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NRL Memorandum Report 1035

# FEASIBILITY OF A REMOTE UNATTENDED HIGH POWER ACOUSTIC SOURCE

(UNCLASSIFIED TITLE)

A. T. McClinton and John Cybulski

SOUND DIVISION

1 August 1960

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NRL MEMORANDUM REPORT, 1095 ✓

FEASIBILITY OF A REMOTE UNATTENDED  
HIGH POWER ACOUSTIC SOURCE (21).

by

A. T. /McClinton  
John/Cybulski

1 August 1960

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#### ABSTRACT

The feasibility of developing the amplifier transducer and energy storage system to be associated with a nuclear-powered, remote, unattended high power acoustic source has been investigated. The results of this study indicate that such a system is not only feasible but can be obtained within the next three to five years.

#### PROBLEM AUTHORIZATION

ONR NR 1418, RF 001-03-43-4062  
BUSHIPS Project NE 050 962, ~~AS 02101~~, S-1834  
NRL Problem 55S05-15

#### PROBLEM STATUS

This is an interim report on one phase of the project. Work on the problem is continuing.

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### INTRODUCTION

The concept of active acoustic ocean surveillance systems introduces the need for new approaches to the over-all sonar system. This has already been demonstrated with the study and development to date for the high power acoustic source required for Project ARTEMIS. The development of the bottom-mounted transducer array remote from land masses obviously leads to the need for placing all of the components of the acoustic sources on the ocean bottom with a resulting increase in over-all complexity of requirements.

This study is part of an over-all investigation being carried out by the Office of Naval Research to investigate the feasibility of a remote underwater sonar transmitter which would use power from a nuclear-powered supply. The entire installation of source and transmitter would be located in a remote and unattended location. It is assumed that there will be no communication into the transmitter for purposes of corrective control actions. The capability of this complete system will ostensibly be equivalent to that of the present ARTEMIS program with respect to acoustic power level, duty cycle and source depth. In addition, reliability of the entire system is to be such that there is to be no maintenance for the first year of operation. This entire program is also constrained by a four-year time period allowed for readiness. Thus it is imperative that every subsystem of the sonar transmitter with which this report is concerned, the transducer, the transmitter amplifier and the controls, have the highest reliability yet provide for the efficiency, size, weight and cost consistent with the present state of the art.

The requirements for this source have been taken to be comparable to those previously set forth for the ARTEMIS high power acoustic source. These are as follows:

|                |                                                                                     |
|----------------|-------------------------------------------------------------------------------------|
| Acoustic power | 1000 kw                                                                             |
| Frequency      | 400 cps                                                                             |
| Frequency band | 100 cps with constant frequency,<br>frequency modulation and noise<br>transmissions |
| Pulse length   | 100 milliseconds to 60 seconds                                                      |
| Water depth    | 2000 feet                                                                           |
| Installation   | On or near the bottom                                                               |

In addition to the above, Project ARTEMIS requires an acoustic beam of 12° in the vertical by 20° in the horizontal. The center of the beam is tilted up from the horizontal to 11°. These requirements may not be applicable to the nuclear-powered source and therefore have not been imposed. This will be discussed in a later section.

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This study is predicated on at least two separate packages for the complete system. One of these will contain the nuclear power source and its associated energy conversion devices. The output of this component will be alternating current of an appropriate voltage and frequency. The second package will contain the required amplifier, transducer, pressure release components and other devices required to produce and control the acoustic transmissions. This package will be cable-connected to the nuclear power supply.

## TRANSDUCER

The obvious stringent requirements for this source and the complexity that is bound to exist require that each component part be selected with due consideration to all other components which it may affect. Evaluation of the several possible types of transducers for this application must be made in light of their influence on the amplifier as well as on their own technical merits. Other factors to be considered are the ability to meet the frequency and frequency spectrum for pulsed operation at constant frequency, frequency modulation and noise transmissions and ability to meet the power handling requirements as well as to satisfy reliable operation in the specified ambient conditions.

The time scale requires that proven methods be employed. Adequate time does not exist to develop new and novel transducer techniques; therefore, proven methods must be applied wherever possible. Reliability is also of utmost importance. A factor of lesser importance, but one which should be recognized nevertheless, is flexibility offered by the transducer to permit different array configurations. It is not believed possible to specify the most desirable nor necessarily the only array configuration needed at this time. Therefore, a transducer that is amenable to various array shapes would be desired.

Although there are several types and configurations of transducers, only four basic ones have been considered. These are the hydraulic, magneto-strictive ring, barium titanate segmented ring and variable reluctance transducers. Considerable merit has been assigned of late to the hydraulic transducer. If all of these were true, it would be without question the only transducer for the application. Unfortunately, there has been insufficient experimental work to verify or refute these claims. No attempt will be made to restate them here; on the other hand, it should suffice to say that development of the hydraulic actuated transducer is necessary before it is known that the device is suitable for this application. This work should be carried on separate from the development of this source.

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The use of magneto-strictive materials for transducers has been in existence for a long time. Recently, cobalt nickel has been demonstrated to have improved characteristics over previous materials. The initial transducer on which development work was started for the ARTEMIS source was a resonant cavity type fabricated from cobalt-nickel rings. Although the work was not finished, efforts were carried far enough to demonstrate that a 400 cps device of this kind could be manufactured after further engineering effort to overcome certain difficulties. Such a transducer would be approximately 12 feet in diameter by 3-1/2 feet deep and weigh 48,000 pounds in air.

It should radiate at least 100 kw acoustic power with an efficiency of 40% and should meet the band width requirements. Ten of these would be required to radiate the one megawatt power. Direct current power is required for its operation.

It is desired that the array be planar. Pressure release material is required to make these resonant cavity devices suitable. On the other hand, if an omnidirectional pattern in the horizontal plane is satisfactory, then the rings can be stacked along their axis to form a long cylinder. The pressure release requirements would be reduced; however, the full extent would not be known until additional model tests were conducted.

Barium-titanate segmented ring transducers offer characteristics and application problems very similar to the magneto-strictive rings. Several 400 cps transducers of this type have been built as a low power source for the ARTEMIS program. Unfortunately, engineering problems have prevented application of these to date. However, it is believed that the feasibility of fabricating a transducer suitable for use with the nuclear source has been demonstrated. The weight of this transducer will probably be considerably less than for the magneto-strictive device. On the other hand, its size, shape, power handling capabilities, efficiency and pressure release requirements will be similar. The unit does offer a major advantage in that it does not require polarization power.

