A Stationary Prototype Configuration Proposal.

In previous chapters of this work, various segments of the proposed prototype have been referred to and illustrated, along with their various functions. It would appear to be prudent, in this Chapter Seven, to examine more closely the configuration of that system, first, part by part and then assembled.

Bear in mind that the configuration offered will be a proposal only, based on the experience of the seventeen year hardware development program, which eventually had to be abandoned for lack of resources, and on the twenty-two year parallel concept development program, which was begun in 1968 and is still on-going, with important refinements, in this year of 1990.

The finalizing designers must ultimately define the final prototype configuration based on their state-of-the-art knowledge and skills and their reference to this proposal as a general specification from which to initiate the design finalization.

However, this Chapter Seven of this work hopes to present all of the essentials, and perhaps some of the desireables, for their consideration and adequate guidance.

A major portion of the hardware development program, referred to above, was concentrated on Rotor Assembly development, since it is the heart and core of the system. The prime mover of the system is developed by the inner surface of one of its parts, the Restraining Agent, in the form of high level pneumatic pressure increases, and that is converted to useful and high level rotational power by its all-important Thrusters.

Early on in the afore mentioned hardware development program, one Environmental Control Vessel was designed and fabricated but it was based on early conceptions of what system configurations should be and it became obsolete before it could be utilized for laboratory testing of the various experimental Rotor Assemblies in the dense air environment required for the complete and fully functional prototype system.

Much knowledge had to be developed concerning appropriate Rotor Assembly configuration as the concept itself was developed to the level presented in this work. Power train development from Rotor Assembly to Generator, the Generator itself together with its electrical controls and transfer systems, were neglected in favor of Rotor Assembly development. No outside technical,and only very meager financial, assistance was available to the effort. Thus it was forced to proceed on a " do-it-yourself" basis with very limited resources, fabrication skills and fabrication equipment.

For these reasons, the Rotor Assembly configuration proposals of this Chapter Seven will be fully authentic and adequately supported by the laboratory testing and measurements of the hardware development program but only in a <u>one</u> atmosphere environment and not in the <u>multiple</u> atmosphere environment,required for the complete and fully functional system,for lack of an adequate Environmental Control Vessel. However, such tests and measurements were totally adequate for the confirmation of advances in the documentary development of the concept itself.

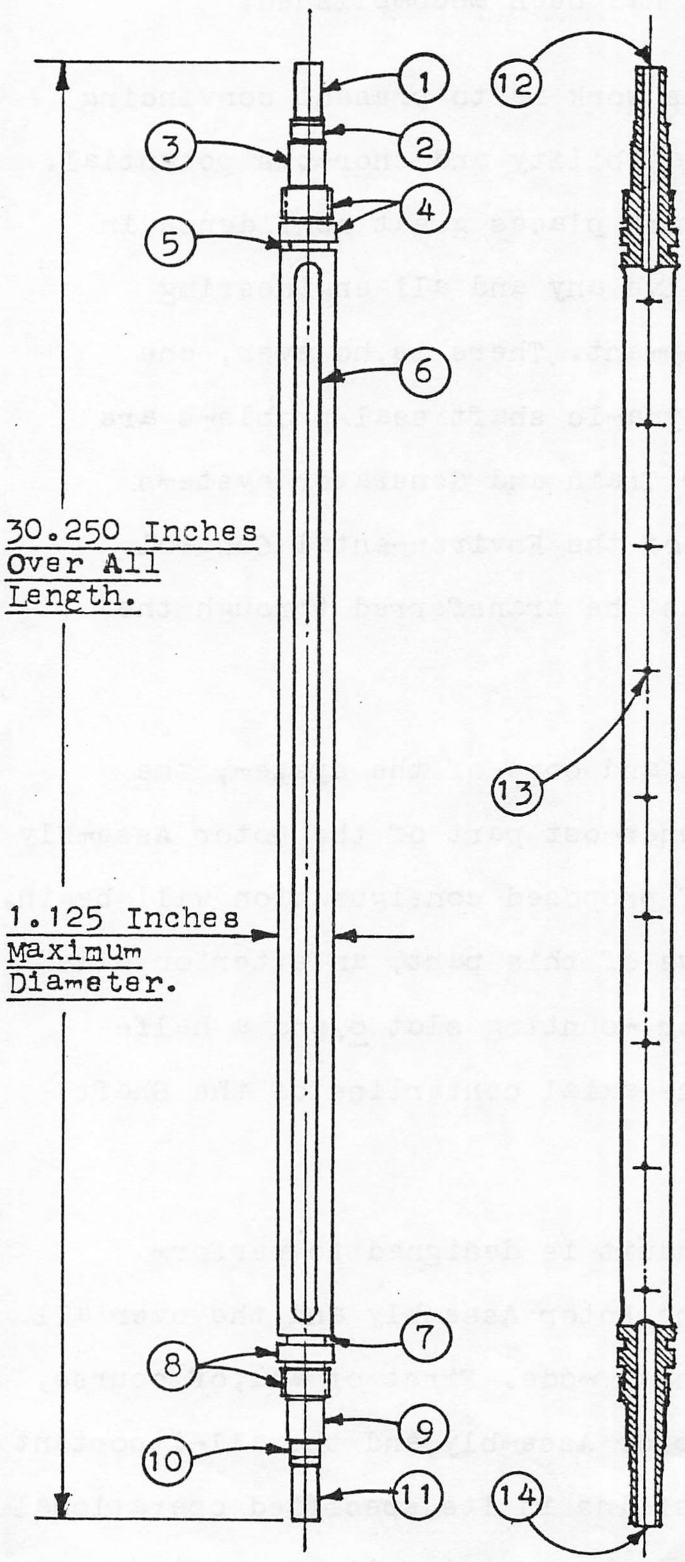
Configuration proposals,relative to the Power Train, the Generator,the Electrical Controls and the electrical Transfer Systems, are suggestive only because of meager data and experience available to this work regarding the appropriate design of these areas. Actually, the design of these areas could not be adequately developed until absolute finalization of Rotor Assembly design had been accomplished.

However, the primary objective of this work is to present convincing evidence of this concept's truth , feasibility and enormous potential. If this has been accomplished, this work places great confidence in modern day finalizing designers to solve any and all engineering problems involved in prototype development. There is,however, one configuration requirement if severe dynamic shaft seal problems are to be avoided. Rotor Assembly , Power Train and Generator systems must function within the inner walls of the Environmental Control Vessel. Only Electric Power, Pep , must be transferred through the Vessel walls.

While the Rotor Assembly is the heart and core of the system, the Shaft and Pneumatic Conduit is the innermost part of the Rotor Assembly and that is where this examination of proposed configuration will begin. Figure 46 on page 192 offers two views of this part, an exterior side view at left, looking through Impellor mounting slot 6,and a half-section view at right, taken along the axial centerline of the Shaft and the center plane of slot 6.

Note that the Shaft and Pneumatic Conduit is designed to perform multiple operational functions for the Rotor Assembly and the over all system while they are in the operational mode. First of all,of course, it is the axis of rotation for the Rotor Assembly and the all-important Pneumatic Mass that it houses and sustains in its specified operational orbital or rotational velocity and thereby sustains its specified critical time factor t.

Figure 46.



Shaft And Pneumatic Conduit.

LEGEND:

1) R.H. No-Contact Seal Surface.

2) R.H. Bearing Mounting Surface.

3) R.H. Driver Gear Mounting Surface.

4) R.H. End Closure & Nut Thread & Mounting Surface.

5) R.H. O Ring Seal Groove.

6) Impellor & Pneumatic Conduit Mounting Slot.

7) L.H. O Ring Seal Groove.

8) L.H. End Closure & Nut Thread & Mounting Surface.

9) L.H. Driver Gear Mounting Surface.

10) L.H. Bearing Mounting Surface.

11) L.H. No-Contact Seal Surface.

12) R.H. Pneumatic Infeed Bore.

13) Impellor & Pneumatic Conduit Fastener Holes. Typical Nine Places.

14) L.H. Pneumatic Infeed Bore.

It therefor incorporates the exterior surfaces 2 and 10 , fabricated to precise diameters and concentricity for the precise mounting of two single-row Ball Bearings which control the precise interface of the rotating Rotor Assembly to its two equally precise suspension systems. The precision of this interface is fundamental to precise rotation of the Pneumatic Mass through its orbital or rotational circular path about the axial centerline and equally fundamental to smooth rotation of the Rotor Assembly.

Its second important function provides a mounting platform ,slot 6 , for the vital Impellor and Pneumatic Conduit which assures rotation, in precise unison, of the Rotor Assembly and the Pneumatic Mass within it.

Its third important function provides pneumatic conduit bores 12 and 14 which transfer incoming pneumatic replacement particles from entrances at either end of the Shaft to the Impellor and Pneumatic Conduit at its mid-section.

Its fourth important function provides the precisely fabricated exterior surfaces 1 and 11 which serve as the moving inner face of the two no-contact Pneumatic Seals, which are actually flow restrictors rather than flow prohibitors , at the interface of stationary pneumatic conduits to rotating pneumatic conduits.

Its fifth important function provides precisely fabricated surfaces 3 and 9 for mounting the two very important Driver Gears which transfer the Generator Drive Power Pgd to the two Driven Gears which reduce rotational speed and drive the Electric Power Generator or Generators, depending on which the finalized design specifies.

Its sixth important function provides the precisely fabricated threads and pilot surfaces 4 and 8 for mounting the two Nuts and End Closures shown in Figure 49 on page 203 .

Its seventh important function provides the two O Ring Seal grooves 5 and 7 for mounting the O Rings which prohibit pneumatic leakage at the interface of Shaft and End Closures.

The key to successful Shaft and Pneumatic Conduit operational function is appropriate selection of material by the finalizing designers,along with appropriately precise dimensioning and fabrication through out this very important foundation part of the Rotor Assembly. Very close tolerances on diameters, concentricity and axial alignment are critical.

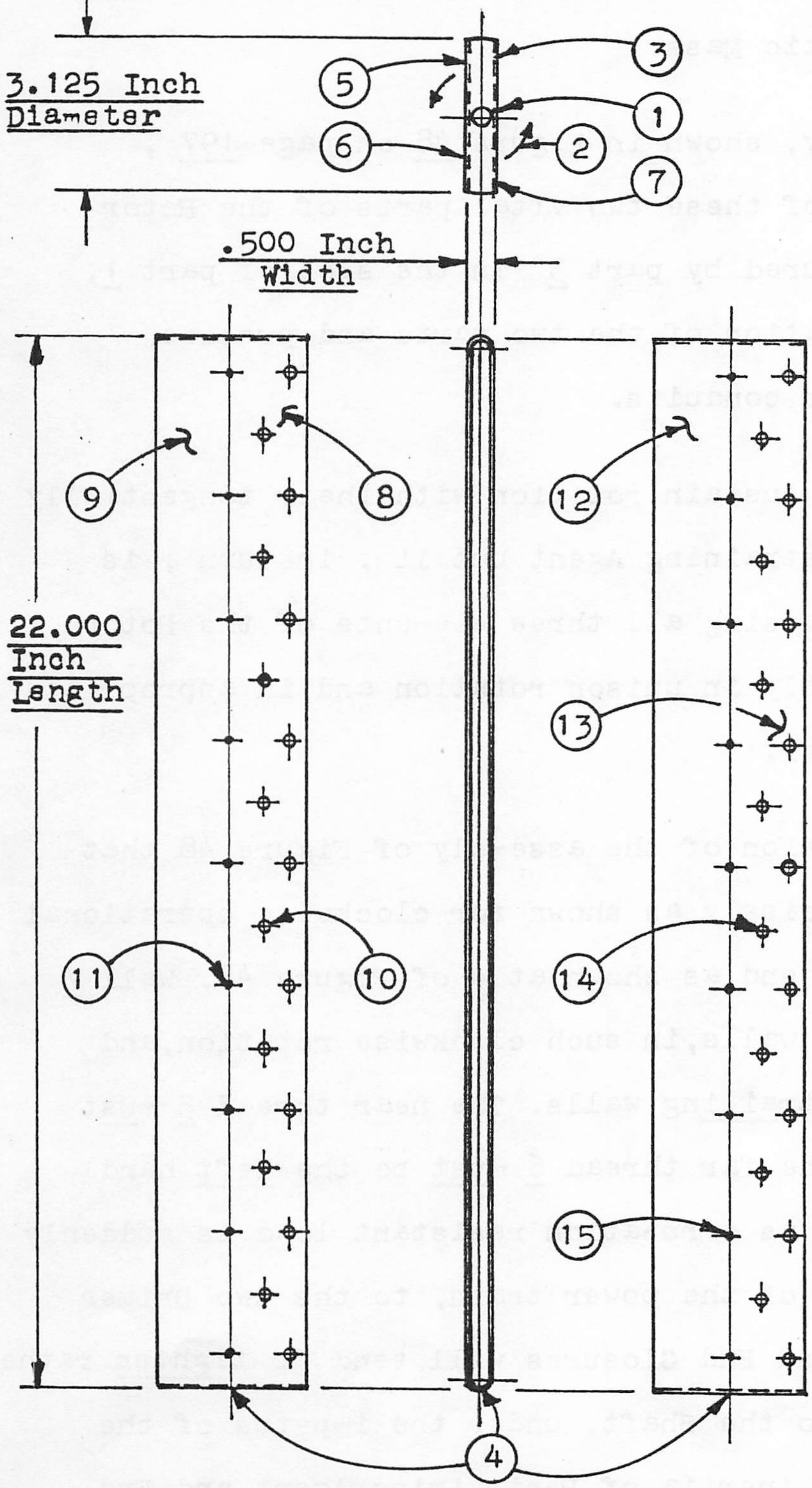
The Impellor and Pneumatic Conduit, shown in Figure 47 on page 195 , is given this title because of its vital dual functions within the Rotor Assembly.

Its first important function provides the two solid leading surfaces, shown in the multiple views of Figure 47 as 5 and 7 or as 9 and 12, which force all particles of the Pneumatic Mass within the Rotor Assembly to rotate at precisely the same RPM as that of the Rotor Assembly and thereby assure fully effective Inetial-Pneumatic compresion of the Pneumatic Mass.

Its second important function provides the two pneumatic transfer entrance holes, shown as 1 in Figure 47, which assure easy transfer of pneumatic flow from the two bores of the Shaft and Pneumatic Conduit into the interior of the Impellor and Pneumatic Conduit which, in turn, because of its ample spaciousness, provides very easy pneumatic flow radially outward, under the impetus of Inertial-Pneumatic Compression.

Figure 47

Impellor & Pneumatic Conduit



LEGEND:

1) Pneumatic Transfer Entrance Hole, Near And Far End.

2) Counter-Clockwise Rotation Looking Into This End.

3) Perforated Trailing Pneumatic Transfer Wall.

4) Clockwise Rotation Looking Into This End.

5) Solid Leading Pneumatic Mass Impellor Wall.

6) Perforated Trailing Pneumatic Transfer Wall.

7) Solid Leading Pneumatic Mass Impellor Wall.

8) Perforated Trailing Pneumatic Transfer Wall.

9) Solid Leading Pneumatic Mass Impellor Wall.

10) One Of 17 Holes Through Near Wall For Transferring Pneumatic Particles From Impellor To Pneumatic Mass.

11) One Of 9 Fastener Holes Through Near Wall For Securing Impellor To Shaft.

12) Solid Leading Pneumatic Mass Impellor Wall.

13) Perforated Trailing Pneumatic Transfer Wall.

14) One Of 17 Holes Through Near Wall For Transferring Pneumatic Particles From Impellor To Pneumatic Mass.

15) One Of 9 Fastener Holes Through Near Wall For Securing Impellor To Shaft.

