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NEW YORK, NEW YORK 10027

DIVISION OF PHILOSOPHY,
THE SOCIAL SCIENCES, AND EDUCATION

Robert McClintock
Box 136
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Lawrence A. Cremin, President
Teachers College, Columbia University

Dear Larry:

Belatedly, I am following-up on our conversation of last summer in which I mentioned certain technical ideas that have occurred to me and that may be significant relative to the growing expense of energy. As I said in that conversation, the ideas may be worthless or they may be of vast value. The more I have worked on them, the more convinced I am that they are at least in part sound, and if they are worth developing, I would like to see it done through an arrangement with Teachers College and Columbia University whereby the former institution would receive 35% of eventual royalty proceeds, the latter 35%, a foundation of my designation would receive 10%, I or my estate would retain 10%, and the other persons who might substantively work on the development of the ideas would share the remaining 10% of the rights. I would expect that formal arrangements governing such an allocation of rights would be made by lawyers for Teachers College and Columbia, subject to my agreement. And should it become probable that the amount of royalties that might come to Teachers College and Columbia under such assignment of rights was to be substantial, I would expect to specify in the agreement certain intents concerning the spirit in which the funds should be used by those institutions.

My purpose in this letter, however, is not primarily to set specifications for these arrangements. As you suggested, before that be done, I am seeking to ascertain through the School of Engineering whether there is any probability that the ideas will pay off. Accordingly, I have spoken to Dean Likins of the CU School of Engineering, and he has suggested that I talk with Professor William W. Havens, Jr. who heads their energy development projects. Since Teachers College will have a major stake in the ideas should they prove of value, it seems to me desirable to provide the College with a basic account of them prior to that conversation, especially since writing that basic account will help me be clear in the conversation.

By way of introduction, let me say that, in what follows, I write as a common sense inventor. In the past I have shown very high aptitude in natural science, but I have chosen to develop my professional career as a humanistic scholar. I have studied a certain amount of the history and philosophy of science and more or less keep up as a layman with scientific and technological developments, but I have only an informed layman's acquaintance with physics and although adept mathematically, I lack the formal training that would allow me to develop detailed designs for the ideas I am advancing. Hence, in what follows, I will explain as best I understand it the design problems I am addressing, and the basic principles of the solutions I am proposing. Owing to my lack of formal training, my vocabulary may be rather non-standard in the explanations; I hope however that my explanations will be clear to the willing reader. Since this letter is very long, let me give a brief summary of its contents to aid the reader. The letter is in two parts, the first dealing with the efficiency of rotary electric motors and generators, the second with the efficiency of converting heat from fossil, atomic, or solar sources to useful work, especially for the generation of electricity.

Part I: Parallel-axis, non-cyclic electric motors and generators.

Pages 4-7: Here I suggest a configuration for generators and motors that will allow all the coil to interact with all the magnetic field at a right angle all of the time. Such a configuration should produce significant marginal improvements in the efficiency of electric motors.

Pages 8-11: Here I suggest that a right angle movement by a coil in a magnetic field, although the best interaction so far attained for moving coils, is not as effective an interaction as that utilized in alternating-current transformers, and I set the goal of finding a configuration for rotary generators and motors that allows the functional equivalent of the transformer interaction.

Pages 11-16: Here I reflect on an elementary explanation of the phenomena of induction based on the explanations of classical physics in search of a way to configure a generator and motor so that a functional equivalent of the transformer interaction can be attained. From these reflectiona I suggest a strategy for reaching this goal, but do not pursue it fully because the explanation of induction seems to me faulty.

Pages 16-26: Here I construct a speculative account of what might be occurring in the processes of induction on the level of molecules in the conductor and on the basis of this hypothesized explanantion of induction I derive certain design principles which might permit configuring motors and generators so that the interactions between their magnetic fields and coils would approach being the functional equivalents of those in transformers.

Pages 26-37: Here I describe the basic prototypes of generators and motors that could be built according to these principles. If these were to work, the electrical input for a given electrical output for rotary generators could be cut up to a factor of one half and for motors the output from a given input could increase by up to a factor of two.

Part II: Isothermal, isobaric, hydraulic drive condensing engines.

Page 38: Here I note that a thermally efficient engine that could use steam at low temperatures as a source of work would be advantageous and that, whereas Carnot's cycle presumes an ideal gas and that steam is not such a gas, carrying most of its heat as latent heat, a steam condensing engine might be as efficient as a steam expansion engine.

Pages 39-43: Here I describe the basic components necessary for a large isothermal, isobaric, hydraulic drive condensing engine and work out principles for maximizing its thermal efficiency, showing that this will depend primarily on the density of the hydraulic fluid used.

Pages 43-44: Here I briefly outline how such an engine might be designed to derive most of the heat it requires from solar energy.

Pages 45-46: Here I note that since the density of the hydraulic fluid primarily determines the thermal efficiency of the condensing engine, mercury might be the best hydraulic fluid for it, and that since mercury is a reasonably good conductor, it might be advantageous to attempt to make a fluid-coil generator an integral part of a condensing engine. I describe how such a generator might be built using the basic principles of classical physics for moving coils in a straight magnetic field.

Pages 46-54: Here I note that the movement of fluids differs from that of solids and that as a consequence a fluid-coil generator designed according to the principles of solid-coil generators might be very inefficient. I suggest that in a fluid conductor a magnetic pressure from surrounding magnets all of the same pole might cause negative charged particles in the conductor to move, and, on the untested assumption that such pressure will induce movement in charges, I then design, using concepts of pressure, which seem appropriate to fluids, a generator housing that will organize the moving charges into flowing currents, and I attempt to deduce from this mental construction what the classical principles of operation would be for such a fluid-coil, magnetic-pressure generator and finally I indicate what kind of work an isothermal condensing engine driving it would need to do.

Pages 54-58: Here I try to work out the potential thermal efficiency of an isothermal, isobaric, hydraulic drive condensing engine driving a fluid-coil generator. I find that the primary work cycle would allow a nearly direct conversion of the latent heat of steam condensed in the engine to electrical output, a part of which would be needed to run the magnetic system of the generator. Heat lost through the secondary work cycles of the engine would be a very small percentage of the total heat output. Depending on the efficiency of boilers, the heat equivalent of the electricity generated and available for use might amount to a very high percentage of the heat value of the fuel used to drive the system.

Pages 58-60: Here I close with certain reflections on a theory of "enclosed engines." I suggest that the technology of the industrial revolution has depended on the ability to link engines; future technology will increasingly seek to enclose engines inside one another, insofar as possible, for such enclosure avoids the problem of compound inefficiencies.

Part I: Parallel axis, non-cyclic, rotary generators and motors

My first set of ideas pertains to electric motors and generators, and I shall call the devices I am proposing parallel axis, non-cyclic, rotary generators and motors. I will propose two types of these, a plain type, adapting established principles of motor and generator design, producing incremental but significnat efficiencies, and a speculative type, using principles of design so far, to my knowledge, only utilized in the design of transformers, producing, if my reasoning is correct, substantial efficiencies. To begin.

Electric motors and generators appear to be basically the same devices, generically the dynamo, the one utilized to convert mechanical energy to electricity and the other to convert electricity to mechanical energy. A basic improvement in the efficiency of these would be a compound improvement in the sense that more electricity could be derived from a given input to generators and more work could be performed by a given input to electric motors. The basic design problem is this: is there a configuration for electric motors and generators that might be more efficient than the configurations presently in use? My reasoning with respect to this question starts with the observation that electric transformers have very high efficiency ratings whereas electric motors and generators do not. A major part of this difference arises from the obvious condition that the former have no moving parts whereas the latter do and that they consequently waste energy in friction. The question remains, however, whether friction accounts for all the difference in efficiencies.

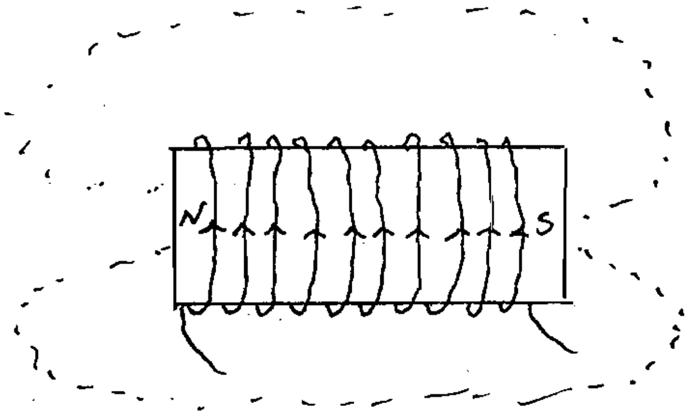
It may be that friction does account for all the difference. I am not equipped to put the question to empirical test, although I am quite sure that recent patents that led Exxon to acquire Reliance Electric have to do, not with reducing friction in electric motors, but with improving the efficiency by which magnetic fields are exploited within motors. I have proceeded simply by assuming that friction is not the only reason electric motors and generators are less efficient than transformers and by seeking for other possible losses of energy in generators and motors compared to transformers. To a layman like myself, it appears that the efficiency of transformers derives from the fact that all the electrical input goes into producing a magnetic field all of which is working all the time in producing the electrical output. Electric motors and generators operate on slightly different principles than do transformers, but they too function with magnetic fields and conductors and the configurations in standard use are ones in which not all the magnetic field and current is working in an optimum way all of the time. As we will see in pursuing the problem--and I apologize to the scientifically trained reader should I seem at times to be groping my way to a clear perception of things that would be immediately evident were I better trained--the question of perfecting the configurations in motors and generators has two dimensions, one pertinent primarily to motors, and another, a far more speculative one, applicable to both. This is to say, as we shall see, that the goal of exploiting all of the potential work in the magnetic field all of the time is a goal that leads us into subtle questions, for all of the potential is not immediately apparent.

The basic principle for generators is that when a conductor cuts across a magnetic field a current is induced that will flow perpendicular to the direction of the movement and to that of the field, and for motors is that when a current flows through a conductor in a magnetic field a force will operate to move the conductor perpendicular to the flow of the current and to the direction of the field. With both, the strength of the induced current or motion is a function of the strength of the magnetic field and the angle at which the coil moves relative to the field, and the optimum induction of current or exertion of motion will occur when the coils move or carry current at a right angle to the field of force. Let us try, with this brief preliminary, to define more precisely the first problem of efficiency, that pertinent primarily to motors.

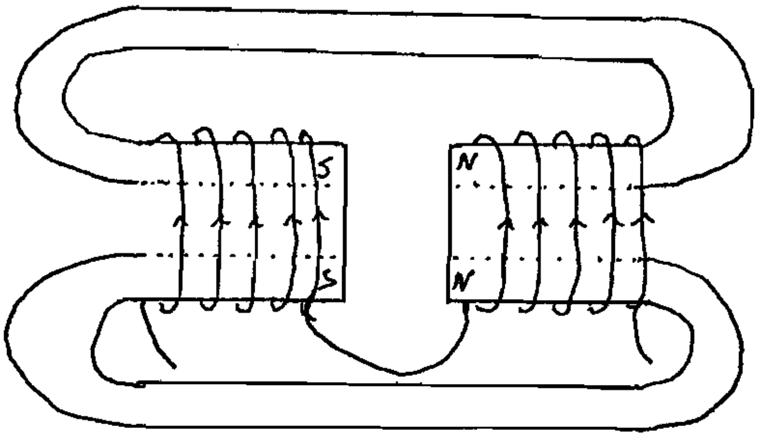
All engines can be divided into two classes: the partially output-determined and the input-determined. In the former class, a somewhat unusual class, the actual inputs required are at least in part a function of the actual output achieved; in the latter, the output achieved, usable and wasted, is a function solely of the actual inputs. Generators and electirc motors appear to be one device: the former operated so as to be partly output-determined, the latter to be input-determined. Thus, the actual current that a generator produces, given its internal resources, will determine how much rotary force must be delivered to run it, whereas the rotary force delivered by the same device run as a motor will be determined by the input, the current driving it. As a result of this difference, certain inefficiencies that result from imperfect configurations between magnetic fields and electric coils within the device are noticeable primarily with motors. The rotary work put into the generator varies with the current it actually produces, with the result that even though the coils are actually producing less current than they might, so too they are producing less resistance to rotation, and no inefficiency is apparent. With the motor, however, the results are more manifest. Here the output, rotary motion, is a function of the input, current supplied to the coils. If the coils are oriented to the magnetic fields of the motor in such a way that less rotational force is created than might be created were the same current more perfectly oriented to the fields, a very evident inefficiency arises. For this reason, I believe, a given device will appear more efficient when run as a generator, less so when run as a motor. To find a way of removing these inefficiencies, we need to understand more precisely how they arise.

Let us, in the following discussion, concentrate on generators, realizing that the same principles and problems apply to motors, our real concern with respect to the inefficiency here in question. With rotary electric motors and generators, that is the vast bulk of motors and generators, one of the key but little noticed design choices concerns the orientation of the axis of rotation of the coil to the magnetic field. The standard configuration is one in which the axis of the rotation of the coil is perpendicular to the magnetic field, as is evident in the basic sketch diagrams in any physics text. A major consequence of the standard configuration is that the current generated goes through a cycle as the coil rotates in the magnetic field. This cycle is most evident with the elementary sketch generator found in textbooks. When the coil is vertical, one strand of its cutting element at the top, the other at the bottom of the circumference of rotation, both elements are moving parallel to the magnetic field and no current is induced. As the coil rotates around the circumfrence of rotation, the angle of cut increases and an increasing current is induced: at a quarter rotation, at the instant the elements are descending and ascending vertically relative to the field, the current is at a maximum, from which it will decrease again to nothing at a half rotation, and then it will rise and fall again as a rotation is completed. This characteristic result of the configuration of the axis of rotation to the magnetic field is what gives a cyclic character to generator supplied current, the swings being modulated by the use of many coils and complex magnetic fields. Nevertheless, even in a very complex generator of this basic configuration, part of the time the magnetic field being generated is being cut at a less than optimum angle, with the result, it would seem to me, of a certain waste of the energy being used to create the magnetic field of the generator, and when the device is run as a motor, there is a waste not only of magnetic field, but more importantly of the current flowing in the coils. The design problem that we have set then first resolves into the following: is there an alternative configuration for the axis of rotation of the coil that will allow the coil at all times during rotation to be moving at a right angle to the field of magnetic force?

Let us try to construct an elementary example of such a configuration. Imagine a simple magnet shaped as a cylinder wound by a coil so that one end of the cylinder is the N-pole and the other the S-pole. Such a magnet would create a field of force that would move out from each pole and arch around to the other thus:



Imagine now that a hole was drilled lengthwise through the center of the cylinder; the magnetic field would remain basically the same. Imagine further that we cut a vertical section through the cylinder mid way along its length and reconnect the cut windings. Again, the magnetic field would stay basically the same with a new, short, intense field jumping the cross cut. Imagine now that we elongate the outer ends of the cylinder, bending the elongation out and back symetrically along the main lines of the field of force--with this we have a new magnet shaped approximately like the field of force created by the original magnet, thus:



With this inverted magnet, the inward protruding stubs with a hole in their center would still be wound so that one was the N-pole and the other the S, and a strong, short magnetic field would run from one stub to the other with a hollow in its center like the core drilled in the original magnet. Imagine now that through this core, one ran the axis of rotation, an axle made of strong, but non-magnetic material. On this drive-shaft, inside the inverted magnet, one could put a copper flywheel. This wheel would be the generator coil in our simple, concpetual model: as it rotated in the magnetic field, an electric potential would be induced between its hub and its rim, and with a proper set of shoes around the rim and another at the hub a current would flow through a connection of the two. Diagram 1 gives a side-view cross-section of such a generator.

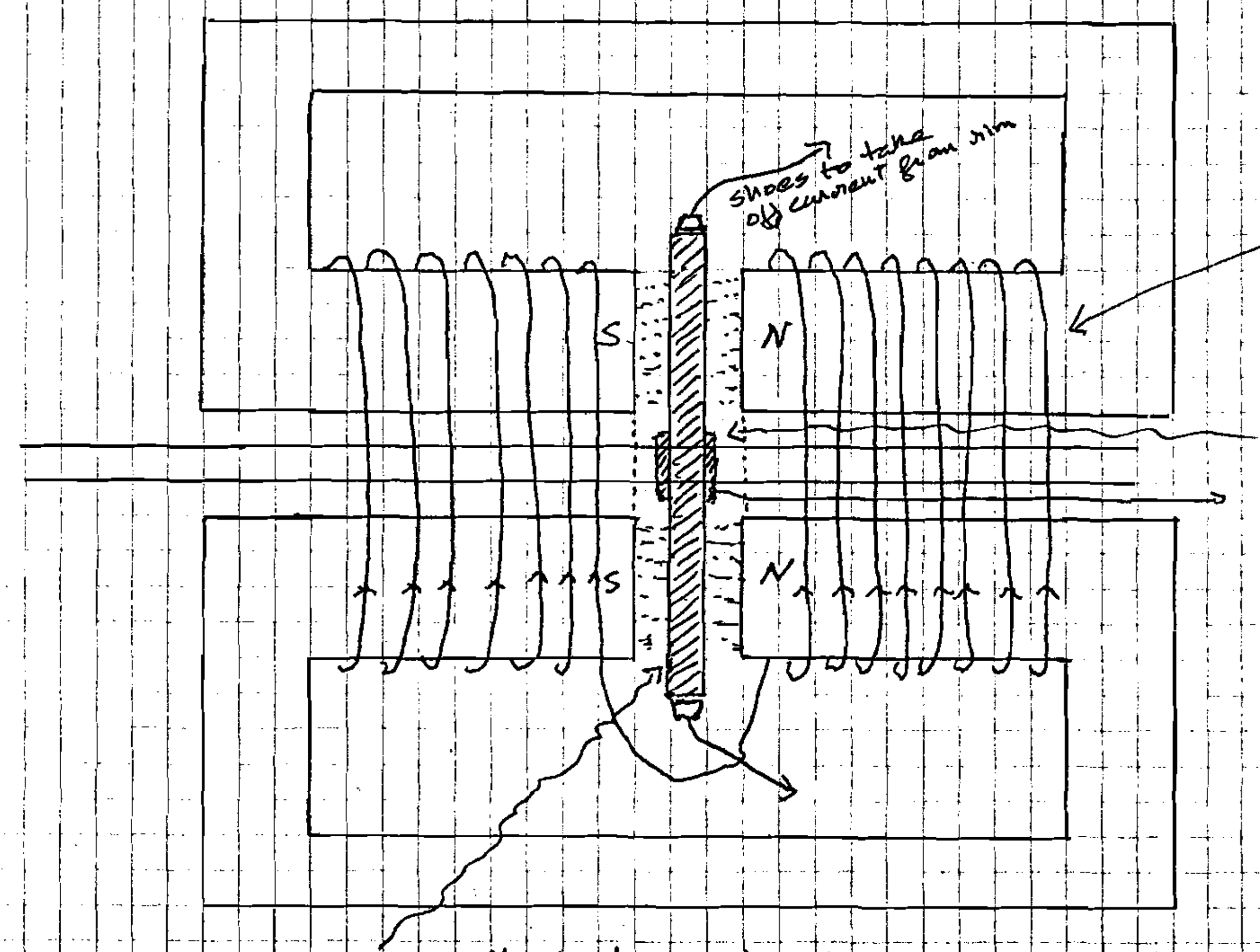
With such a configuration, all of the magnetic field would be cut by all of the generating coil at the optimum angle all of the time. If any of the inefficiency of existing motors and generators results from the fact that their configuration dictates that part of the magnetic field is being cut at a less than optimum angle some of the time, this configuration should avoid that inefficiency. Assuming that the costs of friction would be roughly the same in both configurations, there would be a net gain in efficiency for the new configuration, a net gain apparent primarily with motors. Furthermore the characteristics of the current produced or utilized would be very different, for the new configuration functioning as a generator would yield a non-cyclic direct current. The intensity of the magnetic field in such a configuration could be very high, but the coil, being limited in length to the radius of the flywheel, would perforce be relatively short. As a result the current yielded by this elementary version of a parallel axis generator probably would tend towards low voltage and high amperage, but it might not be difficult to alternate it and then use a transformer to step up its voltage. Since it would be non-cyclic, it would be easy to resynthesize into direct current after stepping up its voltage, which could be advantageous, since, so I am under the impression, direct current can be transmitted at high voltages in a distribution grid more efficiently than alternating current. At distribution end points, the current could be realternated and stepped down to standard voltage for use. Whether the conversion to current of such characteristics would be worth the required investment and inconvenience, would, of course, depend on the relative efficiencies of this configuration compared to present configurations and to other possible ones.

Conceptual model of a parallel-axis, rotary generator

Side view, cross-section

Diagram 1

Between Page 7 and 8



drive shaft - parallel to the direction of the magnetic field

shoes to take off current from rim

drive magnets creating field parallel to the axis on which the coil, the copper flywheel rotates.

shoes to take off current from hub.

copper flywheel - as it rotates current will flow along its radii. If necessary to control eddy currents it can be made of copper vanes, each running from hub to circumference, laminated together with insulation between each.

What I have described so far, however, deals only with the first of the two problems of inefficiency that I mentioned, the imperfect orientation of coils to fields, significant primarily for input-determined motors, relatively insignificant for partly output-determined generators. There is, I think, a second problem of inefficiency, one affecting both generators and motors, one that is far more speculative than what we have just discussed, but one that can be of great import. In the design we have suggested, run as a generator, the coil, the copper flywheel, will be cutting through the magnetic field at right angles all the time. We can say, therefore, so it seems, that all of the coil is exploiting all of the field at the optimum angle all of the time. Yet are we really sure that a right angle cut by a conductor is the real optimum, the cut that actually exploits <u>all</u> of the field?