The variable-reluctance transducer differs radically from the previous two units. The unit developed for the ARTEMIS high power acoustic source is approximately eleven inches square on the radiating face by twelve inches deep and weighs 160 pounds in air. This transducer can radiate at least 1 kw acoustic power at an efficiency of 40% or greater and meets the band width requirements. A planar array of 1440 of these elements (thirty elements by forty-eight elements) is being manufactured for the ARTEMIS source: the transducer as now designed requires direct current polarization power. However, investigations indicate this can be achieved with built in permanent magnets.

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The variable-reluctance transducer offers one distinct advantage; namely, its versatility to achieve various array configurations. Furthermore, being of lower power input for each transducer element (relative to the other devices) makes it applicable to being powered from an amplifier of lower output. The requirements for pressure release for either a planar array or a cylindrical array composed of these elements remain approximately the same as for either the magneto-strictive rings or the barium-titanate segmented rings. There are indications, however, that this type of device can be used in conjunction with a stiff walled tube to eliminate the pressure release requirements. Several such devices would be grouped together to form an array having the required acoustic source level. The resulting pattern of such an array would be omnidirectional in the horizontal plane.

It should be noted that a cylindrical array formed of variable-reluctance elements will lend itself to beam formation and steering whereas this cannot be readily achieved with the magneto-strictive or barium titanate rings. This may be advantageous with a source located in an area where it can "see" through 360°.

There are problems which are common to all of the above transducers and which will require special attention in the development of this source. These are associated with reliability of the device, development of a suitable long-life pressure-release system and sealing against water leakage. The transducer design must be thoroughly tested to ascertain that reliable operation is possible. This must be followed by the highest standards of quality control during manufacture. There can be no compromise on either of the two. The usual philosophy of manufacturing shipboard equipment with an installation followed by "ship alts" cannot be condoned.

The pressure-release problem will be similar to that for the ARTEMIS source. If the problems of reliable long-life operation are achieved for that application, they should also be applicable to the nuclear-powered source. Unfortunately, the ARTEMIS system requires a large gas storage system which is heavy and bulky. Furthermore, it requires pressure regulators and relief valves which add to complexity and reduce reliability. The requirements for and configuration of the pressure release require further investigation if this facet is to be adequately handled.

The third area of concern, that is, sealing against water leakage, is applicable to all component parts of the nuclear-powered source. It is impossible to over-emphasize the need for an extensive program to assure that proper sealing techniques are applied or developed. Of the transducers, the variable-reluctance device probably offers the greatest number of problems with the multitude of elements and electrical

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connections. It is not believed that the problem is insurmountable. However, it will be solved only by great diligence with the best engineering talent.

Throughout the discussion of transducers, a few comments have been made of array configurations. There are many configurations which the array might take with the limitations being the practical limits imposed by the transducer elements. Without knowing the site location and associated bottom topography where the nuclear powered source might be placed, it is not possible to concentrate the discussion on only the applicable array shape. It is believed, however, that the desirable configuration would be either a planar array or a cylindrical array. The former configuration offers the advantage of highest source level with the least material and power. On the other hand, it is directive, thus reducing the area of coverage to a narrow beam. An alternative is to provide mechanical rotation of the array. However, this sacrifices simplicity and reliability.

The cylindrical array provides for 360° coverage in the horizontal plane. The vertical beam can be as desired but requires some type of beam formation if it is to be other than normal to the face of the array. The obvious disadvantage as compared with the planar array is lower source level for the same total input power. Part of this can be regained if a preformed narrow beam is utilized in the horizontal plane in which case the power is then supplied to only part of the transducer. By means of appropriate phasing of the input signal to approximately one-third of the elements, a preformed beam is obtained. If the elements can accept three times the input power, then the full power can be applied to any one-third of the transducer array. Conversely, if the elements cannot accept this power, then one can reduce the size of the power generating equipment by a corresponding amount.

It must be emphasized again that the selection of the array must be made after selection of a site. That which is applicable in one instance may be unworkable in another. The closeness of reflectors, such as land masses, etc., can easily preclude the use of an omnidirectional source and necessitate a reduced beam aperture.

## TRANSMITTER AMPLIFIERS

The sonar transmitter will contain an amplifier whose input may be either a constant frequency, a frequency modulated or a bandwidth limited noise signal and whose output must be at a sufficiently high power level to develop the acoustic power from the transducer load. The discussion which follows includes electronic, semi-conductor and rotating machinery amplifiers.

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As power demands increased, the vacuum tube capability has increased bringing with it increases in filament power requirements, greater anode accelerating potentials, addition of water coolant complexes, larger envelope size, more weight per tube with attendant shock and vibration problems. Higher powers can be developed by choice of circuitry for higher efficiency and by paralleling tubes. Even higher powers considerably above continuous ratings could be obtained by employing short-pulse lengths and duty cycle operating modes. However, the length of these pulses are of little use for this high power sonar application. The grids and other electrode structures in vacuum tubes were designed for high frequency applications and as a consequence their size as dictated by the geometry within an envelope is not sufficient to withstand power levels much greater than continuous rating for one minute pulses without serious electrode deterioration and degradation of characteristics and a foreshortened operating tube life.

A pair of the high power vacuum tubes developed for the Jim Creek installation, RCA tube type 6949, can produce 1000 kw in class B push-pull cw operation. A plate supply of 20 kilovolts at 50 amperes is required with 88 gpm water cooling. This tube has overall dimensions of 10" diameter, 40" length and a weight of 140 pounds. The filament current at 7.3 volts is 1040 amperes. Unit cost is approximately \$20,000 with a tube life of 10,000 hours.