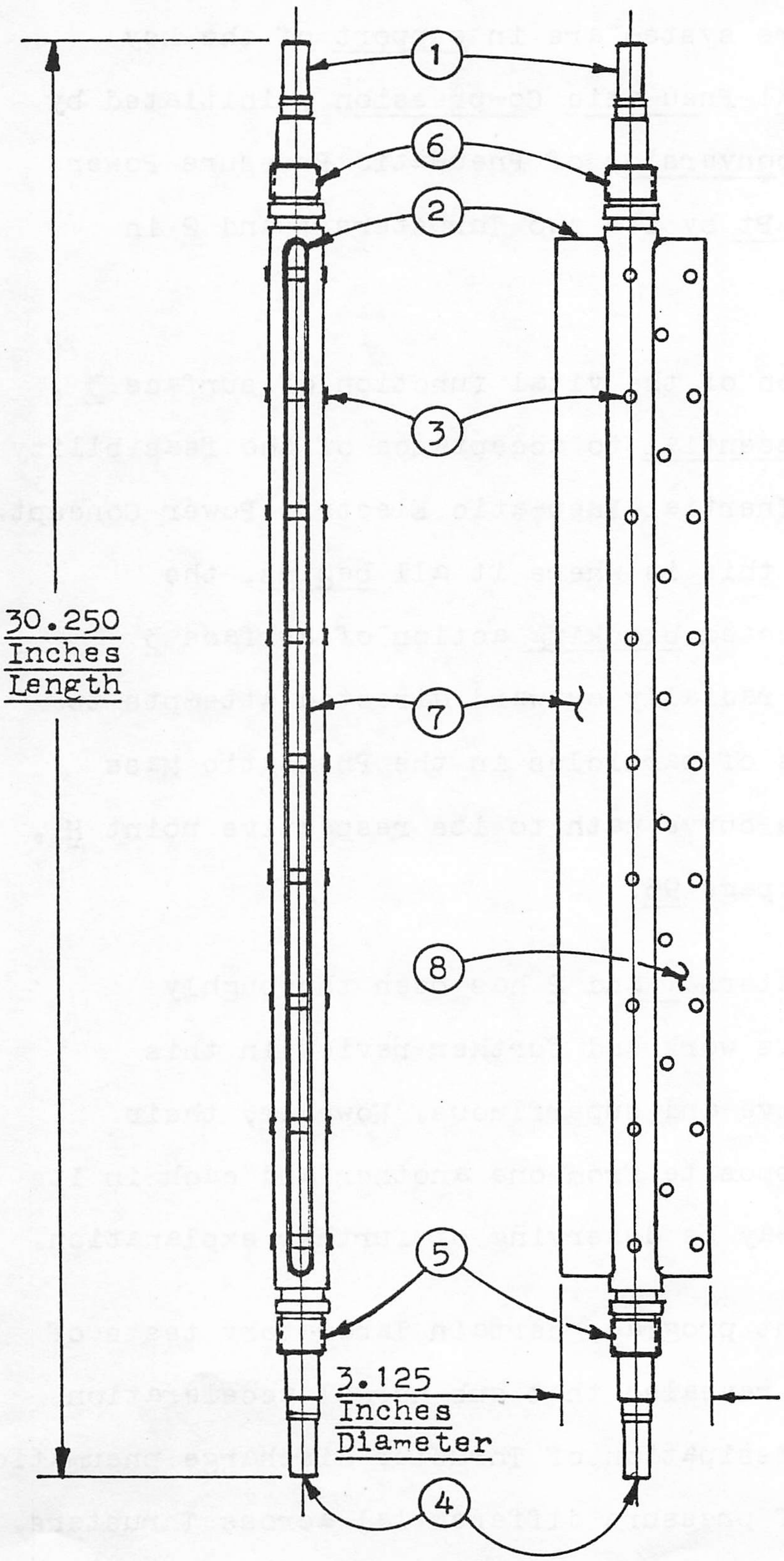
The final portion of its second important function provides the 34 pneumatic transfer holes, shown as 10 and 14 in Figure 47, through its two trailing walls, shown as 3 , 6 , 8 and 13 in various views of Figure 47, which thereby provides easy transfer of replacement pneumatic particles back into the Pneumatic Mass.

The Impellor and Shaft Assembly, shown in Figure 48 on page 197 , rigidly secures the interface of these two vital parts of the Rotor Assembly. Part 2 , tightly secured by part 3 in the slot of part 1, assures absolute unison of rotation of the two parts and precise alignment of pneumatic transfer conduits.

The two Thrusters , of course, sustain rotation with their tangentially directed thrust against the Restraining Agent but it , in turn , is keyed to part 2 of Figure 48 causing all three elements of the Rotor Assembly to be locked permanently in unison rotation and in appropriate position relative to one another.

It is vital to the proper function of the assembly of Figure 48 that parts 1 and 2 be assembled precisely as shown for clockwise operational rotation looking into the near end,as shown at 4 of Figure 48. Wall 7 must be one of the two leading walls,in such clockwise rotation,and wall 8 must be one of the two trailing walls. The near thread 5 must be the right hand thread and the far thread 6 must be the left hand thread. This is to assure that as a rotation resistant load is suddenly applied,by downstream elements of the power train, to the two Driver Gears of the Shaft, both Nut and End Closures will tend to tighten rather than loosen their interfaces to the Shaft, under the impetus of the very significant high velocity inertia of Restraining Agent and End Closures when they are in their normal operational modes.

Figure 48 **Impellor & Shaft Assembly.**



LEGEND:

1) Shaft & Pneumatic Conduit.
2) Impellor & Pneumatic Conduit.
3) One Of 9 Fasteners Securing Impellor To Shaft.
4) Clockwise Rotation Looking Into This End.
5) Right Hand Thread.
6) Left Hand Thread.
7) Leading Wall In Clockwise Rotation.
8) Trailing Wall In Clockwise Rotation.

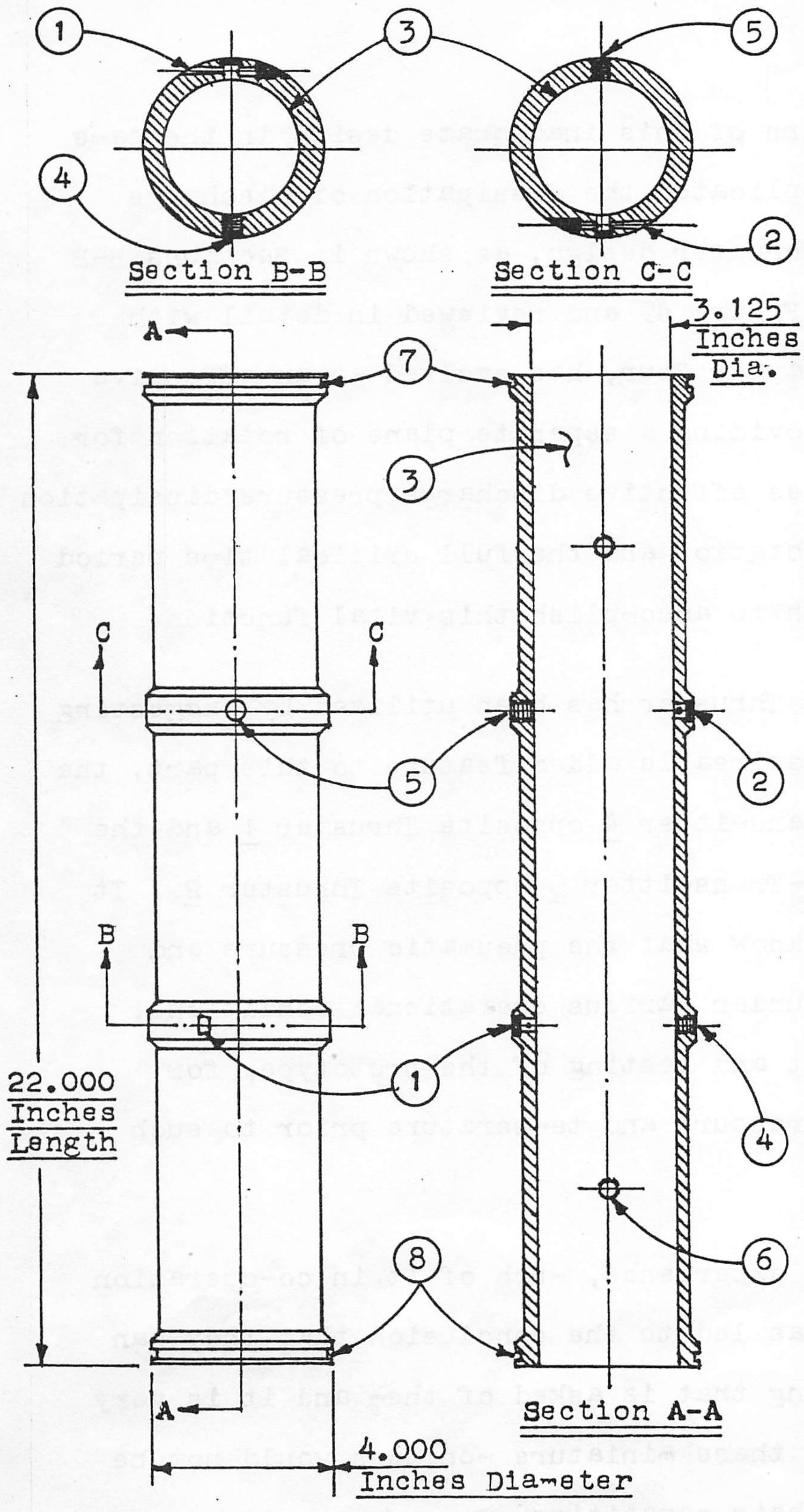
All elements of the Rotor Assembly are ,of course, vital to its effective function but perhaps most vital of them all is the Restraining Agent and Thruster Mounting Base , shown in Figure 49 on page 199. All other elements of the entire system are in support of the key functions of this part, Inertial-Pneumatic Compression , initiated by its inner surface 3 , and the conversion of Pneumatic Pressure Power Ppp to rotational Thrust Power Pt by its two Thrusters 1 and 2 in Figure 49.

The reader's total comprehension of the vital function of surface 3 , in Figure 49 , is absolutely essential to acceptance of the feasibility and enormous potential of the Inertial-Pneumatic Electric Power Concept. As explained in Chapter Three, this is where it all begins, the independent and statically directed blocking action of surface 3 against inertia's constant and radially outward directed attempts to accelerate each of the millions of particles in the Pneumatic Mass through its respective involute curve path to its respective point H , as illustrated in Figure 15 on page 95.

The effective function of Thrusters 1 and 2 has been thoroughly reviewed in Chapter Four of this work and further review in this Chapter Seven would be repetitive and superfluous. However, their designed positioning at 180° opposite from one another and each in its own separate rotational plane may be deserving of further explanation.

Late in the hardware development program, certain laboratory tests of an experimental Rotor Assembly revealed that sub-normal acceleration rates were due to inadequate dissipation of Thruster discharge pneumatic pressure and subsequent loss of pressure differential across Thrusters. This, in turn, was due to the very inadequate straight cylindrical bore

Figure 49



Restraining Agent And Thruster Mounting Base.

LEGEND:

1) Number One Thruster.

2) Number Two Thruster.

3) Restraining Agent Functional Surface.

4) Pneumatic Pressure Sensor-Transmitter.

5) Pneumatic Temperature Sensor-Transmitter.

6) One Of Four Impellor Positioning Keys.

7) Right Hand O Ring Seal Groove.

8) Left Hand O Ring Seal Groove.

passage, incorporated into that particular experimental design for the ejected pneumatic particles, which prevented complete pressure expansion from maximum at Thruster entrance to minimum environmental pressure at Thruster exit.

The placement of six Thrusters of this inadequate design in the same rotational plane further complicated the dissipation of discharge pressure. Consequently the Thruster design, as shown in Sections B-B and C-C , items 1 and 2, of Figure 49 and reviewed in detail with enlarged illustrations in Chapter Four, has evolved as an effective solution to this problem. Providing a seperate plane of rotation for each Thruster further enhances effective discharge pressure dissipation by providing the full 360^{o} rotation and the full critical time period t for one revolution in which to accomplish this vital function.

The blank area opposite each Thruster has been utilized by suggesting a non-essential but highly desireable added feature to this part, the Pneumatic Pressure Sensor-Transmitter 4 opposite Thruster 1 and the Pneumatic Temperature Sensor-Transmitter 5 opposite Thruster 2 . It would be very convenient to know what the pneumatic pressure and temperature is at surface 3 under various operational conditions, especially during development and testing of the prototype, for comparison to the computed pressure and temperature prior to such laboratory testing.

Extensive design engineering experience, much of it in co-operation with electronic engineers, has led to the conclusion that they can accomplish just about anything that is asked of them and it is very probable that development of these miniature monitors would not be too serious a challenge to their capacities.

Something would have to be done with these areas anyway to balance the cavities of the Thrusters 180° opposite and addition of these monitors might automatically accomplish the balance.

The greatly increased thrust, that developed with Thruster redesign, came as a very welcome, somewhat surprising but long anticipated, improvement to system efficiencies and productivity which actually exceeded anticipation. Tests, early-on in the development program, of tapered Thrusters had indicated they produced a superior thrust-to-flow rate ratio but the reason for the superiority was not fully recognized until this design improvement had been accomplished.

The third important function of the part in Figure 49 is that of containment of the highly pressurized Pneumatic Mass within the Rotor Assembly. This is accomplished by the strength of the wall outside surface 3 and the O Ring Seals which seat in grooves 7 and 8 as they interface to specific surfaces of the two End Closures.

The fourth important function of the part in Figure 49 provides four threaded seats 6 for four keys which permanently fix positioning of Impellor and Thrusters at 90° to one another.

The reader should be reminded that this part is also subjected to the greatest bursting forces, exerted by inertia in its centrifugal force function, against its weakest section. It will be the task of the finalizing designers to assure appropriate selection of material with the most effective strength-to-weight ratio and assure that the proposed configuration is the most effective compromise between these conflicting giant effects of inertia, if maximum productivity is to be accomplished.

The Nut and End Closures, shown in Figure 50 on page 203, are also designed to accomplish multiple functions. Their first important function provides end closure containment of the Pneumatic Mass within the Rotor Assembly,which they accomplish with their seal surfaces 4 and 3 , which prohibit pneumatic flow through their respective interfaces with the O Ring Seals of the Restraining Agent of Figure 49 and the O Ring Seals of the Shaft of Figure 46 .

Pressure containment is also accomplished by appropriate wall thickness adjacent to the seal surfaces 3 and 4 in Figure 50.

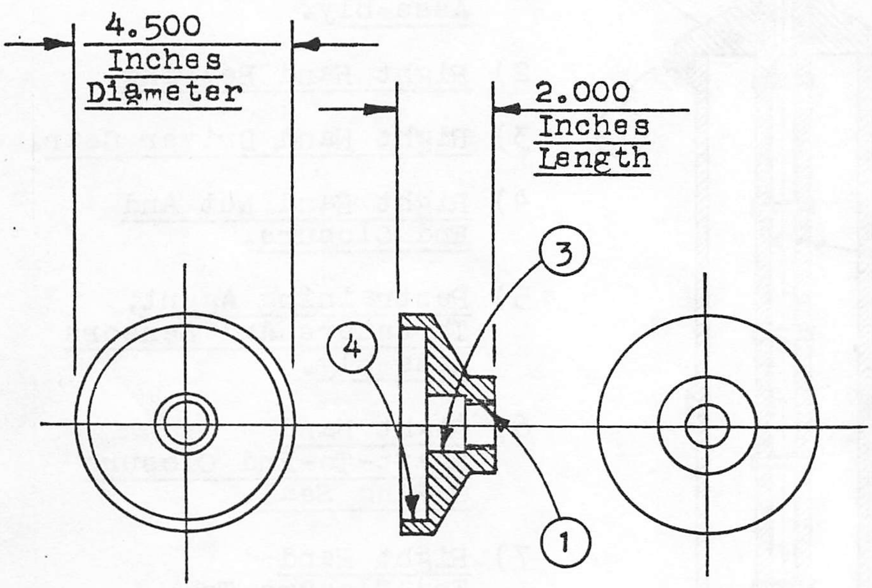
The second important function of the parts in Figure 50 provides the right hand and left hand threads 1 and 2 , along with the heavy wall thickness surrounding them, to form the " Nut " portion of these parts. This permits them to bring together and permanently secure all elements of the Rotor Assembly in an appropriate relationship to one another.

The parts , illustrated in Figures 46 , 47 , 48 , 49 and 50 , all come together very effectively in the Rotor Assembly , illustrated in Figure 51 on page 204. The step by step procedure for this assembly begins with the Impellor and Shaft Assembly , item 1 in Figure 51. Next the Shaft-to-End Closures O Ring Seals 6 and 10 are assembled in their respective grooves.

