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The Live Room : Transducing Resonant Architectures

By

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Abstract

The Live Room is a temporary site specific installation presented in building N51, room 117 on the MIT campus on May 7, 1998 and concluded on June 10, 1998. Using small acoustic intensifying equipment which mount directly to the structure of the foundation at the site, the system creates an enhanced scale of 'tectonic charging' through vibration. The system engages the architecture by running impulsive energy throughout, creating sound and vibration in direct relation to the building and the dimensions of the space. The project describes an intensified site where machines fuse into architecture and combine active forces with the building forms. The action is an attempt towards the liberation of tectonics from the limitations of the static, creating a place where resonant structures vibrate in sympathy to induced frequencies. By using various transducing devises and signal generating equipment, the project effectively 'tunes in' the space by delivering resonant frequencies. The installation engages directly a unique floor system which is already present in the space. Mechanical oscillators are mounted into this floor system so that frequencies are imparted into the building the floor and the persons who are situated in the room. With this work, I am interested in TRANSDUCING ARCHITECTURE, driving the space with external influences of a vibro-kinetic nature.

Thesis Supervisor : Julia Scher
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Introduction

Considering the outgrowth of new technologies in relation to our collective cultural history, the effects of late Twentieth Century technical productions on humanity has been immensely profound. With the speed of communication accelerating and the density of information piling at increasing rates[1], the biological makeup of the body is posing as a limiting factor in the reception of all this change. Studies are needed when considering how this effect manifest as real artifacts. Whether it is the rise in cancer rates in relation to the increased production of synthetic compounds, new types of psychological anomalies which arise from disjunctive social relations[2], or even shortened attention spans and the advent of Ritalin[3] controlled children; all this seems to point to problems of adaptation. We live in a culture of speed, where the body in order to survive this new technological framework, couples to the machinic and is therefore driven at phenomenal rates. Whether the connection is vehicular, electronic, or synthetic, they all reference an accelerated situation which had not existed before the close of the Nineteenth Century. At present it is an unstable situation, balance has yet to be found. The process of finding directional bearings and modes for adaptive behavior suddenly become a necessary project. Perhaps our biology will change in accordance. Evolutionary time scales might shift and fuse within this technological framework which in its own adaptive way also adjusts for weak spots in our all too human condition. Perhaps also systems could be designed which would assist in restructuring this evolutionary time scale. With my work,

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[1] Paul Virilio, *The Lost Dimension*, Semiotext(e), 1991.
[2] *Amok Journal - Sensurround Edition - A Compendium of Psycho-Physiological Investigations*, Edited by Stuart Swezey, Amok, 1995. Chapters on Autoerotic Fatalities and Self-Mutilation /Amputee Fetish.
[3] Type of barbituate used for hyperactive children and for treating attention deficit disorder.

I envision an art of the future where the body along with the mind is driven through intensifying experiences and provoked into new territories in reference to the self, to others and to our machines.

Architecture in relation to the body is similar to that of the body in relation to machines. Buildings and tectonic forms envelope occupants, defining contours of action, positioning a framework for habitation. It is a mode of identity that is modulated by constructed form and which acts in subtle ways, forming operations for living, defining interaction with others, and controlling mobility. The scale differential of the body in relation to buildings mimics a similar situation of the body in relation to machines. There is the same format of designed operation which is specific to the use of technical devices as there is in inhabiting designed space. Machines define their own operative usage which control social relations and provoke tendencies for interaction. If you consider examples such a the automobile for navigating personal trajectories, or telecommunications which allows for immediacy of connection through separation[4], or even the act of writing this text on a machine which processes my words. All typify actions of modulation and control. The Live Room project investigates these two parallel examples of modulation and control in relation to the body and architecture and the body and technology. The project works as a kind of investigative platform for injecting reified experience. Within the amplified framework of the Live Room, the occupant is dynamically connected to the living architecture machine.

[4] Paul Virilio, *The Art of the Motor*, University of Minnesota Press, 1995.

The project

The Live Room is a interactive vibro-acoustic environment which engages directly the architecture, the room and the people who occupy it. The building where the project is located, N51 on the MIT campus, was originally part of the General Radio Corporation which manufactured electronic test equipment up until the late 1950's.[5] In the 1960's and 70's the building was occupied by the MIT Instrumentation Laboratory (later named Draper Laboratory) which developed inertial guidance systems for ICBMs, Polaris submarine missiles and the Atlas rocket.[6] (Fig 4 – 7) It was at this time that the unique floor system was installed into room number 117, where the Live Room is located. (Fig 16 – 17) This space, which housed the Fleet Ballistic Missile laboratory, was utilized for the design and testing of the gyroscopic devices, accelerometers and sensors which were incorporated into the armament systems carried by the U.S. submarine fleet. Because of the degree of precision inherent in the equipment produced here, the need for controlling external vibration was a crucial requirement in the construction of the floors. This room has seven massive concrete isolation pads which float on beds of gravel and sand and are isolated from the rest of the building by their own separate foundation. The pads which are incorporated into the sub-floor system are surrounded by a floor plane of half inch thick aluminum plate mounted on a suspended aluminum girder system. This girder system is connected to periphery foundation which supports the rest of the building. The room has two of these specialized floor areas, one section with two large isolation

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[5] Arthur E. Thiessen, *The History of the General Radio Company*, General Radio Co., 1965.
[6] *Air, Space and Instruments*, Edited by Sidney Lees, Draper Anniversary Volume, McGraw-Hill, 1963.

pads and the other section with five smaller pads. (Fig 19) Each pad originally supported a gyro tilt table which was used in the testing of the directional control instruments.

In the Live Room project I have attached six rotary type mechanical oscillators (vibrators) to the rigid girder system used to support the floors. The oscillators produce intense vibrational energy which is induced into to the structural system, the floor panels and to the surrounding building foundation. The seven concrete isolation pads are immune to this vibrational energy and thus become dead spots or static islands surrounded by a sea of energized wave forms. Quarter inch closed cell foam is used to dampen the area between the underside of the floor panels and the top of the support beams. The foam enables the floor panels float independently of each other which allows different frequencies to be imparted to separate areas. By mounting the vibration inducing devices to the structural members, the twelve by eighteen foot and eight by thirty foot floor areas operate as two independent planar resonators which act like large rigid speaker like surfaces. The design of this system enables the floor area to essentially act like a tunable musical instrument with harmonic pulse frequencies shifting in relation to the fundamental settings of the separate oscillators and which are also modulated by the movement of people walking on the floor surface. When standing on the activated area, the vibration travels efficiently throughout the body as it does also throughout the building. Wave forms propagate in one area of the floor and travel outward towards other areas while passing through those who are standing in the path of this movement. The action of people moving on the floor plates create an interactive counterpoint to the frequency patterns generated by the oscillators.

The exciters used in the project operate over a frequency range of between one to thirty cycles per second. (Fig 13 – 15) Variable voltage from six rheostats control the six direct current motors that make up the oscillators and can be precisely controlled individually. (Fig 22) These rotary devices use offset weighting which generate sinusoidal wave forms throughout the frequency range. The two floor areas that make up the project each have three of these oscillators and are connected to the aluminum sub-floor. This rigid connection allows the separate wave forms produced by the vibrators to connect and build upon each other in an additive way.