The amplifier developed for the ARTEMIS source uses eight RCA type 6949 tubes to develop a rated power of 5200 kilowatts. This amplifier, which is to be installed on board a ship, is actually comprised of four identical amplifiers each rated at 1300 kw with the outputs to be paralleled for the higher power requirements. Each of these amplifiers is contained within six cubicles comprising the control, high voltage rectifiers, power supplies, cooling equipment, amplifiers and output transformer. The cubicles are connected electrically and alignment maintained because of coolant piping. The over-all dimensions of each amplifier is 27 feet long by 7-1/2 feet high by 4-1/2 feet deep. It weighs 32,000 pounds. There are but two tubes in each output stage and four tubes in all the other stages. Salt water must be supplied at the rate of 140 gpm to the heat exchanger within one of the cubicles. This amplifier has not been designed for unattended operation. Thus, it requires at least one man in attendance at all times.

Within the past decade transistors have been developed at a very rapid pace. The transistor has much to offer for this application in that its characteristics and requirements make it more suitable for unattended operation. It requires no filament power, cooling can be simple and the size and weight factors are unquestionably better than vacuum tubes. However, to the designer, there are many things left to be desired. Production tolerances are such that published characteristics are not reliable; therefore, selected units are required for high reliability.

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As in a vacuum tube, the high power per unit device is not attained simply. Transistors can be combined in circuits to provide an increase in power handling capability but pulse lengths of one minute are sufficiently long that there is no overload capability. Attainment of the maximum power handling capability requires good heat sink configurations. For larger power handling capability transistors may be operated in parallel with some derating.

The low operating temperature limits of germanium units are being removed with the development of silicon transistors. More recent developments are directed toward high voltage and current transistors with acceptable gain and reasonable internal thermal resistance. Peripheral problems concerned with radiation degradation, contamination and over-voltage transient are susceptible to design solutions. Thus, the transistor with no filament to burn out inherently has very long life possibilities.

Numerous transistorized power amplifiers have been built for acoustic sources and proved to operate satisfactorily. An amplifier consisting of thirty-six individual amplifiers, each rated at 500 watts, has been constructed to operate with a thirty-six element array of 2000 cps transducer elements. The amplifier continuous rating is 18 kw and is installed in a cabinet, having a dimension of 7 feet high by 2 feet wide by 2 feet deep and weighs 1000 pounds. Cooling city water at a rate of 20 gpm is employed. Two power supplies, each rated at 30 volts and 250 amperes, are required and each one has dimensions of 6 feet high by 2 feet wide by 3 feet deep and weighs 1600 pounds.

Within the past two years rapid progress has been made toward a combination of high voltage and high current in semi-conductor devices known as silicon controlled rectifiers (SCR). Attention is currently being given to applying this device to sonar transmitter applications. The SCR is essentially a thyatron in principle which can perform switching type operations. Therefore, this device is amenable to control for inverting dc to ac and to a controllable dc voltage level rectification of ac. Unlike its electronic thyatron counterpart, it requires no filament power but, like the transistor, there is a heat sink required to develop maximum unit power handling capability.

Operation at high efficiency and with fast transit-time of characteristic between the on and off state permits obtaining frequencies adequate for this application. Inverting of dc under frequency control of an oscillator into ac produces a fundamental frequency component as accurate as that attainable from a vacuum tube or transistor amplifier. The rich harmonic content requires filtering which can be obtained by external circuit

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components in addition to that offered by the transducer. Other procedures have been offered for reducing the harmonic content. These involve synthesizing a sinusoidal wave-shape by the appropriate switching in of different voltage levels of the dc supply.

In inverting dc to ac it is necessary to interrupt the dc power source to regain control of the silicon controlled rectifier with present devices and circuit techniques. This additional function has to be performed either with a conventional circuit breaker or additional SCR's which have extremely high current capability. This extra circuit can also provide over-current protection and controlled turn-on. Cut off of the SCR operating in an inverter mode from a dc source may have a simpler solution in the future. Work is now in progress to develop an SCR with such self-contained properties.

With an ac power source, the opportunity for turn-off is presented periodically at each half cycle. Therefore, the SCR's could be used with an ac source of power as controlled rectifiers to produce the dc which can be turned off and on as required to cut off the SCR's used to invert this voltage for the desired frequency. An alternative to this is to convert directly from the supply frequency to the desired frequency in a multiplier circuit.

It should be noted that the state of the art today is such that these approaches are feasible but additional development work is required in certain areas to assure optimum use of existing devices and to provide the required reliability. The major problem area is development of circuit techniques that will permit single frequency, frequency modulation and noise transmissions.

Rotating amplifiers to generate alternating current normally have an output frequency synchronously related to the speed of the prime mover. Some special rotating systems have an output frequency which is not linearly related to speed but require relatively high power active or passive circuits which supply the proper excitation currents. These have limited speed, frequency and voltage response characteristics.

There are several other approaches to generate a frequency independent of speed, each of which leads to a different rotating machine system and has been reduced to practical working modes. Two of them satisfy in essence the requirement for producing field excitation of proper slip frequency to an induction generator running at other than synchronous speed. One method is to obtain a difference between the reference frequency and the output of a permanent magnet shaft driven generator from a magnetic amplifier demodulator. After suitable amplification, this is switched into the windings of two phase exciter whose output produces the proper rotating magnetic field for the generator. Additional

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effort should yield an automatic voltage regulator and a brushless unit. The second approach combines an induction generator, a synchronous exciter with the addition of an SCR frequency changer within the shaft proper to obtain a brushless unit with windings on the rotor. The variable output frequency from the exciter is taken down to the lower slip frequency through gated control of SCR's. This system has a voltage regulator and includes a free running synchronous condenser to assist in meeting unbalanced load requirements as well as providing reactive kva. The last approach to be discussed deals with a machine with no rotor windings; it is brushless and operates with a rotor speed in excess of 60,000 rpm. The high frequency generated in one stator winding is modulated by the frequency desired and introduced into a second stator winding. The output shape is then effectively demodulated by an external set of gated SCR's to obtain the frequency desired and synthesized by a series of rectified pulses for each half cycle. This unit has a maximum output dictated by the present SCR rating of approximately 10 kw.

## ENERGY STORAGE

The acoustic system presents an intermittent load to the source of power. These load pulses may vary in length from as low as 100 milliseconds to as high as 60 seconds. At the present time, it is not possible to narrow this range. However, experiments in the ARTEMIS program will answer this question. Likewise, it is not possible to accurately specify the duty cycle. However, for the discussion to follow, this will be assumed as ten percent.