Here we enter, what for me at any rate, is the speculative realm, and before trying to specify the design problem further, we need to reflect on what the phrase "all of the field" may in actuality mean. Let us try to define it in a way that will help us think about a solution to it. An electrical transformer can be thought of as a generator, driven by an electrical input, generating a nearly equal electrical output with characteristics different from those of the input--a higher or lower voltage and amperage. Now we can express the inputs and outputs as quantities of heat and state the conservation of energy principle for the transformer with the simple formula: the electrical input expressed as heat equals the electrical output expressed as heat plus heat losses from the core and coils. Now we can do the same for a rotary generator, although the task is a bit more complicated. The total input would be fairly easy. Assuming the magnetic fields are externally excited, the total input is the rotary force applied to the rotator and the electrical current creating the fields, both expressed as heat. Total output raises a question, however. It clearly includes the current generated, expressed as heat, as well as the heat equivalent of frictional losses and heat losses from cores and coils. The induction of current in the coil, in addition, creates an electromagnetic force opposing the movement of the coils, and it is not entirely clear to me whether or not this resistance should be included in a strict accounting of the energy conservation within the generator. I think it must be included in a strict accounting: if the input side of the equation balanced with the output side when one left it out, one would, in a sense, have created a gratuitous force that, if tapable, would yield a perpetual motion machine, violating the conservation of energy. Comparing the conservation equations for an idealized transformer and an idealized rotary generator, we can deduce that the induction of current characteristic of the transformer is twice as efficient as the induction of current when a coil moves at right angles to a magnetic field (Transformer: Input A equals Output A'; Generator: Input A equals 1/2 Output A' as current and 1/2 Output A' as resistance).

This deduction is still not completely clear, for the equation for the generator is as we want it to be, owing to the fact that the object of a generator is to convert rotary work to electricity and the configuration of the generator should be such that work appearing as resistance is part of its output. Our hunch for the generator is that the input of electricity to generate the magnetic field necessary in order to get a given output of current is considerably higher than it would need to be were the induction process exploited as efficiently as in a transformer. Let us try to state our deduction more rigorously: if the interaction for coils moving in a magnetic field were as efficient as it is for coils wrapping a transformer core, then among the possible configurations there should be one in which the induced resistance to the movement of the coil disappears from the equation, creating in effect a rotary transformer in which the rotary input needs simply to overcome the friction slowing the operation of the device and there will be a virtually perfect conversion of the electricity used to generate the magnetic field into the output of the coils interacting with the field. Proof, it seems to me, that "all of the field was being exploited in the optimum way all of the time" would be attained in the construction of such a device, which might even be very useful in certain situations as a direct current transformer. Until such a device has been constructed, the proposition that a right angle cut of a magnetic field by a coil yields the optimum induction means, so it would appear, that it yields the best results among the forms of movement so far readily apparent as possibilities. I strongly suspect that were we to find a configuration that meets the standard of the optimum established by alternating-current transformers, it would prove to be twice as efficient as a right angle cut. By this I mean that it would allow us to create the rotary transformer, taking in the form of current the equal and opposite resistance invariably associated, it seems, with a right angle cut; for generators it would lead to an apparent doubling of the intensity of the magnetic field, allowing a given magnetic field to be productively exploited by twice the rotary force and twice the output of current; and for motors it would permit a doubling of the rotary force produced by a given total input divided between the generation of fields and driving current in coils.

Exploiting all of the field all of the time in the optimum way is what alternating-current transformers have for a long time been doing. It is not what a right angle cut by a conductor through a magnetic field has ever done. Transformers are not ideal engines, conceived as possible in principle but nowhere approximated in practice, but real engines, the best ones operating at 99% efficiency or more. They are tangible evidence of the possibility of an interaction between conducting coils and magnetic fields that comes close to the real optimum in which all of the energy in the field can be usefully exploited. The following meditations in this part of the letter are based on the premise that the optimum interaction between coil and magnetic field is not a right angle movement in a straight magnetic field, but rather an interaction that is functionally the same as that occurring daily in alternating-current transformers. If a right angle movement is a complete, perfect, functional equivalent of the interaction between coil and field in transformers, there is no point in the folloing meditations and they should be skipped. I am convinced, however, that right angle interactions are only half the functional equivalent of transformer interactions and hence I have embarked on the following meditations in search of the other half, of some possible configuration that will yield conversions equivalent to those yielded daily by transformers.

In what I have just said, I have stressed the phrase "functional equivalent of," for we must struggle with a serious problem, the obvious fact that the parts of transformers are all stationary while rotary generators and motors have both stationary and moving parts. These devices will never be, over-all, as efficient as transformers, for they will always loose efficiency to friction. But if we can find a true functional equivalent for the interaction of coil and field in transformers for motors and generators, these latter devices will be much more effecient than they are at present. This is the goal. In order to begin working toward it, we need to start constructing a theory about what gives the interaction in a transformer such a complete conversion of energy from electricity, to magnetic field, and back to electric current. For me, it is not too difficult to grasp how a trensformer works, but a description of how it works, for our purposes, is not helpful enough, for we cannot expect, in a situation where some of the important parts will be moving, simply to reproduce how the transformer works. What we need is a theory that explains, adequately, precisely why a transformer, in working the way it works, attains the optimum conversion of field to current, and if we understand why that is the case, then we can begin to design the functional equivalent of that conversion in other situations, for we will be able to see that these designs might work in equivalent ways because the same reasons governing the operation of transformers can be expected to govern the operations of the new devices.

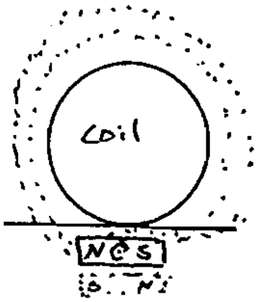
Questions "why?" never yield terribly precise answers beyond the paternal "because that is the way it happens." Hence in trying to explain to myself why transformers drive such efficient interactions between fields and coils, I have, not surprisingly, been torn by a certain perplexity and indecision, which is made more troublesome because I have, at best, only partial command of the relevant physics. Hence, two sets of reflections follow. Both start out from the same device, a transformer, which is essentially a toroid operated to force a magnetic field to escape from, and to return to it, in a most productive way. Hence both sets of reflections culminate in devices in which fields are driven out of toroids and into toroids in ways that should be useful in generating current from rotary motion and rotary motion from current. Both reflections culminate in the design of certain devices, but since I am quite sure that the first gives an erroneous understanding of why the transformer interactions are so efficient, I do not, in order to limit the length of a letter that bill be very long, describe in detail the devices that result from it. I do, however, indicate the basic principle of operation of these devices that I do not fully describe: my reasons for thinking that the reasoning in the first reflection may be unsound can very well themselves be unsound. It may be that the efforts at explanation in both sets of reflections are fundamentally unsound, and that the devices nevertheless work because they embody some tacit insight that I have not yet succeeded in understanding. It may be that the explanations in both reflections are more or less sound and that nevertheless none of the devices work because of practical or theoretical considerations that have not occurred to me. It may be that one or the other reflection is more or less sound and that the devices suggested on the basis of the sound one will work, while those resulting from the other will not. The fist set of reflections is based essentially on my elementary command of the classical physics of electromagnetic induction. It may not be inconsistent with my second set of reflections, I am simply not sure, but at any rate, the second is much the more speculative set. It resulted from the feeling that classical physics perhaps dealt with the phenomena too much on the level of their aggregate appearances, with the result that the observations, although accurate, did not yield sufficient insight into the more minute interactions that were perhaps the ones that needed to be understood, at least partially, in order to find the reasons why transformers should be as efficient as they are. On the other hand, field and quantum theory, particle physics, seemed to yield too minute a perspective. Hence, in my second set of reflections, I construct, all too arbitrarily, I fear, a molecular level view of the interactions of induction, a view that is, I hope, consistent with the relevant principles of classical physics. This second set leads to the design of certain devices, not too different from those resulting from the first, but sufficiently different that it is very possible that one set might work and the other not. Let us proceed to the first set of reflections, recognizing that it, and the one that follows, is premised on the conviction that a right angled movement by a conductor through a magnetic field does not utilize to the full the magnetic energy in the field with which the conductor interacts. If this conviction is wrong, the following reflections are pointless and should be skipped.

Reflections I

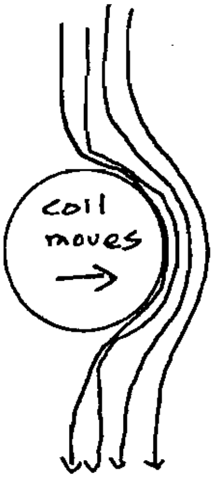
To begin our reflections and to remind ourselves where we stand, let us consider further the conservation of energy as it applies to transformers. So far, we have arrived at the strong suspicion that a right angle cut by a conductor through a magnetic field does not fully convert the potential energy in that field to electrical energy or motive force. We have noted further that working transformers are very efficient, approaching 100% efficiency, which would lead us to suspect that with transformers, the optimum possible interaction of coils and magnetic fields for the induction of electricity is there occurring. The input current to the primary coil creates the alternating magnetic field, which field interacts through its alteration with the secondary coil to yield a current virtually equal to the input: from this, we must conclude that, however imperfectly we can conceptualize the interaction, the interaction nevertheless is an approximation of the perfect one, for if it were susceptible to improvement an output larger than the input would be yielded, violating the conservation of energy.

In classical physics, the basic conceptualization of how and why a transformer works starts from the phenomenon that current carrying coils have magnetic fields circulating clockwise around the direction of flow of the current. These rotating fields of the coils are used to explain why a current being carried in a coil will cause the movement of the coil, why a coil being moved in a field will have electricity induced in it in an amount varying in accordance with the intensity of the field and the angle of motion of the coil relative to the field, and, somewhat less clearly, why an alternating magnetic field will induce current so perfectly in a transformer. For a motor, a current carrying coil has its revolving magnetic field, one of not negligible strength, revolving around it according to the direction of the current. The effect of this revolving magnetic field on a straight magnetic field between two magnetic poles will be to revolve a part of the straight field behind the direction of current flow, with the result that a force will be exerted on the coil proportionate to the extra field behind it, pushing the coil into the area of low magnetic pressure in front of it. For a generating coil the visualization is a bit more complicated, but if we start with the generating coil empty of current, being forced into the field, we can imagine its movement making the field bulge a bit ahead of the movement, creating a resistance against the movement, and we can imagine the bulge acting on a part of the circumference of the coil as if it were the revolving field of a current in the coil, and somehow, in response to that appearance, a current starts to flow proportional to the appearance created by the bulge. If the movement of the coil were at right angles to the field we can easily see that the bulge will be able to act, however it acts, on at most 180 degrees of the circumference of the coil, presumably inducing half the current that it might were the bulge to surround the full 360 degree circumference. Things get considerably more complicated for both motor and generator coils when both are fully in action, the one not only carrying current in a field but also moving rapidly in that field owing to the previous interaction of the field and the current being carried, and the other not only moving in a field, but also carrying current induced by its previous movement. Nevertheless, the net continuing effects are basically the same as these simple cases described above. The simplest case for the transformer can also be visualized with a single section of the secondary coil, and it comes down to observing that the unique action of the magnetic field, as the alternating current in the primary coil forces it to reverse the direction of its polarity, makes the whole field come up out of the transformer core and loop around the coil, surrounding its 360 degree circumference, and thus acting, as with the generating coil, as an ersatz revolving field from a current. Somehow, in response to this appearance a current starts flowing and the current so induced is the current that would need to be flowing in order have a revolving magnetic field of that strength around the coils. In these terms the current induced in the transformer coil equals the current that would be induced in a generator coil were the movement of the latter such that the bulge created by the movement were one that encompassed the 360 degree circumference of the coil.

Let us visualize the interactions for the transformer coil and the generating coil a little more precisely. For the former, imagine a magnetic dipole lying horozontally at the bottom of a cross section of the secondary coil, oriented at a right angle to the direction of the coil, N-pole pointing to the left, S-pole to the right. As the current in the primary coil alternates, the polarity will shift, N to the right, S to the left. If we imagine a line of force emmanating out of the N-pole, prior to that shift, it will be burried in the core. As the shift occurs it will rise out of the core and move along the circumferance of the coil, interacting with it along the full 360 degrees until it is back, horizontal in the core. This visualization is extremely gross--the real interaction is probably taking place on the level of particles, not the surface of the wire coil, but like the wire coil those particles are susceptible to a



As magnetic bipole rotates 180°, a field from it envelops secondary coil 360° around



As coil moves into field at a right angle it makes field bulge and press against its 180° circumference.

similar orientation, positive charge pointing into the paper, negative out, and, like the coil, the particles have an infinitesimal circumference for the field to act on. If we may speak somewhat graphically, the 180 arc of the field probably enables it to envelop each particle 360 degrees around its entire circumference and thus to exert its full capacity to orient the charges that can flow in the coil. We can make the same kind of gross visualization for a coil moving in a straight field at a right angle. It shows that the motion can cause interaction only along 180 degrees of the surface of the coil, giving us our 2 to 1 ratio: the grasp of the field on the particles in the moving coil is only half as firm as with the transformer, and we might therefore expect that this kind of interaction could generate only half as much current from a given field than were the interaction over the full 360 degree circumference. If our visualization is sound, however, it also tells us that there is no way, by motion of the coil in the field to establish more than a 180 degree interaction. This would seem to bode ill for our quest of fundamental efficiencies for rotary motors and generators.

Before giving up, however, we should reflect further on the implications of our reasoning so far. We deduced that the interaction of magnetic field and coils in a transformer approximates a perfect interaction. The magnetic field created by the primary coil receives in that process a capacity for work which is virtually entirely given up in the interaction with the secondary coil. This means that the capacity for work of the magnetic field is exhausted in the interaction, for if the field still had potential for some other kind of work, it would mean again that it was some sort of perpetual motion machine, in principle at least, for theoretically a means could be devised for tapping that further work capacity and the output of the system would then exceed its input. If the electromagnetic induction in a transformer exhausts the capacity for work of the field, and the electromagnetic induction in a moving coil can at best, as we have postulated, be only half as effective, it means that after the moving coil and the magnetic field have interacted in a rotary generator or motor, the field still has in it half its original capacity for work. Can this remaining capacity for work be tapped simply by putting in more and more coils, which might cut in half each successive remainder down to the infinitesimal? This would not seem to work, for it would greatly increase the total resistance of the coil and have the effect of raising the voltage of the output rather than increasing the amount of current induced. The nature of the interaction between magnetic field and coil would seem to be such that the full work capacity of the field can be extracted by electromagnetic induction only when the interaction takes place around the 360 degree circumference of the particles comprising the coil, not by having doubly numerous interactions occur over 180 degrees of the surfaces.

What then is possible? Magnetic fields are capable of doing work other than by means of electromagnetic induction; magnetic fields also exert their capacity for work as attractive and repulsive force, a capacity for work imperfectly utilized, we are suggesting, in electric motors. Our design problem now comes down to this: is a configuration possible for rotary electric generators and motors, in which the remaining work capacity of the magnetic field, that left after the field has been exploited as fully as possible by electromagnetic interaction, can be made to contribute, through attractive or repulsive force, to the useful work output? To begin finding how this might be done, let us start reasoning as follows. If a movement at a 90 degree angle will allow us to extract half the work capacity of the field, perhaps a 90 degree disorientation of one pole of the magnetic field would allow us to extract the other half of the work capacity by attractive or propulsive force. To refine, then, our restated design problem: is a configuration possible in which coils can be rotated in a magnetic field in such a way that the work capacity left in the magnetic field after the coil has interacted with it will act symmetrically along the tangents of the circumference of the rotator, so that the remaining work capaicty of the field will contribute to the rotation of the motor or generating element? I think the such a design is possible, but since I have doubts about the adequacy of the explanation of induction pursued in this set of reflections, I will not describe those designs here, especially as they are structurally similar to designs arrived at through the second set of reflections. Before giving my reasons for doubting the adequacy of the line of reasoning about induction pursued here, however, one important consequence of the design strategy it seems to lead to should be indicated.

In these reflections, we have come to a strategy for improving the efficiency of electric motors and generators which consists in trying to take the energy not exploited through induction as useful attractive force. Such a strategy may result in a better motor. It is, however, fundamentally useless in a generator. The attractive force left in a field after induction by a right angle cut through a field might be deployed to facilitate rotation or to oppose rotation of the induction coil. Used to oppose rotation, that attractive force would simply increase the needed rotary input without increasing the output of current. Used to facilitate rotation, that attractive force would decrease the needed input of rotary force, seemingly very helpful, but in actuality it would have the effect of greatly increasing the relative magnitude of the input current. The function of a generator is to convert rotary force to current; the function of a generating device built on the strategy arrived at here would be to use rotary force to overcome the friction of a device that was using current to produce magnetic field, which in turn produced another current. In short, the strategy so far arrived at can only lead to an improvement of electric motors and the construction of a rather imperfect approximation of the rotary transformer, the possibility of which we hypothesized earlier.

There are, however, basic problems, it seems to me, with the gross visualization of the process of induction as something that essentially involves the magnetic fields revolving around current-carrying coils. The first problem, and most simple one, is this. If induction results from the appearance, over part of the circumference of the coil, of such a revolving field, as the coil is forced into a straight magnetic field and creates a bulge around it, then it would seem that the addition of more and more coils would not simply build up the voltage of a constant current, but would rather build up the amount of current induced until the whole magnetic field had been exhausted. Perhaps in a more refined presentation of why induction occurs in a coil moving in a magnetic field according to classical physics, this difficulty could be dealt with easily enough. That the addition of coils raises the voltage, but not the strength of the current is well documented. To get good clues for the design of better motors and generators from an understanding of the process of induction, I suspect we need to think on a completely different scale of visualization. My reasons for this conviction will become more apparant if we reflect with some care on whether or not the phenomena of the magnetic fields that revolve around current bearing coils can in fact have anything very important to do with the interactions resulting in the induction of current in moving coils.

It has all along bothered me that the descriptions, based on classical physics, of the processes occurring in induction, whether in moving coils or transformers, are very gross. These descriptions, which start out from the magnetic fields revolving around current carrying coils, do not take account, one might suggest, of one very important phenomenon. Such revolving fields will indeed make other fields bulge out or rotate other fields behind them in many situations, but not in that situation that most frequently occurs in motors and generators. I think the precise way to state this exception is as follows: when a straight magnetic field is oriented so that its direction is parallel to the surface of the plane defined by a line of force in a field rotating around a coil, the straight field will pass straight through the rotating field. The problem I have in mind can be easily grasped if one imagines two loose coiled springs--the child's toy which used to be called "slinky springs" or something like that is ideal. If the springs are held so that the gap between each coil is equal only to about the width of the coil itself, in most orientations of one spring to the other it is impossible to slip one spring inside the other, but when the planes defined by each coil are parallel, however, the two springs will easily slide inside each other. This kind of intersection, when the planes of rotation are parallel, must happen easily with rotating magnetic fields. Imagine a row of paralle wires--that is what a well constructed coil is. The fields rotating around each of these coils will all be parallel to each other and they must intersect and slip easily inside each other like the slinky springs, or else they must take paths that are virtually straight up then straight down, or else they must consolidate and rotate, not around each coil, but around the sum of the coils. If such were the case, the classical picture of induction in a moving coil and the production of movement in a current carrying coil, all depending on the putative actions of the rotating fields on other fields, would completely break down.

As I have thought about it, it seems logical and necessary that a field, the direction of which is parallel to the plane of rotation of a rotating field, will pass through it unaltered, without deflection or diminishment. Now, it seems to me that regardless of the angle at which coils in generators and motors move relative to a field, the direction of the moving coil is generally such that the direction of the movement of the straight field is parallel, or nearly so, to the plane of rotation of the rotating field. Further, I suspect, usually, when the direction of the straight field is not parallel to the plane of rotation of the rotating field, the expenditure of energy required to tilt the axis of rotation of the rotating field all down the line, so that the plane of rotation becomes parallel to the direction of the other field, would be <u>much</u> less than the expenditure of energy required to bend the straight field in front of, or behind, the rotating field. It therefore seems to me most likely that only in two cases will a rotating field be a significant barrier to another field, when the rotating field is of much greater intensity than the other field and when both the other field and the rotating field are highly disorganized, as if we had twisted our springs violently and then sought to slip them into each other. These considerations lead to our second set of reflections. It is based on the conviction that the interaction between a magnetic field and a conductor is something that cannot be understood on the level of fields and coils, but rather that the interaction is something that takes place within the molecular mass of the coil by the action of discrete components of the field whose approach to the mass of the conductor has not, in any significant way, been distorted by rotating fields arising from currents in the coil. Classical physics describes accurately the phenomenal aggregate results. What we will be postulating must lead, in the phenomenal aggregate, to those results. It will, however, be a very different picture, a work of imagination informed by a good deal of reflection, a speculative guess thoroughly in need of evidence in its favor, one bit of which would arise should the devices suggested as a result of it prove to work.

Reflections II

An electrical transformer can be thought of as a generator, driven by an electrical input, generating a nearly equal electrical output with characteristics different from those of the input--a higher or lower voltage and amperage. This efficiency of transformers has always seemed anomalous to me, an anomaly potentially of considerable significance with respect to generator design and vast significance for electric motor design. Transformers suggest that there is a form of electromagnetic induction in which the output will virtually equal the input. In order to explain well why transformers have the efficiency that they do, and to begin thinking productively about how to achieve similar efficiencies for electric motors and transformers, we need to construct a theory of the detailed interactions of electromagnetic induction and attraction, a theory that conforms to the phenomena and that gives at least a hypothetical account of why they are as they are. Let us start with some definitional hypotheses. These hypotheses are partly the result of my effort to translate some knowledge gained from basic physics texts into language and images that I find it easier to think with and partly speculative constructs to fill in my ignorance. I am less concerned that they be precisely correct than that they be generally on the right track, leading to insight into certain design problems.