To help visualize the wave form propagation, fine sand can be placed on the floor surface to locate the nodal points and the active areas. (Fig 8 - 11) This technique is an architecturally scaled version of some of the work developed by the eighteenth century Hungarian researcher Ernst Florens Friedrich Chladni[7]. His famous 'Chladni' figures utilized fine powders placed on metal plates which were activated with a violin bow. The powder medium when vibrated would suddenly organize into symmetrical patterns which corresponded to active and non-active areas. The Chladni patterns also relate to the material makeup of the plates, the frequency of excitation and the type of powder used. When participants walk on the floor surface the footsteps disturb the sand and distribute it randomly. At the same time, the vibrations of the floor induce the sand to self-organize, generating a topology that corresponds to the shifting frequencies.

[7] Mary Désirée Waller, *Chladni Figures - A Study in Symmetry*, G. Bell and Sons LTD, 1961.

Tendencies

Other artists have worked in similar territories related to architecture and technology. Gordon Matta-Clark[8] dismantled building forms along with the pre-constructions of habitational use value. Jean Tinguely,[9] Chris Burden[10] and Survival Research Laboratories magnify the icon of the machine to the point of absurd and dizzying spectacle, animating breakdown and mutation through chaotic formulary in this specialized area of the inanimate. All skirt areas where the Live Room is positioned. In this project, though, the intent is less on the technical object amplified and perturbed to the point of exhalation, but rather emphasizing the site as an inhabitable place which echoes the original use of the room. The space is intentionally kept clear of any unnecessary devices or sculptural forms. The room when entered is seemingly bare. It is only when the floor planes are activated, massaged with vibratory pulsation, that the site suddenly becomes alive, resonating both the structure and the viewers with sympathetic harmonics. The room in this sense works as an activated site-object, a machine which you enter into. Room 117 is a technological space which surrounds and infects the body with energized form and surface. When the space is turned on the floor panels are charged with imparted energy, defining the site beyond this place while also locating the occupants within. It integrates the areas of tectonics and technology through the forcing action of penetration, induction and massage. The project is a site where the technical feeds into the environmental and resonates within the viewer, defining a bridge, connecting

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[8] *Gordon Matta-Clark*, exhibition catalog, IVAM Centre Julio Gonzalez, Valencia, 1993.
[9] *Pandemonium – Jean Tinguely*, Benteli, 1988.
[10] *Chris Burden – Beyond the Limits*, exhibition catalog, MAK, Cantz Verlag, 1996.

the occupier to that which is occupied. It is locating a place where the body experiences heightened reality and references our everyday relationship towards machines.

Naum Gabo's[11] kinetic construction is useful to consider in relation to the Live Room. (Fig 12) This piece, made in 1920 and perhaps one of the first kinetic artworks, wasn't intended as a sculptural object itself but was made for his students to demonstrate the principal of the standing wave. Using reciprocating motion to oscillate a thin metal rod the device could define dimensional space through time. Due to the persistence of vision a solidified form or virtual volume would emerge inscribing a sculpture which is present only through its action. The Live Room similarly delineates form through action, only instead of using a metal rod, the piece uses pure vibration to inscribe shape within the body. Organs, bone, and tissue all have particular resonant frequencies, if these frequencies are induced through the body, shapes can be felt along with relational indices of the different body parts. The Live Room, a space devoid of physical objects is therefore composed of virtual objects which haptically interface with the audience. By interacting with the cycling wave forms the occupant is again occupied, infested with frequencies, modulated by vibrational energy and imparted with the volumetric sensibilities inherent within the body. The audience therefore are the activated objects, traversing the site and feeling the liveliness of themselves, others and the space within.

[11] *Naum Gabo - Sixty Years of Constructivism*, Edited by Steven A. Nash and Jorn Merkert, Prestel-Verlag, 1985.

Live Room is a relative of cinematic entertainment, amusement parks and thrill ride attractions. There seems to is no limit to what type and how much intensified experience audiences will take. There was Coney Island of the twenties where people paid to be abused by machines which hurled them about only to be insulted by clowns as they left the park. In the 1950's there was William Castle and his film The Tingler which had the seats of the theater wired up for 'Percepto', and "sought to simulate the monster loose on the floor under the seats and involved small motors from radar cooling units fitted with lopsided cams, bolted under the chairs and activated on cue by the projectionist."[12] In the Seventies there were disaster films like Earthquake which had specialized sensurround subwoofers which physically shook the audience at cues marked in the celluloid.[13] Nowadays it is a fast growing industry which seeks out increasingly jaded audiences who are looking for the next big thrill. Companies such as Disney and Universal Pictures are constantly developing new rides which are seemingly more extreme or are tie-ins to the film projects they produce. With computer imaging, simulation platforms and virtual reality, ride films such as Douglas Trumbull's Luxor attraction in Las Vegas are becoming hybrid forms of spectacle "movie environments in which the audience actually moves in sync with the screen action."[14] The Live Room works to a similar degree in provoking the audience in new and extreme ways. The idea of placing people in these kind of unique situations is one which permeates most of my work. When boundaries are pushed, new awakenings in the self can be located. Through this, social interactions can expand and a new type of referential identity might develop.

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[12] Jack Stevenson, *A Million Frightened Teenagers or: A hundred and One Cheap Ways To Make Your Movie More Exciting - In Praise of the Lowly Gimmick*, Blimp 36, 1997. P. 51.
[13] Ibid., p. 49.
[14] Ibid., p. 49.

Destructive potentials

All materials have resonant frequencies which is a product related to its natural state of induced excitability. Buildings along with bodies too have their own particular resonant frequency. (Fig 1 – 3) If you locate this frequency, the value of efficient excitation, and through mechanical reinforcement impart this frequency you can literally 'ring' material similar to that of a struck bell. If, through a feedback system, you encourage a phase aligned addition to this wave form, potentials for the material oscillate out of control become possible. In 1898 the inventor Nikola Tesla was working with similar energy imparting devices which was said to be so small " you could put it in your overcoat pocket."[15]

> I was experimenting with vibrations. I had one of my machines going and I wanted to see if I could get it in tune with the vibration of the building. I put it up notch after notch. There was a peculiar cracking sound.
>
> I asked my assistants where did the sound come from. They did not know. I put the machine up a few more notches. There was a louder cracking sound. I knew I was approaching the vibration of the steel building. I pushed the machine a little higher.
>
> Suddenly all the heavy machinery in the place was flying around. I grabbed a hammer and broke the machine. The building would have been about our ears in another few minutes. Outside in the street there was pandemonium. The police

[15] Article from the New York World-Telegram, July 11, 1935.

and ambulances arrived. I told my assistants to say nothing. We told the police it must have been an earthquake. That's all they ever knew about it.[16]

This notorious event was said to have also created intense sympathetic vibrations two blocks away from Tesla's laboratory producing a similar extreme reaction which had summoned the authorities.

There is a correlation between bodies and buildings insofar as they relate to oscillatory motion. The same amplitudes and frequencies have corresponding effects in both. Vibration induced pain in humans is relative to the same value of intensity which causes failure in structures. Both bodies and buildings are excited most efficiently at the same frequencies of between one and twenty cycles per second. Though the Live Room is not trying to actually destroy buildings or cause physical pain, defining this extreme range helps to clarify the potential power resident in the project. This parallel relation also helps to reinforce the concept of bridging through sympathetic vibration and connecting a trace between the body and architecture.

[16] Ibid.