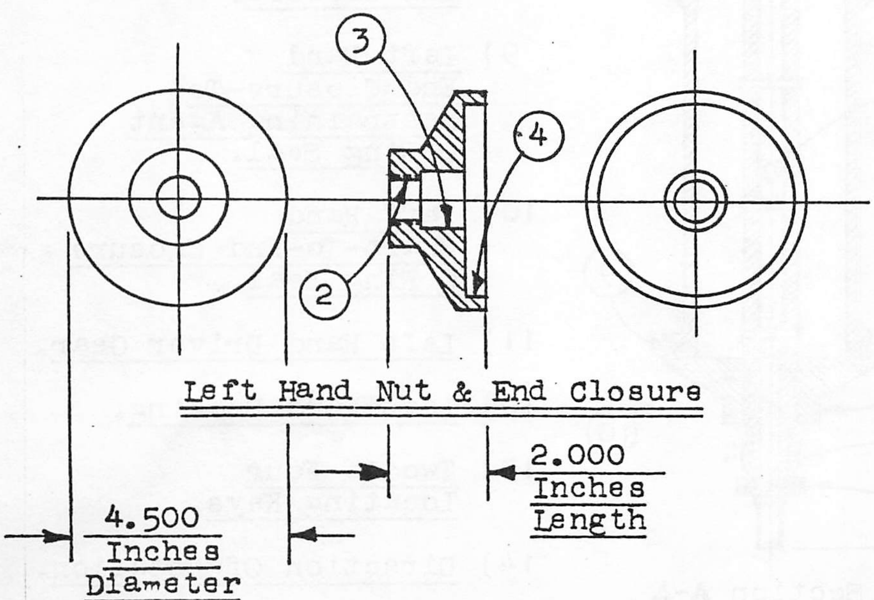
The Restraining Agent , Thrusters and Sensors Assembly 5 consists of the Restraining Agent , with the two Thrusters fabricated into its two Thruster Rings and accurately positioned in respect to other elements, the Pneumatic Pressure Sensor-Transmitter, also accurately positioned in one of the two Rings in the same rotational plane but 180° opposite its respective Thruster, the Pneumatic Temperature Sensor-Transmitter, also positioned in like manner opposite the other Thruster,

Figure 50

Nuts & End Closures.



Right Hand Nut & End Closure



Left Hand Nut & End Closure

LEGEND:

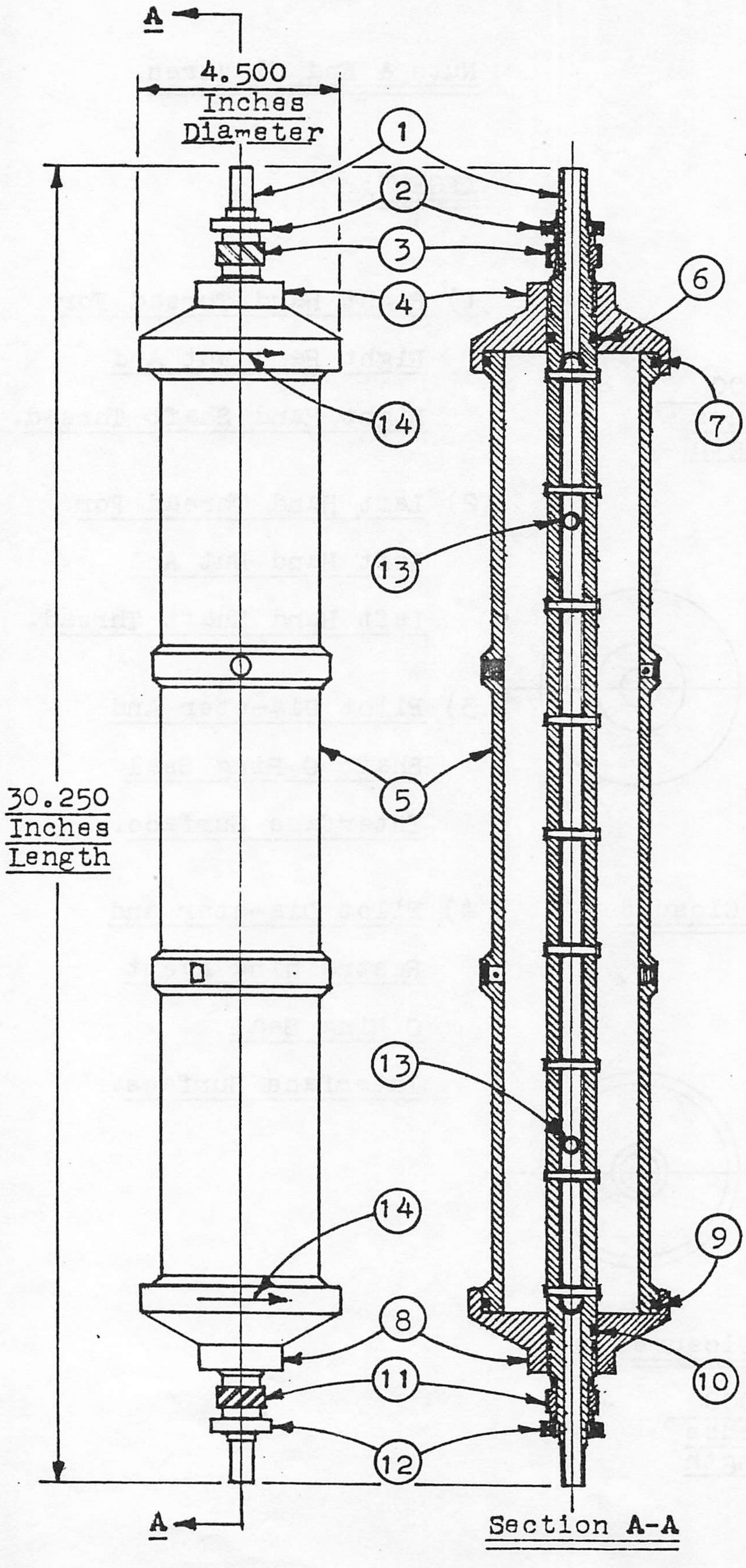
1) Right Hand Thread For Right Hand Nut And Right Hand Shaft Thread.

2) Left Hand Thread For Left Hand Nut And Left Hand Shaft Thread.

3) Pilot Diameter And Shaft O Ring Seal Interface Surface.

4) Pilot Diameter And Restraining Agent O Ring Seal Interface Surface.

Figure 51



Rotor Assembly

LEGEND:

1) Impellor And Shaft Assembly.

2) Right Hand Bearing.

3) Right Hand Driver Gear.

4) Right Hand Nut And End Closure.

5) Restraining Agent, Thrusters And Sensors Assembly.

6) Right Hand Shaft-To-End Closure O Ring Seal.

7) Right Hand End Closure-To-Restraining Agent O Ring Seal.

8) Left Hand Nut And End Closure.

9) Left Hand End Closure-To-Restraining Agent O Ring Seal.

10) Left Hand Shaft-To-End Closure O Ring Seal.

11) Left Hand Driver Gear.

12) Left Hand Bearing.

13) Two Of Four Locating Keys.

14) Direction Of Rotation.

and , finally , the four threaded Keys for positioning Assembly 5 in proper relationship to Assembly 1 , item 13 in Figure 51.

Before assembling Assembly 5 to Assembly 1 , the four Keys must be removed. The diametrical outer extremities of Assembly 1 have been fabricated , that is machined or ground to a precise diameter, so that they are a snug slip fit to the inside diametrical extremity of Assembly 5 , making it possible to manually slip Assembly 5 into its appropriate position over Assembly 1 .

However, before this step is initiated, the assembler must be very sure of such appropriate positioning, since effective Rotor Assembly function depends on it with absolute certainty.

Referring to the exterior side view of the Rotor Assembly , at left in Figure 51 ,note that the near Thruster exit opening appears on the top or near side and to the left of the centerline. This indicates that Rotor Assembly operational rotation is to be clockwise, looking into the bottom or near end of the Rotor Assembly , as indicated by the directional arrows 14.

Since Assembly 1 is also designed to rotate in one direction only, the assembler must be absolutely certain that Assembly 5 is positioned over Assembly 1 with Assembly 1 in position to also rotate clockwise, looking into its bottom or near end. This is determined by holding Assembly 1 in the position shown in Section A-A of Figure 51. Next , examine the right hand wall of the top or near end of the Impellor. It must be a solid leading wall if Assembly 1 is to be fully functional while rotating clockwise. Maintaining this relative positioning, Assembly 5 may now be moved manually into position over Assembly 1. Shaft threads will automatically position with left hand at top or far end.

However, Assembly 5 must be rotated clockwise or counter-clockwise until the four Key holes are in appropriate alignment with the interior of the Impellor, as indicated by item 13 in Section A-A of Figure 51, where two of the four holes , on the bottom or far side of Assembly 5, are visible through the interior of the Impellor.

Appropriate axial positioning of Assembly 5 will have been accomplished when the end surfaces of the Restraining Agent of Assembly 5 are flush with the end surfaces of the Impellor of Assembly 1. Both will have been machined or ground to precise length so that both ends will be precisely flush simultaneously. The four Keys 13 may now be reinserted into their respective threaded holes thereby permanently securing this relative positioning of Assembly 5 to Assembly 1 , as their respective precisely machined inner ends interface snugly to the Impellor interior surface.

O Ring Seals 7 and 9 are next in the assembly sequence of the Rotor Assembly as they are fitted manually to their respective grooves in Assembly 5 . It is quite probable that finalizing designers will specify application of an appropriate lubricant to all O Rings at assembly to facilitate the assembly process as well as the effective function of O Ring Seals.

The Nut and End Closures 4 and 8 are next in the assembly sequence and it makes no difference which is assembled first. However , the assembler will automatically assemble the Nut with the left hand thread on the left hand Shaft thread at the upper or far end and the Nut with the right hand thread on the right hand Shaft thread at the lower or near end , since that is the only way they may be assembled. Finger tight interface between End Closure and Assemblies 1 and 5 will suffice for initial assembly of the first Nut, which ever it is. It is also probable that the finalizing designers will specify that a commercial thread adhesive, such as Loctite, be applied to the Shaft threads prior to assembling the Nut, for added security.

As mentioned earlier , these two parts are designed and fabricated with right hand and left hand threads for the functional security of the Rotor Assembly while in its high velocity operational mode. The logic behind this suggested design feature considers the possible effects of the high level of inertial or kinetic energy of the two parts developed as they rotate with other elements of the Rotor Assembly at 120,000 RPM , for example. If some sudden severe load, in opposition to rotation, should for any reason be applied to the system downstream from the Rotor Assembly, its braking effect would be transmitted upstream through the Driver Gears 3 and 11 to Assembly 1 and through the four Keys 13 to Assembly 5 .

However, Nuts 4 and 8 have no such rigid interface to Assembly 1 or Assembly 5 . Therefor 4 and 8's high level of tangentially directed inertia would tend to sustain their normal operational velocity while the sudden braking load would tend to retard the velocities of Assemblies 1 and 5. Therefor, to assure that the two " Nut " portions of 4 and 8 tend to tighten rather than loosen in such a scenario , right and and left hand threads are effectively employed. Now, perhaps, the assembler may understand and more fully appreciate the incorporation of right hand and left hand threads and the appropriate positioning of 4 and 8 as previously determined in the correctly assembled Assembly 1 as specified by the finalizing designers, and will resume the assembly process by assembling the second Nut to finger tight interface to Assemblies 1 and 5 .

The exterior surfaces of Assembly 5 and of Nuts 4 and 8 are , by design , very smooth finished and very concentric round configuration for the purpose of minimizing windage at the interface of these surfaces to the very dense pneumatic environment in which the Rotor Assembly must effectively function. Therefore manufacturing engineers would provide special wrenches for the final tightening of Nuts 4 and 8 and special holding device for Assembly 5 during the process so that the final specified tightening torque may be applied without damage to these critical surfaces.

As 4 and 8 are tightened they will automatically finalize their axial positions as their inner surfaces interface to the end surfaces of Assemblies 1 and 5 , and they may be tightened alternately to the specified torque wrench level without jeopardizing the axial positioning.

It must be obvious to the reader that state-of-the-art concentricity is mandatory through out Rotor Assembly design and fabrication for maximum functional efficiency at the specified operational rotational velocity. Such emphasis on concentricity minimizes problems with the vital dynamic balancing process which must follow completion of the assembly process. Experience has shown that such balancing must occur at the Rotor Assembly's most pronounced critical speed which will be identified by vibrations of greatest amplitude.

Next in the assembly sequence are the Driver Gears 3 and 11 . It is quite probable that finalizing designers will specify hardened steel right hand and left hand helical pinions for these important power transmission parts. Their function is to transfer the Generator Drive Power Pgd from the Rotor Assembly to the downstream power train that drives the Electric Power Generator system.

As illustrated in Figure 51, their pitch diameters are 1.000 inch and their faces are .500 inch. Figure 51 makes no attempt to illustrate positioning and security of Driver Gears 3 and 11 to the Shaft of Assembly 1 but leaves this to the better judgement of the finalizing designers. Suffice to suggest that their mountings must be as concentric and secure as state-of-the-art design engineering will permit while bearing in mind that power transmission will be at relatively high pitch circle velocity but relatively low tooth interface pressure and driving torque at the interface of gears and shaft.

It seems certain that finalizing designers will employ the right hand and left hand helicals in such a manner as to cause gear tooth pressure to tend to move the two gears toward the mid-section of the Rotor Assembly. With helicals mounted so as to oppose one another with their tooth pressure axial components, they automatically become axial positioning locks for the Rotor Assembly in respect to the downstream Driven Gears Assembly, thereby lending assistance to the Rotor Assembly's suspension systems in this important function.

It seems equally certain that finalizing designers will recognize the capacity of interfacing helical gears for smooth and quiet operation at the higher levels of operational rotating velocity, especially if the hardened steel pinions , such as 3 and 11 of the Rotor Assembly , interface to laminated phenolic ring gears of the Driven Gears Assembly appropriately lubricated at the interfacing helical teeth.

Finally , in the assembly sequence, are the suggested standard single row Ball Bearings 2 and 12 , lightly and permanently lubricated, in view of their superior performance during laboratory tests of experimental Rotor Assemblies during the hardware development program.

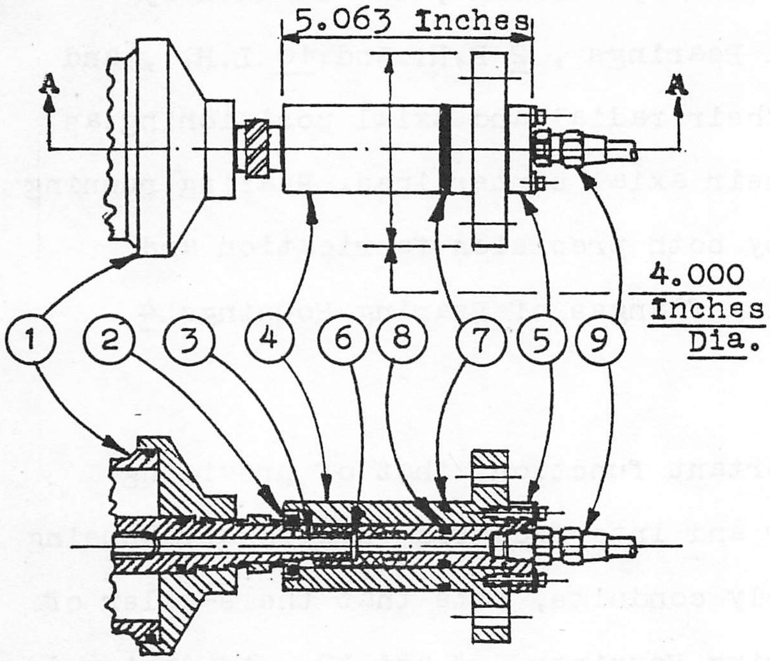
Again the selection and mounting of Bearings 2 and 12 is left to the better judgement and decisions of the finalizing designers as they arrive at their specification for the maximum safe operational value of N , for maximum safe operational productivity. It is assumed that appropriate Retainer Rings will be specified for the axial security of Bearings 2 and 12 .

The two Rotor Assembly suspension systems , illustrated in Figure 52 on page 211 , are actually identical but opposite and each of them provide important dual functions. First, each provides an effective interface of the rotating Rotor Assembly to an appropriate area of the stationary Environmental Control Vessel and , second, each provides an effective interface of the rotating pneumatic conduit bores of the Shaft to the appropriate areas of the stationary pneumatic transfer and control parts of the system, governing the flow of pneumatic replacement particles from the Environmental Control Vessel interior into and through the Rotor Assembly.

Considering first their Rotor Assembly suspension function, note that this is accomplished primarily by the two Bearing Housings 4 and 12 which are very strong , very rigid and very precisely fabricated devices which at installation will interface externally, with high precision and security, to the precisely fabricated in-line bores prepared for them in the Rotor Assembly Housing section of the Environmental Control Vessel.