Magnetically permeable material seems to consist, on the level of the molecule or smaller, of magnetic bipoles that can emmanate vectors of magnetic force that we can conceive of as trajectories of potential attraction. We realize that these trajectories sometimes act as a field of flux, sometimes as lines of force, that precise conceptualization of them is impossible, and that perhaps the vague term trajectories will suit both their apparent linearity and their evident field qualities. For our purposes here, we will personify them, so to speak, as trajectories of potentail attraction, each discrete, each having a quantum of energy. These trajectories seem capable of almost infinite extension and what such vast extension does in the way of attenuating their quantum of potential attraction we will leave aside as an interesting but irrelevant question. We will be dealing with trajectories extended over relatively short distances, and we suspect that in these conditions their quantum of potential attraction can be treated as close to a constant. These trajectories are either, by convention, N-seeking, coming from S-poles, or S-seeking, coming from N-poles. Trajectories from sources of the same polarity repel each other so that they will not cross, avoiding the risk that their lines of trajectory will intersect and cut each other, dissipating their action. The exception to the rule of repulsion, as we noted at the end of the first set of reflections, occurs when a trajectory approaches a revolving trajectory on a path, parallel, or nearly so, to the plane of rotation, in which case the former will nudge by the latter, perhaps slightly altering the axis of rotation to make the plane of rotation more parallel to its path. Trajectories from the same pole, meeting head-on, unable to veer to the side will exert their quantum of potential action in a stiff thrust, the opposite of their normal tautening, trying to push the opposing trajectory back: thus the repulsive force exerted between identical poles of magnets. Trajectories from one pole, however, will join with those from the opposite pole. Once joined, the trajectory exerts its attractive force, its work potential, by tautening itself until it has exerted a constant quantum of attraction between its anchor points, exerting pressure against adjacent fields or bodies that may impede its straightening action, and when the force on the anchor points reaches the level of its constant quantum, a trajectory will pull loose from its anchor points and the line of potential along the trajectory collapses, and a new trajectory of potential attraction immediately emmanates from the source, seeking another new trajectory of opposite polarity with which to join. The constant quantum of potential work that each trajectory can exert seems approximately to equal that of the electric potential of a single charged particle. The actions of magnetic trajectories take place very, very rapidly, not at the speed of light, but at something more on the order of the speed of electric currents.

Charged particles that can move in a conductor are ordinarily held loosely, not bound tightly as part of the atomic structure of the conductor, but normally held by a weak atomic structure or perhaps within a small magnetic field enveloping the atoms or molecules. Such enveloping fields might arise from the charged particles, bound and unbound, in the molecular structure of the conductor. For simplicity, perhaps in conformity with the phenomena, let us postulate that in conductors there is always a predominance of negative charged particles, that the enveloping fields are always made up of encircling, N-repulsive, closed but not anchored, magnetic waves or trajectories. Further, when trajectories of potential attraction from N and S poles of magnets join, the line they traverse becomes both N and S repulsive along their lengths, and as soon as they join, thus linking together an N and S pole, they immediately tauten, thus exerting their quantum of work potential, at which point they pull loose and dissipate. We have suggested that the work potential of each trajectory of potential attraction is equal to that of a single charged particle, for otherwise the near perfect conversion of electric current into magnetic field and back into a virtually equal electric current in transformers would seem impossible. At any rate, the work potential of a magnetic trajectory anchored to an N and S pole would seem to be exercised by the tautening of the trajectory until its anchors pull loose from their sources and the trajectory dissipates, but this action seems to manifest itself phenomenally in one of two forms, either by breaking charged particles loose in conductors, allowing the charge to flow as part of a current, or by exerting attractive force between the two anchor points of the trajectory. The first form of work is electromagnetic induction and the second magnetic attraction, but we postulate that whichever of the two forms the work appears in to us phenomenally, the magnetic force has essentially only one mode of acting, tautening the trajectory it has traversed, exerting a quantum of attraction between its anchor points and, consequently, a directly related quantum of pressure on bodies or fields that it may pull against in tautening along the line of its trajectory. Electromagnetic induction, according to this postulate, must be a by-product of the basic mode of action of a magnetic trajectory, however that should be understood, not a special mode of action that the magnetic trajectory sometimes performs in a different way from its usual mode of action. All this is preparatory to an effort to understand why the phenomena of electromagnetic induction in a coil moving in a magnetic field might occur as they seem to occur.

At the end of our first set of reflections, we noted that it seemed reasonable to hold that the fields revolving around current-bearing coils, or the outer mass of moving coils themselves, probably have no significant effect on a straight magnetic field passing through the coils. If the events that determine the well documented relationships governing the interaction of moving coils in straight magnetic fields do not take place outside the coils, in the space immediately environing the coil, they must take place inside the coils. We need to grasp how the known relationships might result from events inside the coils. First, let us notice that trajectories of potential attraction can penetrate through a conductor with no induction taking place and no degradation of the field. This is what happens when a rotating coil of the textbooks moves parallel to a magnetic field. We must visualize the trajectories finding a gentle path through the adjacent N-repellant fields of the molecules of the conductor, exerting mild pressure on some of those fields, but nothing adequate to break charges loose, and with such penetration, the entire work potential of the field will be exerted as attractive force between the anchoring magnetic poles. For induction to occur there must be movement of the conductor relative to the direction of the field. The basic principle, well grounded in empirical observations, for moving coils is that the current induced will vary according to the angle, relative to the direction of the field, at which the coil moves through the field. This is an elementary phenomenon, one with which discussions of electromagnetic induction begin, but it is a phenomenon that is much more often stated than explained. On the level of gross visualization, real coils seem to move very rapidly and seem very solid, and it is hard to conceive that the angle of motion should make much difference, for regardless of the angle, the motion seems to be a quick and decisive sweep that thoroughly cuts the field. Let us try to figure out, on the level of molecules and discrete trajectories of magnetic force, assuming they are such, why the angle at which the conductor moves relative to the direction of the field might make a difference inside the coil affecting the strength of the current induced or the rotary force exerted.

After puzzling about this for some time, I am aware that one can easily embark upon many erroneous paths of explanation, and I recognize that the one I shall give is highly tenuous, suppositious, probably wrong, but perhpas sufficiently correct to allow us to design useful devices whose principles of operation, if fully understood, might require explanations more sophisticated than I am giving. But let us try to do the best we can. At first, I thought the angle of movement between the conductor and the field must have something to do with the actual act of induction, but have come to postulate that it does not, that it has to do not with the act itself, but with preparing the conditions for induction, in choosing, so to speak, the actors. If the straight magnetic field remains of constant intensity and the current induced in a coil moving through that field will vary with the angle of movement relative to the direction of the field, a sorting process at the surface of the coil and within it must occur. We have postulated that all the components of the field have essential only one mode of action, a tautening or stiffening of their trajectories, yet the current induced from a constant field varies according to the angle of movement, the field must be sorted into a part that will cause induction as they act and a part that will not. Thus we are looking for a sorting process that can divide the components of the field into two parts, one component that will cause induction, and another component that will pass through the coil and exert its work potential as attractive force between the poles of the field. Division of the field has to occur--that is the lesson of the revolving coil. If the division does not happen outside the coil, it happens inside the coil. If we can understand how that division of the field occurs in moving coils, we can compare that to how it might happen in transformers, where we suspect it happens more efficiently, for human purposes. If we can understand the dynamics of sorting the field into an inducing component and an attracting component, perhaps we can begin to develop a strategy for achieving the functional equivalent of the transformer action for generators and motors. Somehow the

Before going much further, which takes us into very problematic constructions, let us give ourselves a consolation. That the current induced varies with the angle of movement by the coil relative to the field is blatant evidence that a sorting of the field occurs. Our reflections so far have shown us that this sorting must give a part of the field very minute leverages that allow that part to induce current, the lack of which relegates the remainder to exerting a useless jerk. Relative to thise minute leverages, what transformers do by way of creating leverages of fields on conductors is vastly overdetermined. If the sorting process is as fine as it must be within the mass of a moving coil, any real intervention with it should prove very decisive, for we cannot guage any possible intervention to such minute differences as seem to make a dependable difference within the coil. As long as we can get ourselves on the right track, chances are that a strategy of intervention will be very decisive. Let us now try to do that, recognizing that it will be a most tenuous, albeit reasoned, guess.

We noted that movement of the coil is not alone the determinant, or else a simple speeding up of the coil would be the solution. Any velocity we can give the coil will be but a lumbering step to the fleeting magnetic phenomena; hence we will speak not of movement, but of increments of movement. Having tried many constructs to explain the sorting, I think we must postulate two steps to the sorting process, one at the surface or top layers of the conductor, one in its internal mass. Let us turn to the first step. We do not know exactly on what level the components of the magnetic field exist as discrete components, but at whatever level it is--the molecular, atomic, particle, sub-particle--the mass of the conductor has a certain solidity for the field. I suspect the conductor has such solidity for the field on the molecular level; let us say it does for convenience; things would be pretty much the same at other levels. As a straight magnetic field encounters solidity, each of its components need to make a slight deflection, one way or another, to move by the solidity. This movement, we postulate, is the first step in the process of sorting. Regardless of what angle a conductor moves relative to a straight magnetic field, it will present to that field its full face, a 180 degree circumference. Depending upon where on that face each component of the field impinges, the angle of incidence that each component has, relative to the solidity of the conductor, will vary from the perfectly parallel at the extreme edges of the conductor to head on at the center, and this angle will greatly affect how the trajectory moves as it enters the conductor. Each component of the field will have a point of first impingement upon the solidity, and for each trajectory, we can mark the spot of this first interaction and draw a small arrow in the direction of the movement of the conductor. We can then draw a line through the spot perpendicular to the direction of the arrow. Marking such a line for each component of the field, we can then observe whether each trajectory enters the conductor ahead of or behind that line, which we shall call the line marking the direction of movement of the conductor. If we do this across the whole circumference of the conductor, we will find that the field divides itself in two, according to the movement of each of its components on meeting the conductor: one half moves so as to enter <u>ahead of the direction of movement</u> and the other half moves so as to enter <u>behind the direction of movement</u>. This is the first step in the process of sorting caused by movement, by movement of the comangle of motion of the coil relative to the field is crucial to the sorting process; somehow it must establish the probability according to which the trajectories get sorted into those that will exert their work by freeing loosely-bound charged particles, and by exerting, in that, resistance to movement, and into those that will exert it as attractive force on the magnetic poles without contributing to induction or resistance.

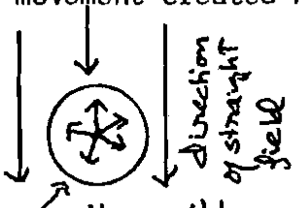
This hypothesis that the angle of incidence between field and the movement of the conductor is significant solely because it establishes a probability according to which the components of the field are sorted into two classes: inducers and attractors, is fundamental to the designs for generators and motors that will eventually be proposed. These designs are essentially efforts to plan probabilities, to control the sorting, so that all the field will usefully become inducers for generators and attractors for motors. It is my contention that transformers are so efficient because they control the sorting effectively and that electric generators and motors can be made much more efficient by finding ways to do the same for them. Let us try to understand in some detail how the angle of incidence between field and conductor establishes the probability by which the magnetic trajectories are sorted.

We have postulated that the trajectories of potential attraction are sorted into two classes, inducers and attractors, according to some probability ratio established by the angle of their incidence to the direction of movement of the conductor. Now we have postulated that induction takes place as some trajectories exert their normal mode of action when they establish a link between two opposite poles, that is by a tautening action. All the trajectories, both inducers and attractors, will act in this way, but some in acting in this way will induce current, other will not. Induction occurs, we postulate, when losely-bound charged particles are set in motion, either by breaking weak molecular or atomic structures, or by breaking weak magnetic links. For such breaking to be caused by a tautening trajectory, a certain amount of leverage will be needed by the trajectory on the structure or magnetic envelop. By this reasoning, we can conclude that the sorting process is one in which the components of the field are divided into two parts, one comprising trajectories that have sufficient leverage for induction and another comprising those that lack such leverage. Now we are dealing with straight fields, at this point, and if the components of the field all remain straight, none of them will have any leverage on anything except the poles at which they anchor. Movement by the coil, therefore, obviously has something to do with creating the leverage needed by inducers, but not everything in that process can be attributed to movement of the coil. If its movement were the sole determinant of the leverage necessary for induction to occur, the current induced would vary primarily with the velocity of the coil, relative to the field, not with the angle of movement by the coil relative to the field. The angle of movement is significant, and in trying to understand why that is so, we should remember that the actual increments of movement that the coil makes in the brief instant of the magnetic events is very, very small, and that consequently, we should note, a minute purchase, a tiny angle of leverage, makes the difference between a trajectory becoming an inducer or an attractor.

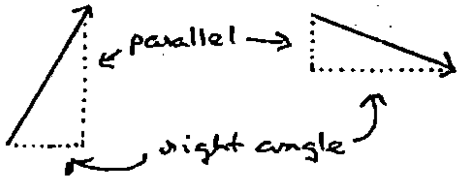
ponents of the field from a perfectly straight path, not by movement of the conductor. This first step divides the field equally: that part ahead of the direction of movement may develop sufficient leverage to become inducers, that part behind the direction will not.

We find, here, in the way the components of the field move in order to enter the conductor, the first step in the sorting. This division according to movement by components of the field is of great importance, although it does not by itself complete the sorting. Whatever the angle of movement by the conductor, in this step, as trajectories move slightly from a straight path to enter around a blocking solidity, the field always divides itself in two. One half, by moving behind the direction of movement of the conductor, define themselves as attractors; the other half, by moving ahead of the direction, define themselves as potential inducers. Once the standard has been grasped, it seems inevitable that such a division should occur, and it seems a logical necessity that some significant part of the sorting should depend on something other than the actual movement of the conductor, for if it did not, and the movement by the conductor were the only relevant determinant of the sorting, then it would seem that current again would vary with the velocity of the conductor. There are several reasons why the movement by the components of the field should be taken into account in explaining the sorting. First and most simply, if the sorting somehow involves movement, we should not, in our account of it, fixate single-mindedly only on the movement of the conductor when we are very sure another movement, that of trajectories from their straight paths when they encounter solidity, is also occurring. Furthermore, once we decide to take it into account this movement begins to appear very relevant to the process by which some trajectories develop sufficient leverage to cause induction and others do not. For that purpose, those behind the direction of movement are at a significant disadvantage. To develop sufficient leverage to cause induction, a trajectory must be ahead of the snail-like incremental movement of the conductor in order to bring its work potential to bear in breaking loose a charged particle. Of course it is possible that a particular trajectory, one that entered at the surface behind the direction of conductor movement could be deflected ahead of the direction by a chance impingement with another solidity further along its path, but that works equally the other way too, and these random sports should cancel one another out. Thus the first step in the sorting process can be conceived to occur at or near the surface of the conductor: impinging on solidity, each component of the field must move from the straight line, either ahead of or behind the direction of movement by the conductor, with the result that the field divides into two equal parts, the attractors and the potential inducers. Our basic strategy in designing better generators and motors will be to interfer first with this essential division, trying to bend what would be straight fields so that, for generators, all the field enters the conductor as potential inducers, and for motors, all the filed passes through it as attractors.

How might the second stage of the sorting work? Here the conductor gets its turn, the movements by the components of the field having had theirs. This stage sorts the half of the field comprising potential inducers into two parts, non-inducers, functionally the same as attractors, and actual inducers. In this process, the angle of movement of the conductor relative to the field seems fundamental. Why does this angle matter so much? Let us start out with a right angle direction: this direction seems to guarantee that a potential inducer will become an actual inducer. Why? I think the answer must be that when the increment of movement is at a right angle to the direction of the field, the only way that a trajectory ahead of the direction can experience the movement is as a creation of leverage, which leverage makes induction possible. At other angles, the movement of the conductor can be experienced in part as a creation of leverage, and in part as a movement parallel to the trajectory, a slipping of the conductor forwards or backwards along the line of the field, and such a movement creates no leverage. As is illustrated in the sketch at the right, we can triangulate all possible angles of movement, using an equal increment of movement along the angle of direction for each, finding for each the component of movement at right angles to the field and the component parallel to the field. For the right angle movement, the former component is 100% of the increment, the latter nil. For every other angle, there is a ratio of the one component to the other. Someone more adept at mathematics than myself could easily plot a curve showing this ratio for all possible angles of movement of the conductor relative to the straight field, and if the reasoning about the sorting process here is correct, that curve should be the same as the curve for current induced in a single coil rotating in a straight magnetic field.



coil, possible movements schematized by arrows. All these can be expressed as two components, one parallel, another perpendicular to the direction of the field.



Why should the ratio of the parallel component to the right angle component make a difference? Those trajectories that entered the conductor behind the direction of movement will experience the increment of movement as a slight movement away from them by any structure or field that they may have passed close behind; to them the angle of movement makes no significant difference. If a particular trajectory, however, has entered the conductor a smidgen ahead of the movement, that movement by the trajectory will not by itself be enough to give the trajectory sufficient leverage to cause induction. The movement of the conductor that will then take place, in the fleeting instant between the trajectory's entry into the conductor ahead of the movement and its tautening jerk, will have a component parallel to the trajectory, which will give the trajectory no added leverage, and a component at right angles to it, which will give leverage. Some trajectories, which after entry take ever-so-slightly undulating paths through the solidity of the conductor, will experience the movement of the conductor primarily as parallel to their paths, others primarily as at right angles, The probability, given vastly numerous cases, of how that movement will be experienced, is determined by the ratio of the parallel component of the movement to the right angle component. Thus, according to the angle of movement, that half of the total field defined at the surface as potential inducers becomes again divided into non-inducers, which experience the increment of movement as one sufficiently parallel to their trajectory to give them no leverage adequate for induction, and into actual inducers, which experience the increment of movement by the conductor as one sufficiently at right angles to their trajectory to give them the necessary leverage to break free loosely-bound charged particles. What is essential in this process for our purposes is that very small differences on the molecular level in the paths that trajectories traverse seem to make, in the aggregate, very decisive, dependable, predictable differences in the amount of current induced.

We can use this explanation of sorting and the associated conception of the process of induction to explain why the resistance against the movement of the coil also varies according the the angle of the movement by the conductor. All the trajectories of potential attraction, both those we have called attractors, non-inducers, and actual inducers, will link with their opposite pole and each will exert a quantum of attraction on the magnetic poles. That half which entered behind the direction of movement, however, will pass through the conductor along a path where they are cushioned by the magnetic fields and structures of the molecules. The increment of movement during the time in question will, on the average, give them a bit of added room relative to the molecules moving away from them, but will not, on the average, relative to the molecules moving towards them, bring them close enough for their tautening to exert sufficient pressure on any particular field or structure to break loose a charge. When the trajectory behind the movement tautens, the pressure that its straightening action exerts on molecular fields will, on the average, be distributed evenly, front and back, and the conductor will receive from these trajectories no net resistance, perhaps even a very slight propulsion. The case is much the same for those trajectories that entered in front of the direction of movement, but then experienced the increment of movement primarily as one parallel to their path; they may exert a very slight net resistance on tautening, balancing the net effect of those behind the movement. The actual inducers, however, are also the source of effective resistance. The increment of movement by the conductor will be experienced by them at a right angle, and it will press the enveloping field of the molecules and the weak structures binding charges closer, pushing their trajectory further ahead of the movement. Somewhere along its path, each inducer-trajectory will develop a pressure point against a charge-carrying molecule where the force along its line in the act of tautening will be sufficient to break the charge free. Thus the inducer will exert its increment of resistance against the direction of movement and in doing so it will contribute its increment to the flow of current. In contrast to the attractors and non-inducers, whose tautening force is felt amorphously, front and back, along the line of its trajectory, with no net effect, with the inducers, their tautening force will be localized at the points where the charges are broken free, and since, by the definition of the sorting process, these trajectories are ahead of the direction of movement, the force will act on the conductor as resistance to its movement. If trajectories that entered behind the direction of movement broke a significant proportion of the charges loose from behind, the resistance to movement of the coil would not vary with the current induced.

The random sorting performed by the movements of components of the field relative to the conductor and of the conductor relative to the field establishes, we reason, three classes: attractors, non-inducers, and actual inducers. Let us turn for a moment to transformers, where, we suspect, a firm allocation of the components of the field takes place, not a random sorting. What kind of passage through the conductor do components of the field make in this case and what sort of probability for division into attractors, non-inducers, and acutal inducers is established by this mode of passage? Recall the magnetic dipole lying horozontally at the bottom of a cross section of the secondary coil, oriented at a right angle to the direction of the coil, N-pole pointing to the left, S-pole to the right. As we noted earlier, as the current in the primary coil alternates, the polarity will shift, N to the right, S to the left. As this shift occurs, the dipole revolves 180 degrees on an axis through its center. In doing this it projects a trajectory up, out of the core and from there the trajectory will curve up into the conductor, back around and down, reentering the core at its point of origination, linking to the S-pole of the dipole, describing a loop. Imagine that that loop is like a loop of thread around a mass of molecules, lying across their enveloping magnetic fields and their various structures, held away from them a bit perhaps by the N-repulsion of the fields of particles nearby. When the loop is completed a tautening jerk will pulse through it and somewhere along the line the tightening trajectory will break a magnetic or structural bond loosely holding a negative charge to a molecule, and that charge will then flow as current in the conductor. In the case of the transformer, there is no motion by the conductor, but a great deal by the trajectory, and it is such that it decisively sorts the field into only one class, that of actual inducers. What is interesting with the transformer, with respect to its sorting, is how thoroughly over-determined its allocation of all the field to the class of actual inducers seems to be. With the moving coil, very small deflections from the straight line combined with very small increments of movement of a certain type by the conductor seemed to lead to a clear-cut sorting of great statistical dependability. With the transformer, the deflection is a full 360 degree circle, the loop, a much greater deflection, judging by the fine distinctions of the random sorting, than would be necessary to allocate all the field to the class of actual inducers. Thus, to replace the sorting that takes place in coils moving in straight magnetic fields with a planned allocation of the field to a desired class, we may not need deflections anywhere near as radical as the reversal of poles in alternating-current transformers to achieve startling results.

