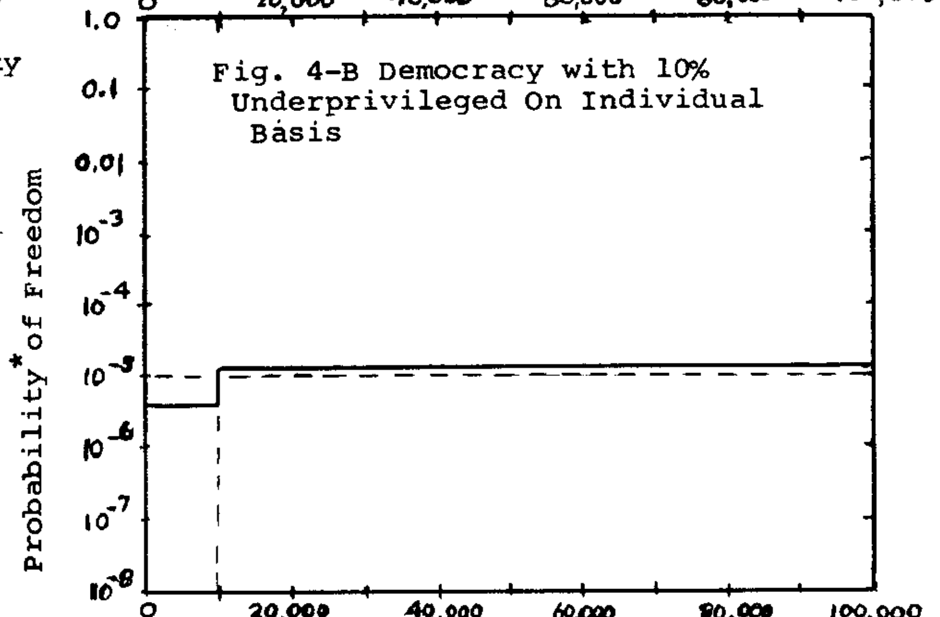


Fig. 4-B Democracy with 10% Underprivileged On Individual Basis

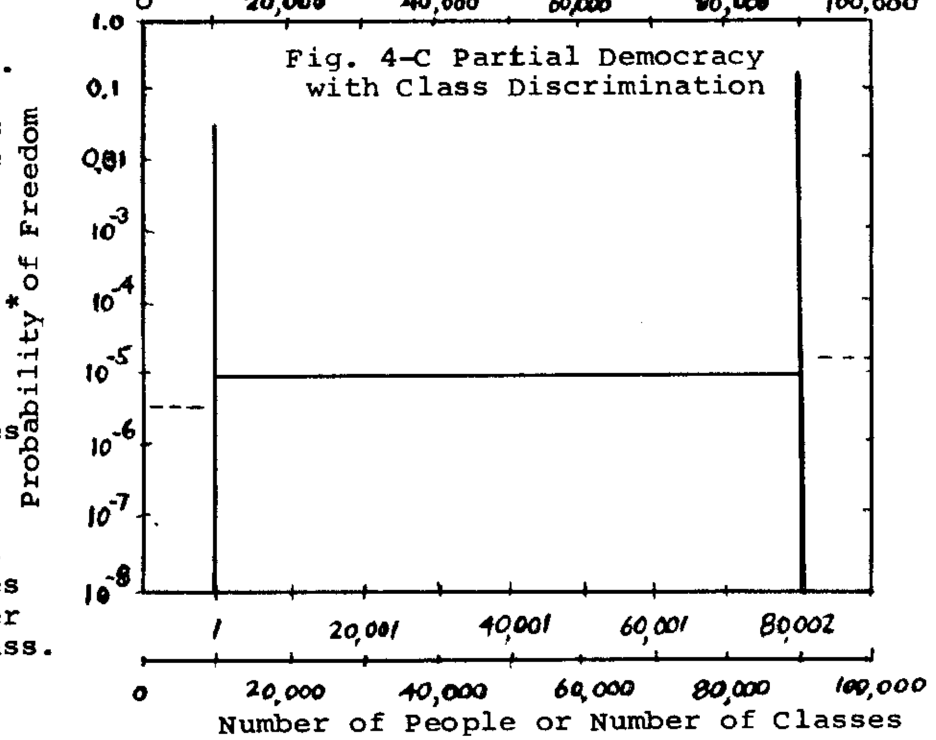


Fig. 4-C Partial Democracy with Class Discrimination

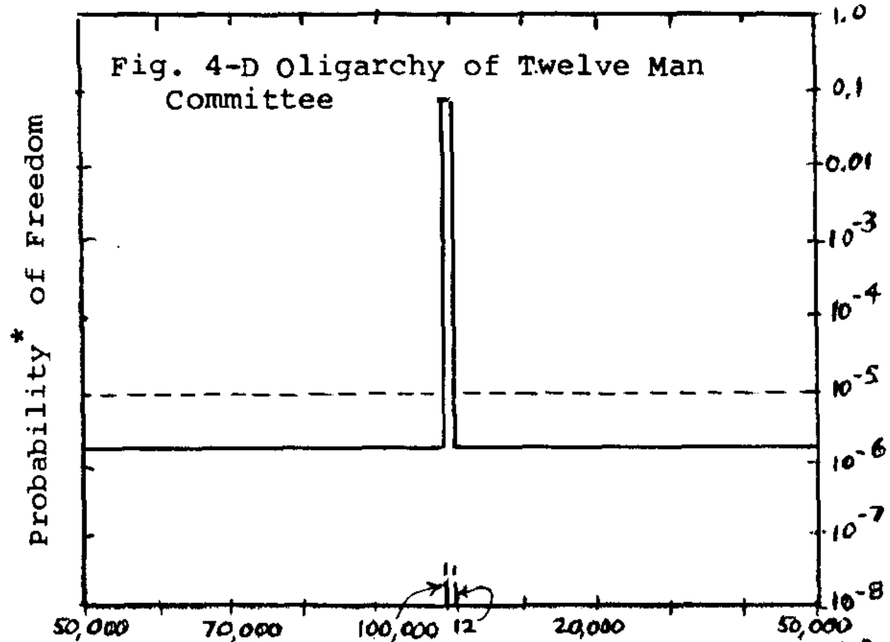


Fig. 4-D Oligarchy of Twelve Man Committee

The solid lines in Fig. 4-D represent the probability distribution of freedom in an oligarchy controlled