Sound and infrasound

Normally we think of sound as waves of energy traveling through a medium (such as air) on its way to the ear. Because the molecules are more spread out, gasses like air are in fact less efficient mediums for sound to travel than liquids or solids. Therefore the solids which make up most architectural forms can be thought of as very efficient conductors of vibro-acoustic energy. In the design of the project, the mechanical oscillators are bolted to the structural members which make up the floor of room 117. Even though these mechanical devices do not produce their own sound, the energy they impart charges the surfaces into what is in essence an acoustic resonator. This technique transfers the vibration energy to the air in the form of sound while still maintaining a transference through the structure. With the use of these specialized transducers, the room is driven with an acoustic energy that is derived in direct response to the shape and material makeup of the space. It is a place where periodic wave forms are propelled into the structure and propagate throughout as a type of drone sound which traverses the site. In this way the space operates as an architectural sounding instrument which is controlled by the six channels of actuation that permutate into infinite combinations of relational frequencies.

By using the multiple oscillators, different combinations of frequencies can be generated and experimented with. This works in the same way as additive synthesis which is a technique for sound production that is commonly found on electronic musical instruments. All six exciters operate at relatively low frequencies, peaking in amplitude at

between twenty and thirty cycles per second. At these rates the vibration is still audible, with the threshold of hearing beginning at twenty cycles. When combining several of these oscillators, potentials for harmonic interaction is possible. Beat frequencies (separate wave forms which raise and lower in amplitude in relation to two or more fundamental frequencies which are combined and are of similar but not the same value) are readily produced and enrich the overall effectiveness of the soundscape. For example if you generate one frequency at twenty eight cycles per second (cps) and combine that with another frequency of thirty cps then the addition will reinforce as a two cps beat frequency (i.e. subtract 28 from 30). This slow cycling beat frequency is thus operating at a sub-audible level or what is also known as infrasonic sound. Infrasound[17] and vibration are similar in their makeup, both are more felt then heard. Though you can hear the rise and fall of amplitude in the form of audible clicks, these low frequency sensations operate at below the hearing threshold. This does not mean that the lower frequencies do not have an effect on the body and on the architecture. The scale of the project and the massive size of the floor plane resonators are conducent to the efficient propagation of large amounts of infrasonic energy. The infrasound that the Live Room generates is what is most effective in the transferring energy throughout the building. The subtle strangeness of this project revolves around the production and injection of these unique low frequencies.

[17] *Infrasound and Low Frequency Vibration*, Edited by W. Tempest, Academic Press, 1976.

Physiological aspects

When the body comes in contact with infrasound and vibration unique phenomena develop. Frequencies below the threshold of hearing effect the body and perception in ways which can seem unpredictable. As mentioned before, parts of the body can be excited through differing frequencies allowing the spaces inside to be felt.[18] (Fig 1) Certain feelings and tendencies can also be elicited whether it is nausea, headache, the gag reflex, or the urge to defecate. These physical responses have induction components which relate to certain cycle rates. In the Live Room, a common occurrence related to the vibration is the effect on the vestibular system and the sense of orientation and balance. When positioned on the active floor panels a feeling of shifting horizon can be felt. While standing here, balance will be altered and suddenly your perception is that of surfing the architectural plane. Existentially this is interesting in the context of the space. Because the site was originally used for the isolation of vibration in order to test devices specific to balance and orientation, the fact that this has been reversed in the viewer is quit profound. Through the precise control of the vibration the inertial guidance system within the observer is now at play; the reference point of location suddenly shifts with stability no longer a given. The potentials for this site can even be greater than this. If the floor is driven to its maximal amplitude, standing and balance no longer become possible. The audience can be literally be taken to its knees involuntarily overcome with the technical moment.

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[18] H. Dupuis, G. Zerlett, *The Effects of Whole-Body Vibration*, Springer-Verlag, 1986.

Sympathetic vibration

The technique of inducing sympathetic vibration is one that can have profound impact. Like Tesla's experiment which imparted effect at a distance of two blocks, sympathetic vibration refers to energy transferred. As stated before all materials have a dominant resonating frequency. If you have two like or unlike objects which happen to have the same resonant frequency, you can vibrate one object without touching the other and yet still cause the untouched object to resonate. This efficient activation or relational connection provides a type of crude form of communication between objects. The line of communication works when wave forms travel through a medium such as air or by solid coupling and activate at the point where similar resonance's match. In fact Tesla developed a whole plan for terrestrial communication through the ground plane via his geodynamic intensifiers and sympathetic resonators. In the Live Room, I envision a similar sympathy or bridging between the resonant frequency of the occupying body and that of the resonant form of architecture. There is a relationship here and through the imparting of vibration, location can be sited within the constructed framework of the building and those who inhabit the building. Perhaps by this and through variation of frequency, a mapping could occur where sites located within the body correspond to sites within the building. It could be a true connection or perhaps displacement of all internal organs within this "body without organs."[19]

[19] Gilles Deleuze, Felix Guattari, *A Thousand Plateaus - Capitalism & Schizophrenia*, University of Minnesota Press, 1987, P.153.

A social project

When groups of people occupy the Live Room, interesting social interactions begin to emerge. (Fig 24) The site is at once very personal, in that the wave forms react differently in each individual. The frequencies produced transcribe and define the interiors of the subjects bringing you to a place within the self. Yet sharing this experience with others creates a far more dynamic experience which is another type of sympathetic vibration operating between people. It works in a similar way that intensified experiences such as natural disasters can have. Events like earthquakes where groups of strangers suddenly have a shared experience and thus form bonds within the crisis. The Live Room generates a similar situation where patterns develop, people talk about the strange sensations and compare notes as to effects. Some gather on the isolation pads where the sensations are the least. Others are constantly looking for the most intense areas, or follow the wave forms as they travel across the floor. People take their shoes off while some will lie down so that they feel it in their back. Sensitive types who can not deal with it stand by the edge and watch all the commotion while the jaded snuff at it and say "so what." By far the most common reaction are those who begin to learn how to control the varying frequencies through themselves. This process usually involves traversing at a slow pace the platform as they investigate the sensations cascading through their body. If you can imagine forty or more people doing this movement at the same time, what develops are patterns of integration and separation. Seemingly chaotic actions begin to turn into self organizing systems which follow the shifting frequencies that are continually changed by the operator. As the audience moves,

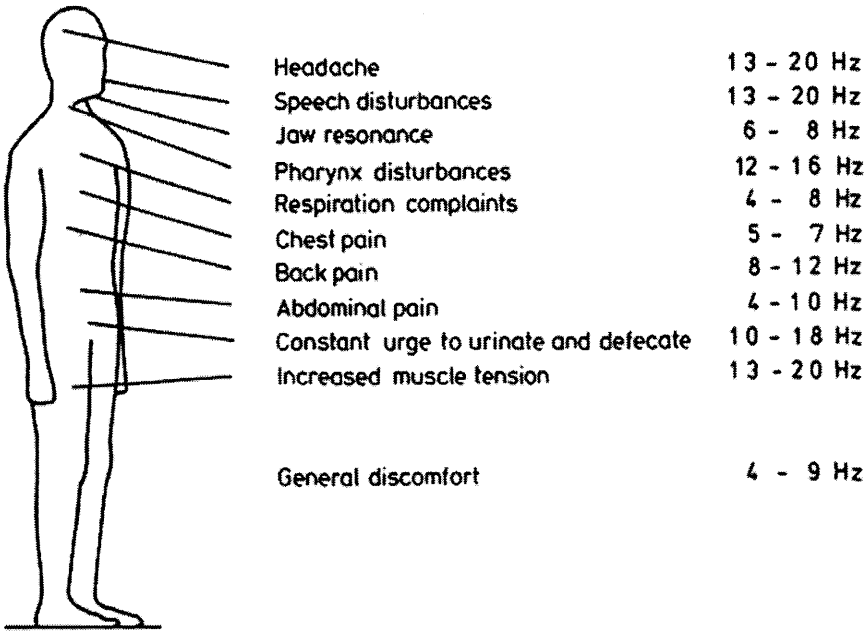
it mimics the patterns of sand found in Chladni figures. Individuals act as the separate grains shifting in relation to others and locating the nodal points along with the active areas.