It is understood that the nuclear power source to be proposed will have an electrical power output from an ac generator. Thus, the pulse loads with a ten percent duty cycle would reflect onto the generator and thence to the nuclear source by way of the steam-turbine prime mover. In view of the requirements for an extremely reliable operation of this system, it was specified that the net load reflected to nuclear source be as uniform as is possible. This will obviate the need for numerous control functions necessary if this were not the case and thus preclude conditions that may lead to reactor deterioration and a short life. With these objectives in mind, it was a prerequisite that the system contain elements for storage of energy. These components would enable power to be withdrawn during the acoustic pulses and to be recharged during the off-time periods. This procedure, in addition, will reduce the peak power rating of the nuclear source.

The storage of energy may take many forms but can be grouped according to whether they are mechanical, thermal, chemical and electrical. Examples of these include inertia, hydraulic and pneumatic accumulators, steam accumulators, storage cells, inductors and capacitors. An NRL Memorandum Report 1038, "Energy Storage Devices for Sonar Applications",

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March 1960, discusses many of these storage mechanisms. In high energy storage systems, electrical energy storage by capacitors has been replaced by inertia storage because of more optimum combinations of the size, weight and cost factors evidenced. This is being used in conjunction with ac generators which supply plate power to the amplifier. Hydraulic storage looks very promising but does not appear applicable to this system. Storage batteries have recently been shown to possess characteristics suitable for acoustic sources where long pulses of high discharge current are required. Work completed since preparation of NRL Memorandum Report 1038 reveals that previous work on single cells is generally applicable to series arrangements.

The employment of one rotating inertia in place of the battery is worthy of consideration. Furthermore, the complexity and reliability of a storage cell and its charger must be evaluated against the acceleration and deceleration of the steam turbine and a wide speed range voltage regulator.

Sufficient data is not available to determine the feasibility of steam storage. However, it is recognized that large space is required and there are problems associated with utilization of the wet stored steam. The presence of water is highly detrimental to turbine blades. A combination of steam and inertia storage may present a feasible solution.

Energy storage and control could also be made through utilization of several variable speed constant frequency generators. Each generator could be driven from its own motor-inertia unit and in turn powered from the nuclear source generator. Sufficient inertia would be required to limit the speed range to within the capability of this system.

## PROPOSED SYSTEM

### Nuclear Power Supply

The Office of Naval Research is obtaining information on the nuclear power supply. Recommendations made in the paragraphs to follow are predicated on this supply, furnishing alternating current power, 4160 volts, 1000 kw in the range 60-3000 cps. Furthermore, this is based on the assumed limitation that a nearly constant load must be presented to simplify the nuclear reactor control.

### Transmitter

The amplifier will be part of an electronic package which would include transistorized amplifier, battery for energy storage and a battery charger. The proposed transistor amplifier is a push-pull circuit

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utilizing four transistors per side in parallel and the collectors common with the walls of the package which serve as a heat sink. Based on conservative current limits, this circuit can produce 2 kw. If the dissipation limits for this circuit of 1.6 kw is attainable, a theoretical maximum output of approximately 4.5 kw would be possible before these dissipation limits would be exceeded. Thus, there is some extra margin available in this design which will allow for different loading conditions between groups of elements as determined by their respective positions in the overall array. A detailed schematic of the transistor amplifiers and some of the control circuits are shown in figure 1. The output power stage is composed of 300 volt, 10 ampere transistors. These are not available in commercial quantities at present. However, developmental samples can be obtained. High voltage silicon high power transistors are in development by the industry and expected before 1962. The driver stage will consist of a push-pull 2N1016 stage which is a 300 volt, 5 ampere transistor now in production. This stage will require a pre-driver consisting of a push-pull 2N174 stage which also has collectors in common, thus simplifying the heat sink design and construction for the energy to be dissipated. The thick aluminum frame illustrated by the arrangement in figure 2 provides a low thermal resistance and will permit complete water submersion for additional conduction and convection factors. It is expected that the three transistor stages outlined will operate satisfactorily within the single metallic non-magnetic case. However, it is not known whether there will be sufficient magnetic coupling between adjacent amplifiers to necessitate steel-case configurations to prevent parasitic oscillations.

The battery selected is composed of type S108, size 4, Sonotone rechargeable sealed nickel cadmium cells. These cells have a four ampere-hour rating. The proposed discharge of 22 amperes for a maximum of one minute followed by nine minutes of recharging is expected to yield a long reliable life. The anticipated voltage per cell under load at 1.05 volts will provide approximately a 95 volt amplifier battery for ninety cells in series. At present, there is no reliability data available on this specific battery for the duty cycle stated. However, results for tests on single cells as well as several cells in series indicates this system is feasible. The final battery for this application will probably be a modified version of the commercial battery. This may require selection of cells by special test and a new case design.

A block diagram of the complete transmitter is shown in figure 3.

### Transducer

The variable reluctance transducer having the characteristics described under the section on Transducers has been selected as the

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best device for the application. Each transducer element would be powered by its own electronic package to make one complete module. Thus, each module would consist of the battery charger, battery, amplifier and transducer. The electronic package and the transducer would be interconnected with an appropriate length of cable. The pressure release required would be part of an over-all pressure-release system and would be inserted between the transducer and the electronic package.

A development program should be initiated immediately to eliminate the polarization requirement for this transducer. Although this is only 100 watts per transducer, an appreciable saving in power and circuit requirements would result from the use of permanent magnets to replace the dc polarization current.

### Array

Three arrangements of transducer elements and electronic package are proposed. Final selection will depend on the site geometry and other requirements which are not specified at this time. The first of these, illustrated in figure 4, is a planar array thirty elements wide by forty-eight elements high. The electronics package would be placed behind each transducer element a suitable distance to allow space for the pressure-release material.

The second configuration, figure 5, is a cylindrical array composed of several rings stacked on one another to give the desired vertical beam. Each ring would in turn be made of several elements to form a close packed array. The location of the electronic packages would require further study; however, they may be redesigned and placed entirely in the center of the array, or may have to project beyond the ends of the array.

An alternate arrangement would be to utilize a stiff wall tube around each transducer, with an array made up of the required number to satisfy the beam dimensions and power requirements. This is illustrated in figure 6. The arrangement complicates the problem of locating the electronic package in a low pressure area at the transducer. Further study is required to obtain the best solution to the problem if this alternative is selected.