by a group of twelve men. The dotted line represents the freedom distribution for an ideal democracy for comparison.

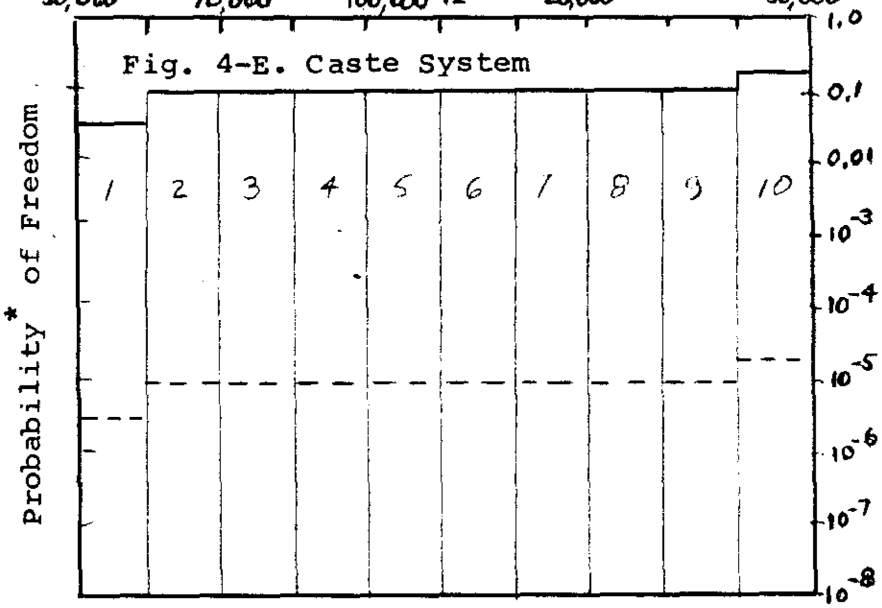


Fig. 4-E. Caste System

The dotted lines in Fig. 4-E represent the the distribution of freedom normalized by the number of individuals in the city-state. The solid lines represent the distribution of freedom by groups(castes).