Let us ask now how a transformer effects its over-determined allocation. A transformer is basically a toroid, a carefully constructed closed electromagnet, the field in which is created by a primary coil, and the output of which is taken off through a secondary coil. The characteristics of the toroid are what makes it possible, as current alternates in the primary coil, to channel all the magnetic trajectories, as they come out of the magnet as the current alternates, into the class of actual inducers, those establishing a path through the conductor as a result of which they have ample leverage to make loosely bound charges flow as current. What is advantageous with transformers, may also be advantageous, if properly applied, in the design of electric motors and generators. Let us, in the light of these reflections, restate our design problem: can we adapt our parallel axis design to take advantage of the action of toroid windings to bend magnetic fields so that their entire capacity for work can be exploited to induce electricity for generators and rotary motion for motors?

A pause is needed to make sure that we are not slipping back into a way of thinking that we found inadequate at the end of our first set of reflections. There we observed the probability that a rotating field of force around a current-bearing coil would not, in fact, bend a straight magnetic field, but now we are proposing to bend fields with toroids in order to control a sorting process that otherwise would be random. Such bending as we now seek does not conflict with our criticism of the classical account, for here we are not speaking of the ability that revolving fields might have to bend straight fields in mid course, but we are instead proposing to use the toroid windings to bend the field at its source. We can remain quite skeptical about the capacity of a revolving field to alter the course of a straight field in free space moving close to parallel to the plane of rotation of the revolving field, and at the same time we can be very respectful of the evident power of such revolving fields to align magnetic bipoles within the mass of magnetically permeable matter. It is in this way, not by bending fields in free space, but by aligning the poles askew in magnetic material, that we here propose to take advantage of the capacity of toroid windings to bend magnetic fields. With such windings, deflecting the poles from the perpendicular, we may be able to interfer with the random process by which a field is sorted into inductive and attractive parts and thus exploit the entire capacity for work of the fields in rotary generators and motors.

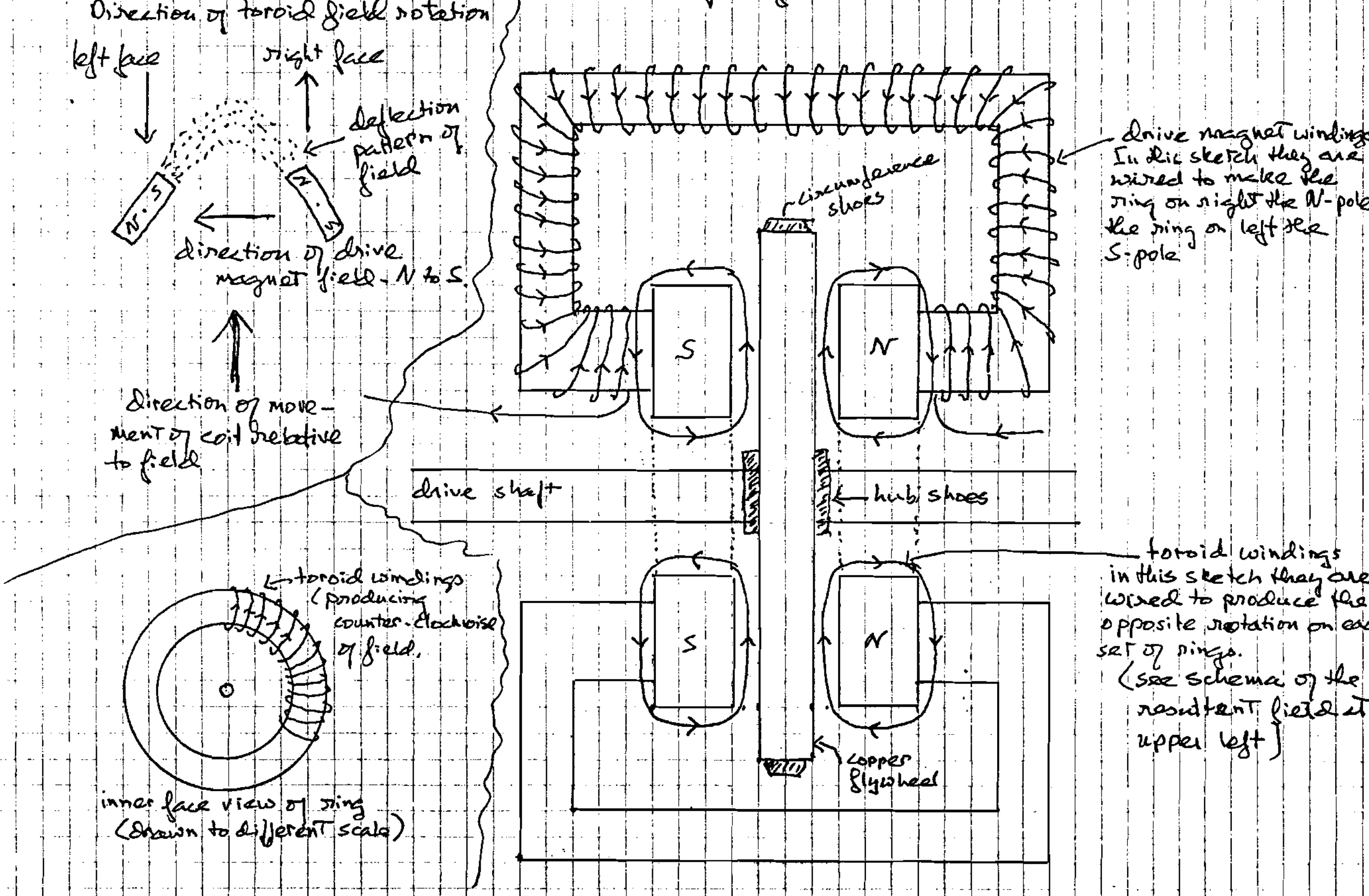
Such a bending of fields with toroid coils will not be hard to do. Let us return to our original design of a simple parallel-axis, non-cyclic generator and motor. To begin with, let us first make the magnet for it rather more complex. We begin with the stubs facing each other, the N and S poles. Let us make these rings of laminated, highly permeable, nickel-iron alloy, each of which can be wound as a toroid. Before doing that, let us attach to the back faces of the rings, those pointing away from each other, numerous rods of nickel-iron alloy, with the rods extending out, up, back, and around, down and in, joining the two rings from their backs. Let us now wind the rods so that one ring becomes the N-pole and the other the S-pole, and then let us wind the rings with toroid coils. With these windings, there should be just enough space between the N and S pole faces for a copper flywheel to rotate freely in the gap. Shoes, as in our original design should be arranged to take current off from the hub and circumference of the flywheel. With this we have a prototype our our second generation parallal axis, non-cyclic generator and motor. Its basic components are diagrammed in a cross-section in Diagram 2. Will it work?

Let us test its components. Using direct current, let us first pass current through the windings on the rods connecting the two faces. A strong,

Diagram 2

between pages 26 and 27

Schema of parallel axis generator with toroids curving its field.



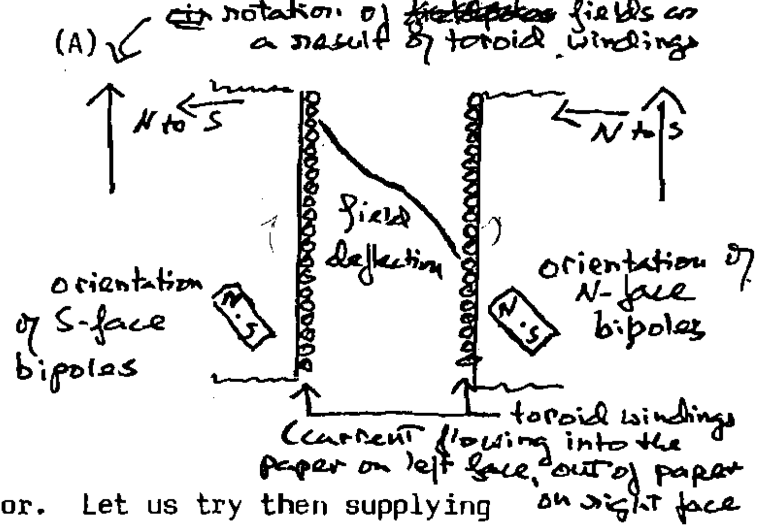
drive magnet winding
In this sketch they are wired to make the ring on right the N-pole the ring on left the S-pole

toroid windings in this sketch they are wired to produce the opposite rotation on ea set of rings.
(see schema of the resultant field a upper left)

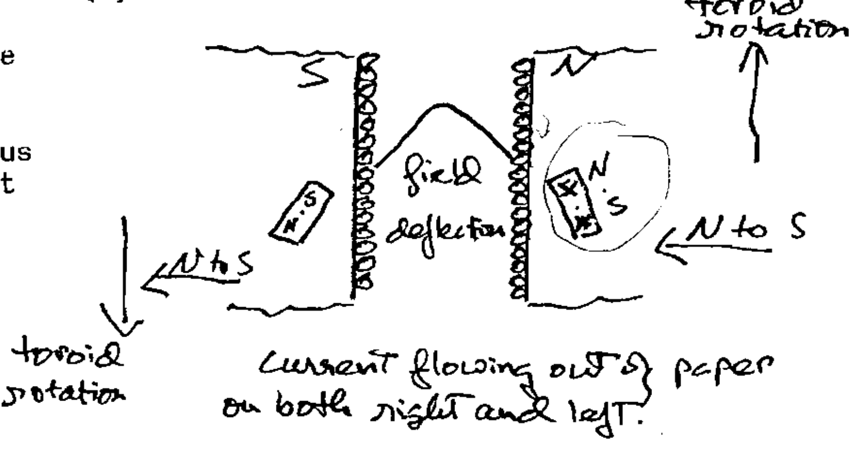
straight field should move between the adjacent faces of the two rings. To refine our prototype, we should test how evenly the strength of the field is distributed across the surfaces of the two faces, and we might make some adjestments in the drive magnets to even out any imbalances, for an even distribution of this field would be desirable. Next, let us test our toroid windings, again using direct current, so that we know how to produce a clockwise and counterclock-wise rotation of the magnetic field that courses through each. In doing this, let us pay special attention to the joints between the rods and the rings. The windings on the former should in under the toroid windings, which will have to be displaced at the back by the joints. It may prove desireable to jacket, beneath the toroid windings, the back and edges of the rings with relatively magnetically unpermeable material, in order to channel the greatest possible proportion of the field generated between the adjacent inner faces of the rings. Let us see first if we can understand how this device might work as a generator.

We can do this most easily simply by using only our drive magnets and supplying rotary force to the flywheel--this would simply be a working version of our first design with the flywheel cutting the magnetic field at a right angle, a current flowing along the radii of the flywheel. What are the options with respect to the toroid coils? Let us turn off the drive magnets, remove the flywheel, and study how we can use these coils. To begin with, we supply a weak current to the drive magnets, creating a weak, perpendicular field between the faces. Then, using a rheostat, we begin to supply direct current to the toroid coils so that they would both rotate the field in the same direction. The result would be that the trajectory of the field would move from the perpendicular as if twisted on an axis in the center of the gap, perhpas with a slight S-like undulation in it. Such an alteration of the field would not seem to help much with a rotary generator. Let us try then supplying current to the toroid coils so that they would rotate the field in opposite directions. As a result of this, the field would start out from one face along a line roughly similar to our first attempt, but as it approached the center of the gap, it would begin to turn sharply and then return on an angle opposite to that it had taken to a point on the opposite face more or less directly across from the point at which it had started. Such a curve looks promising. Let us reinstall our flywheel and rotate it so that the direction of rotation moves into the bend in the field.

(A)



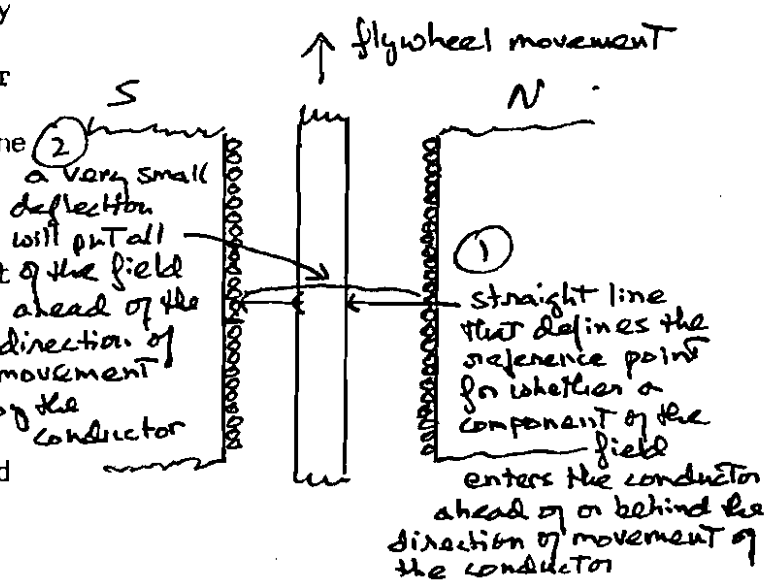
(B)



By normal principles this arrangement would appear to be a highly inefficient one, for the magnetic trajectories are at a low angle of incidence to the conductor. But the normal rules concern straight fields, and it is conceptually hard to determine the proper way of calculating the angle of incidence with a sharply curved field. The situation is much more like that with a transformer than with a normal induction coil. With the tranformer there was a 360 degree loop through the conductor, which virtually guaranteed that as a magnetic trajectory tautened, somewhere along the loop it would bring enough pressure to bear to free a charged particle. Here we have something approaching a 180 degree bend in the trajectory as it passes through the conductor, not as advantageous as with the transformer loop, but here we also have movement, absent in the transformer. Furthermore, this movement is much more radical, if we can speak of incremental movements being radical, than with a moving coil, In the latter case the maximum increment of movement would come as the coil was moving at a 90 degree angle to the field. Here, however, the movement is almost directly away from the anchor points of the field. It would not seem, therefore, too much to expect that the conductor, under these conditions, could make a cut of the field that would, like a transformer, almost completely exploit its potential for inducing electricity.

This does not mean, however, that the over-all efficiency of such a generator would approach that of a transformer. For one, there is still the phenomenon of friction. Also, although the field will have been bent to maximize the probability that it will induce electricity, its intensity may be attenuated somewhat. Here again we border into a speculative domain, for me at any rate. It is not clear to me whether the intensity of a magnetic field varies primarily with distance or dispersion. I suspect it is a function of both. The effect of the toroid coil will be primarily to lengthen the distance that magnetic trajectories traverse, but not to increase greatly their dispersion. A certain amount of experimentation with prototypes will need to be done in order to determine whether, and to what degree, they can deliver an improved conversion of the potential in the field into electricity. One of the first things that would need to be determined in such experiments would be how the current induced varies, given a certain velocity of rotation, according to the degree of deflection of the field by the toroid. The sharper the deflection, the more attenuated, at any point along their paths, will the trajectories of the field probably become. The experiment would not be difficult: starting with no current in the toroid and instrumentation that could measure the output current and a source of rotary motion that could maintain a constant speed of rotation in the face of mounting resistance, one could steadily increase the current into the toroid coils and find out where the output current peaked. Unless there was a considerable gain in output for a relatively small input into the toroid, the generator we have constructed might not be of much value, for if our conception of a generator as a partly output determined engine is correct, then the only way to get an ostensible improvement in its efficiency is by significantly lowering, for a given output, that part of the work that goes into it that is independent of the output, namely the work needed, the current, to create and structure the magnetic field. This is a discouraging reality that must be kept in mind in testing the prototype generator.

It is my sense, however, that a small added input to the toroid coils to bow the magnetic field modestly will yield an optimum output of the generator relative to the input of the current used to create and deflect the magnetic field. We can use the speculative principles of explanation for the phenomena of normal induction of current to show why this should probably be the case, and such an anticipation, should it be confirmed by experience, should give grounds for greater confidence in our theory. Recall that for a coil moving in a straight magnetic field, we postulated that the surface of the conductor acted as a random sorting machine according to the angle of incidence putting half the trajectories in front of the direction of movement and half behind. To observe this process we marked the spot of first impingement of the trajectory on the molecular surface, drew an arrow indicating the direction of movement and a line perpendicular to that arrow, and watched whether the actual entry by the trajectory into the conductor was ahead or behind the line. That difference, we postulated, determined whether the trajectory would be a potential inducer or a mere attractor; it determined whether the trajectory could later develop the leverage or would necessarily lack the leverage to break a charged particle free. Note that we were dealing with straight magnetic fields. Trace back from the point of first impingement, our marker, along the angle of incidence, a straight line, and we will find the point of origin of the trajectory in question. Trace forward along that line and we will find its anchor on the opposite pole. A very slight deflection ahead of that straight line by the magnetic fields of the molecular structure of the conductor will allocate all trajectories to the class of potential inducers; a slight deflection behind it will make all mere attractors. Further, we noted that when the increment of movement by a coil moving in a straight magnetic fields was at right angles to the field, it virtually guaranteed that all potential inducers would become actual inducers, for they could experience that movement only as a contribution to their leverage. Now our parallel axis design guarantees that all increments of movement by the conductor will be at right angles to the field, and with our toroid coils, using very little electricity, we can easily make the trajectories bow forward a little bit so that their entry into the conductor is several, perhaps many, molecules ahead of where a straight line between origin and anchor would enter. If a random deflection from the straight line of half a molecule makes a dependable difference, we can well expect a planned deflection of several molecules or more to do so as well. Hence, with a very slight expenditure of energy in our toroid coils, we should be able to define for our conducting coil all the components of the magnetic field as inducers. By such a simple intervention, we do little to weaken the intensity of the field, yet we virtually double its value as a



source of current. To be sure, that will mean that we have to put twice as much rotary force into the generator to overcome the added resistance, but our purpose is to convert rotary force to electricity, so this increased input is in a sense not an added cost. But we do not have to put in twice as much current to generate the field, perhpas only a tenth more, or even less, resulting in a net gain in usable output. Such an improvement could lead to a significant, but incremental increase in the supply of electricity.

How would our device run as a motor? In discussing moving coils in magnetic fields, we concentrated on the process of induction associated with generators. On the level of molecules and trajectories of potential attraction, how might we envisage rotary force on the coil arising? It is nearly the reverse of the process of induction. Imagine the surface having sorted the trajectories into those ahead of the direction of movement and those behind, the trajectories having established their paths, and the increment of movement having tightened those in front of the direction. The only difference is that the conductor is carrying current, charged particles flowing along the conductor molecules, from one side to another, relative to the trajectories. Since the conductor molecules themselves already have a full complement of loosely bound charged particles, these new particles with their N-repellant enveloping fields, create a certain magnetic pressure, all around, on the N-repellant trajectories. Those that are behind the movement and relatively slack will have enough room to move as the particles flow against them, allowing the particles to pass by. So too with those trajectories, in front of the movement, that experience the movement as parallel to their path. But those that are in front of the movement, and have experienced it at right angles to their path will have tightened down somewhere and will be hit from the side there by a particle and those trajectories will be broken or pulled from their anchors. These leveraged trajectories in front of the movement will have been exerting primarily backward pressure. When they are broken from the side by a collision or interaction with a moving charged particle, the force exerted by that interaction itself neither adds nor subtracts from the over-all front-back balance, but the backward pressure that the broken trajectories would have exerted suddenly disappears, and as the trajectories behind the movement tauten, exerting their somewhat amorphous action, there is a net gain advancing the movement of the coil proportional to the number of broken trajectories in front that are unable to act as restrainers. Now, while there is a certain elegance in the process of induction in a moving coil, this process of driving a motor, should it be close to what actually happens, seems rather cumbersome.

Can we run the device we have just created as a motor in this way? If normal motors get their rotational energy through a process something like what we have here described, our generator cutting into a bowed field may not work as a motor. Assume that the generator achieves a situation analogous to a transformer in which all the magnetic field works to induce current. If now, instead of inducing current, we supply current, and try to induce motion, all we manage to do is break all the potential restrainers and we are left with no magnetic field behind the direction of motion to produce, through its amorphous action a net forward thrust. We must begin to entertain the proposition that the concept of dynamo is a concept that has appeared pertinent to electric generators and motors because of the way established design practices permit the accidental sorting of the field according to the angle of incidence between the field and the coil. We can use our principles of explanation to show how this accident comes about. With coils rotating in a normal field, the optimum angle for both motor and generator is 90 degrees, at which angle the field will split itself precisely in two. The so-called dynamo, when acting as a generator, utilizes the capacity for induction of one half of the field, and when acting as a motor, it uses the net effect of the other half of the field. When the coils are at less than optimum angle, the matter is a little more complicated, but it comes out to the same thing. Electric motors and generators, designed to maximize the work extracted from a magnetic field, should be quite different devices. Existing generators utilize the capacity of a field to induce electricity. Existing electric motors rather indirectly utilize the attractive force that a field can exert after a part of it has selectively been neutralized by the flow of current in the coils. It would make sense in designing an electric motor to maximize the work potential of a field to try to exploit that attractive force directly. How might we do that with our device?

We can easily state the essence of the arrangement we seek. Sketch B on page 27 gave us the deflection that, we think, will allocate all components of the field to the class of inducers, that being the deflection suitable for generators. Sketch A on page 27 gave a deflection unsuitable for generators, but that would be very suitable for motors, were the magnetic faces closer to one another and the deflection sharper. This basic deflection will sort all the field into powerful attractors. The essence of such an arrangement is not hard to see; finding a way to embody it is more difficult, however, and we must work our way through certain practical problems. To begin, let us take out our copper flywheel and the shoes to take current off, and substitute a new flywheel that has a ring of highly permeable nickel-iron filling the gap between the two toroid faces, and made otherwise of less magnetically permeable material. Let us install it and consider how this might operate. We should immediately realize that with it we have something of a problem, with respect to which there are several design choices. We can realize what the problem is if we imagine such a flywheel and two permanent magnets, one pointing to an N-pole the other to an S-pole at angles to make a bowed field. The flywheel will turn and rotate the field towards it until the field no longer exerts a rotational force on it. Will the same thing happen with our flywheel? The easiest thing to do would be to test our prototype and find out what happens, but since we have not built the prototype, we have to try to find out through thought experiments with it.