### Nuclear Power Supply Load

The load on the nuclear power supply presented by the system for a full transducer power output for a one minute and off for nine minutes is as follows:

| <u>Item</u>                 | <u>Load in kw</u> | <u>Duty</u>  |
|-----------------------------|-------------------|--------------|
| Pre-driver and driver stage | 144               | 10% of time  |
| Battery charger             | 576               | 100% of time |
| Transducer polarization     | 144               | 100% of time |

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These values are based on:

- a. 1440 modules each composed of an electronic package and a transducer element,
- b. 100 watts pre-driver and driver power,
- c. 100 watts polarization power, and
- d. battery charging efficiency of 60%.

It is noted that under these conditions a peak power of 720 kw occurs ninety percent of the time. This increases to 864 kw during the transmission period or the remaining ten percent of the time. Special filtering, regulating and control circuits may be required in each electronics package to assure this uniformity of load. The regulation of the battery between the charge and discharge part of the cycle can cause large pulsations or variations in the generator load unless this voltage variation is reflected into the battery charger output voltage. This voltage fluctuation will necessitate a control system for the charger that will limit the output current to nearly a constant level regardless of battery voltage.

The several approaches to energy storage should be re-evaluated in terms of the over-all system before a final selection is made. It may be possible to do the job better in the nuclear supply package by means of inertia or inertia in combination with an appropriate control system.

## CONCLUSIONS

It is considered feasible to design and fabricate an acoustic source for remote unattended operation providing a suitable nuclear powered alternator is available. The time required for this is estimated to be four years from initiation of the work.

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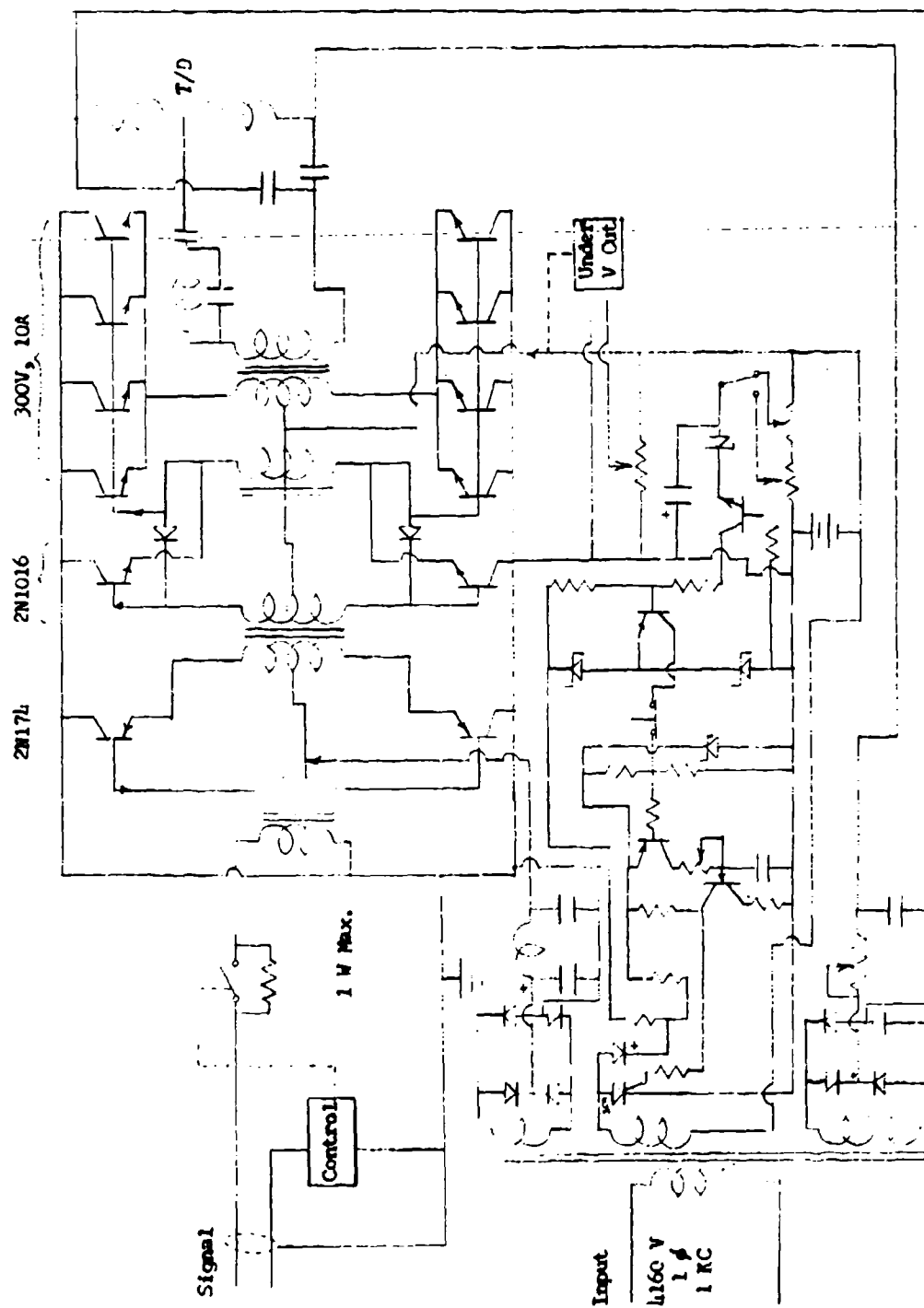