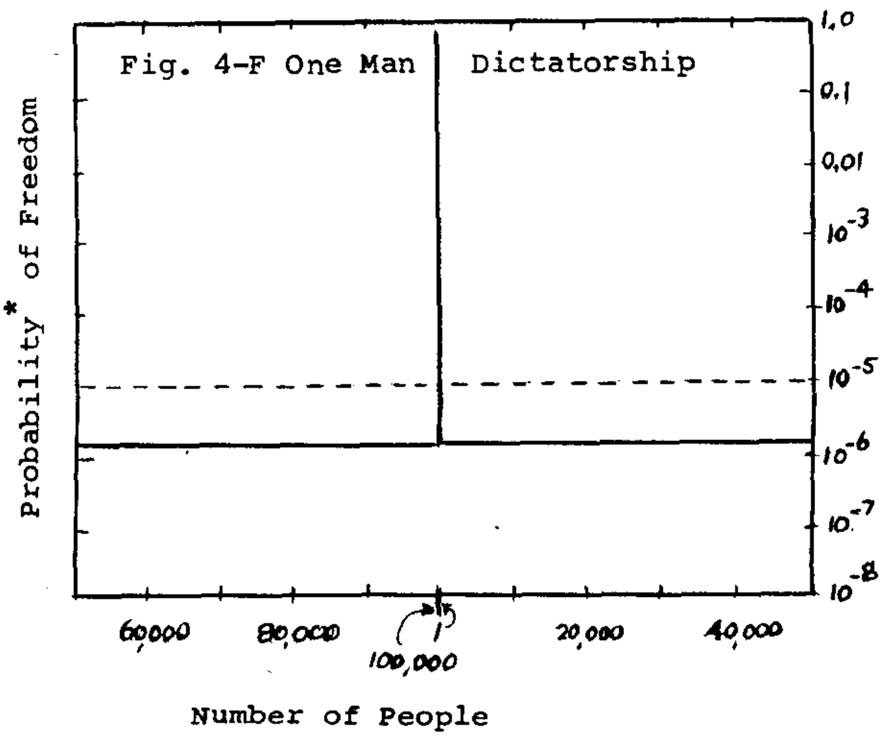


Fig. 4-F One Man Dictatorship

The spike in the center of Fig. 4-F represents the relatively greater freedom held by the dictator compared to the solid horizontal line representing the freedom of the people in the dictatorship. The dotted line represents the freedom distribution in an ideal democracy for comparison.

Study of Table II 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 "freedoms" G_i . These functions are defined and sample calculations tabulated in Appendix I.

Another feature is that a democratic country like case B can have an appreciable portion of its population with seriously curtailed freedom, provided the restrictions are based on an 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 origin instead of individual performance reduces the negentropy by 16.4%.

Comparison of Countries E and F indicates that a rigid caste system or a one man dictatorship knocks the negnetropy 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. This may also have relevance to centralized business and governmental agency accounting systems.

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.

Since the hypothetical countries were all taken to have a population of 100,000 each, it is desirable to be able to extend these results to other size countries. Values for countries A and F over a large range of population change are listed in Table III.

The model studied in this section based upon a pair of electrical wires using the discrete noiseless channel viewpoint from Information Theory gives us a good estimate of the negentropy or "democracy," but does not give an indication of the countries ability to withstand attack by external and internal enemies. In the next section another electrical communication network will be considered that will include a measure of the stability of the system.

Table II. Negentropy of City-States of 100,000 Population.

Case	Type of Government	Negentropy	Negentropy Case X/Case A
A	Ideal Democracy	16.61	100.0%
B	Democracy with 10% underprivileged on individual basis	16.52	99.5%
C	Partial Democracy with class discrimination	13.89	88.6%
D	Oligarchy of twelve man committee	6.31	38 %
E	Caste system	3.25	19.5%
F	Dictatorship	3.10	18.7%

Table III. Negentropy of Cities-States-Nations of Different Populations for Dictatorships and Ideal Democracies

	Negentropy	
Population	Dictatorship	Democracy
100,000	3.10	16.61
1,000,000	3.52	19.92
10,000,000	4.10	23.24
100,000,000	4.60	26.56
1,000,000,000	5.10	29.88

References:

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2. Description of "Maxwell's Demon" in THERMODYNAMICS article in Encyclopaedia Britannica, 1945 edition, p.22-108C.