Working in conjunction with this social aspect of the project is also the notion of the operator, the one who composes the mix. This is an important part of the project and works in a similar way that a disk jockey plays musical selections in a dance club. When controlling the separate frequencies, one has to be acutely aware of how the wave forms combine with each other. A successful mix will generate complex patterns which help define the audience within the space. One that is confused and muddy serve only to misdirect the crowd. It takes practice, it truly is a musical instrument which needs to be learned for it to be most effective. Part of playing the room involves the slight tuning of the beat frequencies so that the wave forms shift in infinitely variable patterns and allow the space to play itself automatically. The issue of control is also interesting in that one can modulate the actions of many. You can choose whether to amplify certain areas or not. You find the audience travels in accordance to these changing patterns.

Synopsis

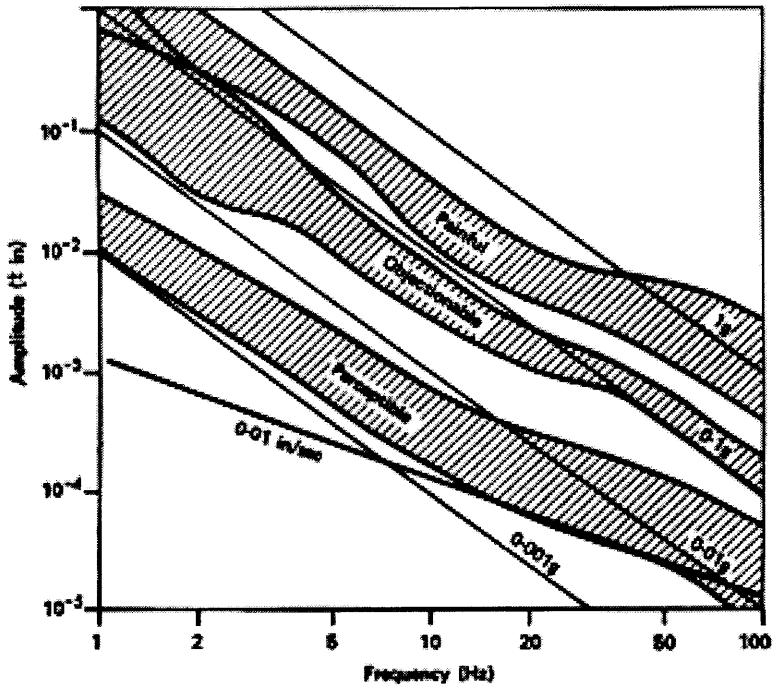
The Live Room is an experimental project produced to study the working relationship between our built environment and ourselves. It attempts to draw a line of connection related to areas within the body, while defining surfaces and locus within our architectural environment. Using vibro-acoustic energy as the working medium, the project investigates the unique properties of low frequency wave forms as it affects structures and people. It is an artistic project which is positioned between the areas of science and architecture, a hybrid space for experiential use.

Plates

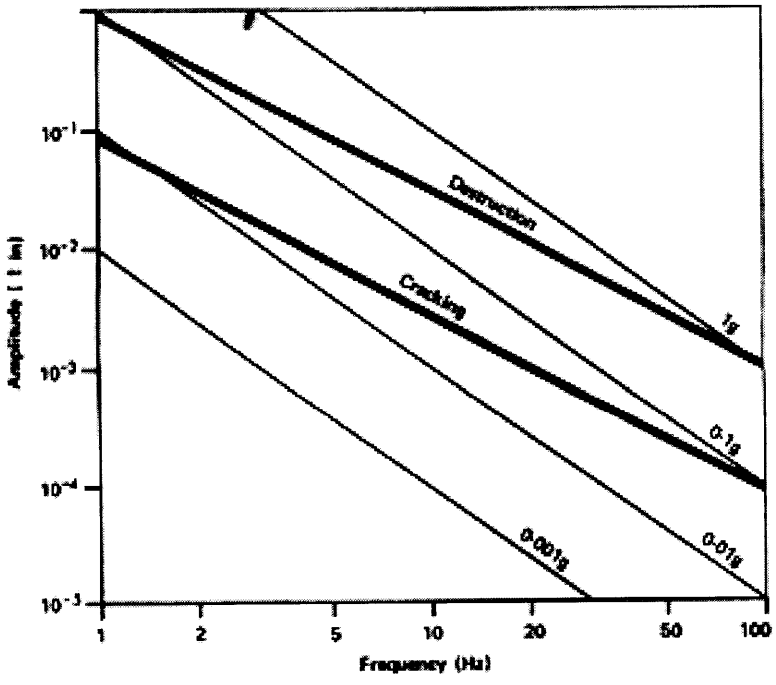


Complaints in various organ regions in relation to stimulating vibration frequencies (Magid and Coermann 1960)

Fig 1 (Dupuis, Zerlett)