Figure 1 - 2 KW Amplifier Module

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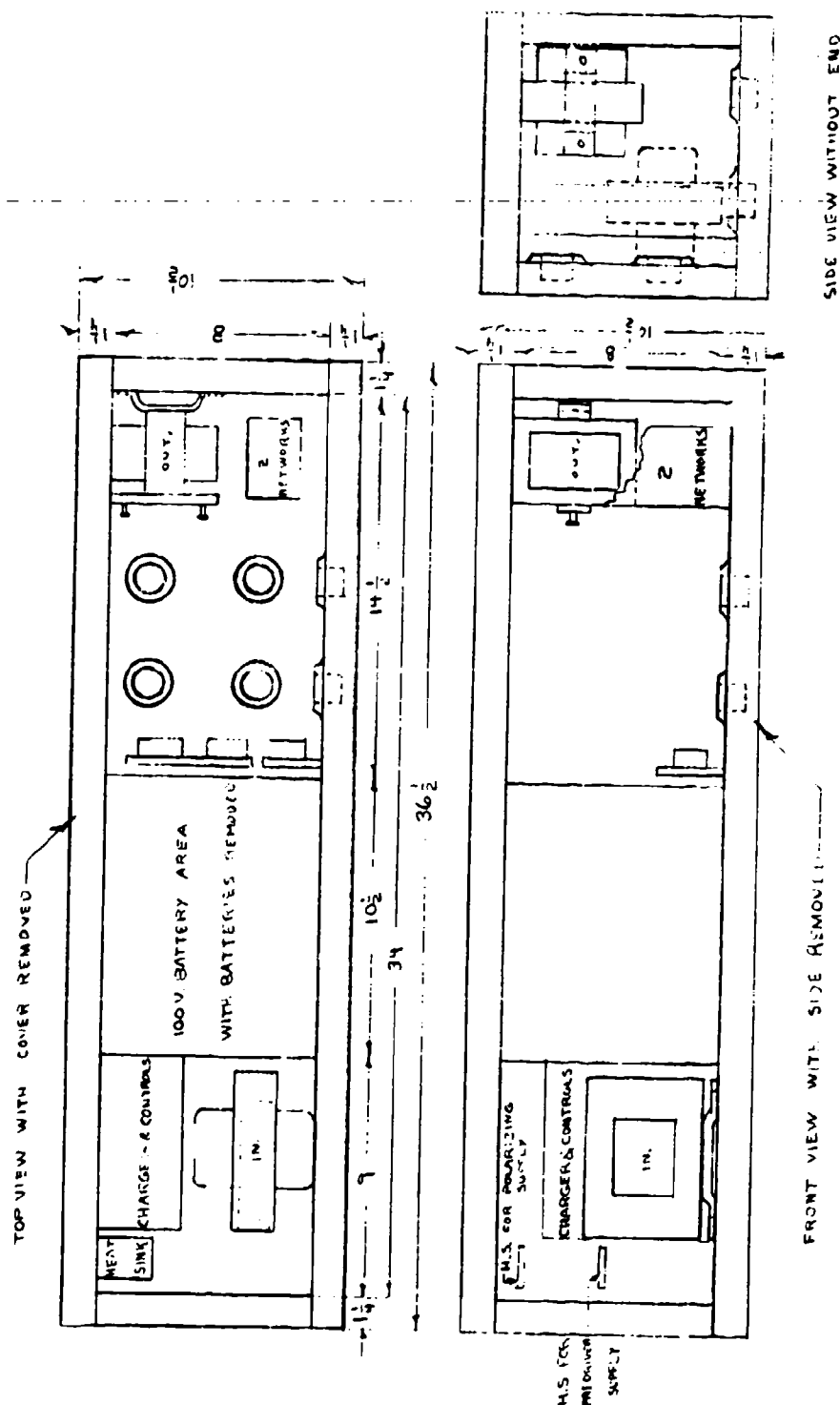


Figure 2 - Arrangement of Parts Amplifier Module

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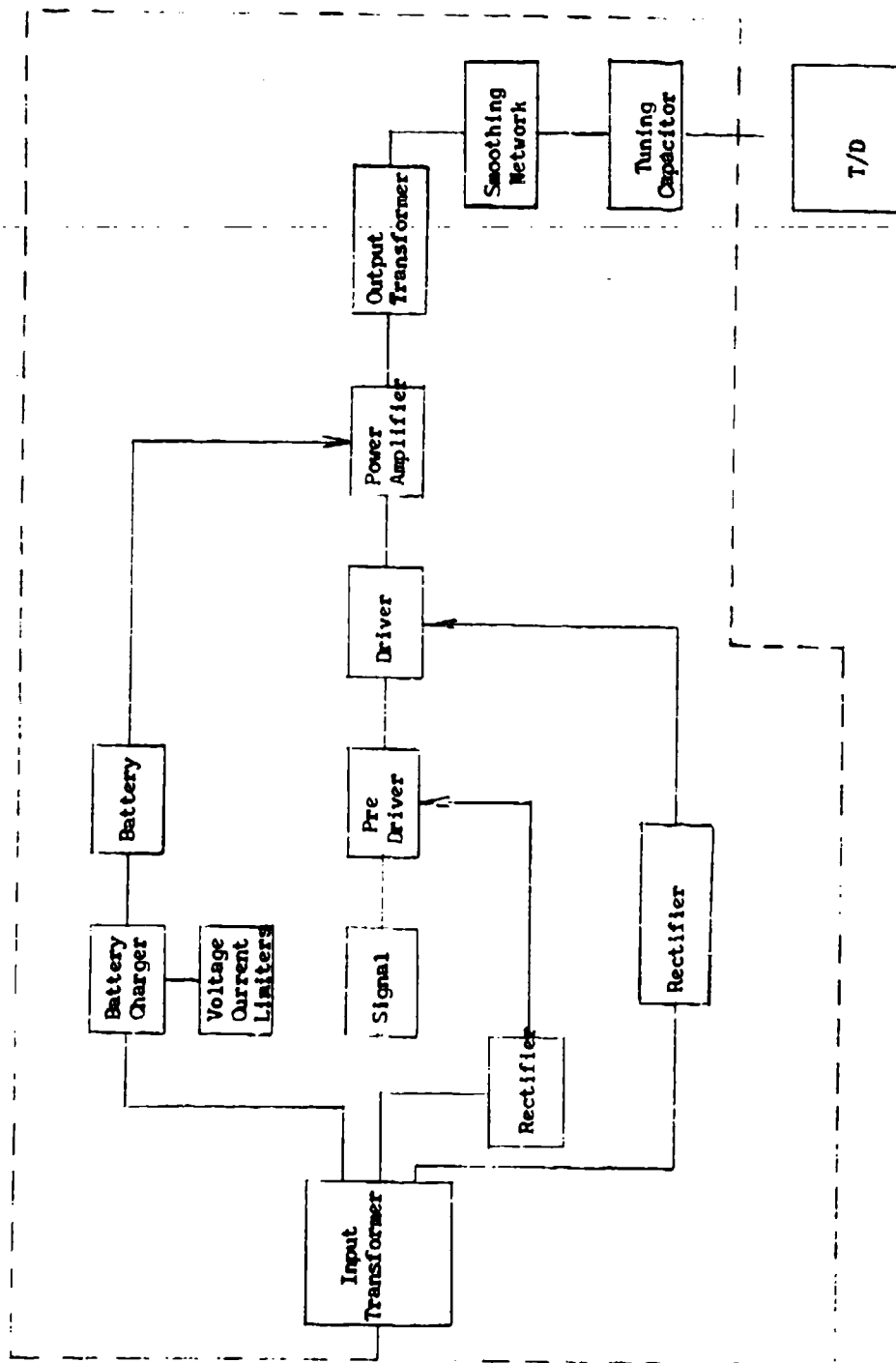