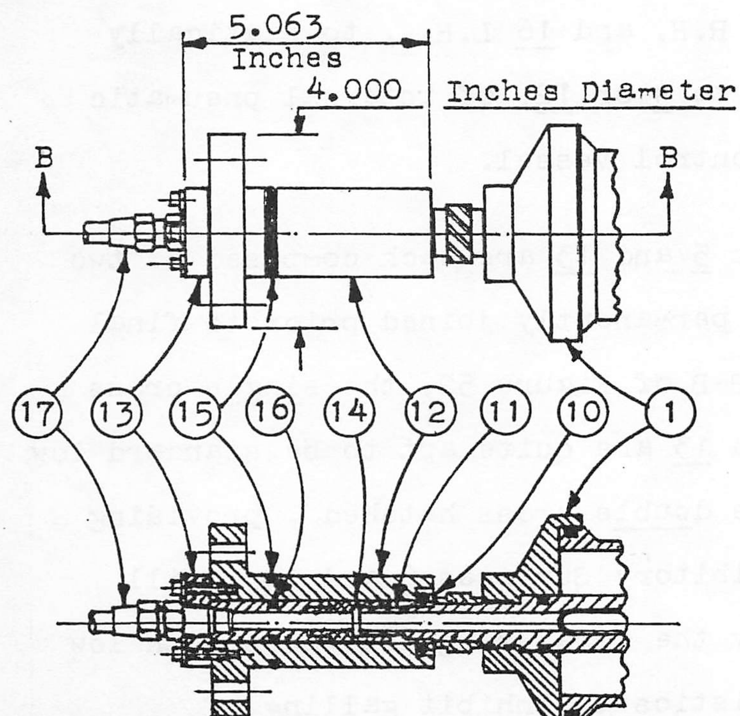
Each provides its own static O Ring Seal , 7 R.H. and 15 L.H. , to prevent escape of pneumatic pressure through the interface of the high pressure level within the Vessel to the relatively low standard air pressure level enveloping the Vessel's exterior.

Figure 52



Section A-A

Right Hand System



Section B-B

Left Hand System

Rotor Assembly Suspension Systems

LEGEND:

1) Rotor Assembly.
2) Rotor Assembly R.H. Bearing.
3) R.H. Rotating Pneumatic Flow Inhibitory Surface.
4) R.H. Bearing Housing.
5) R.H. Pneumatic Infeed Housing.
6) R.H. Stationary Pneumatic Flow Inhibitory Surface.
7) R.H. Bearing Housing-To-Environmental Control Vessel O Ring Seal .
8) R.H. Bearing Housing-To-Pneumatic Infeed Housing O Ring Seal.
9) R.H. Pneumatic Transfer Line Connector.
10) Rotor Assembly L.H. Bearing.
11) L.H. Rotating Pneumatic Flow Inhibitory Surface.
12) L.H. Bearing Housing.
13) L.H. Pneumatic Infeed Housing.
14) L.H. Stationary Pneumatic Flow Inhibitory Surface.
15) L.H. Bearing Housing-To-Environmental Control Vessel O Ring Seal.
16) L.H. Bearing Housing-To-Pneumatic Infeed Housing O Ring Seal.
17) L.H. Pneumatic Transfer Line Connector.

Each provides two precisely fabricated internal bores , the larger of the two sized to accept , with maximum precision , the stationary outer race of one of the two Ball Bearings , 2 R.H. and 10 L.H. , and thereby permanently secure both their radial and axial positioning as well as precision alignment of their axial centerlines. Bearing running clearance is precisely governed by both precision fabrication and adjustable shimming at the mounting flanges of Bearing Housings 4 R.H. and 12 L.H.

Considering now their second important function, that of providing effective pneumatic flow transfer and interface from stationary housing conduits to rotating Rotor Assembly conduits, note that the smaller of the two bores in each of the Bearing Housings , 4 and 12 , is designed and precisely fabricated to accept , and securely retain, one of the two Pneumatic Infeed Housings , 5 R.H. and 13 L.H , with each of them providing its own O Ring Seal , 8 R.H. and 16 L.H. , to statically prohibit escape,via its interface to 4 or 12, of internal pneumatic pressure from the Environmental Control Vessel.

Actually Pneumatic Infeed Housings 5 and 13 are each composed of two different materials , rigidly and permanently joined prior to final fabrication. In Sections A-A and B-B of Figure 52, the single cross hatched portions of Housings 5 and 13 are quite apt to be standard low carbon cold rolled steel while the double cross hatched , providing the Stationary Pneumatic Flow Inhibitory Surfaces 6 and 14 , will probably be a material selected by the finalizing designers with low coefficient of friction characteristics to inhibit galling of interfacing materials should rotating surfaces 3 or 11 inadvertantly contact stationary surfaces 6 or 14. In normal operational mode, a minimal running clearance of perhaps .005 inch would be provided.

It would seem prudent, at this point in Chapter Seven, to provide a full explanation of the " No-Contact Dynamic Seal " , referred to earlier in this work , which actually is not a true seal , in the sense that it is designed to inhibit pneumatic flow rather than prohibit such flow through the rotating-to-stationary interface. It is illustrated in Figure 52 , Sections A-A and B-B , by stationary surface 6 versus rotating surface 3 and stationary surface 14 versus rotating surface 11.

Fortunately for the finalizing designers, the pressure differential across this interface of moving and stationary surfaces is non-existant when the system is in the operational mode. Bear in mind that the Rotor Assembly functions in a high-pressure , high-density , pneumatic environment, controlled and contained by the Environmental Control Vessel. The pneumatic flow from Vessel interior to Rotor interior requires external control if , and when , the system is in the " Start-Up " , " Shut Down " or " Emergency " modes.

For this reason, external pneumatic transfer lines conduct the flow out of the Vessel , at appropriate points , through the external lines and controls which terminate with Connectors , such as 9 and 17 in Figure 52 , and thence through the stationary pneumatic conduits , illustrated by 5 and 13 in Figure 52 , into the two pneumatic infeed bores of the Shaft of Rotor Assembly 1 in Figure 52.

Thus, in the operational mode, the pneumatic pressure on the infeed bore side of each interface is identical to the pressure on the bearing side of each interface , as at 2 and 10 in Figure 52. There can be no pneumatic flow through such an interface if there is no pressure differential across it and therefor a positive dynamic seal that absolutely prohibits pneumatic flow is not required.

However, finalizing designers will find that some restriction of flow through this interface is desireable in each of the other three system modes. Consider first the "Start-Up" mode of the system which specifies the process for accelerating the Rotor Assembly and the Pneumatic Mass within it from idle or zero value of N up to the specified operational value of N which may be as high as 120,000 RPM , for example.

As the "Start-Up" program is initiated, the Environmental Control Vessel and its contents has been charged with the specified operational Environmental Pressure Ep , which may be 2000 psig , for example. Since this is injected directly into the Vessel and not through the Rotor infeed bores exclusively , the interior of the Vessel and that of the Rotor Assembly become fully charged without pressure differential across the Thrusters so no rotation of the Rotor Assembly is generated by the process.

Thus, as the " Start-Up " program is initiated , both suspension systems of Figure 52 are charged with 2000 psig pneumatic pressure from their infeed bores to all exterior surfaces inside O Ring Seals 7 , 8 , 15 and 16 and there is zero pressure differential across the interfaces 3 versus 6 and 11 versus 14.

To achieve the operational value of N , however, there must be a pressure differential across the two Thrusters and this is obtained from an external source of pneumatic pressure which is injected for a few seconds at a higher pressure level into the lines which terminate with Connectors 9 and 17 , in Figure 52 , upstream from Check Valves in each of the two lines which prevent flow into the Environmental Control Vessel.

If the injected start-up pressure is , for example, 2500 psig , this will provide a 500 psig pressure differential across the two Thrusters which is sufficient to accelerate the Rotor Assembly , in a very few seconds, to values of N where Inertial-Pneumatic Compression is generating more than enough pressure differential across Thrusters to assume acceleration of the Rotor Assembly on up to the specified operational level of N and pressure from the external source is terminated at that point in the start-up program.

During the brief five seconds or so of external pressure injection, pressure relief valves sustain Environmental Pressure Ep at its specified 2000 psig level and the pressure differential across interfaces 3 versus 6 and 11 versus 14 begins with a value of 500 psig and pneumatic flow from the infeed bores through the interfaces and through the Bearings 2 and 10 into the Vessel is at maximum.

During that brief five second period the loss of external pressure through these interfaces would be low for the dual reason that the elapsed time has been so small and passage of leaking pneumatic particles through the .005 inch running clearance and through the Bearings 2 and 10 became increasingly difficult as the value of N increased.

The conditions at these interfaces during " Shut-Down " and "Emergency " modes are identical so they will be considered simultaneously. In the normal operational mode, the value of N is governed by automatic variations in electrical load on the Generator system. If , for any reason, these normal controls should fail, the Rotor Assembly would quickly accelerate to values of N dangerous to its structural strength. For this reason the value of N is automatically and continuously monitored for such sudden and dangerous increase. Instantly as it occurs, the computer programmer senses it and closes valves in the transfer lines which totally interrupts pneumatic flow through Connectors 9 and 17 into the Rotor Assembly which will instantly begin decelerating back to safe values of N , provided that leakage through interfaces 3 versus 6 and 11 versus 14 is minimal, which it normally will be because of its restriction at these interfaces and through the rapidly rotating Bearings , 2 and 10 . The same sequence applies to the " Shut-Down " mode except the line valves are closed by the programmer on signal from the operator on duty rather than on signal indicating excess N.

A back-up emergency program is also incorporated into the system to cover other contingencies , such as the dumping of Environmental Pressure Ep should the " N sensing " system fail. Also, under normal operational conditions, the line valves governing pneumatic flow through Connectors 9 and 17 and the valves governing the dumping of Ep are solenoid operated and held in operational mode by them. Thus , should a power failure occur, line valves would close and Ep dump valves would open automatically, shutting the system down.

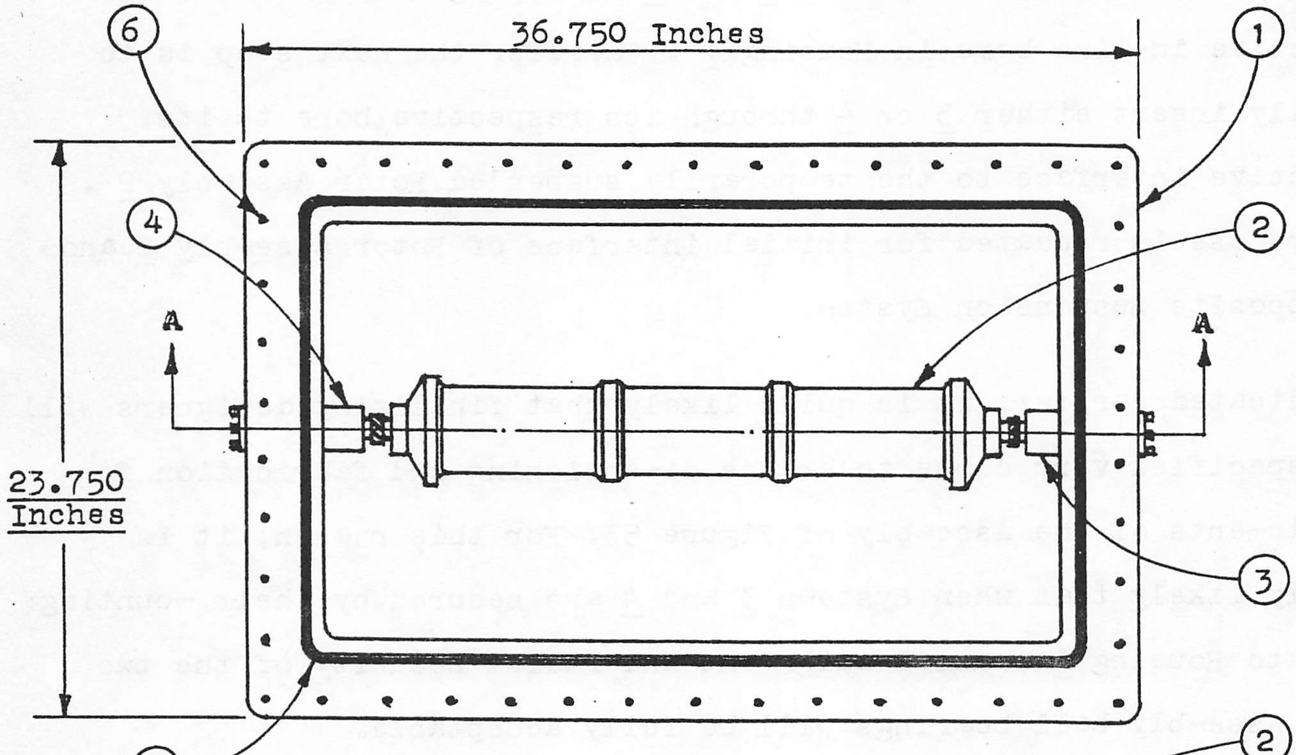
Figure 53 on page 217 illustrates how the Suspension Systems of Figure 52 are assembled to the Rotor Assembly simultaneously with their assembly to the Rotor Assembly section of the Environmental Control Vessel. The top view looks squarely down into the assembly and the Section A-A is taken through the Housing 1 only at the axial centerline of the Rotor Assembly, its two Suspension Systems 3 and 4 , and the in-line bores of Housing 1 in which they are mounted.

Section A-A in the lower view looks directly into the cutting plane

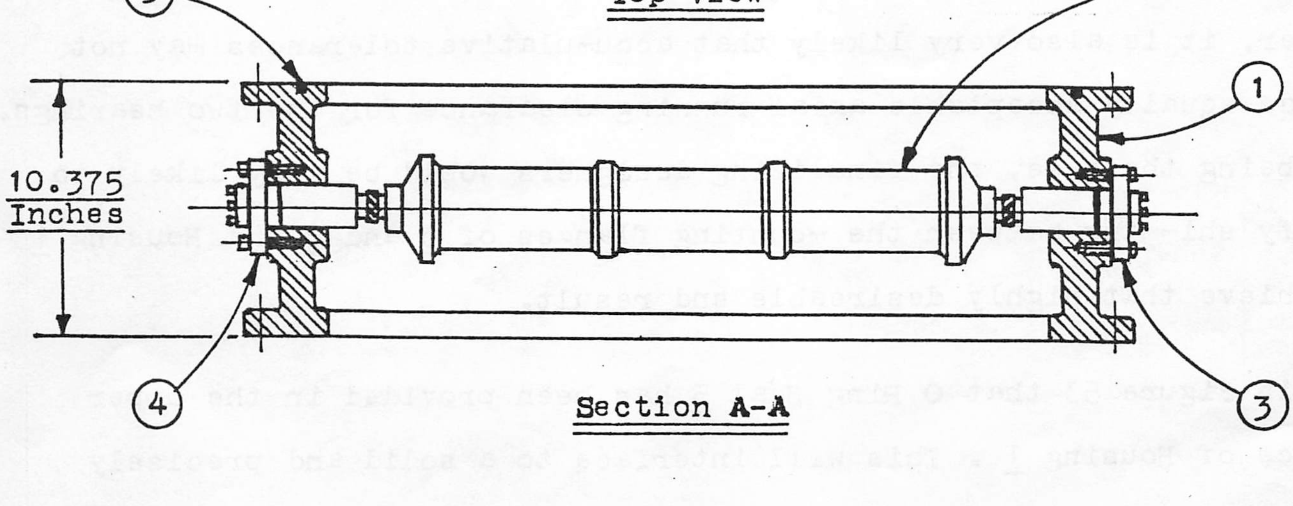
Figure 53

Environmental Control Vessel Rotor Assembly Section. LEGEND:

1) Rotor Assembly Housing Section. 2) Rotor Assembly
3) R.H. Rotor Assembly Suspension System.
4) L.H. Rotor Assembly Suspension System.
5) Rotor Assembly Housing-To-Housing Cover O Ring Seal.
6) One Of 46 Cover Security Bolt Threaded Holes.



Top View



Section A-A

through Housing 1 and clearly illustrates the wall configuration of Housing 1 as well as the interface of its two in-line bores with Suspension Systems 3 and 4 .

The opening at the top of Housing 1 and the space between its two in-line bores is sufficient to permit lowering and suspension of the Rotor Assembly into the approximate position shown in Figure 53. Therefor this is the first step in the assembly procedure.