3. L. Szilard, "Uber die Entropieverminderung in einem Thermo-dynamischen System bei Eingriffen Intelligenter Wesen," Z. Physik, 53, 1929, p. 840. Discussed on p. 50 of ref. 36.

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(a) NEGENTROPY OF A SET OF FREEDOMS IN A SOCIOLOGICAL SYSTEM

Detailed calculations and assumed values of freedom used in the calculations are listed and discussed in this appendix. The list of freedoms used in the calculations are defined in Table II.

TABLE II.

ASSUMED COMPONENTS OF HUMAN FREEDOM

Number (j)	Description	Democratic Ideal Value
(1)	Freedom of speech	0.1
(2)	Freedom of religion	0.1
(3)	Freedom to print, broadcast, televise and listen	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 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
	Total F =	1.0

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. For example, if a dictator reduces the freedom of his subjects to 0.5 each and there are 100,000 people under his control then the dictator's freedom is $F_1 = 50,001$.

To obtain a measure of freedom that behaves like a probability function, we define a normalized "freedom" function, G; to be substituted in equation [4],

$$G_i = F_i / n, \qquad [9]$$

where n is the population of the country sub-system. In the above case the normalized freedom for each subject is $G_i = 0.000005$ and that of the dictator $G_1 = 0.5$, i.e. the dictator has 100,000 times the freedom of a subject of his. The distributions of freedoms used in these calculations are tabulated in Table III.

TABLE III.

DISTRIBUTIONS OF FREEDOMS USED FOR SAMPLE CALCULATIONS OF NEGENTROPY

population of 100,000

Country A $F_i = 1.0 \qquad G_i = 1.0 \times 10^{-5}$

Country B

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
	$F_1 = \overline{0.34}$	$F_2 = \overline{1.072}$
	$G_1 = 0.34 \times 10^{-5}$	$G_2 = 1.072 \times 10^{-5}$
	$0.10 \times 0.34 = 0.034$	$0.90 \times 1.072 = 0.966$

Country C

	j	Group 1 (10%)	Group 2 (80%)	Group 3 (10%)
	1	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
		$F_1 = \overline{0.34}$ 10%	$F_2 = \overline{1.0}$	$F_3 = \overline{1.66}$ 10%
Class		$G_1 = 0.034$	80 out of 100,000	$G_3 = 0.166$
Individual			$G_2 = 1.0 \times 10^{-5}$	

Groups 1 & 3 are considered as classes, not by individuals, while Group 2 is treated by individual case.

TABLE III (cont.)

DISTRIBUTIONS OF FREEDOMS USED FOR SAMPLE CALCULATIONS OF NEGENTROPY

Population of 100,000 each country.

Country D	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
		$F_o = 7001.0$	$F_p = 0.16$
		$G_o = 0.07001$	$G_p = 0.16 \times 10^{-5}$
		$12 \times 0.07 = 0.84$	$10^5 \times 0.16 \times 10^{-5} = 0.16$

Country E				
	Caste 1	$F_1 = 0.34$	G_1 (class) = 0.034	10%
	Castes 2 -9	$F_i = 1.0$	G_i (class) = 0.10	10% each
	Caste 10	$F_{10} = 1.66$	G_{10} (class) = 0.166	10%

Country F	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
		$F_1 = 85,000$	$F_i = 0.15$
		$G_1 = 0.85$	$G_i = 0.15 \times 10^{-5}$

Using the equation: $$D = -\sum^{n} G_i \log_2 G_i \qquad [10]$$

with the restraint: $$\sum^{n} G_i = 1.0 \qquad [11]$$

we now calculate the degree of democracy (negentropy) for each of the hypothetical countries for which we have distributions of freedoms in Table III.