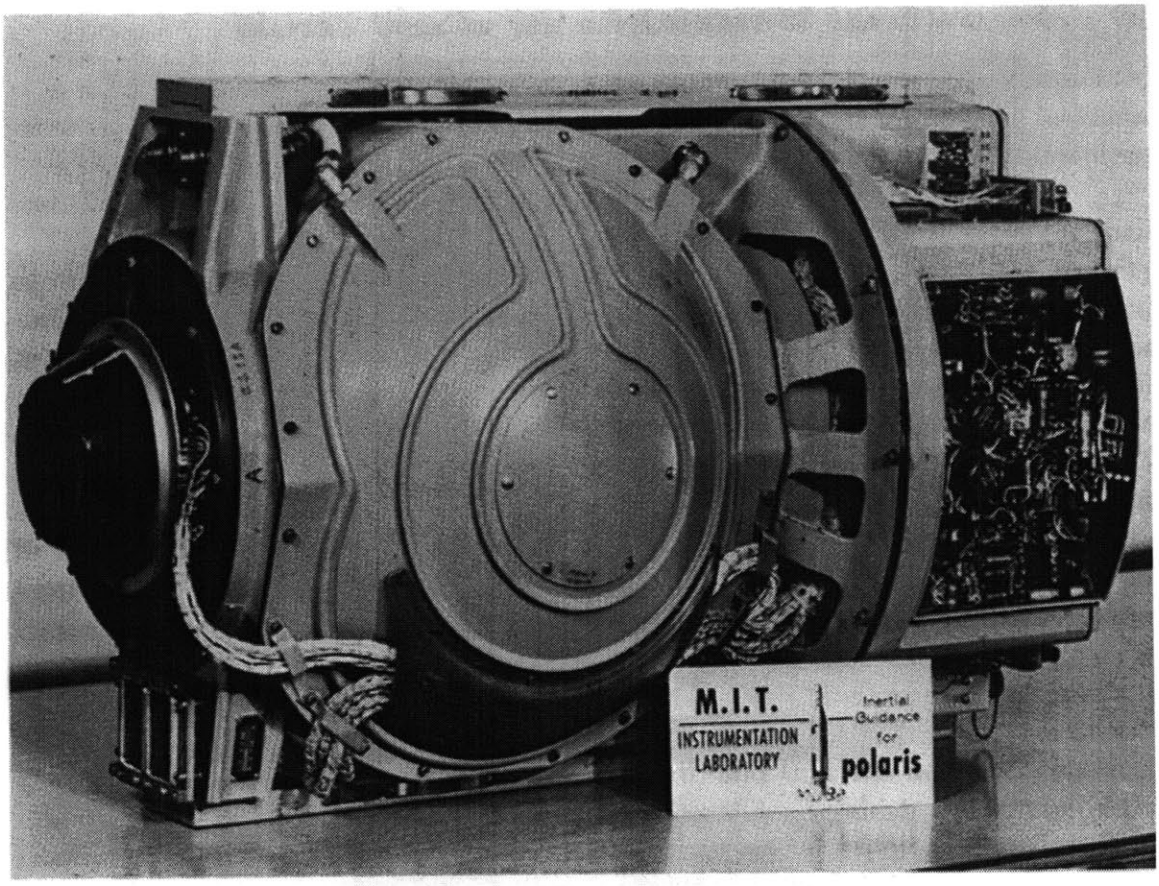


Effect of vibration on people.



Effect of vibration on structures.

Fig 2, 3 (Dupuis, Zerlett)



Mark 1 guidance capsule.

Fig 4 (Raborn, Craven)

Fig 5 (MIT Museum Archives) Mark 1 inertial guidance capsule for Polaris, Fleet Ballistic Missile laboratory, MIT

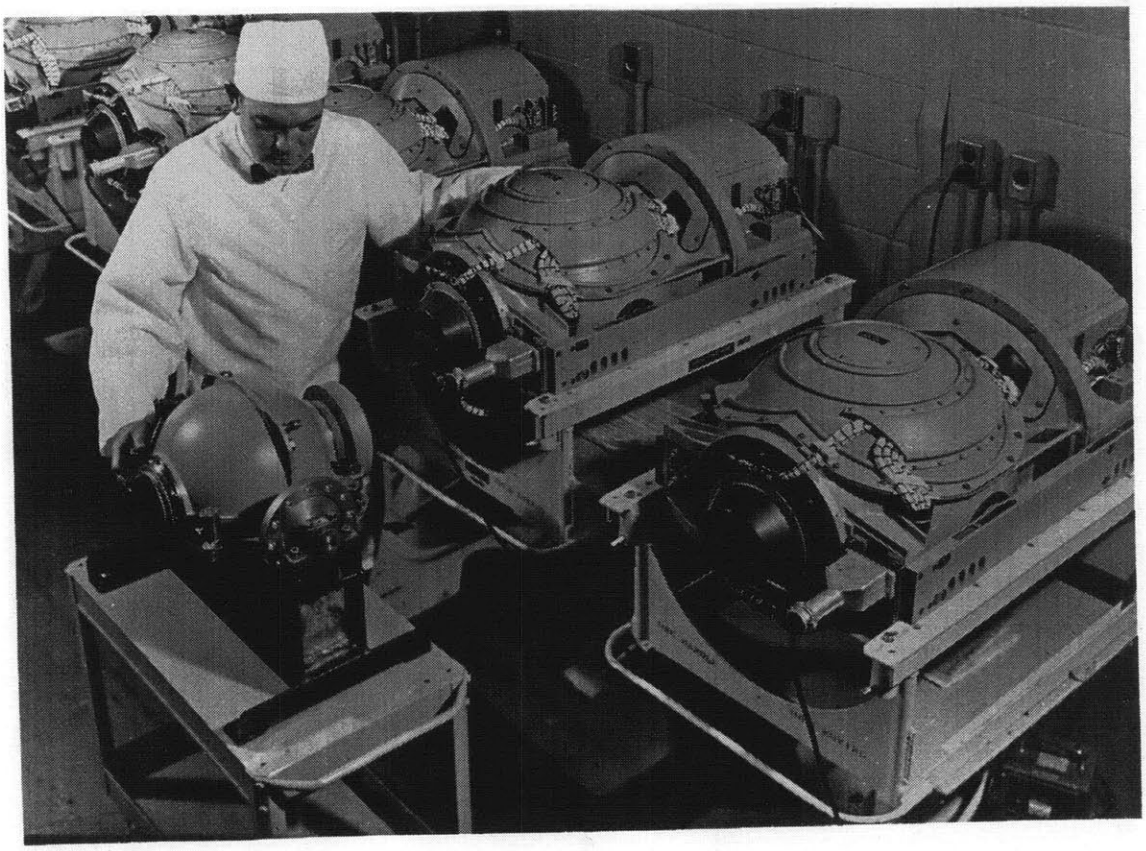


PHOTO #NOD-C 21177 - UNCLASSIFIED - MK.I & MK.II POLARIS GUIDANCE SYSTEMS
ANNUAL REPORT - 5/13/63

Fig 6 (MIT Museum Archives) Assembly of Mark 1 inertial guidance capsules for Polaris, Fleet Ballistic Missile laboratory, MIT

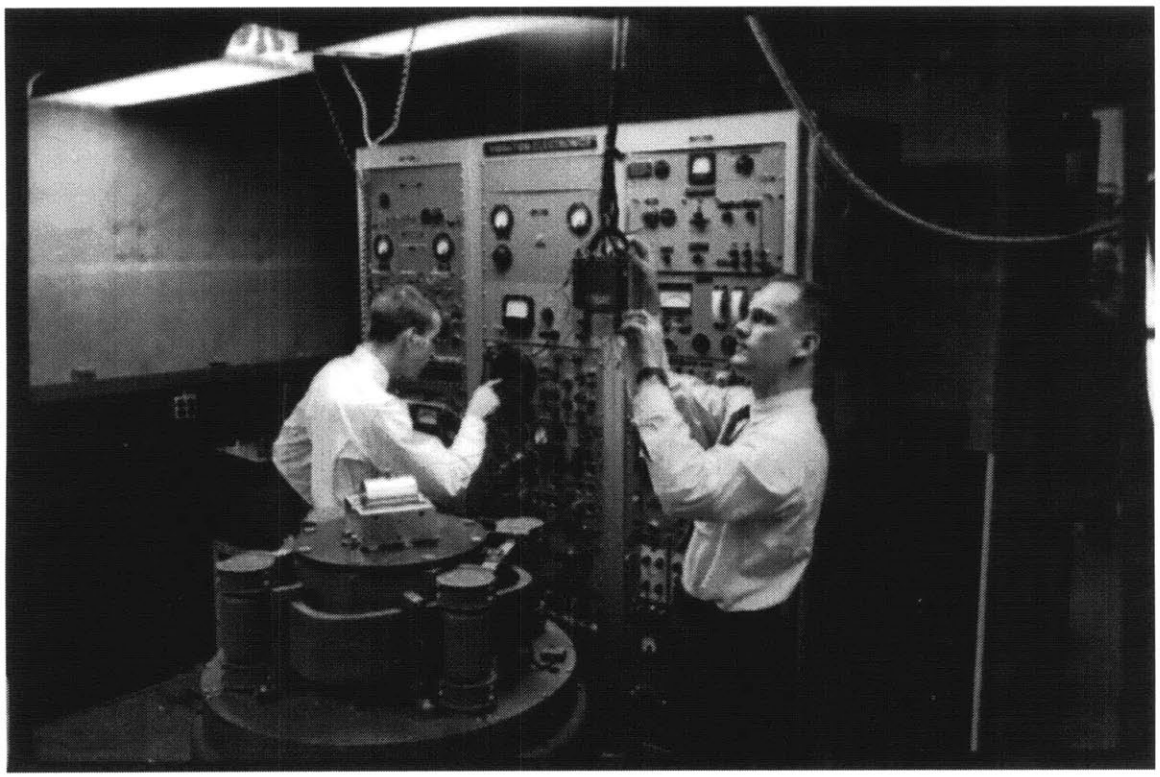


Fig 7 (MIT Museum Archives) Gyro testing with vibration platform and amplifiers, Instrumentation Laboratory, MIT