Each Bearing Housing of Systems 3 and 4 is a snug slip fit to its respective in-line bore in Housing 1 . Therefor the next step is to manually insert either 3 or 4 through its respective bore to its respective interface to the temporarily suspended Rotor Assembly 2 . The process is repeated for initial interface of Rotor Assembly 2 and the opposite Suspension System.

As indicated earlier, it is quite likely that finalizing designers will have specified very close tolerance dimensioning and fabrication for the elements of the Assembly of Figure 53. For this reason, it is equally likely that when Systems 3 and 4 are secured by their mounting bolts to Housing 1 , axial alignment and radial security of the two Rotor Assembly ball bearings will be fully acceptable.

However, it is also very likely that accumulative tolerances may not provide equally acceptable axial running clearance for the two bearings. This being the case, the finalizing designers would be very likely to specify shimming between the mounting flanges of 3 and 4 and Housing 1 to achieve that highly desireable end result.

Note in Figure 53 that O Ring Seal 5 has been provided in the upper surface of Housing 1 . This will interface to a solid and precisely fabricated surface of the Cover for Housing 1 and thereby form a very reliable static seal against leakage of Environmental Pressure Ep from its containment.

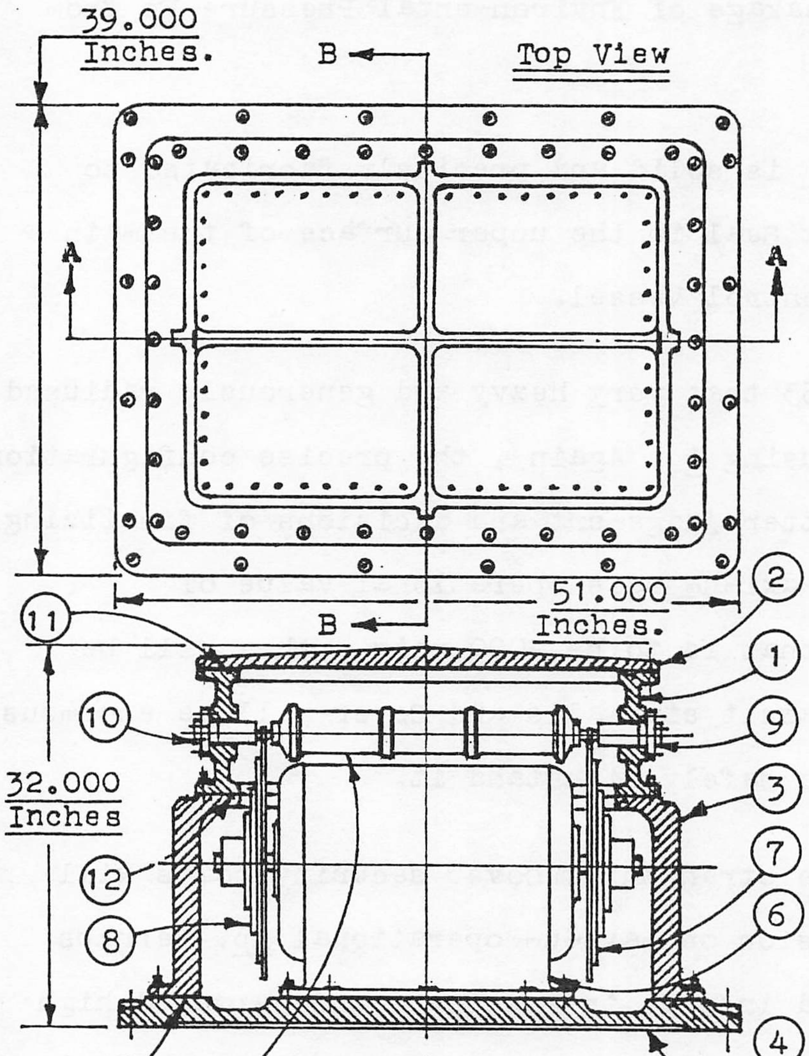
The bottom surface of Housing 1 is solid and precisely fabricated to interface with a similar O Ring Seal in the upper surface of the main section of the Environmental Control Vessel.

Note in Section A-A of Figure 53 that very heavy and generously radiused sidewalls are suggested for Housing 1 . Again , the precise configuration of sidewalls is left to the better judgement and decisions of finalizing designers as they specify the maximum safe operational value of Environmental Pressure Ep. If that is to be 2000 psig , they will be well aware that total force against sidewalls and Cover will be enormous and they must be very strong to safely withstand it.

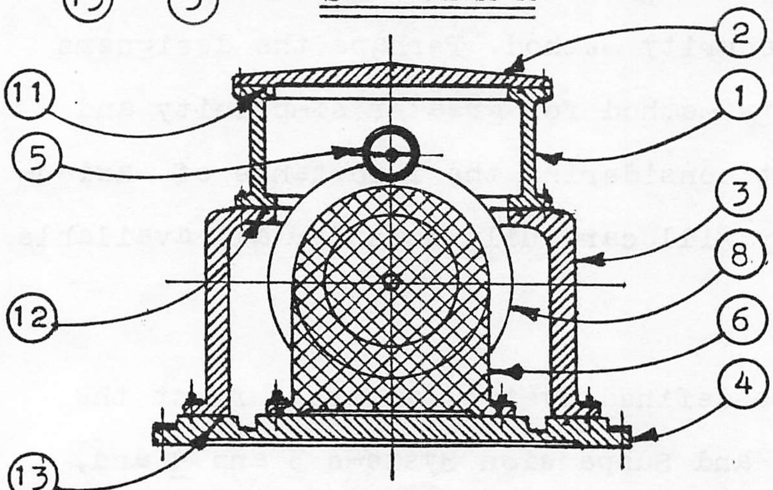
The size and number and tensile strength of Cover security bolts will also be compatible to the decision on maximum operational Ep. Perhaps hardened high strength threaded inserts in Housing 1 and hardened high strength security bolts interfacing to them may be specified for maximum containment strength by this security method. Perhaps the designers may specify an optional security method for greater simplicity and strength. It seems certain that considering the importance of maximum Ep to system productivity, they will carefully consider all available options.

The dimensions of Housing 1 are defined by two factors , first the dimensions of Rotor Assembly 2 and Suspension Systems 3 and 4 and, second provision for the interface of the two Rotor Assembly Driver Gears to the Driven Gear Assemblies of Figure 54 on page 220, which occurs through the bottom opening of Housing 1 in Figure 53.

Figure 54



Section A-A



Section B-B

Rotated Clockwise 90°

Environmental Control Vessel Assembly.

LEGEND:

1) Rotor Assembly Compartment.
2) Rotor Assembly Compartment Cover.
3) Generator System Compartment.
4) Base.
5) Rotor Assembly.
6) Generator Assembly.
7) R.H. Driven Gear Assembly.
8) L.H. Driven Gear Assembly.
9) R.H. Rotor Assembly Suspension System.
10) L.H. Rotor Assembly Suspension System.
11) Cover-To-Rotor Compartment O Ring Seal.
12) Rotor Compartment-To-Generator Compartment O Ring Seal.
13) Base-To-Generator Compartment O Ring Seal.

Something would have to be done with these areas anyway to balance the cavities of the Thrusters 180° opposite and addition of these monitors might automatically accomplish the balance.

The greatly increased thrust, that developed with Thruster redesign, came as a very welcome, somewhat surprising but long anticipated, improvement to system efficiencies and productivity which actually exceeded anticipation. Tests, early-on in the development program, of tapered Thrusters had indicated they produced a superior thrust-to-flow rate ratio but the reason for the superiority was not fully recognized until this design improvement had been accomplished.

The third important function of the part in Figure 49 is that of containment of the highly pressurized Pneumatic Mass within the Rotor Assembly. This is accomplished by the strength of the wall outside surface 3 and the O Ring Seals which seat in grooves 7 and 8 as they interface to specific surfaces of the two End Closures.

The fourth important function of the part in Figure 49 provides four threaded seats 6 for four keys which permanently fix positioning of Impellor and Thrusters at 90° to one another.

The reader should be reminded that this part is also subjected to the greatest bursting forces, exerted by inertia in its centrifugal force function, against its weakest section. It will be the task of the finalizing designers to assure appropriate selection of material with the most effective strength-to-weight ratio and assure that the proposed configuration is the most effective compromise between these conflicting giant effects of inertia, if maximum productivity is to be accomplished.

The Nut and End Closures, shown in Figure 50 on page 203, are also designed to accomplish multiple functions. Their first important function provides end closure containment of the Pneumatic Mass within the Rotor Assembly, which they accomplish with their seal surfaces 4 and 3 , which prohibit pneumatic flow through their respective interfaces with the O Ring Seals of the Restraining Agent of Figure 49 and the O Ring Seals of the Shaft of Figure 46 .

Pressure containment is also accomplished by appropriate wall thickness adjacent to the seal surfaces 3 and 4 in Figure 50.

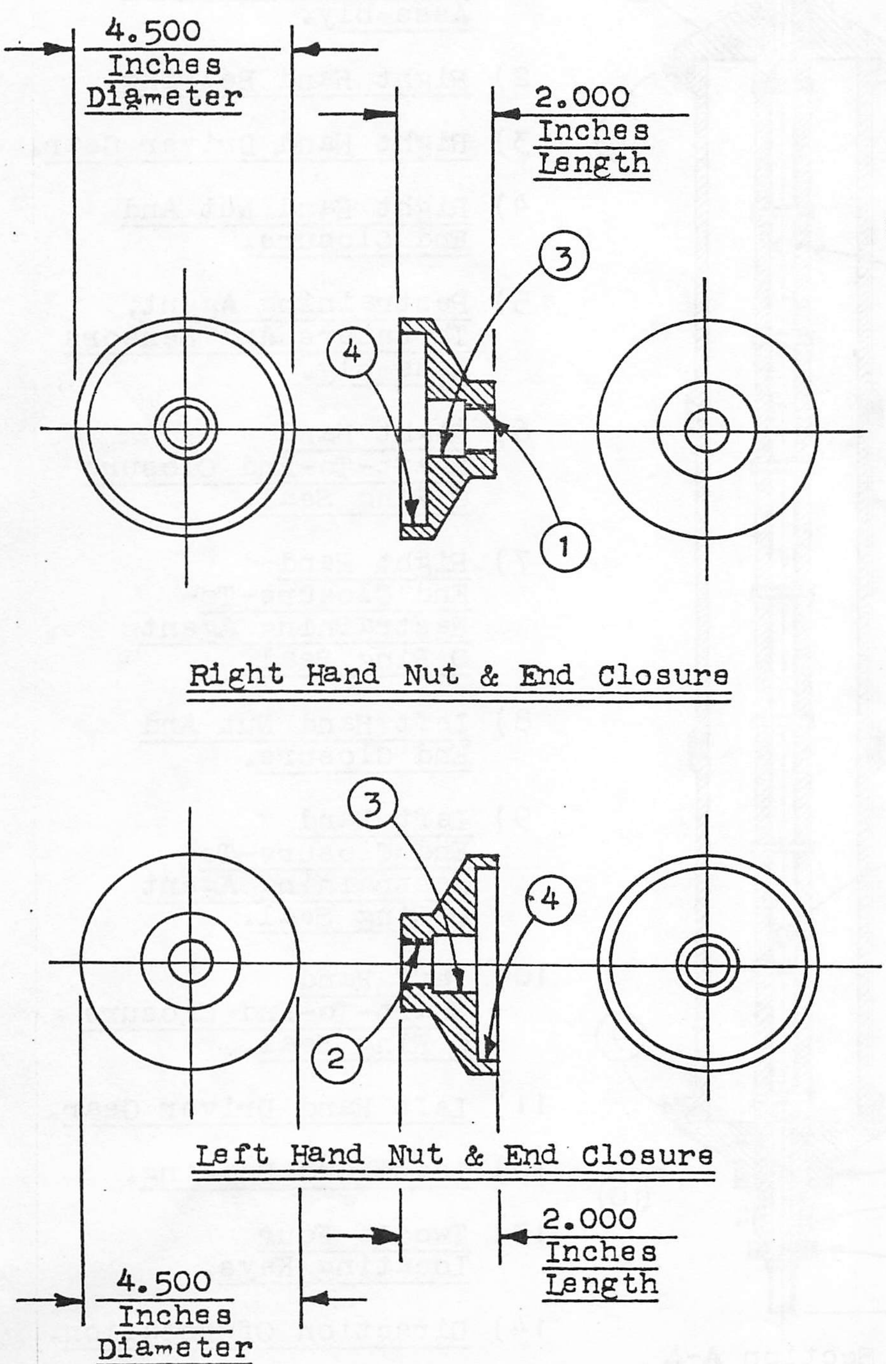
The second important function of the parts in Figure 50 provides the right hand and left hand threads 1 and 2 , along with the heavy wall thickness surrounding them, to form the " Nut " portion of these parts. This permits them to bring together and permanently secure all elements of the Rotor Assembly in an appropriate relationship to one another.

The parts , illustrated in Figures 46 , 47 , 48 , 49 and 50 , all come together very effectively in the Rotor Assembly , illustrated in Figure 51 on page 204. The step by step procedure for this assembly begins with the Impellor and Shaft Assembly , item 1 in Figure 51. Next the Shaft-to-End Closures O Ring Seals 6 and 10 are assembled in their respective grooves.

The Restraining Agent , Thrusters and Sensors Assembly 5 consists of the Restraining Agent , with the two Thrusters fabricated into its two Thruster Rings and accurately positioned in respect to other elements, the Pneumatic Pressure Sensor-Transmitter, also accurately positioned in one of the two Rings in the same rotational plane but 180° opposite its respective Thruster, the Pneumatic Temperature Sensor-Transmitter, also positioned in like manner opposite the other Thruster,

Figure 50

Nuts & End Closures.



LEGEND:

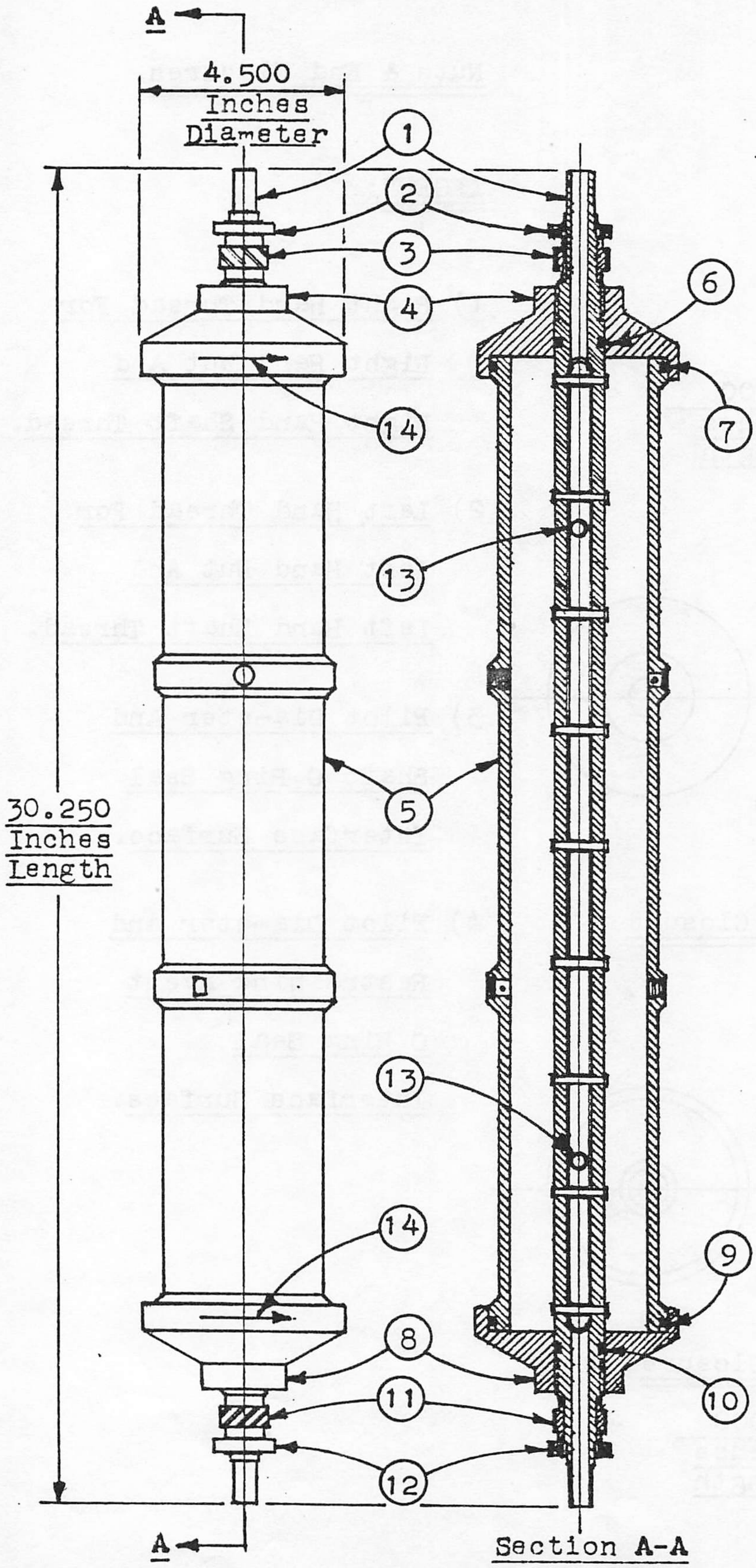
1) Right Hand Thread For Right Hand Nut And Right Hand Shaft Thread.