Country A (Ideal Democracy):

$$D_A = -100{,}000 \times 1.0 \times 10^{-5} (\log_2 10^{-5}) = 16.61 \text{ entropy units}$$

Country B (Democracy with some underprivileged groups):

$$D_B = -10{,}000(0.34\text{x}10^{-5})\log_2(0.34\text{x}10^{-5}) +$$
$$-90{,}000(1.072\text{x}10^{-5})\log_2(1.072\text{x}10^{-5}) =$$
$$= 0.34(18.17) + 0.966(16.51) = 0.61 + 15.92 = 16.52 \text{ entropy units}$$

Country C (Partial Democracy with Class Discrimination):

$$D_C = -1.0(0.034)\log_2(0.034) + \quad \text{⟨one class of 10,000 individuals}$$
$$-80{,}000(10^{-5})\log_2(10^{-5}) + \quad \text{⟨80,000 individuals}$$
$$-1.0(0.166)\log_2(0.166) = \quad \text{⟨one class of 10,000 individuals}$$
$$= 0.034(4.88) + 0.8(16.61) + 0.166(2.59) =$$
$$= 0.166 + 13.3 + 0.431 = 13.90 \text{ entropy units}$$

Country D (Oligarchy):

$$D_D = -12(0.07)\log_2(0.07) + \quad \text{⟨12 leaders of the oligarchy}$$
$$-99{,}998(0.16\text{x}10^{-5})\log_2(0.16\text{x}10^{-5}) = \quad \text{⟨99,998 subject people}$$
$$= 0.84(3.84) + 0.16(19.255) = 3.23 + 3.08 = 6.31 \text{ entropy units}$$

Country E (Caste System):

$$D_E = -1.0(0.034)\log_2(0.034) + \quad \text{⟨one low caste}$$
$$-8.0(0.1)\log_2(0.1) + \quad \text{⟨eight middle castes}$$
$$-1.0(0.166)\log_2(0.166) = \quad \text{⟨one high caste}$$
$$= 0.034(4.88) + 0.8(3.32) + 0.166(2.59) =$$
$$= 0.166 + 2.65 + 0.431 = 3.25 \text{ entropy units}$$

Country F (Dictatorship):

$$D_F = -1.0(0.85)\log_2(0.85) + \quad \text{⟨one dictator}$$
$$-99{,}999(0.15\text{x}10^{-5})\log_2(0.15\text{x}10^{-5}) = \quad \text{⟨99,999 people}$$
$$= 0.85(0.236) + 0.15(18.506) = 0.200 + 2.78 = 2.98 \text{ entropy units}$$

Question 13: How can we use these concepts from cybernetics and information theory now?

A list of thirteen problem areas where these concepts have potential application can be found in CTCM Vol. I, No. 12 in Section 1.1.5. Some progress has been made in the first ten items on the list. References are given in the issue of CTCM mentioned above. The ten problem areas are repeated below by title only:

(1) Develop a better understanding of social evolution.

(2) Measure the degree of democracy in a social system.

(3) Improve our understanding of the potential for social change in a social system.

(4) Measure the degree of stability in a social system.

(5) **Analyze** the inter-industry relationships in a country or region.

(6) Develop better understanding of political and economic systems through analysis of their feedback loop structure.

(7) Develop better understanding of business and political systems through computer simulation of major functions.

(8) Development of computer based aids to management systems.

(9) Simulate the impact of the population explosion.

(10) Keep track of unbalance in the ecological environment.

Question 14: You are starting from abstract ideas and then trying to apply them to social problems. Can you not find a way to start with more direct human problems involving human feeling, and then look for ways to use abstract concepts to help solve these problems involving direct human feeling?

My answer to this is that direct human feelings are involved in these analyses, but that their interaction has probably **occurred more** actively on a subconscious level in the process of "technological meditation." I will try to bring some of these interactions up to the verbal level and relate them in a future issue of CTCM.

Question 15: Why can't you provide a simple explanation of "entropy" for the layman?

I am attempting to develop a simple explanation of "entropy" for the layman, but find that it is difficult. A university physics professor tells me that it is difficult to get the fine distinctions involved in understanding "entropy" across to college seniors. Also there is some confusion between philosophers and scientists in the interpretation of entropy in regard to some applications.

Question 16: Why can't you improve the format of COMMUNICATION THEORY in the CAUSE of MAN, by typing the material double-space? It would be easier to write comments and suggested changes, if the articles were double spaced.