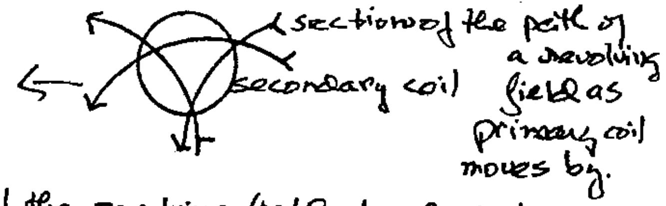
First, there are several explanations possible for the situation with the permanent magnets. One is that our postulate about magnetic force is all wrong and that once two poles are linked by trajectories of potential attraction, these trajectories will stay linked by a continuous attractive force. If this is the case, our earlier postulate that magnetic trajectories exert one pulse-like tautening action in which a quantum of attraction or repulsion is exerted that ends with the trajectory pulling loose from its anchors and dissipating is wrong. It certainly seems in the case we have postulated, that our picture of magnetic action is wrong, but not necessarily so. If there is an enduring line of connection between magnetic poles once joined, it would seem hard to grasp why the angle of incidence in a coil rotating in a magnetic field makes a difference. In enduring links, all trajectories of magnetic force would induce electricity in a moving generator coil, for eventually all would be pulled down taut like a hawser holding a boat against a tide.

There is an explanation of the way the field bends back in our primitive experiment with the permanent magnets that does not require an enduring link between poles. Once linked and oriented in the general direction of the pole from which the linking trajectory is coming by the tautening jerk on joining, the magnetic molecule stays in that orientation, greatly increasing the probability that a new trajectory will again link with it. In our primitive experiment, we have sensitized a certain area of the flywheel face to receive the magnetic field, and as each pulse goes out, it tends to go back to that presensitized area even though the trajectory has to bend more and more to do so. Since, with our prototype in real operation, the whole face will be so sensitized, such a bending back of the field may be less pronounced. If, despite this complete sensitization, the field still tends to bend in to the perpendicular, loosing its capacity to exert rotary acceleration on the flywheel, we still have the radical option of switching the operation of our magnetic system to alternating current. By doing this for both the drive magnets and the toroid coils, we would slimply flop the poles back and forth while patterns of attractive force on the flywheel would remain the same. The flywheel would then receive this force in pulses in which any tendency for the field to bend back would be relatively insignificant.

Further, in our primitive experiment we are using a permanent magnet simply set at an angle, whereas the actual prototype will be using a field bent by the action of the toroid. Here, however, a very real problem jolts us. Since the toroid coils along the faces of the drive magnets will be very close to the magnetic faces of the flywheel, they will have a toroidal effect of inducing a certain rotation of the magnetic field in the flywheel also. This effect will be to circulate the magnetic field near each face of the flywheel in a direction opposite to the direction of circulation in the face adjacent to it. And this counter rotation of the field on the opposite face is very inconvenient, for the curve of the field that it will produce is not the one we postulate is suitable for a motor, but the one for a generator. Here we must start desperately trying other expedients. After trying this and that in my head and on scrap paper and conceiving of all manner of bizarre rotating forms, two courses seem to me worthy of discussion. The first is rather obvious, the second requires a certain change of mind set, but is probably the one that nature itself had in mind.

If the secondary effect of one toroid coil is to impose an inconvenient bend in the field as it approaches the flywheel face, why not add a toroid to that face, wind the spokes of the flywheel so that its rim in general becomes the S-pole, and adapt the drive magnets so that both those faces are N-poles. Current on the flywheel toroid could be made to flow in the direction that would make its field circulate in the same direction as the toroids on the N-poles make their fields circulate. In this way we would have our deflected straight line of attraction, which should exert a substantial rotary force on the flywheel. This expedient would seem potentially feasible, but we need to return to our continuing troubles with fields revolving around current-bearing coils, the toroid coils. There should be no difficulty, if our reasoning has been sound, in their cleaving between each other, for their planes of rotation are parallel. But there is introduced in this situation a rather significant movement of these revolving fields relative to each other. It may be that the movement will not make them affect each other, but my hunch is that it will, and that the effect will be rather surprising. My suspicion is that each will induce the current it is carrying in the other, and since the current each is carrying will be flowing in the opposite direction to the current the other carries, the effect, if the currents in each are equal in strength, will be to cancel out the current in each and the magnetic force from the drive magnets will cross the gap in a useless perpendicular.

I am not sure that this reaction would take place, but I have a strong hunch that it will, and we might note in passing that if it does we have hit upon our hypothesized rotary transformer. If we rotate a current-bearing toroidal coil inside a passive, secondary toroidal coil of a different number of turns, I would not be surprised were the current in the primary coil reproduced without significant resistance in the secondary coil at a voltage and amperage that varied according to the ratio of turns in each coil. This is merely an intuition; I have not taken time to reason it through as I do not have a clear understanding of how revolving fields may interact with coils relative to which they are moving. Revolving fields, however, may to like to preserve the symmetry of their rotation, and if they enter an adjacent coil while moving relative to it, the revolving coil will, as it moves relative to the coil it has penetrated, develop a significant bend in its arc of rotation. The leverage exerted in order to cause this forced flexing of the coil might well be developed simply from the tension of its perimeter, its path of rotation, and it might be enough leverage to set a charge moving. Hence, it seems to me not impossible that revolving fields are such that they cannot, under conditions such as here hypothesized, exert directional force on the coils around which they circulate, while they may nevertheless be capable of inducing current. Such induction without resistance seems to happen in alternating-current transformers, and if it can happen with direct current toroidal coils moving relative to each other, I think it will be in the way postulated here. A test could be made relatively easily by winding two cylinders, one slightly larger than the other. Starting with the first, winding it like some balls of string, the coils parallel to each other running the length of the surface of the cylinder, bending slightly at the ends around an axle shaft. No core would be necessary, unlike an alternating-current transformer. The inner cylinder would be the secondary coil, and

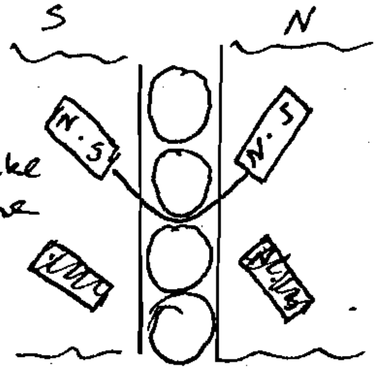


If the revolving field closed circles, these will either distort greatly as the primary coil moves by the secondary or cut through the secondary with much leverage on its structures.

shoes to take current off from it would be needed. The outer cylinder frame, made as thin as possible so that only a small gap would separate the two coils, would then be slipped over the inner cylinder and coil. The outer part could then be wound in the same way as the inner, but with a differing number of coils. With the primary coil connected to a source of current the device would be ready for a test.

We have, however, digressed. We have developed the suspicion that our first expedient for controlling the secondary effect of a toroid meant to bend a field so that its full attractive power can be used for propulsive force will not work. In search of our second expedient, instead of trying to evade the secondary effect, let us see if we can work with it. Let us put two magnetic faces up close to one another, forgetting for now rotation, and let us put one toroid coil around one of those faces. Now we can examine the primary and secondary effects and play with ways to get a sharply deflected, but straight field. It is clear from the illustration of Case 1 at the right, assuming that the current in the coil is flowing into the paper, and that the drive magnet on the left is an N-pole, on the right an S-pole, that we cannot deploy the <u>attractive</u> force of the field to produce optimum rotation. In Case 2, we do not try to evade the secondary effect, but to make use of it by deciding to drive our motor, not with the attractive force of the field, but with the <u>repulsive</u> force of it. Here the secondary effect of the toroid coil will be to keep the N-poles pointed directly at each other no matter how sharp the angle of deflection. Such a head-on orientation is precisely what we want, and an electric motor designed to exploit the full force of its magnetic fields will do it by tapping the repulsive force of those fields. If a pulse action is necessary, the whole magnetic system, the drive magnets and toroid coil, can be run on alternating-current and the juxtaposition of alternating, opposied polarities will remain the same. We now know how to build our motor and we must choose a proper design for it.

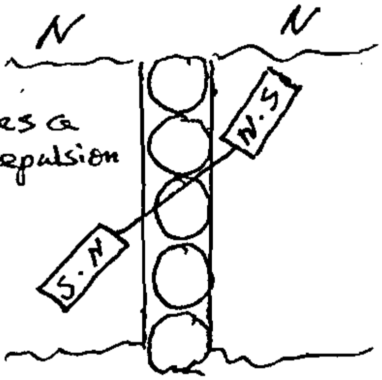
(Case 1)



the result does not make a strong line of attraction

current flowing into paper Deflection down ↓ on right, up ↑ on left

(Case 2)

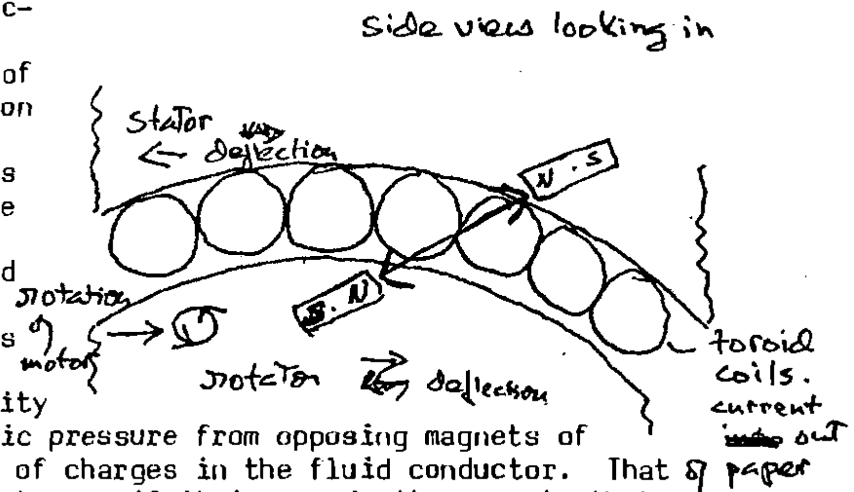


the result makes a strong line of repulsion between ↑ opposing poles

Current flowing as above ↓

It would not be wise, I think, to use flat facing rings such as those we have so far been working with, making one the rotator, the other the stator. In such a configuration, the pressure separating them from the opposing poles would require a very strong abutment bearing for the drive-shaft of the rotator to keep it from moving backwards, allowing the opposing faces to move apart. It would be better that the drive magnet of the rotator be the outer face of a cylinder, the spokes to the drive shaft being wound to provide the magnetic force of the face, the outer surface of the cylinder.

This cylinder would rotate inside a stator cylinder, the inner face of which would be the opposing pole of the drive magnet and would carry the toroid coil, the windings of which would run from end to end of the cylinder, parallel to one another. The deflection the toroid coil would cause is illustrated to the right, the line of repulsion could be almost directly on the tangent of the rotator, and all of the field from both drive magnets would exert its full repulsive force along that tangent. I think with this arrangement, the magnetic field of repulsion would not in any way produce unexpected induction effects in the toroid coils. Later in the letter, I will discuss the possibility in fluid conductors of using magnetic pressure from opposing magnets of similar polarity to induce the flow of charges in the fluid conductor. That discussion is highly speculative, but even if it is sound, it suggests that such pressure will merely set charges in motion, but will not, by itself, organize a coherent flow for them. While it is not, therefore, inconceivable to me that the magnetic pressure between the two faces of the rotator and stator in this situation may have some surprising effects on the current in the toroid coil, I do not really anticipate them.



If this pressure has no untoward effects, and the motor functions as anticipated, it should be very efficient. All the field will act all the time at close to the optimum angle, on the tangent of the rotator. A certain amount of experimentation will be necessary to find out how strong a current will be needed in the toroid coil to produce the full range of desirable deflections. To what degree the strength of a magnetic field diminishes with distance and to what degree apparent diminisment of it by distance is really the result of dispersion, I am not sure. The deflections we hope to create here will increase the distance traversed by the field, but they will not have much effect in increasing the dispersion of the field. I think it is fair to say that the deflection will not greatly diminish the intensity of the repulsion it exerts on the rotator, and that a configuration such as this will nearly exploit all the work potential of the field all of the time at the optimum angle, along the tangent of the rotator. If this is the case, and our reasoning about present motors exploiting at best only half the potential of the field, a motor such as this one should approach being twice as efficient as present electric motors. Such a gain would be of vast significance.

In addition to being very efficient, such a motor would have very interesting operating characteristics. If one could vary separately with rheostats the current to the drive magnets and the toroid coil, a wide range of operating options would arise. Maximum torque and a low rpm would be achieved, I think, by a strong current going into the drive magnets and a relatively weak one into the toroid, giving a less radical deflection. The highest rpm, but a relatively weak torque, would come with a relatively weak current to the drive magnets but a stronger one to the toroid coil, bringing the line of repulsion flat down on the tangent. Further, if the motor were built to take the strain, by reversing the direction of current in the toroid coil, the motor could be made to act as a positive break. Should the motor work well in principle, a good deal of developmental work would need to be done to find ways to control heat losses, to distribute the fields on the faces of the cylinders as evenly as possible, and perhaps to help spent field escape after it has exhausted its potential for work in repulsive force. (I am not sure whether, once the field has exerted its force, it spontaneously disintegrats or remains, incapable of work, a kind of magnetic debris that will need to be extracted--disintegration seems the more probable).

If the first set of reflections we pursued earlier are actually the sounder, a device structurally close to what we have just described might work as a motor. The toroid coil would need to be moved to the rotator, the rotator magnet wound as an S-pole, and the surrounding magnet of the outer cylinder as an N-pole. The toroid coil would generate rotary force partly as a normal motor coil. The remaining force in the field would then be exerted on the tangent of the rotator as in the motor we have just described. There would be some problems with the secondary effects of the toroid coil on the outer magnet, but these would not be serious, perhaps even beneficial, if the reasoning of the first set of reflections is sound. Actually, however, the motor using opposing poles of similar polarity deflected by a toroid coil does not really depend, for its feasibility, on the validity of the reasoning in either set of reflections. For us, the intellectual trajectory by which we arrived at the idea for its design came from the second set of reflections, but both sets concerned the process of induction. This motor, however, if all goes well, is designed to avoid induction of current or an interaction of current in the coils with magnetic fields in free space exerting rotary force. The current driving this motor, whether in the coils of the drive magnets or the toroid, is performing work on the magnetic poles, not the fields, performing work on the poles in such a way that the resultant fields can perform their work on the rotator.

Let us close this part of the letter with a brief summary. We started by suggesting a configuration for rotary motors and generators that will allow the coil, a copper flywheel, to move in a magnetic field so that all of the coil is interacting with all of the field at a right angle all of the time. We then suggested that such an interaction is less than the optimum reached daily by alternating-current transformers. We then embarked on a long search for ways to achieve a functional equivalent of the interaction characteristic of transformers, a functional equivalent that could be utilized in generators and motors with their moving parts. We hypothesized that the inefficiency of moving coils in straight fields, relative to transformer coils, arose because the former relied on a random sorting process according to the angle of their movement relative to the field to divide the components of the field into a part that would cause induction and a part that would not. Transformers, in contrast, accomplished a uniquely efficient interaction between magnetic field and conductors because the action of the alternating current in the primary coil channeled all the parts of the field into the class of inducers. We found a way to bend a magnetic field in front of a coil rotating on an axis parallel to the field that should, if our reasoning is sound, nearly double the rotary input and electrical output of a generator relative to a given electrical input. In addition, we found a motor configuration, deploying, through a deflection by a toroid coil, all the repulsive force of opposing magnets of similar polarity so that the force will act along the tangents of a rotator all of the time. If such a motor will perform as we expect it to perform, its efficiency should exceed that of existing rotary motors by up to 100%. Finally, in passing, we noted the possibility of a device that may approximate a rotary transformer suitable for transforming the voltage and amperage of direct current. Let us turn to the second part of this letter.

Part II: Isothermal, isobaric, hydraulic-drive, condensing engines.

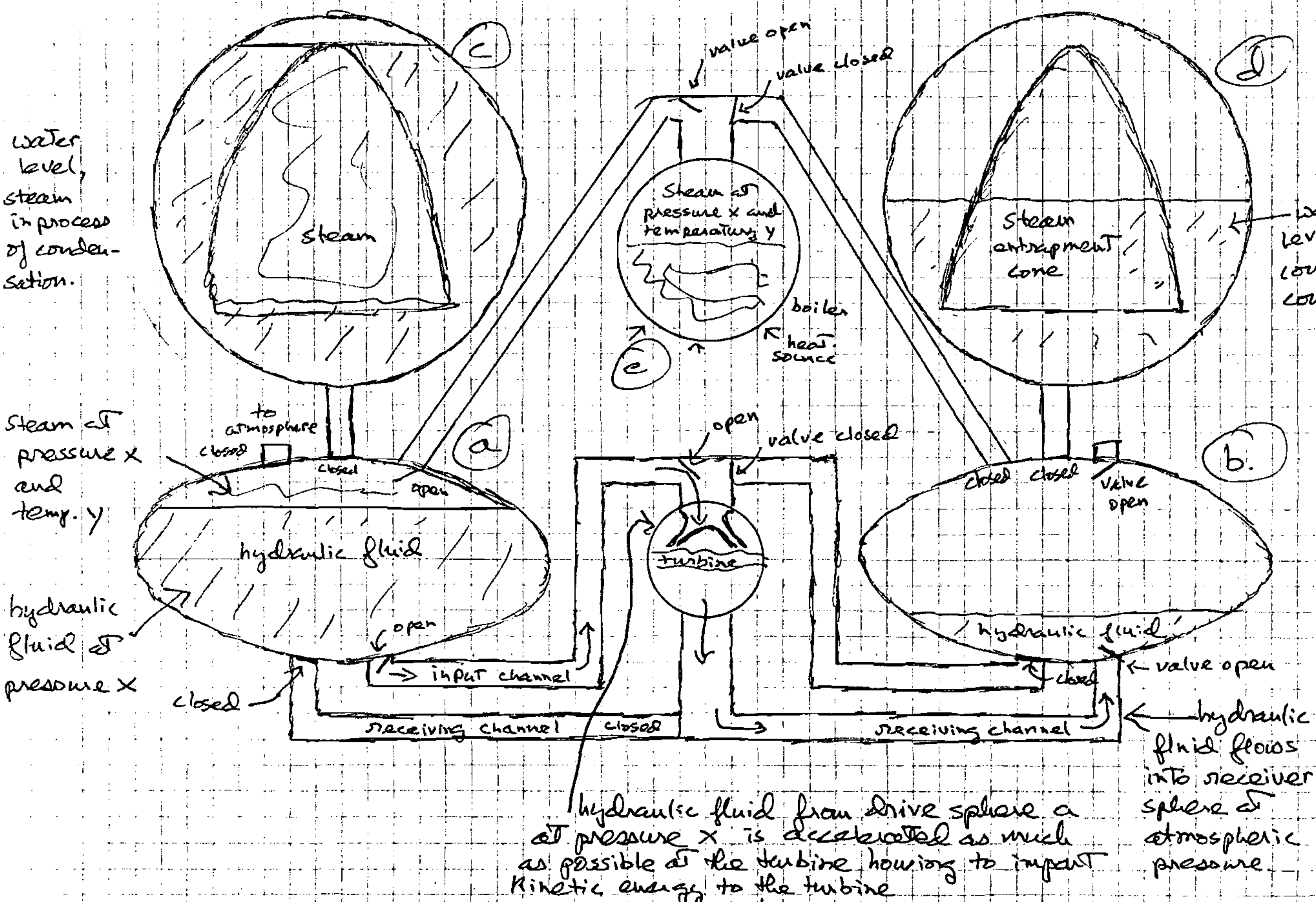
My second set of ideas pertains to the conversion of heat to mechanical energy. The basic intent is to bring the exploitation of solar energy closer to large scale economic feasibility and to improve, if possible, the thermal efficiency by which other sources of heat, fossil or nuclear, can be converted to electricity. I leave aside entirely the direct conversion of solar energy to electricity through devices such as silicon chips and concentrate to begin with on the problem of using the properties of steam as a medium of exchange between solar and other heat sources and mechanical work. The difficulties in deriving heat for steam driven generators from solar energy, as I understand them, arise from the properties of steam engines, particularly the steam turbine: they require very high temperature steam to work efficiently. To use solar energy to supply the bulk of the heat needed to drive a steam turbine, a very large capital investment is required in order to concentrate enough radiant energy from the sun on a volume of water to heat it to the temperature required. The design problem is this: can a steam engine be designed that will efficiently use relatively low temperature steam to produce mechanical energy?

Carnot's cycle would seem to suggest that this design problem is surely a question mal posée, but let us remember as we proceed that Carnot's theories dealt with ideal engines driven by ideal gases. The vapors of boiled liquids are not ideal gases, so let us not be daunted from our question: can a steam engine be designed that will efficiently use relatively low temperature steam to produce mechanical energy? To find a solution to this question, let us think briefly about the properties of various types of turbines. Steam and gas turbines work efficiently only at very high pressures. Steam turbines were developed as a replacement for the steam piston engine primarily as a means of propulsion for large ocean ships in which minimizing the bulk of the engine was, along with efficiency of fuel consumption per unit of output, an important constraint. For the generation of electricity, however, the bulk of the engine is not a basic constraint and steam driven alternatives to the steam turbine may be desirable, provided their efficient operating temperatures can be significantly lower and their over-all thermal efficiency is high. Fluid turbines, unlike steam turbines that demand high pressures, can be designed to work efficiently across a very wide range of pressures, ranging from that of two or three meters of water up to 1500 meters or more. Furthermore, fluid turbines are very efficient in converting kinetic energy in water or in another hydraulic medium into mechanical work. Let us set about to design a system that will convert the potential energy in steam held under pressure to mechanical work by using a hydraulic fluid and turbine as an intermediary.