Figure 3 - Block Diagram Amplifier Module

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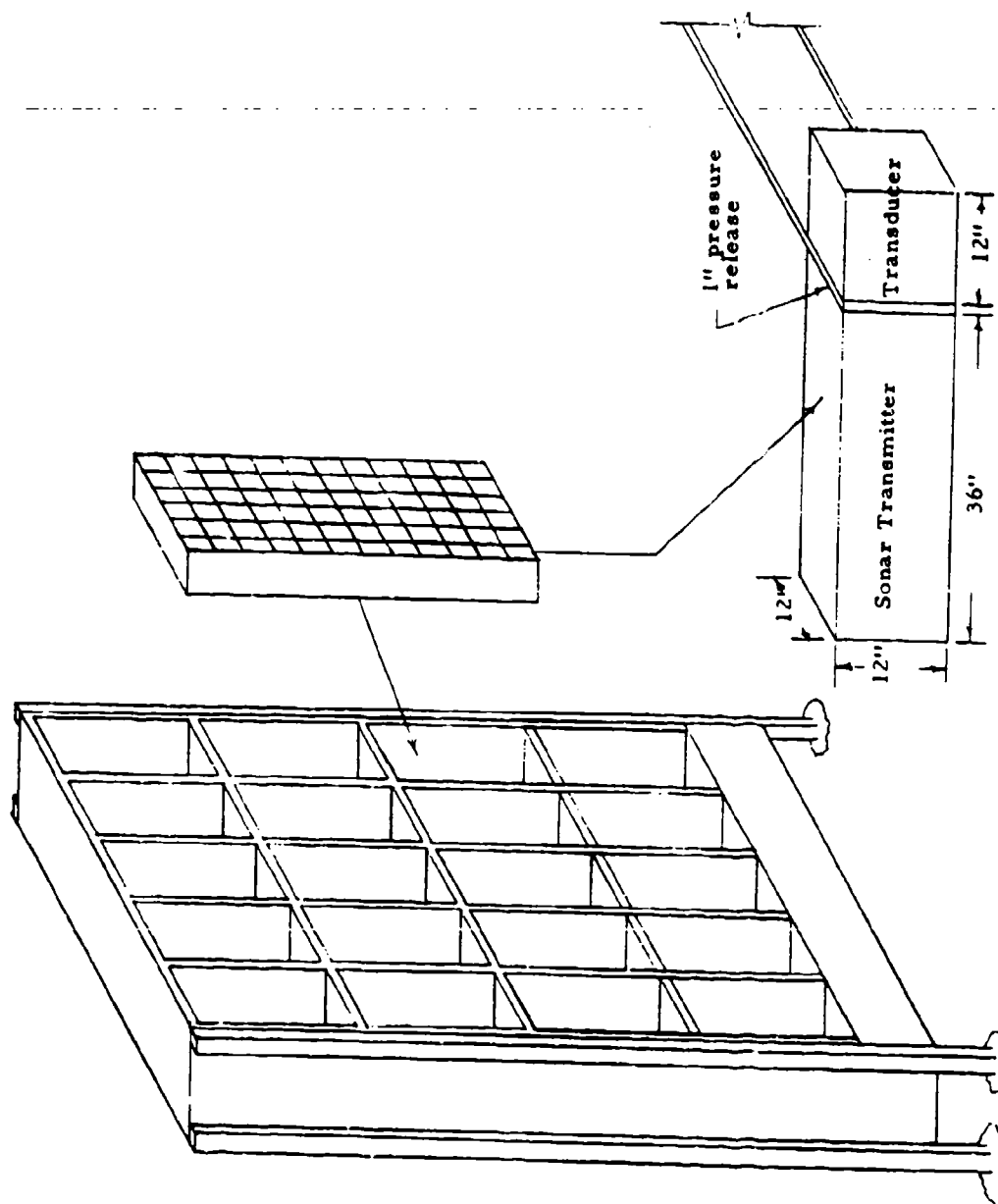


Figure 4 - Planar Array

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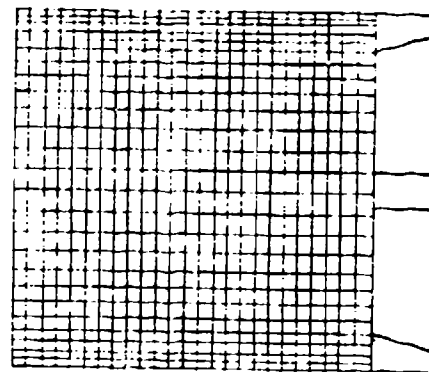
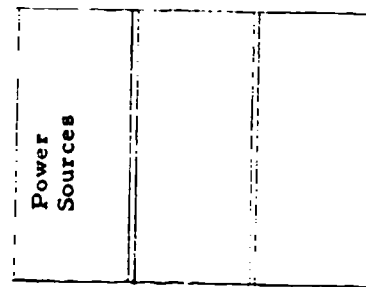
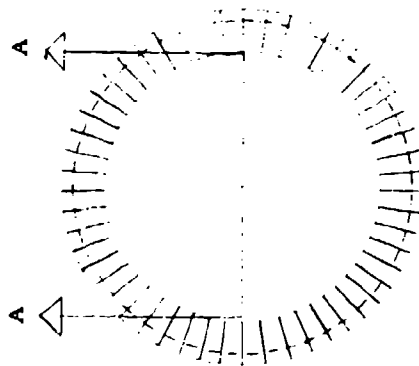
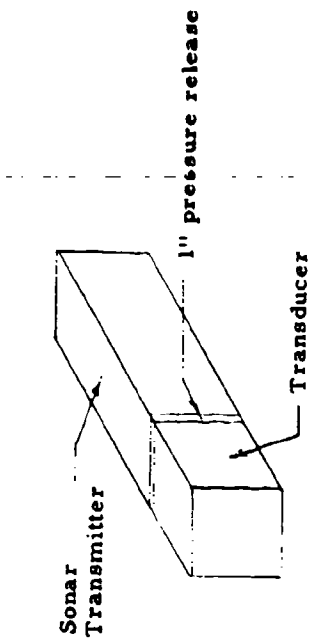