Where possible, I will change to space-and-a-half to allow space for comments. Where sections have already been typed in single space format and can be used as is, I shall use the single space material to save time and expense.

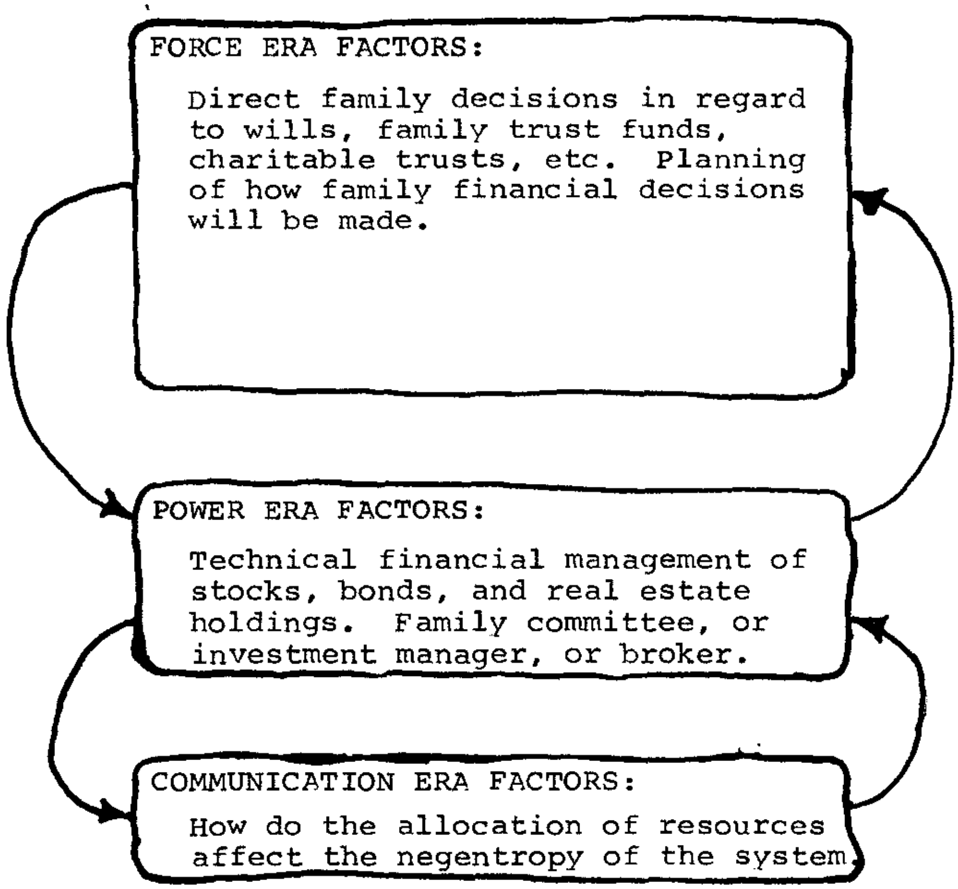
Question 17: Why can't you provide more definitions in CTCM? Many of the words are either not defined in ordinary dictionaries, or are used in a special technical way that doesn't seem to be covered by the primary dictionary definition.

I am planning a glossary for inclusion in a future issue of CTCM.

Question 18: How can we use the concepts in CTCM to develop a more relevant investment policy?

I think the direction to go is to examine whether our present investment policies take into account force era, power era, and communication era factors. It appears that typical investment policies only consider force era and power era factors. We need to develop means of evaluating the impact of corporations on the entropy of the total social system. A few investment management organizations have started evaluating social priorities. Calculations of the entropy of social, political, and economic systems may make it easier to more systematically rate social priorities.

As a first approximation to how an individual should apportion his effort in developing an adequate investment policy, the following diagram is proposed. The area of the rectangles are roughly proportional to the amount of attention needed by the Force Era, Power Era, and Communication Era factors.



The stage of social evolution of our industrial society has brought our social-economic system to a state of complexity such that if one decides under 'Force Era' factors that one wants to maximize the estate available for the next generation, it is no longer sufficient to find a good investment manager for the 'Power Era' factors, To insure that the system doesn't go down the drain like ancient Greece and Rome, one must examine principles like the 'thermodynamic imperative' to see how one can find decisions which help increase the 'communication entropy.'