What I propose might be called an isothermal, isobaric, hydraulic drive, condensing engine. At first, such an engine will appear, when described, very simple but cumbersome, and probably very inefficient, but in actuality its physics will be radically different from normal steam engines, be they piston or turbine driven, and its potential practical efficiencies may be very high. In what follows, I will use the term "steam" for ease, although in a working version the "steam" may be some liquid other than water boiled into a gaseous state. At any rate, a simple version of such an engine would consist of the following: a boiler that could deliver a substantial constant volume of steam per unit of time at a constant pressure; three pressure spheres, one filled with a hydraulic fluid, each connected to a turbine housing through a system of pipes and valves so that, whether fluid was flowing into or out of a particular pressure sphere, it would always pass through the turbine housing in one direction; and a turbine in the housing. In addition, for each pressure sphere there would be a substantial condenser to recapture a portion of the unused heat remaining in the steam after the primary work cycle was complete. At any time in continuous operation, two of the spheres would be linked in the primary work cycle, one driving the hydraulic fluid under pressure through the turbine, the other receiving it from the turbine at atmospheric pressure, while the third sphere would be in a secondary condensing cycle. Throughout this part we will continue to use the term "pressure sphere," although we should note that to minimize the build up of a counter pressure from a column of fluid as one sphere empties and the other fills, the pressure spheres should in actuality be low tanks, broad in girth, specially constructed to withstand considerable changes in internal pressure.

Let us imagine such an engine in operation, concentrating first on two pressure spheres linked in the primary work cycle. Assume that at the start of a work cycle one sphere is filled with the hydraulic fluid, the other is empty, and that a pressure valve at the top of the empty one is open so that through the primary work cycle pressure in that sphere will remain that of the external atmosphere. Steam from the boiler will enter the pressure sphere full of hydraulic fluid, establishing a pressure within the sphere that will act hydraulically on the fluid, creating a pressure head at the turbine. The hydraulic fluid, accelerated by the pressure, acquiring kinetic energy in the process, will move through the turbine, transmitting the kinetic energy to it. As this happens more steam at the input pressure and temperature will have to enter the pressure sphere in order to maintain the pressure head. The flow of steam will have to equal the volume of hydraulic fluid flowing through the turbine plus that of a volume of steam in the pressure sphere that will be condensing as work is performed by the turbine. The work delivered to the turbine expressed in heat will equal the latent heat given up by the steam condensing in the pressure sphere. If the flow of steam is controlled correctly, this primary work cycle will last until all the hydraulic fluid is driven through the turbine housing into the empty sphere, at which point the valve to the atmosphere on the sphere newly filled with hydraulic fluid will be closed, steam channeled into it, and it will become the drive sphere in the primary work cycle, and the third, yet unused sphere, open to atmospheric pressure, will become the receptor for the hydraulic fluid.

On completion of the original primary work cycle, the first pressure sphere, the original drive sphere, will have in it a large volume of steam and hot water. Assume that the valves to and from the turbine housing have been closed, and no other valves have yet been opened. Assume also that provision has been made for pumping out to a heat conservation system the accumulated water that condensed during the primary work cycle. This would slightly lower the pressure and temperature of the steam in the sphere,



hydraulic fluid from drive sphere a at pressure x is accelerated as much as possible at the turbine housing to impart kinetic energy to the turbine

Diagram 3 and 4 consolidated. between pages 40 and 41

a = pressure sphere operating to drive the engine; b = pressure sphere receiving hydraulic fluid. c = condenser having received steam from third pressure sphere (not shown) which recently completed Primary work cycle; d = condenser ready to receive steam (it should link to ⓐ); e = a schematized boiler as source of constant supply of ste but if it were perfectly insulated, this sphere could hold the steam at the established temperature and pressure indefinitely. Note also, that the steam so held is under considerable pressure and is still capable of considerable work: the work so far performed has been performed not by the expansion of the steam, but by the condensation of it back into water. When steam exits a normal steam engine, the heat it has given up in the form of work to a turbine or piston is heat given up through expansion and a concomitant drop in temperature and pressure, not through a change of phase such as condensation, and in normal steam engines the exiting steam is capable of little further work. Such is not the case with the engine we are describing; if pressure on the first pressure sphere were released, the pressurized steam in it would be able to do considerable work by expansion. This work will be utilized in the secondary work cycle, driving the heat conservation system of the engine.

Imagine a large storage tank for hot water being held to be recirculated to the boiler. In this there could be a large submerged hollow cone, open end pointing downwards. Steam released from the first pressure sphere would be allowed to expand and bubble up into the cone, pumping the hot water out of it. This pumped water will in turn create a pressure head on the steam trapped in the cone: when the pressure on the steam in the cone equals the pressure of the expanded steam in the cone and pressure sphere, the capacity for work in the secondary cycle will be exhausted, and the valve allowing steam into the cone should be closed. Work will continue, however, within the storage tank, for the raised water in the tank will, according to the pressure it exerts on the steam, force the steam to condense while raising its temperature. If the storage system were perfectly insulated, the heat lost by the steam on expanding and pumping the water should equal the heat added to the tank in the condensation process. Remaining in the pressure sphere is a volume of steam, now at the temperature and pressure at which its capacity to pump water in the storage tank was exhausted. Whether it would be worthwhile to decompress this steam further into a secondary condensing system would depend on how much heat could thus be recovered in comparison to the cost of the secondary condensers and the output of the engine and the heat recovered in the primary condensing system. Diagram 3 gives a schema of how two pressure spheres would be joined in the primary work cycle of an isothermal, isobaric, hydraulic-drive condensing engine, and Diagram 4 sketches a secondary work cycle between a steam-filled pressure sphere and the primary condenser.

Let us now consider the possible efficiencies of such an engine. At first, reasoning about a very primitive version of it, I thought the physics would be basically those of what might be called a "fluid piston" steam engine, but on further reflection I saw that there were some radical differences between the way the rigid piston of the traditional steam engine is driven and the way the fluid in the proposed isothermal engine is forced through the turbine. Provided the hydraulic fluid in the new engine had a boiling point above that of the temperature of the steam driving it, the whole system of pressure spheres and turbine housing could be jacketed like a steam engine, better than a steam engine, and the system would operate at the temperature of the steam and heat losses to the surrounding environment would be minimized. In the new engine, losses of energy to friction would also be very low, depending primarily on the viscosity of the hydraulic fluid driven through the turbine. It is difficult, however, to estimate the probable thermal efficiency of the energy conversion because the physics of an isothermal engine would actually be radically different from that of steam engines or turbines.

With conventional steam engines, the work they can perform is a function of the difference between the temperature of steam as it enters a work cycle and the temperature as it exits the cycle. This fact is what puts a premium on high operating temperatures, for the higher the steam temperature at the beginning, the bigger the difference between it and the temperature on exit can be. These conditions are arrived at on the assumption that there are no changes of phase in the steam during the work cycle, that is, the theory assumes the steam approximates an ideal gas in which the heat it carries is a function only of its temperature. The engine we are describing derives the work in its primary cycle precisely because liquids boiled into gases are not ideal gases, for they carry a great deal of heat, not as temperature, but as latent heat absorbed in the change of phase from liquid to gas, returnable in the opposite change of phase from gas to liquid. The temperature-in, temperature-out rule can be used only to calculate the amount of work the new engine can perform in its secondary work cycle, and it is not clear that one can or should try to maximize the absolute amount of work performed in this cycle. With the engine we are describing, calculations of its thermal efficiency have to be based on consideration of the total quantity of heat, not the short hand for ideal gases of mere temperature. The principle of the conservation of energy would suggest that the total heat in the steam entering the engine must equal the work performed expressed as heat plus the heat losses to friction and imperfect insullation of the system plus the heat conserved in the secondary work cycle plus the heat expelled in the steam not trapped in the secondary work cycle.

From these considerations we see that the problem in maximizing the efficiency of an isothermal, fluid drive, condensing engine would be to maximize the work performed in the primary work cycle relative to the heat lost to the environment. There are two variables affecting the work that can be performed in the primary work cycle: the pressure of the steam and the density of the fluid driving the turbine. Since, in this cycle, we are converting latent heat in the steam to work, and since the higher the pressure of steam, the lower its ratio of latent heat to total heat, an increase in pressure will probably be unpromising as a means of maximizing efficiency. In order to increase the work performed by raising the pressure of the steam, one must not only add more heat to the steam delivered, but one must also deliver a considerably greater quantity of steam in order to fill the pressure sphere, since the higher the pressure of the steam, the lower its volume. Hence, although increasing the pressure in the primary work cycle will increase the total work performed, it will probably not increase the ratio of the work performed to the total heat put in or to the heat lost to the environment.

An increase in the density of the hydraulic fluid, however, is a much more promising way of affecting the ratios. At a particular pressure, the denser the hydraulic fluid, the more work exerted on the turbine, and therefore the greater the latent heat extracted from the steam. To make up this extra heat extraction, one will need to supply only an added increment of steam equal to the added increment condensed. Thus by increasing the density of the hydraulic fluid, one will increase the ratio of work performed in the primary cycle to total heat or to heat lost.

Having found the principle for maximizing the work performed in the primary cycle relative to input and loss, let us look at how the secondary work cycle can best contribute to maximizing the efficiency of the engine. The secondary work cycle conserves heat, but does not contribute to the work output of the engine. What is crucial in this cycle is not to maximize the absolute amount of heat conserved, but to minimize the heat not conserved after the cycle is complete. Hence, the object should be, given the steam at whatever pressure it has at the end of a primary cycle that has been designed to maximize the efficiency of its output, to decompress the steam as far as possible. There will be a basically fixed time with an operating engine for the steam expanded in the condenser to condense before a new input of steam arrives. Although the temperature-in, temperature-out rule will explain how much work can be done in this cycle in the absolute, the object of minimizing the temperature-out, and thus the pressure and volume of the steam that cannot be recycled, as well as the amount of heat it contains, suggests that a high input temperature is not desirable. The higher the input temperature, the greater the volume of steam the condenser would need to condense in a fixed time for the steam remaining after the primary work cycle to decompress to a given exit temperature. Thus the optimum ratio between work performed and heat lost depends on the secondary work cycle concluding at the lowest possible pressure, which can most likely be done if the pressure at the start is not high.

Having worked out these principles, it is nevertheless difficult to have a clear sense of the probable thermal efficiency of such an engine relative to the efficiency of steam turbines. Before anything approaching an estimate could be made, a number of design choices for the isothermal engine would need to be made: preeminent among them whether water should be used for steam and a very heavy liquid, perhpas mercury, albeit expensive and dangerous, for the hydraulic fluid, or whether water should be used as the hydraulic fluid and some light, volatile liquid as the source of "steam," or whether some other combinations would be optimal. Nevertheless, although a real estimate cannot be made, it would seem reasonable to expect that the new engine might be as or more efficient than steam turbines. Fluid turbines are very effective at extracting work from a given amount of kinetic energy, I think considerably more efficient than steam turbines. Frictional losses in the new system would be low, not, I would imagine, significantly greater than in steam turbines. Because the new engine, over-all, would be bulky, heat losses from it to the environment might be higher than with a more compact steam turbine, but because the new engine would utilize a lower heat differential between it and the environment, they might be lower. Both systems can only imperfectly re-cycle heat from spent steam, and since steam turbines extract no latent heat, a major portion of the heat in steam, I suspect the losses through spent steam are greater for steam turbines than they would be with the new engine.

In addition to an apparent likelihood of a reasonable thermal efficiency compared to steam turbines, other factors might make the use of the new engine desirable under certain conditions. A low operating temperature could yield several important advantages. Some I am simply not at all sure about: an atomic reactor designed to deliver low temperature steam, say 150 degrees centigrade, might be safer in its operations than one delivering steam at 300 degrees centigrade; fossil fueled boilers delivering low temperature steam might be more efficient or cleaner burning than those delivering high temperature steam. Lower operating temperatures might also change the useful life of capital intensive components, boilers, ducts, condensers, etc., as well as alter their original cost. One advantage I feel fairly certain of: being able to use low temperature steam to generate electricity would improve the investment economics preventing the use of solar energy as a basic heat source for steam driven electrical generation.

To drive a steam turbine with an operating temperature of 300 degrees centigrade, and steam turbines optimally should use steam a good deal hotter than that, by heat from solar energy, very heavy capital outlays are required to build a solar collection system that can heat water to that high a temperature--the best device so far is a tower with a boiler atop it surrounded by a vast field of computer controlled mirrors, focussing concentrated sunlight on the boiler. To raise water, albeit a larger volume, to a temperature of 150 degrees requires far less elaborate solar collectors. Exactly how the energy and capital economics of an isothermal system using solar heat would work out is a very complicated question, but one that is perhaps worth serious investigation. As a step towards that, let us outline the components of a large isothermal, fluid drive generating system, deriving all, or at least a significant portion of the heat used, from solar energy, but a system capable, nevertheless, of operating effectively twenty-four hours a day.

Design of such a system would begin by specifying the final output desired. From that, one would seek the most efficient generator or set of generators that could deliver that output. From the efficiency ratings of the the generating unit, one could find the power output required by the turbines. At this point, one would start looking at the capital costs of solar collectors, seeking to determine the maximum heat collection capacities per investment dollar. The collectors would need to feed into a storage tank that would keep the water at the pressure of the steam driving the engine, and the solar collectors should be such that they can provide not only enough heat to raise the temperature of the water to the desired level, but also the latent heat at that temperature that will be needed to convert the water to steam. On finding the characteristics of the solar collecting system that can deliver properly heated water at the lowest investment cost, one can calculate the steam temperature at which the engine should be designed to run and the pressure at which the turbines should be designed to operate, namely at the pressure equal to that of the steam. One then selects the most efficient possible turbines for operation at that pressure, and knowing the output needed and the pressure available, one can calculate the volume of hydraulic fluid that must flow under the specified pressure through the turbines to drive the system and the volume of steam that will be needed at the operating pressure in order to drive the fluid. At this point the isothermal engine can be designed with three pressure spheres for each turbine, a boiler that can turn preheated water to steam at the desired pressure and rate, and a condensor that can recapture as much heat in the exiting steam as possible. Finally, knowing the volume of the steam needed to operate the system, the scale of the solar collecting system can be calculated.

The solar collection system should consist of two well insulated water storage tanks, one designed to hold water under pressure at the operating temperature of the engine and the other that can hold water at the temperature of the condensing system. Assume that the whole system has been warmed up and is in operation. Water from the condensor, at some temperature below the operating temperature of the engine would collect in one storage tank. During the day, this water would be pumped through the solar collecting system to be heated to the engine operating temperature by solar energy and stored at that temperature in the other storage tank. The capacity of the solar collecting system should be sufficient to impart to a volume of water equal to the twenty-four hour needs of the engine the amount of heat equal to the actual and latent heat that will be in the steam used throughout the day minus the heat that will be recovered during a day's operation by the condensor. In addition, a further amount of heat will be needed from the solar collectors equal to that lost to the environment owing to imperfect insulation of the storage and operating components. Since the system being outlined is one for twenty-four hour operation, it might be necessary for the actual boiling off of steam to be assisted with some fossil energy, but the heat requirements at this stage would be very low compared to normal fossil-fueled steam-generating systems, for this stage would be supplying, not the total heat in the steam, but only a small part of the latent heat absorbed during the conversion to steam. And if it was feasible to store the water heated by the solar collecting system with sufficient latent heat at a temperature somewhat higher than the operating temperature of the engine, it might be possible to boil off the steam without the imput of fossil-feuled energy simply by decompressing the stored, heated water somewhat.

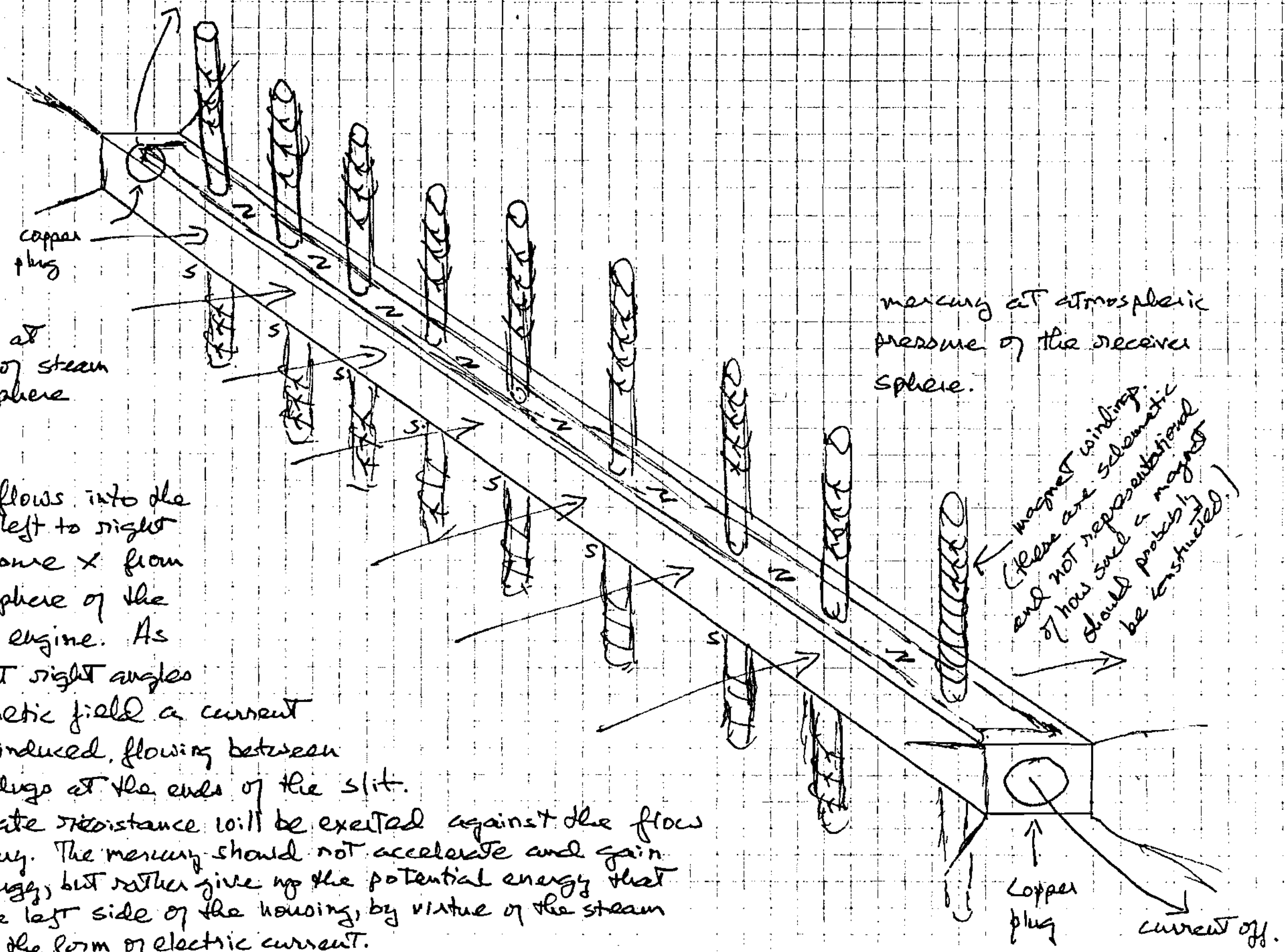
Be that as it may, the essential idea in all this is the isothermal, hydraulic drive condensing engine. The absolute thermal efficiency that can be attained by such an engine is moot, something that I suspect can be determined only through testing it. This efficiency depends on two things: the efficiency of extracting latent heat from the steam in the primary work cycle and the efficiency of the condenser in reducing the amount of heat that must finally be expelled from the system. As we shall shortly see, it is my suspicion that the thermal efficiency of such an engine can be startlingly high. Even if it is not, however, an isothermal engine may prove attractive for some uses because of the low operating temperature at which it can be relatively thermally efficient. If this low operating temperature makes possible the relatively efficient conversion of heat into mechanical work at temperatures significantly lower than those required by steam turbines, it might facilitate the large scale, economical use of solar energy, improve the saftey nuclear reactors for electrical generation, and have presently indeterminate effects on the use of fossil energy. This for now will suffice as an introductory outline of my ideas concerning an isothermal, isobaric, hydraulic-drive condensing engine.

As you will recall from my letter to you of July 17, 1979, I there mentioned three sets of ideas. The third set I had in mind depended on the isothermal, hydraulic drive, condensing engine being reasonably attractive as a source of work. If that proves to be the case, and if mercury proves to be a plausible hydraulic fluid for its drive system (it certainly being the one that would make it most thermally efficient), it may be worthwhile looking into a further version of it. In reflecting on this elaboration of the isothermal engine, I have developed, I think, a better understanding of how and why such a system may offer startling efficiencies of thermal conversion. In what follows, I explain these ideas and conclude with certain reflections suggested by them.

What I have in mind may be called an elaboration; in another sense it is a simplification. In essence, it is a version that would dispense with a turbine and would generate electricity directly from the work capacity of the hydraulic fluid, mercury, functioning as it moves from one pressure sphere to another as a fluid-coil in a generator. I have somewhere encountered mention of electromagnetic mercury pumps, which I think may be used in some nuclear reactors as parts of their cooling systems. I do not know anything about how these pumps function, but if they are possible, so too should fluid-coil generators using mercury be possible. In what follows, I describe a device for use in an isothermal condensing engine that might work as a fluid-coil generator, assuming the fluid-coil acts in the same way as the solid coil of ordinary rotary generators, using a normal, straight magnetic field, the established rules for calculating the flow of induced current and the direction of resistance, and so on. All this may or may not work: in either case, I have the hunch that the best mode of induction in a fluid conductor may be rather different from the modes of induction appropriate for solid conductors. Consequently there follows a speculative discussion of how a generator specifically designed with a fluid conductor in mind <u>might</u> be conceived to work.