2) Left Hand Thread For Left Hand Nut And Left Hand Shaft Thread.

3) Pilot Diameter And Shaft O Ring Seal Interface Surface.

4) Pilot Diameter And Restraining Agent O Ring Seal Interface Surface.

Figure 51



Rotor Assembly

LEGEND:

1) Impellor And Shaft Assembly.
2) Right Hand Bearing.
3) Right Hand Driver Gear.
4) Right Hand Nut And End Closure.
5) Restraining Agent, Thrusters And Sensors Assembly.
6) Right Hand Shaft-To-End Closure O Ring Seal.
7) Right Hand End Closure-To-Restraining Agent O Ring Seal.
8) Left Hand Nut And End Closure.
9) Left Hand End Closure-To-Restraining Agent O Ring Seal.
10) Left Hand Shaft-To-End Closure O Ring Seal.
11) Left Hand Driver Gear.
12) Left Hand Bearing.
13) Two Of Four Locating Keys.
14) Direction Of Rotation.

and , finally , the four threaded Keys for positioning Assembly 5 in proper relationship to Assembly 1 , item 13 in Figure 51.

Before assembling Assembly 5 to Assembly 1 , the four Keys must be removed. The diametrical outer extremities of Assembly 1 have been fabricated , that is machined or ground to a precise diameter, so that they are a snug slip fit to the inside diametrical extremity of Assembly 5 , making it possible to manually slip Assembly 5 into its appropriate position over Assembly 1 .

However, before this step is initiated, the assembler must be very sure of such appropriate positioning, since effective Rotor Assembly function depends on it with absolute certainty.

Referring to the exterior side view of the Rotor Assembly , at left in Figure 51 ,note that the near Thruster exit opening appears on the top or near side and to the left of the centerline. This indicates that Rotor Assembly operational rotation is to be clockwise, looking into the bottom or near end of the Rotor Assembly , as indicated by the directional arrows 14.

Since Assembly 1 is also designed to rotate in one direction only, the assembler must be absolutely certain that Assembly 5 is positioned over Assembly 1 with Assembly 1 in position to also rotate clockwise, looking into its bottom or near end. This is determined by holding Assembly 1 in the position shown in Section A-A of Figure 51. Next , examine the right hand wall of the top or near end of the Impellor. It must be a solid leading wall if Assembly 1 is to be fully functional while rotating clockwise. Maintaining this relative positioning, Assembly 5 may now be moved manually into position over Assembly 1. Shaft threads will automatically position with left hand at top or far end.

However, Assembly 5 must be rotated clockwise or counter-clockwise until the four Key holes are in appropriate alignment with the interior of the Impellor, as indicated by item 13 in Section A-A of Figure 51, where two of the four holes , on the bottom or far side of Assembly 5, are visible through the interior of the Impellor.

Appropriate axial positioning of Assembly 5 will have been accomplished when the end surfaces of the Restraining Agent of Assembly 5 are flush with the end surfaces of the Impellor of Assembly 1. Both will have been machined or ground to precise length so that both ends will be precisely flush simultaneously. The four Keys 13 may now be reinserted into their respective threaded holes thereby permanently securing this relative positioning of Assembly 5 to Assembly 1 , as their respective precisely machined inner ends interface snugly to the Impellor interior surface.

O Ring Seals 7 and 9 are next in the assembly sequence of the Rotor Assembly as they are fitted manually to their respective grooves in Assembly 5 . It is quite probable that finalizing designers will specify application of an appropriate lubricant to all O Rings at assembly to facilitate the assembly process as well as the effective function of O Ring Seals.

The Nut and End Closures 4 and 8 are next in the assembly sequence and it makes no difference which is assembled first. However , the assembler will automatically assemble the Nut with the left hand thread on the left hand Shaft thread at the upper or far end and the Nut with the right hand thread on the right hand Shaft thread at the lower or near end , since that is the only way they may be assembled. Finger tight interface between End Closure and Assemblies 1 and 5 will suffice for initial assembly of the first Nut, which ever it is. It is also probable that the finalizing designers will specify that a commercial thread adhesive, such as Loctite, be applied to the Shaft threads prior to assembling the Nut, for added security.

As mentioned earlier , these two parts are designed and fabricated with right hand and left hand threads for the functional security of the Rotor Assembly while in its high velocity operational mode. The logic behind this suggested design feature considers the possible effects of the high level of inertial or kinetic energy of the two parts developed as they rotate with other elements of the Rotor Assembly at 120,000 RPM , for example. If some sudden severe load, in opposition to rotation, should for any reason be applied to the system downstream from the Rotor Assembly, its braking effect would be transmitted upstream through the Driver Gears 3 and 11 to Assembly 1 and through the four Keys 13 to Assembly 5 .

However, Nuts 4 and 8 have no such rigid interface to Assembly 1 or Assembly 5 . Therefor 4 and 8's high level of tangentially directed inertia would tend to sustain their normal operational velocity while the sudden braking load would tend to retard the velocities of Assemblies 1 and 5. Therefor, to assure that the two " Nut " portions of 4 and 8 tend to tighten rather than loosen in such a scenario , right and and left hand threads are effectively employed. Now, perhaps, the assembler may understand and more fully appreciate the incorporation of right hand and left hand threads and the appropriate positioning of 4 and 8 as previously determined in the correctly assembled Assembly 1 as specified by the finalizing designers, and will resume the assembly process by assembling the second Nut to finger tight interface to Assemblies 1 and 5 .

The exterior surfaces of Assembly 5 and of Nuts 4 and 8 are , by design , very smooth finished and very concentric round configuration for the purpose of minimizing windage at the interface of these surfaces to the very dense pneumatic environment in which the Rotor Assembly must effectively function. Therefore manufacturing engineers would provide special wrenches for the final tightening of Nuts 4 and 8 and special holding device for Assembly 5 during the process so that the final specified tightening torque may be applied without damage to these critical surfaces.

As 4 and 8 are tightened they will automatically finalize their axial positions as their inner surfaces interface to the end surfaces of Assemblies 1 and 5 , and they may be tightened alternately to the specified torque wrench level without jeopardizing the axial positioning.

It must be obvious to the reader that state-of-the-art concentricity is mandatory through out Rotor Assembly design and fabrication for maximum functional efficiency at the specified operational rotational velocity. Such emphasis on concentricity minimizes problems with the vital dynamic balancing process which must follow completion of the assembly process. Experience has shown that such balancing must occur at the Rotor Assembly's most pronounced critical speed which will be identified by vibrations of greatest amplitude.

Next in the assembly sequence are the Driver Gears 3 and 11 . It is quite probable that finalizing designers will specify hardened steel right hand and left hand helical pinions for these important power transmission parts. Their function is to transfer the Generator Drive Power Pgd from the Rotor Assembly to the downstream power train that drives the Electric Power Generator system.

As illustrated in Figure 51, their pitch diameters are 1.000 inch and their faces are .500 inch. Figure 51 makes no attempt to illustrate positioning and security of Driver Gears 3 and 11 to the Shaft of Assembly 1 but leaves this to the better judgement of the finalizing designers. Suffice to suggest that their mountings must be as concentric and secure as state-of-the-art design engineering will permit while bearing in mind that power transmission will be at relatively high pitch circle velocity but relatively low tooth interface pressure and driving torque at the interface of gears and shaft.

It seems certain that finalizing designers will employ the right hand and left hand helicals in such a manner as to cause gear tooth pressure to tend to move the two gears toward the mid-section of the Rotor Assembly. With helicals mounted so as to oppose one another with their tooth pressure axial components, they automatically become axial positioning locks for the Rotor Assembly in respect to the downstream Driven Gears Assembly, thereby lending assistance to the Rotor Assembly's suspension systems in this important function.

It seems equally certain that finalizing designers will recognize the capacity of interfacing helical gears for smooth and quiet operation at the higher levels of operational rotating velocity, especially if the hardened steel pinions , such as 3 and 11 of the Rotor Assembly , interface to laminated phenolic ring gears of the Driven Gears Assembly appropriately lubricated at the interfacing helical teeth.

Finally , in the assembly sequence, are the suggested standard single row Ball Bearings 2 and 12 , lightly and permanently lubricated, in view of their superior performance during laboratory tests of experimental Rotor Assemblies during the hardware development program.

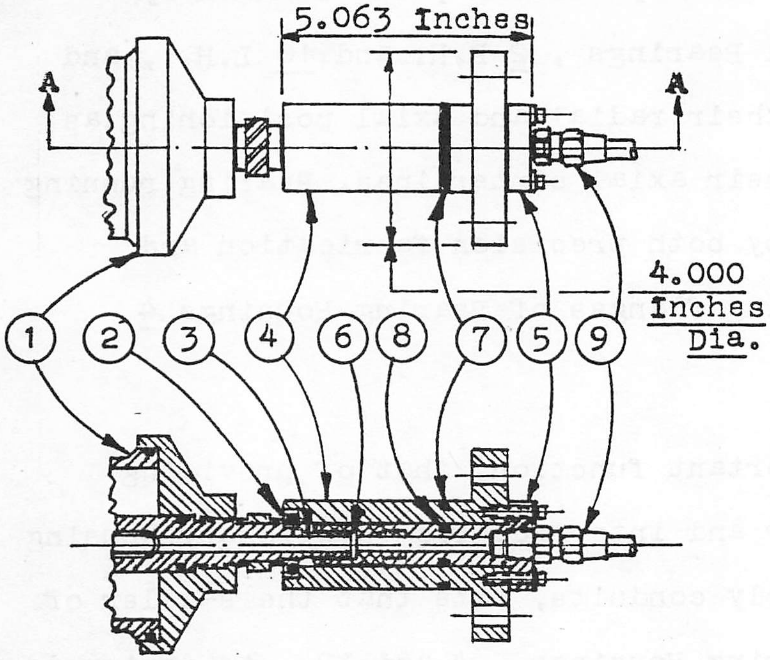
Again the selection and mounting of Bearings 2 and 12 is left to the better judgement and decisions of the finalizing designers as they arrive at their specification for the maximum safe operational value of N , for maximum safe operational productivity. It is assumed that appropriate Retainer Rings will be specified for the axial security of Bearings 2 and 12 .

The two Rotor Assembly suspension systems , illustrated in Figure 52 on page 211 , are actually identical but opposite and each of them provide important dual functions. First, each provides an effective interface of the rotating Rotor Assembly to an appropriate area of the stationary Environmental Control Vessel and , second, each provides an effective interface of the rotating pneumatic conduit bores of the Shaft to the appropriate areas of the stationary pneumatic transfer and control parts of the system, governing the flow of pneumatic replacement particles from the Environmental Control Vessel interior into and through the Rotor Assembly.

Considering first their Rotor Assembly suspension function, note that this is accomplished primarily by the two Bearing Housings 4 and 12 which are very strong , very rigid and very precisely fabricated devices which at installation will interface externally, with high precision and security, to the precisely fabricated in-line bores prepared for them in the Rotor Assembly Housing section of the Environmental Control Vessel.

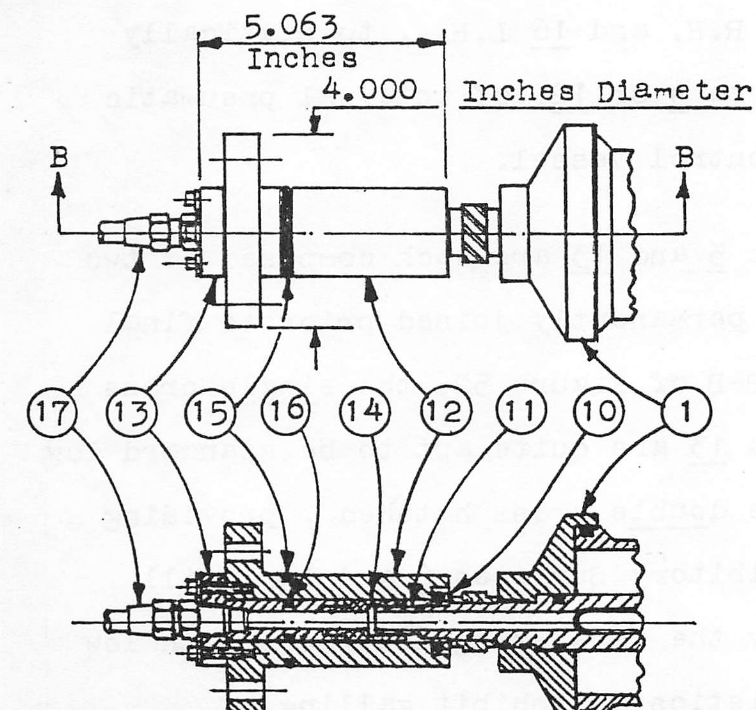
Each provides its own static O Ring Seal , 7 R.H. and 15 L.H. , to prevent escape of pneumatic pressure through the interface of the high pressure level within the Vessel to the relatively low standard air pressure level enveloping the Vessel's exterior.

Figure 52



Section A-A

Right Hand System



Section B-B

Left Hand System

Rotor Assembly Suspension Systems

LEGEND:

1) Rotor Assembly.

2) Rotor Assembly R.H. Bearing.

3) R.H. Rotating Pneumatic Flow Inhibitory Surface.

4) R.H. Bearing Housing.

5) R.H. Pneumatic Infeed Housing.

6) R.H. Stationary Pneumatic Flow Inhibitory Surface.

7) R.H. Bearing Housing-To-Environmental Control Vessel O Ring Seal.

8) R.H. Bearing Housing-To-Pneumatic Infeed Housing O Ring Seal.

9) R.H. Pneumatic Transfer Line Connector.

10) Rotor Assembly L.H. Bearing.

11) L.H. Rotating Pneumatic Flow Inhibitory Surface.

12) L.H. Bearing Housing.

13) L.H. Pneumatic Infeed Housing.

14) L.H. Stationary Pneumatic Flow Inhibitory Surface.

15) L.H. Bearing Housing-To-Environmental Control Vessel O Ring Seal.

16) L.H. Bearing Housing-To-Pneumatic Infeed Housing O Ring Seal.

17) L.H. Pneumatic Transfer Line Connector.

Each provides two precisely fabricated internal bores , the larger of the two sized to accept , with maxi-um precision , the stationary outer race of one of the two Ball Bearings , 2 R.H. and 10 L.H. , and thereby permanently secure both their radial and axial positioning as well as precision alignment of their axial centerlines. Bearing running clearance is precisely governed by both precision fabrication and adjustable shimming at the mounting flanges of Bearing Housings 4 R.H. and 12 L.H.

Considering now their second important function, that of providing effective pneumatic flow transfer and interface from stationary housing conduits to rotating Rotor Assembly conduits, note that the smaller of the two bores in each of the Bearing Housings , 4 and 12 , is designed and precisely fabricated to accept , and securely retain, one of the two Pneumatic Infeed Housings , 5 R.H. and 13 L.H , with each of them providing its own O Ring Seal , 8 R.H. and 16 L.H. , to statically prohibit escape,via its interface to 4 or 12, of internal pneumatic pressure from the Environmental Control Vessel.

Actually Pneumatic Infeed Housings 5 and 13 are each composed of two different materials , rigidly and permanently joined prior to final fabrication. In Sections A-A and B-B of Figure 52, the single cross hatched portions of Housings 5 and 13 are quite apt to be standard low carbon cold rolled steel while the double cross hatched , providing the Stationary Pneumatic Flow Inhibitory Surfaces 6 and 14 , will probably be a material selected by the finalizing designers with low coefficient of friction characteristics to inhibit galling of interfacing materials should rotating surfaces 3 or 11 inadvertantly contact stationary surfaces 6 or 14. In normal operational mode, a minimal running clearance of perhaps .005 inch would be provided.