Figure 5 - Cylindrical Array

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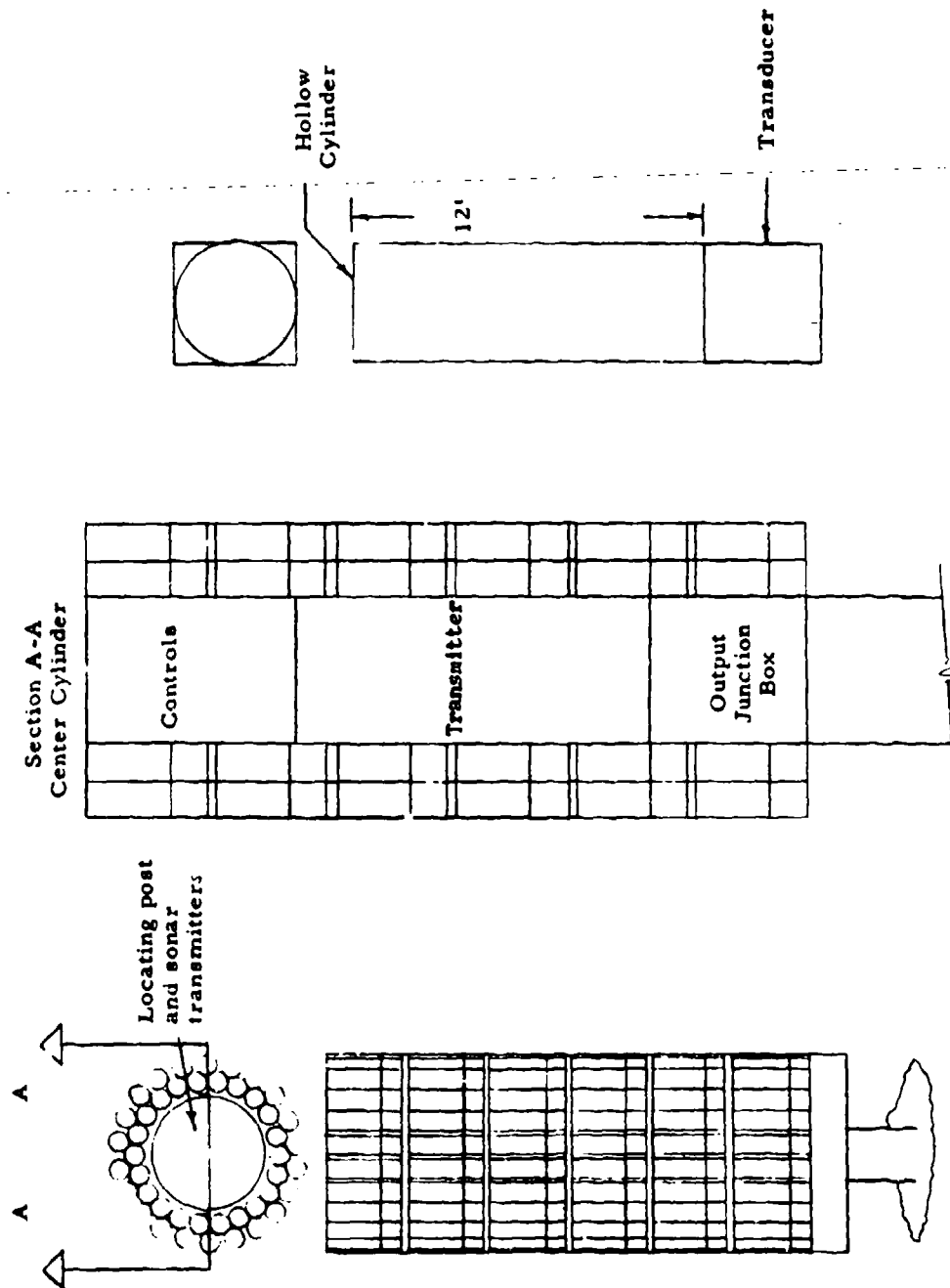


Figure 6 - Loaded Tube Array

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UNITED STATES GOVERNMENT

Memorandum

DATE: 7100-117  
21 November 2003

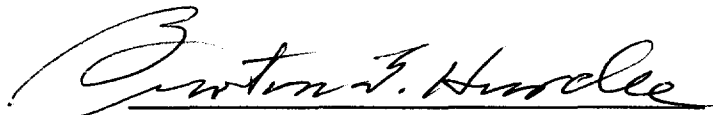
REPLY TO  
ATTN OF: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF (A) FOR DECLASSIFICATION

TO: Code 1221.1

REF: (a) "Feasibility of a Remote Unattended High Power Acoustic Source" (U), A.T. McClinton and John Cybulski, Jr, Sound Division, NRL Memo Report 1095, 1 August 1960 (C)

1. Reference (a) describes a study of the feasibility of developing a transducer and energy storing system to be associated with a nuclear powered remote acoustic source. This would be a part of the ARTEMIS program and would be unattended.
2. The technology and equipment of reference (a) have long been superseded. The current value of these papers is historical.
3. Based on the above, it is recommended that reference (a) be declassified and released with no restrictions.



BURTON G. HURDLE  
NRL Code 7103

CONCUR: Edward R. Franchi 11/24/2003  
E.R. Franchi Date  
Superintendent, Acoustics Division

CONCUR: Tina Smallwood 11/26/03  
Tina Smallwood Date  
NRL Code 1221.1