Let us start on the assumption that the rules for a fluid-coil generator are basically the same as those for a solid coil moving in a straight magnetic field. We could build such a generator into our isothermal condensing engine if, in place of the turbine the mercury were forced through a long narrow slit. Between the long upper and lower surfaces of the opening there would be generated an intense magnetic field, and at the ends of the slit there would be copper plugs to transmit current to the outside (see Diagram 5). As the mercury, a good conductor of electricity, were forced through the slit, it would move at right angles through the magnetic field, inducing a current in it, that is towards the ends of the slit, and a force impeding its passage through the slit would also be created. The flow of mercury through the slit would be determined by the pressure of the steam in the pressure sphere impelling the flow minus the back-pressure impeding the flow caused by the current generated in the magnetic field. The work performed by steam condensed in the pressure sphere during a period of time would equal the sum of

Diagram 5 - goes between pages 45 and 46



mercury flows into the slit from left to right under pressure x from the drive sphere of the condensing engine. As it passes at right angles to the magnetic field a current should be induced, flowing between the copper plugs at the ends of the slit.
A proportionate resistance will be excited against the flow of the mercury. The mercury should not accelerate and gain kinetic energy, but rather give up the potential energy that it has on the left side of the housing, by virtue of the steam pressure, in the form of electric current.

the current, expressed as heat, induced in that period, plus the work that would be expended if, in the peiod of time, a quantity of mercury equal to the quantity of mercury that actually flows out of the sphere through the generator in that period, were to be pumped out through the slit unimpeded by back-pressure. If the generator were constructed to produce considerable current and back-pressure, this latter component of the work performed by condensing steam would be small relative to the former component, and for the sake of simplicity in the following discussion it will be ignored. Ignoring it, we can say that in a somewhat idealized version of the engine under discussion, the work done by condensing steam is a function of the current generated in the magnetic field. The voltage and amperage of the current generated would depend on the length of the slit, that is, the length of the generating coil, and the intensity of the magnetic field along it. In addition, the build-up of condensed water in the pressure sphere might be considerable during the work phase, and pumps would need to be located at various elevations along the wall of the sphere to pump accumulated water back to the heat storage system; but since pressure in both the sphere and that system should be the same these pumps would not need much energy and hence they will be ignored in the following discussion. Finally, we may note that the inside surface of the isothermal engine driving a fluid-coil generator would also have to be insulated, not a difficult problem, in order to insure that the current did not short-circuit out somewhere other than at the copper plugs.

I am not confident that such a fluid-coil generator will work in actuality, for if our considerations of induction in moving coils above, as the events might occur on the molecular level, were approximately valid, it is quite possible that with a fluid coil, regardless of whether trajectories entered it ahead or behind the direction of movement, no components of the field, or only a few of them, would develop sufficient leverage for induction to occur. Since the molecules of a fluid are free to maneuver, few magnetic trajectories would be able to bring sufficient pressure to bear on the magnetic fields or structures of the molecules to force charged particles held in those fields free. Hence, even with the mercury flowing at a right angle to the field, little induction might occur, and even if adequate induction occurred, according to the principles hypothesized in the discussion of rotary electric motors and generators, such a fluid-coil generator would be a highly imperfect generator, extracting at best half the electric potential of the field. Let us reflect on the problem of designing a fluid-coil generator that will extract the full work potential of a magnetic field.

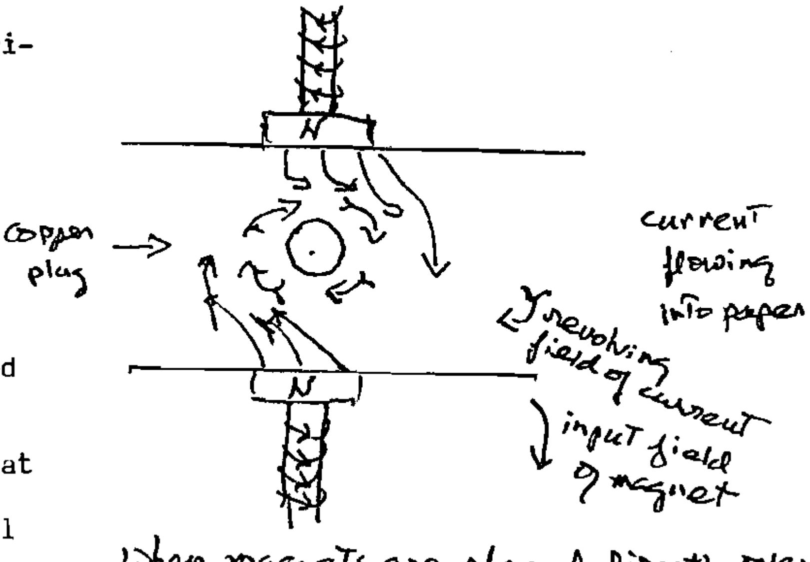
Conceptually, a transformer, motor, or generator needs two types of input, one to create the work potential of the magnetic field, another to drive the continual change of state in the relation of coils and field. We have in the work potential of the isothermal condensing engine a powerful means for continually changing the state in a generator, for it has been designed to pump mercury. What we need is a means of organizing a magnetic field so that it has a substantial work potential for inducing current in the mercury. Let us set aside the concept of movement as irrelevant to the process of induction that we seek, reserving the possibility of moving the mercury soley for dealing with the problem of maintaining the change of state once we have found the means of induction. Movement, which is a fundamental characteristic of rotary work, is less fundamental to work with fluids. With fluids, a fundamental concept pertinent to their capacity for work is pressure. Instead of thinking about using increments of movement to establish the conditions for induction in a solid conductor, let us reflect on the possibilities of some kind of pressure as a means of establishing those conditions. Is it somehow possible to bring magnetic pressure to bear on the magnetic fields of particles in the mercury molecules so that they will constrict and the loosely bound charged particles in the mercury can start flowing as current?

Imagine a somewhat more elaborate slit than we postulated above, neither quite as narrow, nor quite as long, but extend to be deeper, the upper and lower surfaces between which the mercury would flow being rectangulars. Across these surfaces would run rows of electromagnets, pointed to the opposite surface, each row close to the other. Ignoring for now the obvious problem of short-circuiting, let us put, at the sides of the slit, spaced identically to the rows of magnets, copper plugs, wired together so that the current each takes off cumulates in series. The front and back row of magnets, top and bottom, further are slightly tilted so that the force they emit will be pointed somewhat towards the center of the space through which the mercury will be flowing. Now to the wiring of the magnets. Instead of the top ones being wired as N-poles and the bottom as S-poles, imagine that all were wired as N-poles. The field they would create would have difficulty escaping the space between the surfaces; it would be a disoriented field, frustrated, entrapped. Turn on the magnets with a stationary volume of mercury in the space and a current might surge to the copper plugs at the ends of the slits and then subside, and resistance to magnetic induction would build, the magnets, so-to-speak, would rebel and refuse to accept further potential for work.

What might lead us to expect such a surge of current when the magnets were turned on? Negatively charged particles have small magnetic fields; they too will react to the magnetic anti-field. The surfeit of N-repellant force will act on their fields, as well as itself. While the field from the magnets will be disoriented, finding no S-poles, no way out, the charged particles, set in movement, can orient, and move to the negative copper plugs. Alas, they will find themselves recirculated into the repellant field by the series windings on the plugs and voltage should thus build up, but after a few turns through, they will be out and flowing as a useful current. I have no idea whether such a form of induction would really work. It could be tested with a rather simple apparatus--a vial of mercury in a small glass tray, a battery and coil, an instrument for testing a small current in a coil, and two electromagnets fixed with N-poles pointing from beneath and above the mercury in the tray. Set the uninsullated ends of the coil in the mercury at opposite sides of the tray, attach the testing instrument to the coil, and turn on the magnets. If the instrument shows that a spark of current has surged in the coil, the generator is in principle possible. A second test would also be interesting: disconnecting the instrument and attaching the battery, thus passing a current through the mercury, doing so in such a way that the flow of current is in the same direction as the surge of current in our brief test, and then turning on the magnets. Now we must look for any sign of movement in the current carrying mercury. Should there be any movement, it will tell us something important about the kind of work that will need to be done in order to maintain the change of state in our system.

We might postulate what this action might possibly be. Electric currents have their own magnetic fields, which revolve around the direction of their flow clockwise. Such fields, as we know, are utilized in the windings of electromagnets to organize and drive the magnetic fields, and such fields, we postulated, in our discussion of rotary motors and generators, do not significantly affect the trajectory of straight magnetic fields moving parallel to their plane of rotation. In the situation we are creating, the current flowing in the mercury should have such a field rotating around it and these rotating fields might organize a significant pattern of work. Imagine that we have made our copper plugs in the shape of rectangles, emplaced vertically so that they reach almost from the bottom to the top. If current was flowing between them, from one side to the other, then a structured, revolving magnetic field would develop around the line between them. If the rows of magnets were positioned slightly to one side or the other of these lines, the pressure of the frustrated N-field would predominate on one or the other side, and on the aggregate, we must assume, this pressure differential would be exerted on the matter in which the current was flowing, tending to pump it out of the way. Since the sources of the magnetic imbalance, however, would be fixed in place, the pumping action would not be effective in altering the imbalance. If this were the case in our simple experiment, we would probably be able to notice some pattern of circulation affecting the mercury when we positioned the N-poles of our test magnets slightly to the side of the line joining the ends of the wire carrying current. In this way, by supplying current, we will have created an electromagnetic mercury pump, the motor version of what we are looking for.

In addition, with this experiment, we might also notice why, for a working generator, we probably need several sets of plugs with the magnets positioned somewhat between the plugs. Should we conduct our experiment carefully, positioning our magnets directly over the line between the ends of the coil, we should be able to see that as a current built up, creating a field revolving clockwise around it, the effect would be to revolve the incoming N-field from above to the right and the field coming in from below to the left. Thus the induced current would help the disoriented fields to orient sufficiently to avoid each other. This suggests that to develop a working generator of this type we will have to be careful



When magnets are placed directly over current, its revolving field will move the incoming opposed fields away from one another.

in the placement of our magnets. But let us leave this problem aside for a moment, for we cannot decide on the placement of the magnets until we better understand the dynamics of what might happen in the generator.

Before proceeding further, we need to deal with what may appear to be a contradiction between the principles used in the first part of this letter, and those we are beginning to use here; indeed, in fact, it may be a contradiction. In the first part we postulated that a straight magnetic field will pass through a revolving magnetic field if the direction of the former were parallel or close to parallel to to the plane of rotation of the revolving field. Here however we are proposing to use revolving fields to organize a great deal of work through their effects on a frustrated, N-repellant field. We did postulate, however, that a revolving field will exert considerable resistaance to the free passage of a disorganized field. Because revolving fields have that effect on disorganized fields, current bearing windings have a powerful effect of organizing the magnetic material of an electromagnet. With no S-pole to which to orient, the environment of magnetic pressure we are constructing will quickly become a disorganized environment of magnetic repellance, with the result, I think we can expect, that any revolving field around any current that may start to flow will be a real barrier to the N-fields from the magnets. Those components of the N-fields that happen to be travelling parallel to the plane of rotation of the revolving field will enter it, the rest will be pushed away and circulated by it. Hence, inside our generator housing we should expect the rotating fields of currents to help organize a cosmos of work from a choas of force.

Let us proceed. Assuming that magnetic pressure from a frustrated N-field can, as we have hypothesized, indeed be a fairly effective means of making current flow in a fluid conductor, let us see if we can understand the dynamics of what might happen in our generator passage. We do not want to run a generating process from our magnets alone: that would be entirely without purpose. It is not hard to visulaize how the frustrated field could establish a flow of current, for we can easily imagine its pressure forcing the magnetic fields of charged particles to contract, loosening them in the molecular structure, and the particles then flowing, shall we say eagerly out of the repulsive situation, toward the copper plugs. It is also not too hard to imagine fresh mercury flowing into the channel under pressure of our isothermal condensing engine. The problem is: we can all too easily imagine that. Out of respect for the conservation of energy, we need to find a source of resistance, some work for our engine to do. Otherwise the condensing engine would simply accelerate the mercury through the passage, releasing it on the other side with considerable kinetic energy. We cannot have that plus our electricity too.

With moving coils, we tried to think about how well defined, gross phenomena might occur on the molecular level and smaller, looking for some clues about how potentially unused energy in the magnetic field might be exploited. As a telescopic view of the moon from earth does not look like a closeup photograph of a crater face taken by an astronaut, even though, in a sense, they both show the same thing, we accepted a considerable disjunction between how the phenomena of coils moving in straight magnetic fields appear in the telescopic view of the normal eyesight and how they appeared in our closeup view in the imagination--what was there in each might look very different as long as the effects were the same, were consistent with each other. Here, in the present situation with our fluid-coil generator, we are dealing with something in which the telescopic view, that of gross appearances, has itself not yet been experienced. Here, therefore, in our imagination, we need to shift perspective; we need no longer to look as if we could observe the process of induction through an electron microscope yielding a full-color motion picture of it; here we need to try to imagine the dynamics of the big picture, to think of complete fields, the massive volume of the conductor, currents flowing in the aggregate, forces acting as a whole upon each other, that is, in short, we need to try through thought experiment to hypothesize the classical physics of fluid conductors flowing in strong magnetic anti-fields.

We can begin with a clue from the laws governing coils carrying current in magnetic fields: a force will be exerted moving the coil at right angles to the field. Although our field itself will have, to begin with, no very clear definition, we can take the placement crosswise of the magnets as an orientation point, as well as the expectation that the current will flow across the channel, and consequently anticipate that the force we seek will point in or out of the channel. If we think of the mercury flowing in, we can make a fair guess that the force that should develop will point out of it. Let us assume that our magnets are positioned properly, whatever that positioning may be, and that our rather dangerous wiring has somehow been made to function without short-circuiting. Let us postualte that all is working, mercury flowing in and a substantial current being generated. With these assumptions, perhaps we can understand how a force opposing the flow of mercury might arise, and if we can understand that, we will then be able to understand how best to position our magnets and otherwise perfect the system.

To begin, we start with the mercury flowing at a modest rate, and then turn on the N-poles of the magnetic system. Current should start flowing to the negative plugs on one side, and owing to the series winding, which we have so far insullated against short-circuiting solely with an assumption, that current should cumulate with higher and higher voltage and more and more clearly defined currents crossing the passage as it is passed from side to side, deeper and deeper into it. Now we need to start looking at the magnetic phenomena associated with these currents and we immediately come to a small problem: will the magnetic phenomena act on the substance of the conductor, or only on the current in the conductor? I think we need to postulate that, although the actions that cause induction act on the charged particles set free in the process, that is on the current, the aggregate magnetic characteristics of a flowing current act on the aggregate mass of the conductor in which the current is flowing, for otherwise we would have to expect that when a coil carries a current in a magnetic field the force exerted at right angles to the field would simply move, not the coil out of the field, but the current out of the coil. That would be surprising. Consequently we shall proceed on the assumption that the aggregate magnetic phenomena resulting from the currents will be exerted on the mass of the conductor.

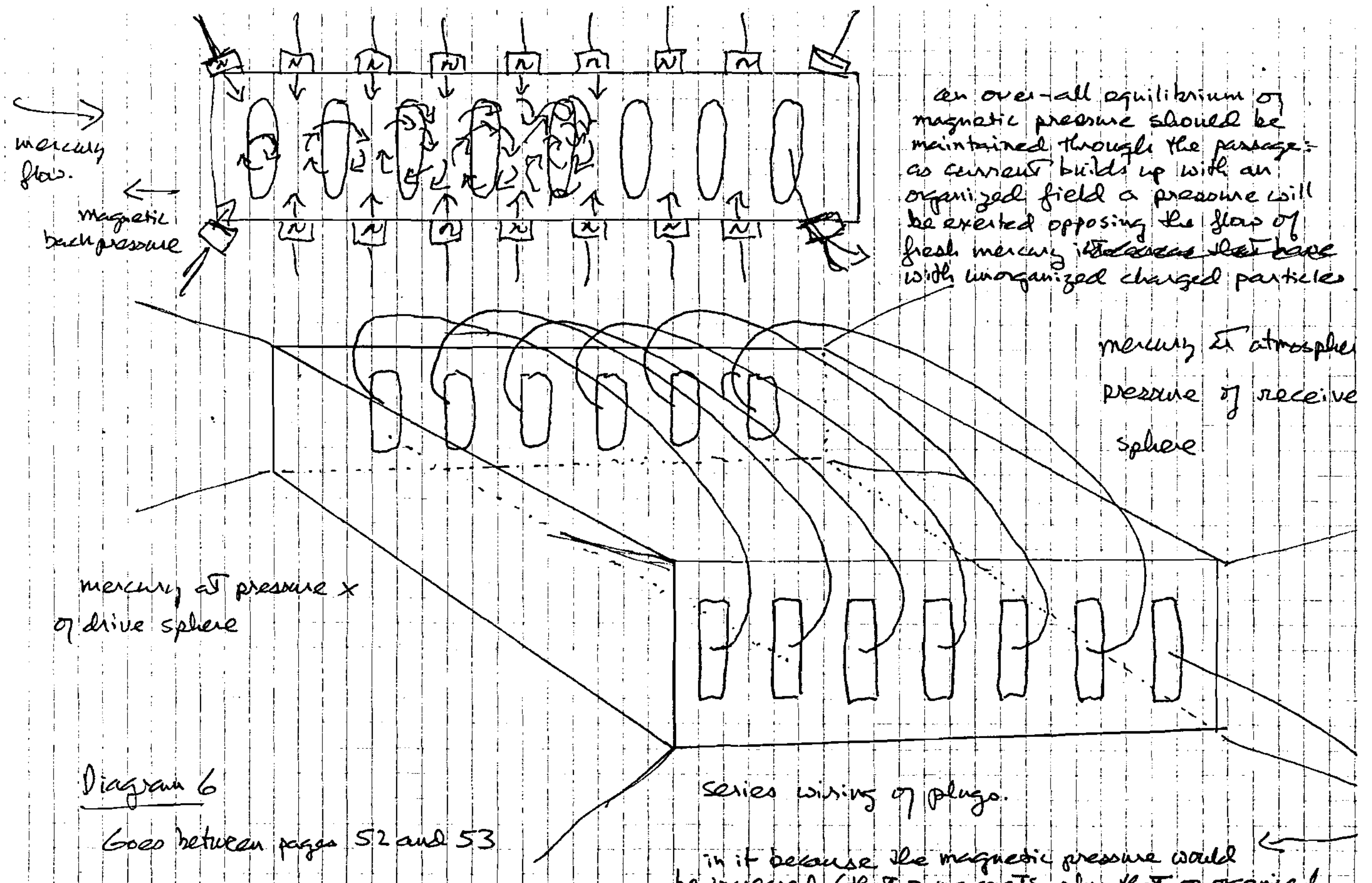
As the mercury flows through the generator, we have a series of currents flowing between copper plugs at each side, each current mounting in voltage. We will return in due course to the possibility of such wiring, the possibility of which we are for now assuming. We need now to look at the magnetic phenomena that will arise from the flow of the currents. We know that flowing currents structure their own magnetic fields that revolve clockwise around the direction of flow. The stronger the current, the stronger these magnetic fields. Hence, for each current flowing across the passage, we should expect that there would build up around it a kind of magnetic, rotating sheath. This would be considerably more compact in circumference than were the current flowing in an otherwise magnetically empty environment, and in the pressurized N-field, it would probably sweep a part of the field into itself, adding that force to its own, and it would also act, something like a whirlpool, one suspects, to funnel loose negative charges into the current running through it. Inbetween these structured fields revolving around the currents, there will by a chaos of N-repellant force. This frustrated field will exert its repelling force on itself, and on the revolving fields to the sides of it, creating a prowerful magnetic pressure on the mass enclosed in the revolving fields, acting to push it aside. Now a fluid under pressure will flow in the direction of least resistance, which, with respect to the magnetic pressure, is in the direction where the revolving field is weakest. Here we have found our source of work for the condensing engine and we can state the fundamental hypothesis of the classical physics of currents generated by fluid-coils functioning under magnetic pressure: a pressure will be established opposing the flow of the coil that will vary according to the strength of the current induced and the intensity of the magnetic pressure.

If we leave the wiring as it is, still assuming that it will not short-circuit, we can observe the generator starting up, magnets on and a flow beginning, and see, not only why the magnetic pressure on the fluid will oppose the flow of the fluid, but also a good deal about the principles that should guide our placement of the magnets. As mercury enters the area of magnetic pressure, negative charges in it will be set in motion by the pressure of the field. But which direction will the current flow? As soon as we try to use the principles of prediction for current in a solid coil in a structured magnetic field, we realize that we cannot start from the direction of the N-pole, for we have purposely put it all around to create pressure. Nor is the coil defined, for it is simply a considerable volume of mercury in which the free charged particles might move in any direction. Once again, we need to resort to the concept of pressure to find the direction of movement and say that a charge in a fluid coil under magnetic pressure will flow in the direction of the lowest magnetic pressure. With this proposition, we begin to learn something about how to place our magnets and plugs. Just as we decide, with a structured magnetic field, how to structure it by planning our windings so that one magnet will be an N-pole, another an S, and locating these so that they can be best exploited by a carefully designed coil, so too here, we count our windings carefully to create subtle pressure gradients and locate our plugs with the same care as we design a rotary generator coil.