It would seem prudent, at this point in Chapter Seven, to provide a full explanation of the " No-Contact Dynamic Seal " , referred to earlier in this work , which actually is not a true seal , in the sense that it is designed to inhibit pneumatic flow rather than prohibit such flow through the rotating-to-stationary interface. It is illustrated in Figure 52 , Sections A-A and B-B , by stationary surface 6 versus rotating surface 3 and stationary surface 14 versus rotating surface 11.

Fortunately for the finalizing designers, the pressure differential across this interface of moving and stationary surfaces is non-existant when the system is in the operational mode. Bear in mind that the Rotor Assembly functions in a high-pressure , high-density , pneumatic environment, controlled and contained by the Environmental Control Vessel. The pneumatic flow from Vessel interior to Rotor interior requires external control if , and when , the system is in the " Start-Up " , " Shut Down " or " Emergency " modes.

For this reason, external pneumatic transfer lines conduct the flow out of the Vessel , at appropriate points , through the external lines and controls which terminate with Connectors , such as 9 and 17 in Figure 52 , and thence through the stationary pneumatic conduits , illustrated by 5 and 13 in Figure 52 , into the two pneumatic infeed bores of the Shaft of Rotor Assembly 1 in Figure 52.

Thus, in the operational mode, the pneumatic pressure on the infeed bore side of each interface is identical to the pressure on the bearing side of each interface , as at 2 and 10 in Figure 52. There can be no pneumatic flow through such an interface if there is no pressure differential across it and therefor a positive dynamic seal that absolutely prohibits pneumatic flow is not required.

However, finalizing designers will find that some restriction of flow through this interface is desireable in each of the other three system modes. Consider first the "Start-Up" mode of the system which specifies the process for accelerating the Rotor Assembly and the Pneumatic Mass within it from idle or zero value of N up to the specified operational value of N which may be as high as 120,000 RPM , for example.

As the "Start-Up" program is initiated, the Environmental Control Vessel and its contents has been charged with the specified operational Environmental Pressure Ep , which may be 2000 psig , for example. Since this is injected directly into the Vessel and not through the Rotor infeed bores exclusively , the interior of the Vessel and that of the Rotor Assembly become fully charged without pressure differential across the Thrusters so no rotation of the Rotor Assembly is generated by the process.

Thus, as the " Start-Up " program is initiated , both suspension systems of Figure 52 are charged with 2000 psig pneumatic pressure from their infeed bores to all exterior surfaces inside O Ring Seals 7 , 8 , 15 and 16 and there is zero pressure differential across the interfaces 3 versus 6 and 11 versus 14.

To achieve the operational value of N , however, there must be a pressure differential across the two Thrusters and this is obtained from an external source of pneumatic pressure which is injected for a few seconds at a higher pressure level into the lines which terminate with Connectors 9 and 17 , in Figure 52 , upstream from Check Valves in each of the two lines which prevent flow into the Environmental Control Vessel.

If the injected start-up pressure is , for example, 2500 psig , this will provide a 500 psig pressure differential across the two Thrusters which is sufficient to accelerate the Rotor Assembly , in a very few seconds, to values of N where Inertial-Pneumatic Compression is generating more than enough pressure differential across Thrusters to assume acceleration of the Rotor Assembly on up to the specified operational level of N and pressure from the external source is terminated at that point in the start-up program.

During the brief five seconds or so of external pressure injection, pressure relief valves sustain Environmental Pressure Ep at its specified 2000 psig level and the pressure differential across interfaces 3 versus 6 and 11 versus 14 begins with a value of 500 psig and pneumatic flow from the infeed bores through the interfaces and through the Bearings 2 and 10 into the Vessel is at maximum.

During that brief five second period the loss of external pressure through these interfaces would be low for the dual reason that the elapsed time has been so small and passage of leaking pneumatic particles through the .005 inch running clearance and through the Bearings 2 and 10 became increasingly difficult as the value of N increased.

The conditions at these interfaces during " Shut-Down " and "Emergency " modes are identical so they will be considered simultaneously. In the normal operational mode, the value of N is governed by automatic variations in electrical load on the Generator system. If , for any reason, these normal controls should fail, the Rotor Assembly would quickly accelerate to values of N dangerous to its structural strength. For this reason the value of N is automatically and continuously monitored for such sudden and dangerous increase. Instantly as it occurs, the computer programmer senses it and closes valves in the transfer lines which totally interrupts pneumatic flow through Connectors 9 and 17 into the Rotor Assembly which will instantly begin decelerating back to safe values of N , provided that leakage through interfaces 3 versus 6 and 11 versus 14 is minimal, which it normally will be because of its restriction at these interfaces and through the rapidly rotating Bearings , 2 and 10 . The same sequence applies to the " Shut-Down " mode except the line valves are closed by the programmer on signal from the operator on duty rather than on signal indicating excess N.

A back-up emergency program is also incorporated into the system to cover other contingencies , such as the dumping of Environmental Pressure Ep should the " N sensing " system fail. Also, under normal operational conditions, the line valves governing pneumatic flow through Connectors 9 and 17 and the valves governing the dumping of Ep are solenoid operated and held in operational mode by them. Thus , should a power failure occur, line valves would close and Ep dump valves would open automatically, shutting the system down.

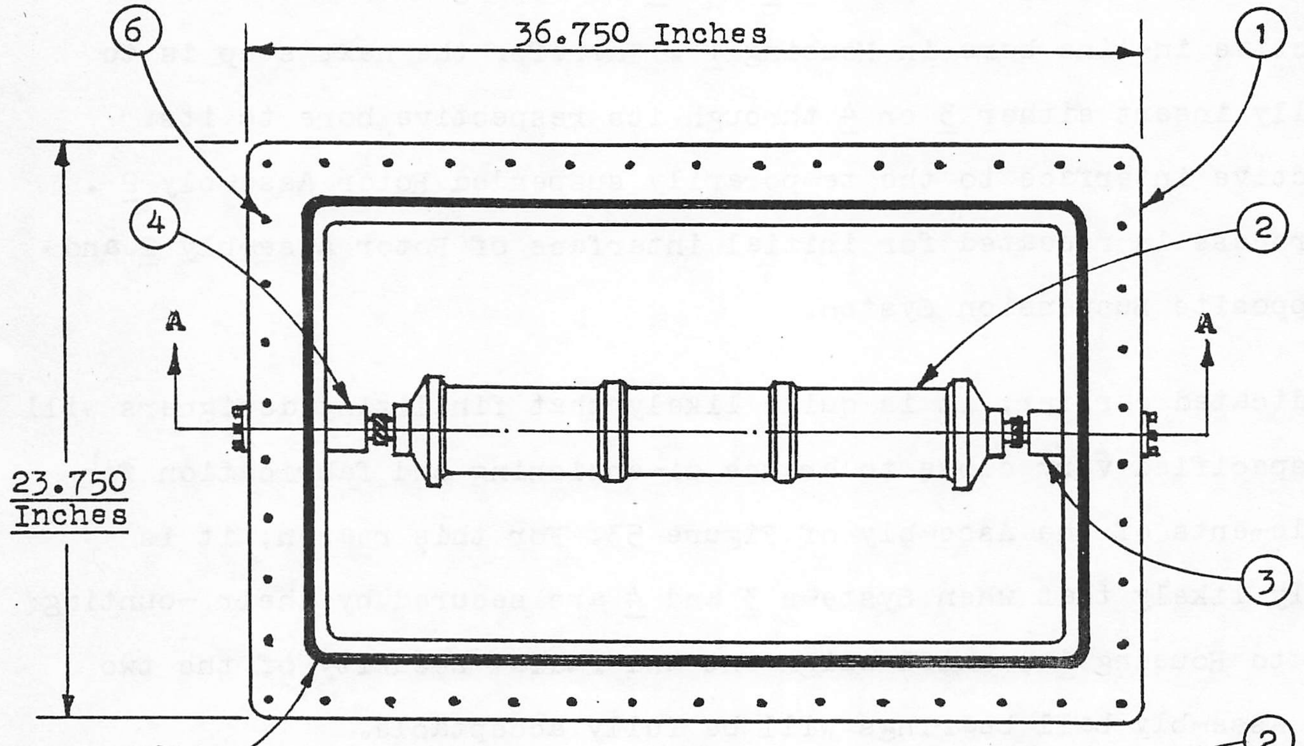
Figure 53 on page 217 illustrates how the Suspension Systems of Figure 52 are assembled to the Rotor Assembly simultaneously with their assembly to the Rotor Assembly section of the Environmental Control Vessel. The top view looks squarely down into the assembly and the Section A-A is taken through the Housing 1 only at the axial centerline of the Rotor Assembly, its two Suspension Systems 3 and 4 , and the in-line bores of Housing 1 in which they are mounted.

Section A-A in the lower view looks directly into the cutting plane

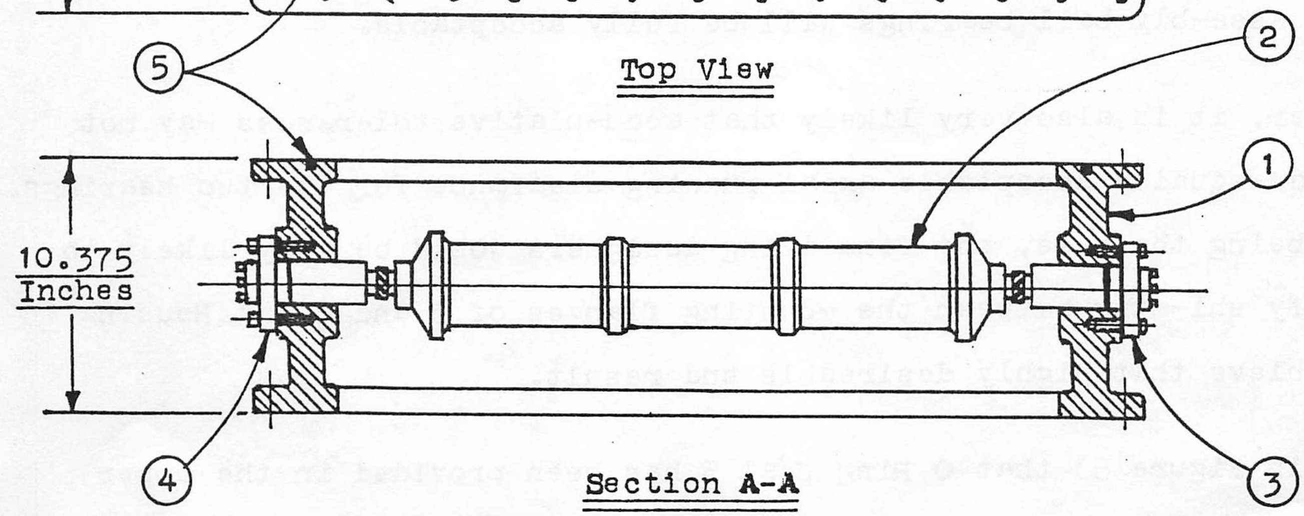
Figure 53

Environmental Control Vessel Rotor Assembly Section. **LEGEND:**

1) Rotor Assembly Housing Section. 2) Rotor Assembly
3) R.H. Rotor Assembly Suspension System.
4) L.H. Rotor Assembly Suspension System.
5) Rotor Assembly Housing-To-Housing Cover O Ring Seal.
6) One Of 46 Cover Security Bolt Threaded Holes.



Top View



Section A-A

through Housing 1 and clearly illustrates the wall configuration of Housing 1 as well as the interface of its two in-line bores with Suspension Systems 3 and 4 .

The opening at the top of Housing 1 and the space between its two in-line bores is sufficient to permit lowering and suspension of the Rotor Assembly into the approximate position shown in Figure 53. Therefor this is the first step in the assembly procedure.

Each Bearing Housing of Systems 3 and 4 is a snug slip fit to its respective in-line bore in Housing 1 . Therefor the next step is to manually insert either 3 or 4 through its respective bore to its respective interface to the temporarily suspended Rotor Assembly 2 . The process is repeated for initial interface of Rotor Assembly 2 and the opposite Suspension System.

As indicated earlier, it is quite likely that finalizing designers will have specified very close tolerance dimensioning and fabrication for the elements of the Assembly of Figure 53. For this reason, it is equally likely that when Systems 3 and 4 are secured by their mounting bolts to Housing 1 , axial alignment and radial security of the two Rotor Assembly ball bearings will be fully acceptable.

However, it is also very likely that accumulative tolerances may not provide equally acceptable axial running clearance for the two bearings. This being the case, the finalizing designers would be very likely to specify shimming between the mounting flanges of 3 and 4 and Housing 1 to achieve that highly desireable end result.

Note in Figure 53 that O Ring Seal 5 has been provided in the upper surface of Housing 1 . This will interface to a solid and precisely fabricated surface of the Cover for Housing 1 and thereby form a very reliable static seal against leakage of Environmental Pressure Ep from its containment.

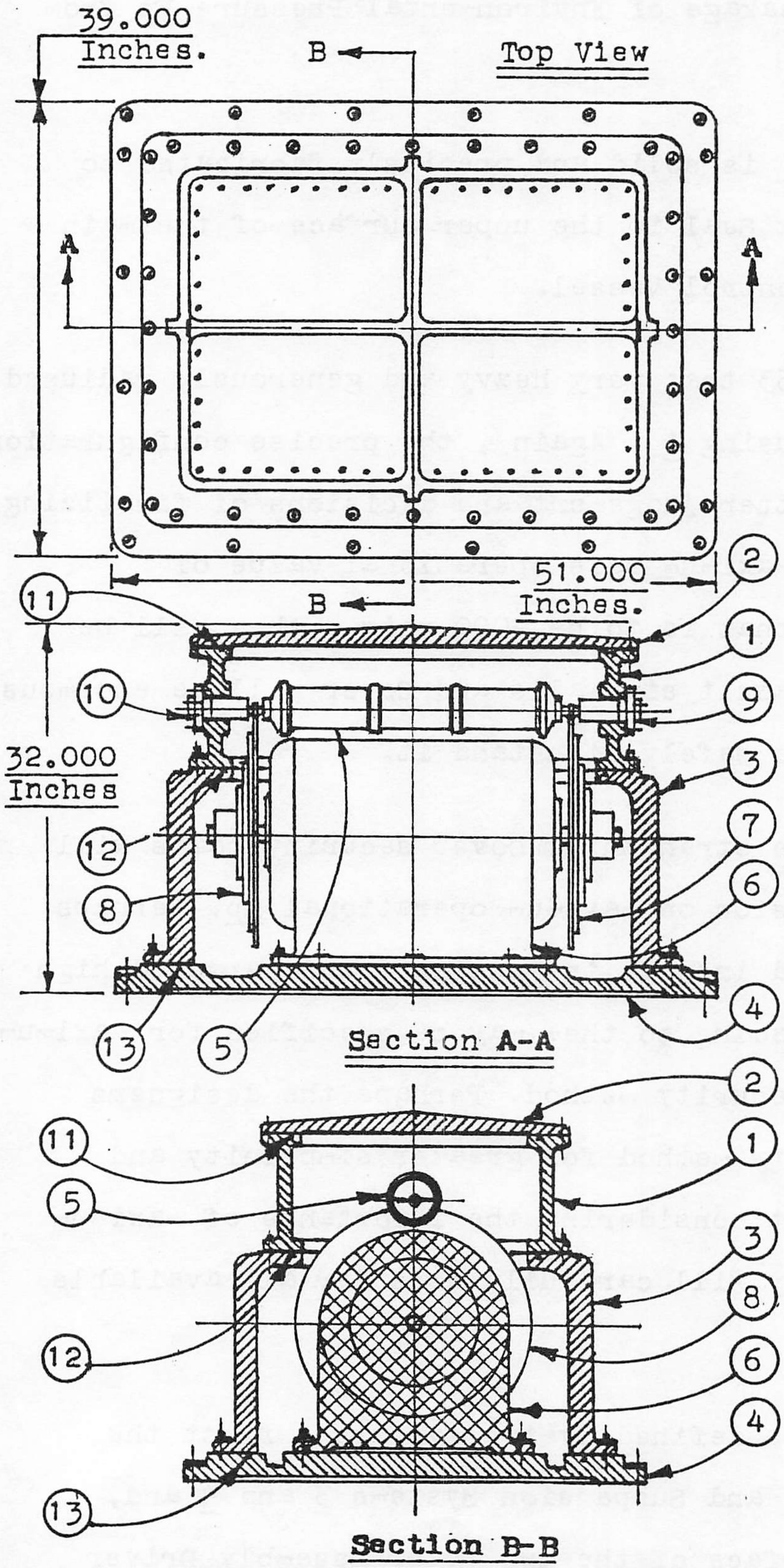
The bottom surface of Housing 1 is solid and precisely fabricated to interface with a similar O Ring Seal in the upper surface of the main section of the Environmental Control Vessel.