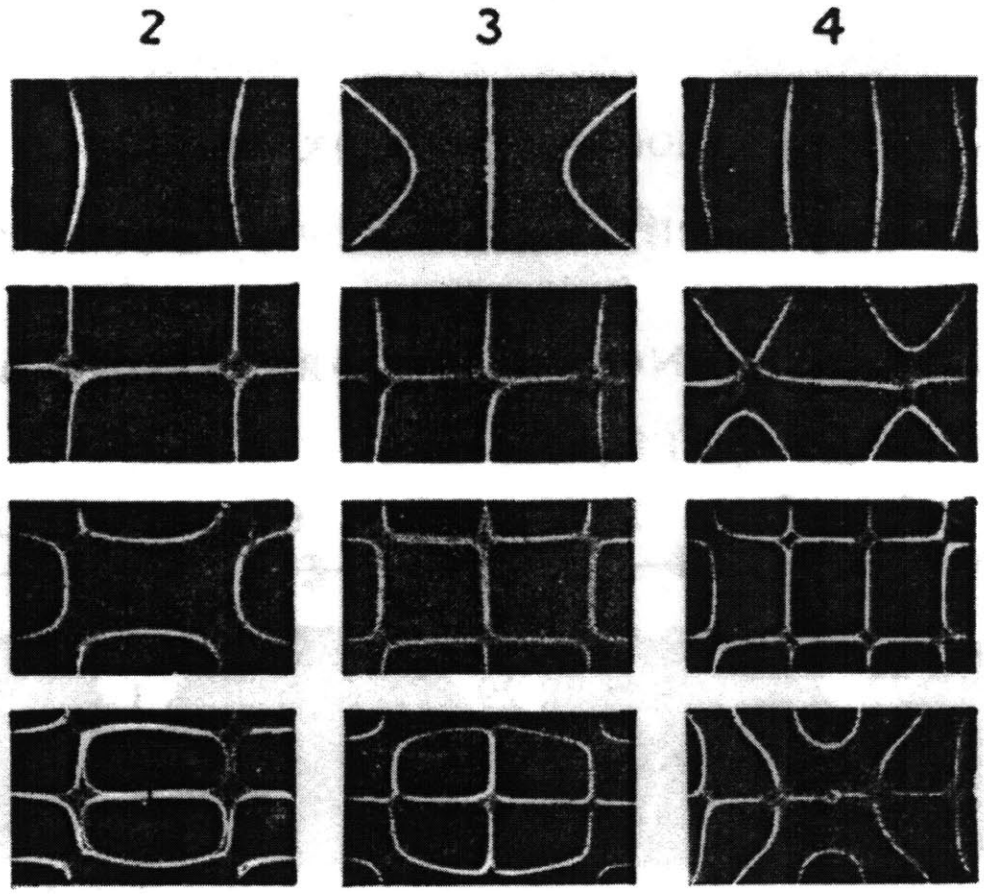


Fig 8 (Waller) Sand patterns produced on vibrating plates

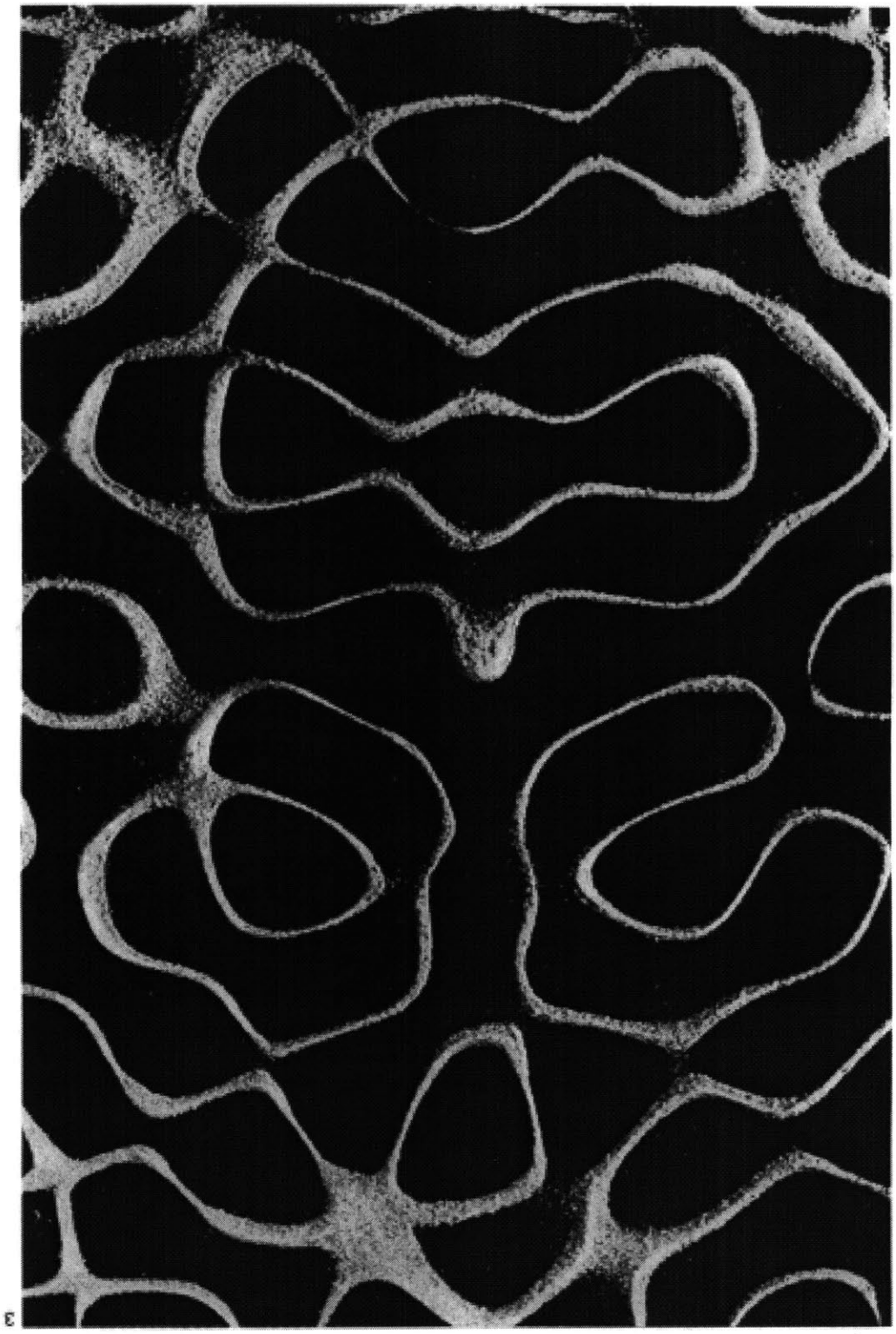


Fig 9 (Jenny) Sand pattern produced on vibrating plate