Let us take some guesses about how to do this. To begin, we locate our plugs, not under the rows of magnets, but between them, and we run the row of magnets, not only along the upper and lower surfaces, but around the edges as well, and we make a very slight gradient in the strength of the magnets as they run from one side of the housing to the other. We put our first plug, relative to the direction of mercury flow, just behind the first row of magnets on the low side of the magnetic pressure gradient, and directly across from it, there should be no plug. From this first plug, we start wiring our series of plugs, the current from the first going over to the first plug on the other side, located just behind the second row of magnets, one opposite to it and so on, over and across, over and across, pairs of plugs behind each row of magnets. The series will stop with the last plug on the side of the very first one, and from there current will be taken off to be fed into a distribution grid, eventually to return, potential exhausted, to the missing member of the very first pair, which I think, although please check with an expert before trying it, should be a well insulated ground probably located far away at the bottom of each pressure sphere. (See Diagram 6 relative to the following discussion).

Now we still want to understand why the current must always build up so that the magnetic pressure on the mercury will always oppose the flow of the mercury, and we also want to begin to understand whether our unorthodox wiring can possibly avoid short-circuiting. Still assuming it can, as we turn on our magnets, designed to create a slight gradient of declining pressure to the right side of the passage as one looks in, the mercury will flow into this frustrated field and the negative charges loosely bound in it will flow towards the side of the passage where the N-pressure is lowest, particularly towards the plugs there, for we have designed these as areas of relatively lower N-pressure. The particles that flow to the first plug will be circulated to the other side to re-enter through the first plug, back one step in the series, on the other side. These will enter the field of magnetic pressure and be free, as far as the conductor is concerned, to flow in any old direction. But to flow to any other plug, they will have to flow through an upwards gradient of pressure direct from a magnet, and since there is a slight gradient of pressure downwards pointing to the opposite plug, most charges will flow there. As long as the intensity of the incoming N-field is high enough that it exceeds the accumulated magnetic field of the accumulated charge flowing at a particular step down the series of plugs, the system will contanin and continue to structure the currents, but when the accumulated magnetic field of the accumulated current, at whatever amperage and voltage it has reached, exceeds the intensity of the incoming field, the containment will break down and the current will flow to the remaining plugs down the series on the low pressure side of the housing and would come off those reamining plugs as if they were all wired together in parallel.

Why, when the back end short-circuits like this, should not the front. We must assume--it should be a design goal--that the magnetic pressure contributed by the magnets, up and down, the passage, is evenly distributed, except for the slight gradient to one side and the channeling pattern that we have designed. To put it another way, each row of magnets should have the same magnitude and pattern of intensity to the field it produces as all the



an over-all equilibrium of magnetic pressure should be maintained through the passage: as current builds up with an organized field a pressure will be exerted opposing the flow of fresh mercury ~~[illegible] that have~~ with unorganized charged particles

in it because the magnetic pressure would be increased (that of magnets, plus that of organized particles plus that of unorganized particles).

Diagram 6

Goes between pages 52 and 53

others. Given a general pattern of equilibrium to the input of magnetic field, the generator will seek to maintain an over-all equilibrium of magnetic field within it, counting not only that entering as input from the magnets, but aslo that carried in by the charged particles in the conductor. It is by taking advantage of this imperative to maintain equilibrium that we use planned, local disequilibria to make the charges flow in the desired pattern. It is also the phenomenon that will prevent the peak current from moving back up the generator passage. The mercury flowing in carries numerous charged particles dispersed uselessly through its mass. Our generator is a mechanism for orgainizing those charges into a useful current of a certain potential and strength. Passage by the first plug removes from the mercury a certain quantity of charged particles and their associated magnetic field. These can re-enter at the first recirculating plug into mercury that has had the same volume of particles and field removed from it; hence they can enter without changing the over-all equilibrium. The same situation holds at the next stage down the line and so on. For a current from a recirculating plug to short-circuit toward the front of the generator, there would have to be some failure of the magnetic pressure being maintained towards the front, for otherwise, the current would be flowing in a direction that would create over-all disequilibrium in the system, from an area of lower total pressure, counting both the magnetic input and the magnetic fields of particles in the conductor, to an area of higher total pressure. Hence we can expect the current to build up in voltage and strength as long as the magnetic field is sufficiently intense and the flowing mercury already well into the passage still has dispersed charges in it.

Thus finally we have arrived at an understanding of why the unorthodox wiring, which we have been assuming will work, can in fact work. We can also now hypothesize the equivalents for two of the major propositions concerning the generation of current in solid coils moving in a structured magnetic field. The strength of the current generated in a coil moving in a magnetic field is proportional to the intensity of the field and the angle at which the coil moves relative to the field. So too with a fluid-coil, magnetic-pressure generator, the strength of the current will vary with the magnetic pressure maintained and the supply of dispersed charges in the flowing coil. The voltage of a current generated in a coil moving in a magnetic field is a function of the number of turns in the coil and the intensity of the field. So too with the fluid generator, the voltage will be a function of the number of plug pairs used and the magnetic pressure maintained. We still, however, may need to reflect a bit further to understand how the resistance to the flow of mercury, namely the work to be done by our condensing engine, arises.

If the system will seek to maintain an equilibrium of magnetic pressure, and a quantity of current cannot flow from back to front without moving up a gradient without a force driving it up, how can there be a pressure opposing the flow of the mercury? The pressure opposing the flow of the mercury is, itself, a feature of the over-all equilibrium, and is in a sense a measure of the degree to which the generator has organized the flow of charged particles flowing through it. The over-all equilibrium of magnetic pressure is a function of the total magnetic flux within the generator, both that of the magnets and that of the charged particles. At the back of the generator, where the current is strongest, a high proportion of the total magnetic pressure is an organized, revolving field. If a lot of fresh mercury, heavily laden with charged particles were to flow into this space, the magnetic pressure in this space would increase. Resistance to the flow of mercury is, like the flow of current induced, a function of the strength of the magnetic pressure, and the availability of negative charges in the mercury. If we assume that passage through the generator successfully strips the mercury of all its available charges, the peak back-pressure that can be sustained will become a function of the intensity of the field, and I think that when a peak current is attained, an increase in the intensity of the magnetic pressure will simply compress the rotating fields and rotate the added magnetic pressure out of the system. Thus the maximum sustainable backpressure against the flow of the mercury would be a function of the current generated, and it should equal the average pressure exerted by magnetic repulsion on the surfaces of the generator. It could be measured by finding the force per square inch needed to hold down a magnet of average output as the system operated at a particular level, one for instance in between a plug that did not drive its field directly onto an opposite magnet, and dividing that by the ratio of the total area of the magnets to the total area of the generator surfaces, top and bottom, both sides and the entry and exit areas. If the magnets were sending in a more an intense magnetic field than was needed, the rotating, organized fields around the currents would be compressed and pressed towards the top of the generator passage, rotating backwards and finally out of the system a considerable part of the excess field, keeping the over-all pressure in the housing at a lower level, one that would reflect the actual amount of current being generated. Since, however, we want to maximize the work performed by our condensing engine relative to the input to the magnetic system, it would be preferable to start with its operating pressure, pick a magnetic pressure slightly below that, making the flow of mercury slow, and then finding how many rows of magnets and plugs were needed to extract the maximum amount of current from that rate of flow.

It might be well, before returning to the condensing engine, to note several other things that we may have happened onto, assuming of course that our original postulate, that a magnetic pressure from N-poles on a fluid conductor will set loosely bound charged particles in the field free, is valid. If this technique of induction works, we may have happened upon another device that will function as a direct current transformer. Let us close up our generator housing. In the center of what had been the front, let us put a plug for the input of a current,and we can bring the rows of magnets around the front and back, perhaps arranging the new ones in rows radiating out from the new plug toward the back of the device, and let us join each pair of plugs internally by a small copper wire. Without turning on the magnets, this device would function as a terminal for circuits wired in parallel, a portion of the input current being available at the input voltage at each of the other plugs. If we turn on the magnets, however, we may be able to think of the input current as a source of charged particles, feeding the change of state within the device, and we may be able to imagine that the incoming particles would not simply flow with equal alacrity to all parts of the device, but would flow to the plugs at the side as in our generator and voltage might build up according to the number of circuits through the fields the current made. The rotating fields where current crossed would not have the function of creating back-pressure or pumping mercury around as much as passing on charges that each was not able to draw into its vortex. The transformer would probably not be terribly efficient, should it work at all, although it would be interesting to test its input and output relative to the cost of maintaining sufficient magnetic pressure for it to work, for this would give us a good clue concerning the potential work ratio between the magnetic input and the input from the condensing engine that we might expect from our fluid-coil generator.

This brings us to a second matter that might bear some consideration. Once a normal, structured magnetic field is created, and a certain level of intensity reached, the current needed by the magnets to maintain it at a steady state is considerably less than that required to set it up. Now with an ordinary alternating current transformer, for instance, only a part of the current delivered to the primary coil is needed in a strict sense to maintain the magnetic field. We could measure that by finding the amount of direct current needed to maintaining the toroid field rotating in a steady state of satuation and comparing that with the amount of alternating current needed by the primary coil at the peak operating output of the secondary coil. The difference between those two currents is an indication of the input needed to drive the change of state in the device. Now we will need to do a certain amount of testing with our magnetic pressure system. If we establish a certain pressure of magnetic repulsion, but do not contain it well, allowing major escape routes for the N-field, the steady state current requirements of our magnets may be a high proportion of their start-up requirements. If, however, we take care to so structure the field that escape routes are effectively blocked, or, if permitted, at least functional with respect to our basic purpose of generating electricity, we may find that the steady-state current requirements of our magnets are not so very high. This, at least, can be our hope, a hope premised on the basic assumption that magnetic pressure can cause the flow of current in a fluid coil.

Let us continue with this assumption and look at how our condensing engine might perform when it directly drives a fluid-coil generator, the main features of which we have here outlined. To begin with we need to distinguish between work problems and operating problems. The former are what are important here, for they have to do with determining how much work the system can do and how efficiently it can do that work. The latter are also very real problems that will need to be overcome should development of this system ever seem desirable, but they should be understood as difficulties of operation, not determinants of work accomplished. One major operating problem will at first appear as a work problem: this is the build up of back pressure as mercury is pumped from one sphere to another. We have specified that the pressure spheres should be broad and low so that a large volume of hydraulic fluid can be moved from one to another without a high backpressure being built up. I think the optimum placement for the generator would be at a height equal to the level the mercury would establish could it could flow freely between two spheres. When all the mercury is in one sphere, and a work cycle begins, part of the mercury has a certain potential energy by virtue of its elevation above the mid point, which it will contribute to the work economy of the engine. Once the level of mercury in the drive sphere has lowered to the midpoint, the steam will need to start, not only driving the generator, but also raising the mercury in the receiving sphere above the equilibrium level. This will appear to be a work drain on the system, but if we conceive of the system as a whole it is not, for it simply gives back to the mercury the potential energy that the mercury contributed to work accomplished during the first part of the cycle. At the end of the cycle, the mercury, now in a different sphere, will possess precisely the potential energy that it possessed at the start of the cycle in the first sphere. The only real work drain in moving the mercury will be that arising from its viscosity, which is fortunately quite low.

Let us assume that we have found means for dealing with the operating problem presented by the backpressure of mercury, realizing that it is not a work problem. From now on, when we speak of backpressure, it is not the backpressure of the mercury, but that exerted by the generator, the equivalent of the resistance exerted against the movement of a generator coil in a rotary generator. If our isothermal condensing engine were driving a turbine, we would want to use the drive pressure established by the isobaric steam to accelerate the hydraulic fluid, converting its potential energy into kinetic energy, most of which could then be imparted to a well designed turbine. With a fluid-coil generator, we want, in contrast, to avoid as much as possible accelerating the mercury. The flow of mercury should be no faster than that necessary to maintain the generating process at the desired level of output, for otherwise one is uselessly accelerating the mercury and loosing possibly productive potential energy in the mercury through an unproductive dissipation of kinetic energy. Learning how to operate a system such as we are suggesting so that the flow of mercury is neiter faster nor slower than that needed to maintain the generating process will be difficult, but so too is it difficult to learn how to operate a steam turbine. Let us assume we learn how to control the operation of our engine. If we do that, the net output of the generator during a single work cycle, expressed, say, as heat, should equal the heat value of the potential energy possessed by the mercury at the start of the work-cycle by virtue of the pressure of steam on it. In order to drive this work cycle, a volume of steam, the latent heat of which equals the heat equivalent of the potential energy of the mercury, will condense in the pressure sphere. To maintain pressure, this condensed steam will need to be replaced by fresh steam from the boiler. During this work phase, thus, the main work drains will be the current needs of the magnetic system of the generator and the inefficiencies of the boiler, assuming good insulation and minimal friction.

Another way of putting it is to observe that the potential energy of a volume X of mercury at pressure Y is much greater than the potential energy of volume X of steam at pressure Y. If we can run our engine properly, the differences between those two amounts of potential energy can be extracted through a very direct set of work exchanges: the mercury yields its potential energy to the generator, and as the mercury does this, steam is forced to give up an equivalent amount of heat by a change of phase back to water, and we, operating our boiler, are forced to provide an equal amount of steam, carrying an equal amount of heat, in order to maintain pressure and temperature in our drive condenser. At the end of the process, we are left with a volume of steam equal to the volume of mercury at the same pressure as it was at. We then have to use our secondary work cycle to recover as much heat as possible in that remaining volume of steam. I do not think it would be very difficult to calculate the theoretical efficiency of such exchanges, but I need some guidance by someone better trained to be able to do so myself. I think, however, assuming good insulation of the system, this theoretical efficiency would be extraordinarily high. At 150 degrees centigrade, the heat in steam is over 80% latent heat, I think, and since we are giving up latent heat to provide the work needed for our output, I think a condensing engine of a particular output would require a much lower volume of steam at a given temperature to supply the heat for its work output than would a steam turbine or piston engine. Further, since the steam remaining at the end of the primary work cycle would still have its potential energy, the problem of recovering its unused heat through a condenser would not be as great as with conventional steam engines. For these reasons, I have come to think that the thermal efficiency of an isothermal, isobaric, hydraulic-drive condensing engine can be extremely high, particularly if a fluid-coil generator can be built into one as an integral component of it.

In closing, let us look at this matter of potential efficiency in a more reflective manner. Perhaps what is here proposed will not work for reasons I have not anticipated. Even if that is the case, the idea of it may suggest a useful principle for the organization of work, through technology or administration. Functioning independently, driven by an external source of work, a fluid-coil generator, such as that we suggest, using mercury under pressure would not be very efficient compared to rotary generators with copper coils, I suspect. Mercury is a good conductor, but nowhere as near as good a conductor as copper. In the version described here, everything is too speculative to have any idea of how efficiently the magnetic field might be converted to current. Friction losses in our system would be low. Whether or not it would be preferable to use a fluid-coil generator with a condensing engine or a turbine driving a conventional generator, or one such as that proposed in the first part of this letter, would depend on which mode of work extraction had the lowest combined frictional and generator inefficiencies. It is at this point, however, that we may note a rather startling feature of the fluid-coil generator driven by an isothermal engine, assuming each is a feasible engine. This feature, which we will explain presuming they each work as postulated, may bear importantly on the theory of engines and may help us explain why a system, comprised of ungainly components, may nevertheless offer startling efficiencies in operation.

If we reflect upon it, we will see that the linkage between the fluid-coil generator here proposed and the isothermal engine differs radically from ordinary linkages between engines. Ordinarily when one links two engines, their inefficiencies compound. A 50% efficient engine driving a 50% efficient engine makes a system that is 25% efficient. This is the normal relationship of a steam turbine to a generator. What we have just described, however, is not one engine, a source of mechanical work, linked to another, an electrical generator, but rather one engine, the generator, that is in a sense partially "inside" the other system, the isothermal condensing engine. Here it is not the case that the output of engine A becomes the input of engine B, but rather the output of engine B, the generator, determines how much work will be done within engine A, the isothermal condensing engine, and the output of engine B is the output of engine A, at least in its primary work cycle. In this case the work done by A, the amount of heat given up in the primary work cycle of the condensing engine as steam condenses to water in the pressure sphere, is determined primarily by how much current is induced in the mercury flowing through the magnetic field in the generator housing. Overcoming the resistance to that flow from the interaction of the current induced with the magnetic field is the work that must be performed in the primary work cycle of the condensing engine, and thus we see that the generator is partially enclosed in the condensing engine. The enclosure is only partial because an input to the generator from outside the isothermal condensing engine is also needed to create the magnetic field, a component of the generator. Even if the magnetic field were self-induced by the generator, being sustained from its own electrical output, that action would be outside the system, a deduction from the generator's useful output of work.

Although the enclosure of the generator inside the isothermal engine is only partial, it is a substantial, significant one. On the basis of it, let us advance the following theoretical hypothesis, pertinent in the case at hand and perhaps applicable elsewhere: to the degree that one engine can be successfully enclosed within another (not merely appended to it), so that the work performed within the enclosing engine is determined by the actual output of the enclosed engine, the inefficiencies of the the latter, however great when it is operating independently, can be regarded, to the degree of enclosure, with respect to the efficiency of the whole system, as a perfectly efficient engine.

Let us reflect further on this hypothesis and the example of the isothermal condensing engine partly enclosing a fluid-coil generator. The partial enclosure that we have been thinking about is on the output end of the over-all system: the work that must be done in A is a function of the actual output of B. Let us call this a partial output-enclosure. Let us note also that the isothermal condensing engine can be described as the complete enclosure of one engine, a steam condenser, inside a normal steam engine capable of work by the expansive power of steam. The condenser we are referring to here is not the condenser that operates in the secondary work cycle, but rather one that has been enclosed within the primary work cycle and that will function internally as the hydraulic fluid under pressure does work. This is a complete enclosure because the only input to the enclosed condenser is the input coming into the entire system and the quantity of this input, during this phase of work, is determined directly, and, assuming no heat losses to the environment, solely by the actual work done by the enclosed condenser. Our hypothesis is that the normal inefficiencies of an engine when it is operating independently can be disregarded when that engine can be successfully enclosed within another, and the enclosed engine will function, relative to the system, as if it is 100% efficient. This would seem to be the case, during the primary work cycle, with the enclosed condenser in the isothermal engine. During this cycle, we have an enclosed condenser linked productively to a partly enclosed generator, and we might therefore expect, within this cycle, startling efficiencies of heat conversion. Assume that our fluid coil generator has been built with a powerful magnetic system so that strong electrical currents are induced in mercury moving across the field and a powerful impeding force is exerted on the mercury, a force nearly equal to the force driving the mercury through the field exerted by the isothermal, isobaric steam on the mercury in the pressure sphere. In this case, mercury will be forced through the field very slowly, but considerable current will be generated as it moves. The work done by the enclosed condenser will have to equal the amount of the current expressed as heat. As current is taken off, latent heat in the steam in the enclosed condenser will be given up, steam will condense to hot water, and new volumes of steam will have to be delivered by the boiler to replace the condensed steam. What we have here is a situation in which the output of the generator is determining the work performed by the enclosed condenser, and the work performed by the enclosed condenser is determining the input into the system. Let us, for the moment, disregard the electrical input needed to create the magnetic field of the generator, and let us assume further that we have an ideal boiler, one in which all the heat delivered to it is absorbed by the water and steam in it. Were this the case, the heat delivered during this phase of the work cycle would become a direct function of the actual output of the generator and we would have a 100% efficient thermal conversion.

On the basis of this observation relative to a somewhat idealized version of the engine we are considering, let us try a second theoretical hypothesis: insofar as two engines can be successfully enclosed within a third, one at the input end, the other at the output end, and so long as the two enclosed engines can be linked in a productive work cycle, their inefficiencies when they are operating independently can be disregarded, and they will both, relative to the whole system, operate as if they were 100% efficient for the duration of the work phase in which they are successfully linked, with the result that the thermal conversion of that phase will be 100% efficient.

There is no violation of the principle of the conservation of energy in this hypothesis, but rather it would seem to be a necessary consequence of the principle. Assuming the generator were perfectly enclosed, its output would be determining the work done in the system. This work would be accomplished by the enclosed condenser, whose function relative to the system is to condense steam and recirculate as much heat back into the boiler as possible. It is driven by the work done by the generator; the heat the generator extracts, the condenser extracts from the steam, recirculating the remainder in the hot condensed water to the boiler. The work the boiler must do is replace the heat condensed out of the steam by supplying new steam at the proper pressure and temperature. If during this work phase the boiler had to deliver more heat than the condenser required while output remained the same there would have to be someplace within the system a heat sink into which heat was flowing up the temperature grade, which cannot be.

I have not had time to think through these propositions leading towards a theory of enclosed work as fully as I would like to do, but I have the feeling it is a theory highly pertinent to present problems of organizing activity more effectively, be it the activity of machines or people. The creativity of the nineteenth and much of the twentieth century can be viewed as a creativity through which the possibilities of linked work were exploited. All forms of linked work compound the inefficiencies of each stage of the linkage. We can, perhaps, view the the growing scarcity of basic resources and the growing difficulty of making institutions work purposefully in an environment of extreme complexity, as an outgrowth of our having relied excessively on the principle of linked work: now we face everywhere the costs of its compounding inefficiencies. If we start looking we can find phenomena of enclosure all around us. The word processor on which I am working is an excellent example. You know well the inefficiencies of all the linked processes that normally go on as an idea moves from a mere intimation to a finished book: drafts and redrafts, a first version to a typist, back in need of proofreading, a revised version back to the typist, more proofreading, then to the editor, then to the typesetter, gallies for more proofreading, and so on--at each stage, at each link the errors of omission and comission from the previous link must again be sought and the whole process creates a lot of internal work, much of which could be consolidated if the processes, instead of being linked, one to the other, can be enclosed inside the whole. In its modest way, a word processor allows for a certain amount of such enclosure.

I suspect that if we reflect on it, there are innumerable opportunities for the enclosure of work processes inside one another, and that to the degree these can be attained, we will find ourselves better able to husband resources and to simplify the complexities of action. Thus I suspect that as we look ahead to the future, the principle of enclosure will loom in importance.

Yet, like anything, a principle of enclosure is not everything. For too long many of the ideas outlined in this letter have been enclosed in one ruminating mind. It is time to see if any productive links can be found for them in the rest of the world.

Sincerely yours,

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