Note in Section A-A of Figure 53 that very heavy and generously radiused sidewalls are suggested for Housing 1 . Again , the precise configuration of sidewalls is left to the better judgement and decisions of finalizing designers as they specify the maximum safe operational value of Environmental Pressure Ep. If that is to be 2000 psig , they will be well aware that total force against sidewalls and Cover will be enormous and they must be very strong to safely withstand it.

The size and number and tensile strength of Cover security bolts will also be compatible to the decision on maximum operational Ep. Perhaps hardened high strength threaded inserts in Housing 1 and hardened high strength security bolts interfacing to them may be specified for maximum containment strength by this security method. Perhaps the designers may specify an optional security method for greater simplicity and strength. It seems certain that considering the importance of maximum Ep to system productivity, they will carefully consider all available options.

The dimensions of Housing 1 are defined by two factors , first the dimensions of Rotor Assembly 2 and Suspension Systems 3 and 4 and, second provision for the interface of the two Rotor Assembly Driver Gears to the Driven Gear Assemblies of Figure 54 on page 220, which occurs through the bottom opening of Housing 1 in Figure 53.

Figure 54



Section A-A

Section B-B

Rotated Clockwise 90°

Environmental Control Vessel Assembly.

LEGEND:

1) Rotor Assembly Compartment.
2) Rotor Assembly Compartment Cover.
3) Generator System Compartment.
4) Base.
5) Rotor Assembly.
6) Generator Assembly.
7) R.H. Driven Gear Assembly.
8) L.H. Driven Gear Assembly.
9) R.H. Rotor Assembly Suspension System.
10) L.H. Rotor Assembly Suspension System.
11) Cover-To-Rotor Compartment O Ring Seal.
12) Rotor Compartment-To-Generator Compartment O Ring Seal.
13) Base-To-Generator Compartment O Ring Seal.

Final dimensions of Housing 1 may be different than shown if finalizing designers specify a different Driven Gear Assembly design than that shown in Figure 54.

It would appear prudent at this point in Chapter Seven to take a closer look at Figure 54 on page 220 and review the meaning of the Sections A-A and B-B illustrated therein. To fully understand these sections reference must be made to the Top View in Figure 54.

Note that this is a top view of the system's Environmental Control Vessel Assembly which consists of not only the Environmental Control Vessel itself but also includes all of the working and moving elements of the system that it houses , the Rotor Assembly , the R.H. and L.H. Rotor Assembly Suspension Systems , the R.H. and L.H. Driven Gear Assemblies , the Generator Assembly and the O Ring Seals between interfacing compartments of the Environmental Control Vessel which assure positive and reliable static seal containment of Environmental Pressure Ep.

Bear in mind that the Assembly in Figure 54 is suggestive only because, as indicated earlier in this Chapter Seven , precise data on the generation of electric power will have a profound influence on Generator Assembly size and operational rotational speed and such data and related experience has not been readily available to this work.

It has been , and is now , the primary objective of this work to suggest a practical configuration for the Rotor Assembly and its Suspension Systems since such suggestions are fully supported by extensive concept and hardware development and equally extensive laboratory testing in support of that development.

However , the actual configuration and dimensions of the system's Environmental Control Vessel Assembly,downstream from the Rotor Assembly's two Driver Gears, will evolve from the better judgement and decisions of the finalizing designers in fully adequate consultation with electrical engineers. Suffice for this work to illustrate the essential elements and their respective interfaces for a successful prototype Environmental Control Vessel Assembly which is obviously the productive section of the over all system.

Section A-A in Figure 54 is taken , as shown in the Top View , through the axial center plane of the probably cast,and very strong , four sections of the Environmental Control Vessel , the Base 4 , the Generator System Compartment 3 , the Rotor Assembly Compartment 1 and the Cover 2 which serves as top pressure containment wall as well.

Section B-B in Figure 54 is taken , as shown in the Top View, through the lateral center plane of the Vessel sections as well as through the midsections of the Rotor and Generator Assemblies but with no attempt to illustrate internal details of these assemblies.

Assembly procedure would presumably begin with the assembly of items 6 , 7 , 8 and 13 to item 4 . It is assumed that the Generator Assembly, item 6 , would include all necessary electrical hardware and that its interface to the Base 4 would probably be shimmed to establish precise dimension from item 4 mounting surface to Generator shaft centerline.

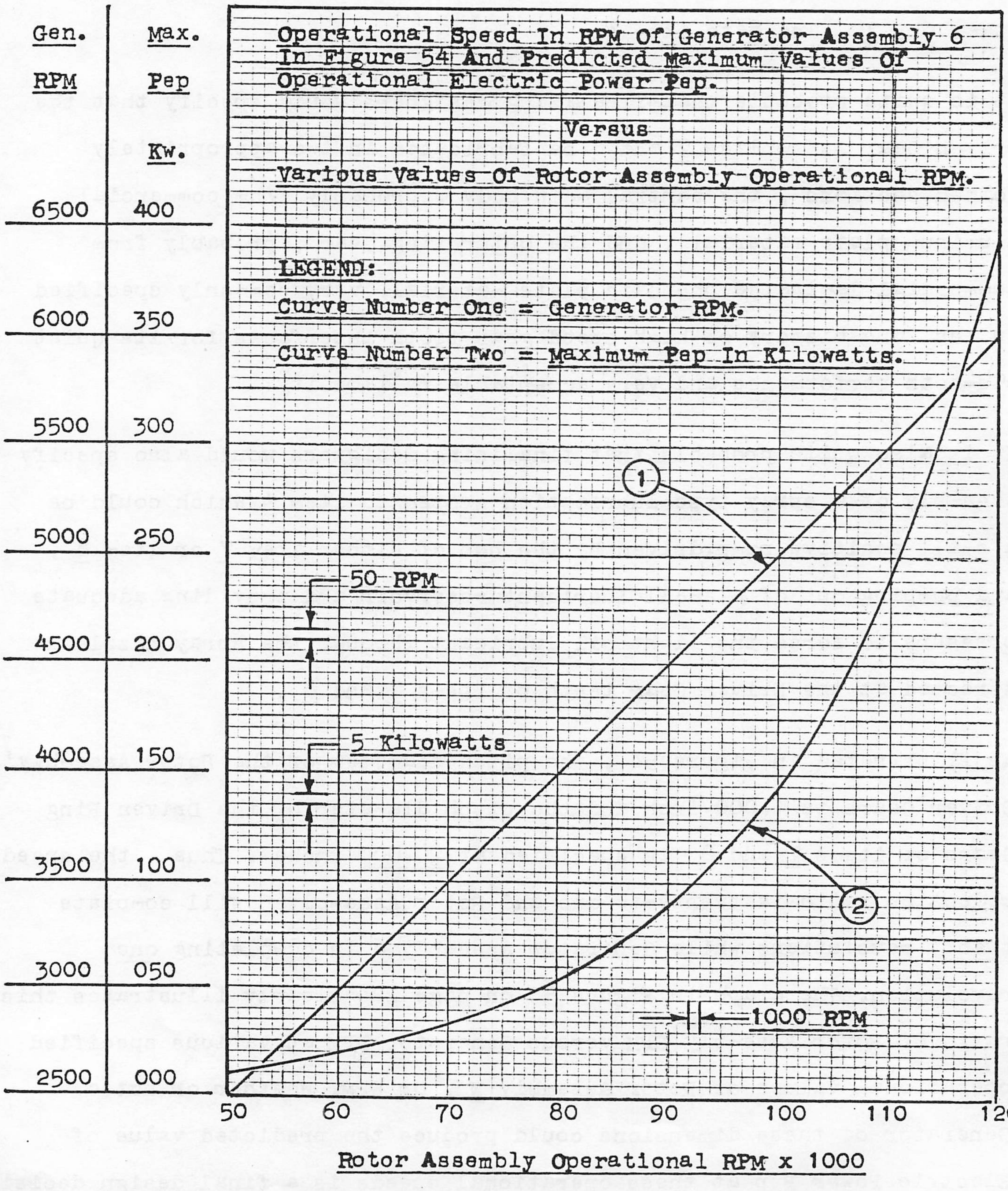
Items 7 and 8 , the R.H. and L.H. Driven Gear Assemblies,would then be precisely and securely mounted on the shaft extensions of item 6. This would include precise alignment and radial positioning of gear teeth for precisely correct interface,with appropriate operational running clearance, to the Rotor Assemblies two Driver Gears. Precise parallelism between Generator shaft , Driven Gear bores , Driver Gear bores and Rotor Assembly shaft would be a necessary objective of the assembly of items 6 , 7 , and 8 to item 4.

It is quite probable that finalizing designers would specify that the Driven Gear Assemblies 7 and 8 be fabricated in two appropriately joined sections , the central main body , probably from commercial aluminum plate material , and the outer Ring Gear , probably from commercial laminated phenolic plate material, very commonly specified in the long history of high speed gear tooth interfaces for its quiet and smooth performance and very acceptable reliability.

It is also quite probable that finalizing designers would also specify assembly of a spray type lubrication system to item 4 which could be a small positive pump,driven by the hub of either item 7 or item 8 , and pumping out of a small lubricant reservoir and providing adequate pressure to force the light oil lubricant through the spray nozzles directed at the Driven Gear teeth of items 7 and 8 .

As illustrated in Figure 54 , the pitch diameter of the Rotor Assembly's Driver Gears is 1.000 inch and the pitch diameter of the Driven Ring Gears of items 7 and 8 is specified at 20.000 inches. Thus , the speed reduction ratio is twenty-to-one and Rotor Assembly 5 will complete twenty revolutions while Generator Assembly 6 is completing one revolution. The graph in Figure 55 on page 224 clearly illustrates this ratio of Rotor Assembly RPM versus Generator RPM at various specified operational values of Rotor Assembly N , or RPM. Whether or not a Generator of these dimensions could produce the predicted value of Electric Power Pep at these operational speeds is a final design decision.

Figure 55


Gen.
RPM
Max.
Pep
Kw.
6500
400
6000
350
5500
300
5000
250
4500
200
4000
150
3500
100
3000
050
2500
000
Operational Speed In RPM Of Generator Assembly 6 In Figure 54 And Predicted Maximum Values Of Operational Electric Power Pep.
Versus
Various Values Of Rotor Assembly Operational RPM.
LEGEND:
Curve Number One = Generator RPM.
Curve Number Two = Maximum Pep In Kilowatts.
1
2
50 RPM
5 Kilowatts
1000 RPM
50
60
70
80
90
100
110
120
Rotor Assembly Operational RPM x 1000

The next step in the assembly procedure would be the assembly of items 3 and 12 to item 4 . The vertical dimension of item 3 between its bottom surface interfacing to item 4 and its top surface interfacing to item 1 has been precisely fabricated to close tolerances in support of appropriate interface between Driver and Driven Gears. Item 12 would be assembled into its operational groove in the top surface of item 3 .

The next step in the assembly procedure would be the assembly of item 1 to item 3. Prior to this , however , items 5 , 9 and 10 have been precisely assembled to item 1. Also the dimension between the in-line bores of item 1 and its bottom surface interfacing to item 3 has been precisely fabricated to close tolerances in support of appropriate interface of Driver Gears to Driven Gears.

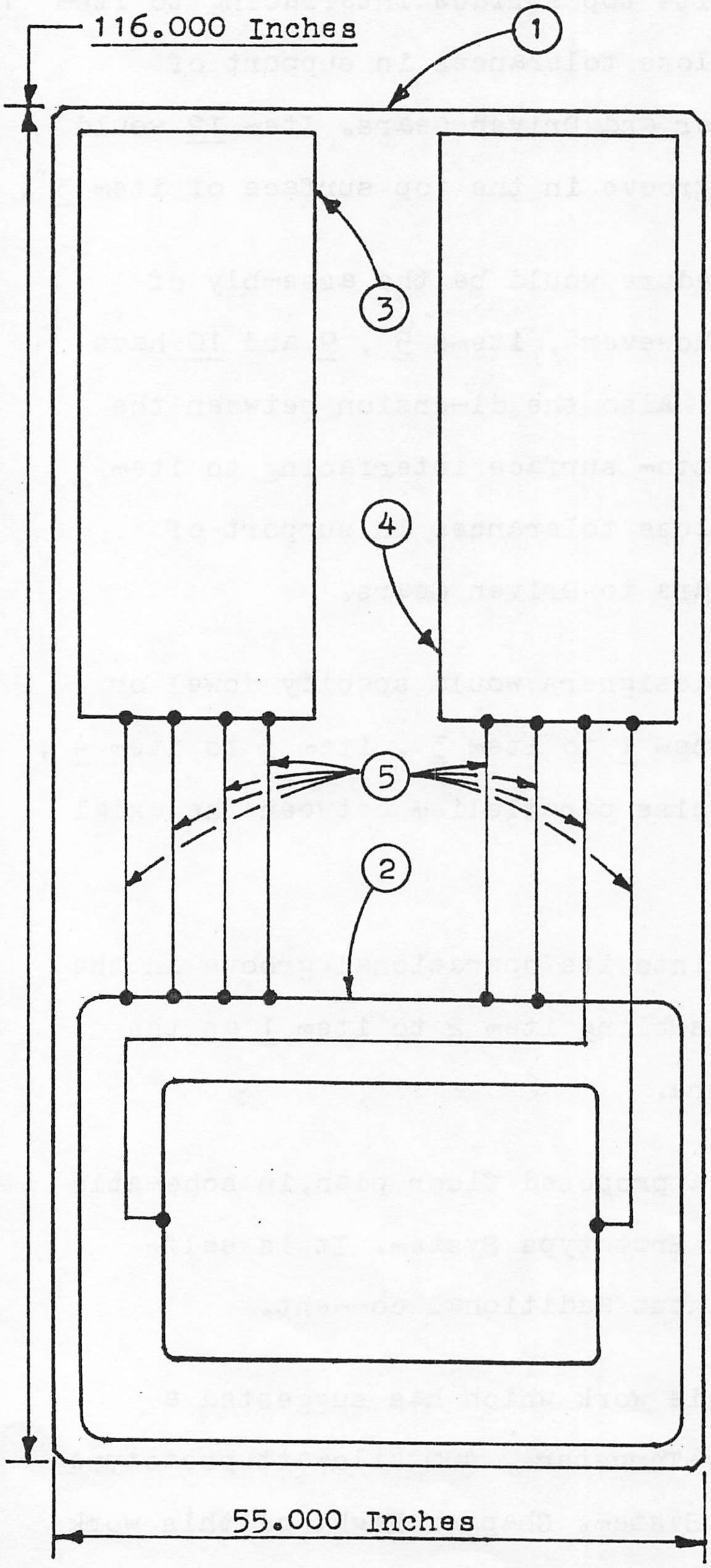
It appears likely that finalizing designers would specify dowel or spring pins at the interfaces of item 1 to item 3 , item 3 to item 4 , and item 6 to item 4 to assure precise parallelism between the axial centerlines of items 5 and 6 .

Item 11 would have been assembled into its operational groove in the top surface of item 1 prior to assembling item 2 to item 1 as the final step in the assembly procedure.

Figure 56 on page 226 illustrates a proposed floor plan, in schematic form, for the complete Operational Prototype System. It is self-explanatory and is referred to without additional comment.

This concludes Chapter Seven of this work which has suggested a configuration for the proposed two-Thruster , 400 kilowatt prototype Inertial-Pneumatic Electric Power System. Chapter Eight of this work will focus attention on the Start-Up , Operational and Shut-Down modes of the System.

Figure 56



A Floor Plan Schematic For The Complete Operational Proposed Prototype System.

LEGEND:

1) A Common Base For The Environmental Control Vessel Assembly And Its Auxiliary Equipment.

2) The Environmental Control Vessel Assembly.

3) An Appropriate Housing For Auxiliary Electric And Electronic Controls, Including A Program Controller.

4) An Appropriate Housing For Auxiliary Pneumatic Controls And Storage, Including A Two-Stage Compressor.

5) Appropriate Electronic, Electrical And Pneumatic Conduits For Inter-Connecting The Environmental Control Vessel Assembly And Its Auxiliary Equipment.