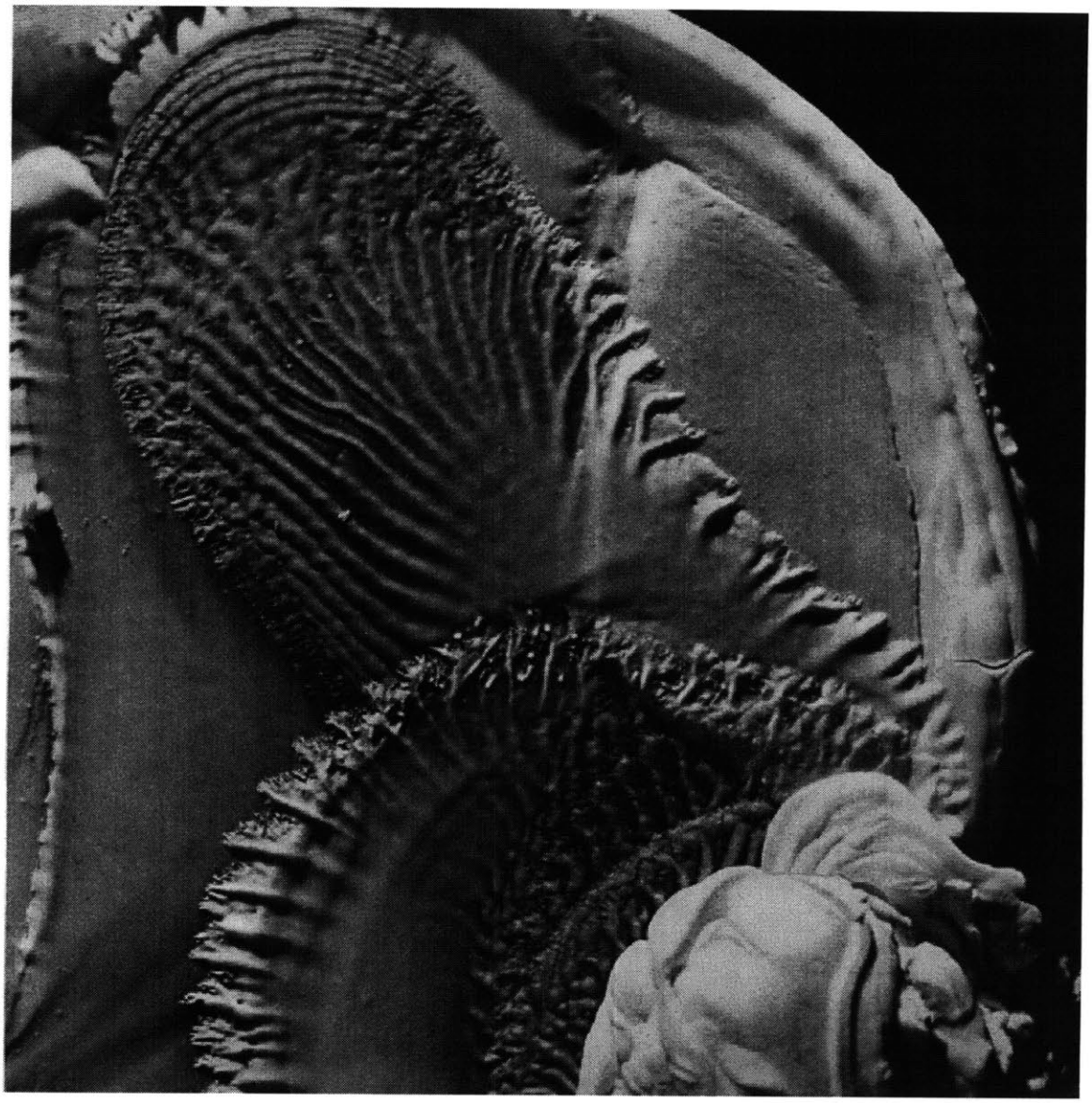


Fig 10 (Jenny) Patterns left in viscous material from acoustic driving

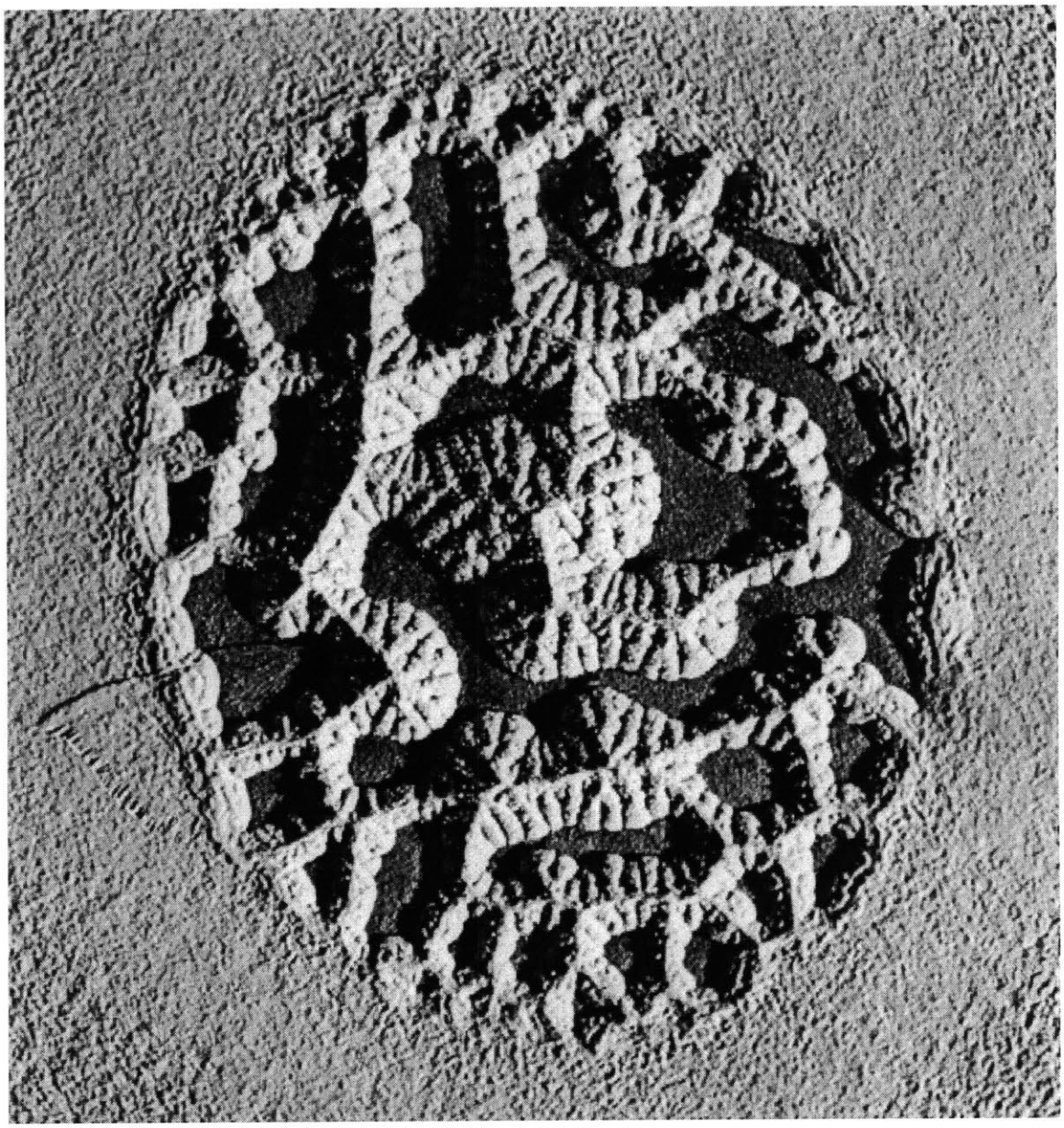


Fig 11 (Jenny) Patterns left in powder material from acoustic driving

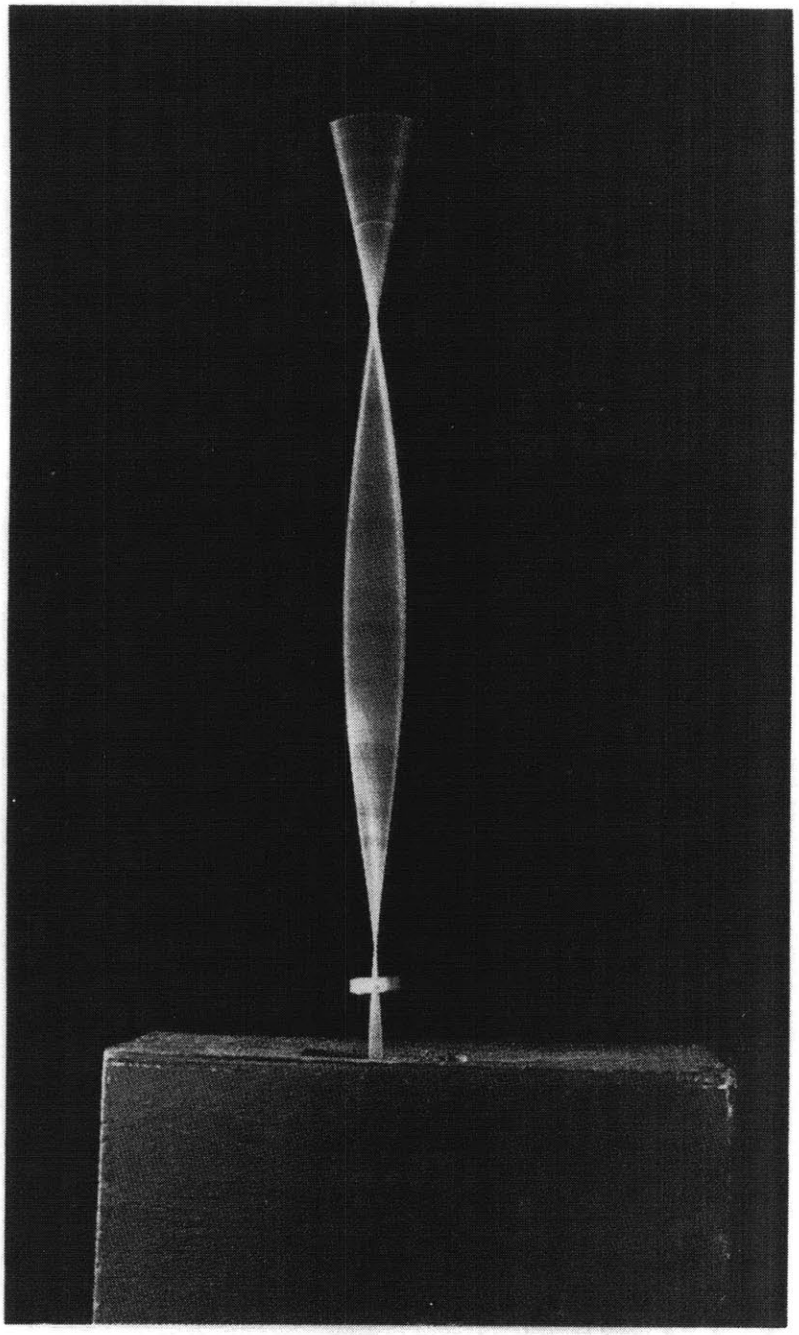


Fig 12 (Blomstrann) Naum Gabo, Kinetic Construction (Standing Wave)

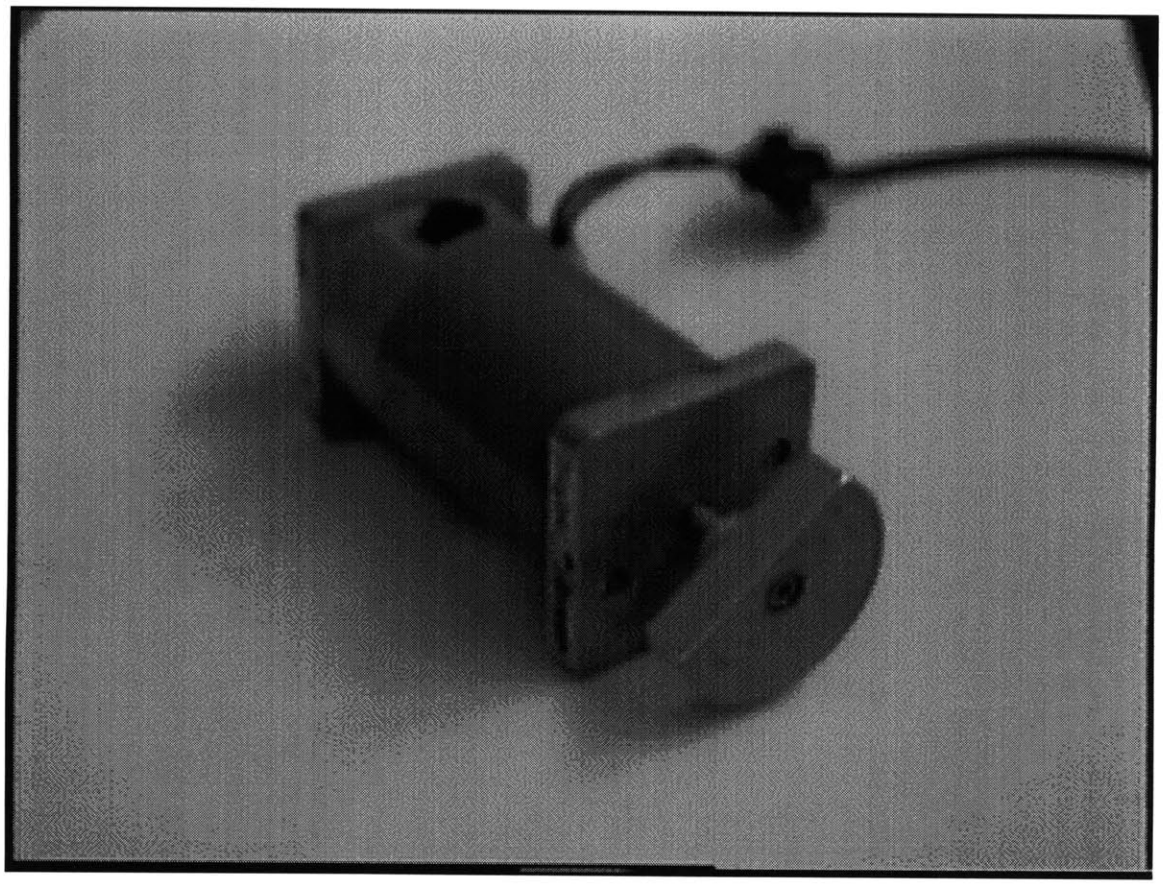


Fig 13 (Bain) Mechanical oscillator

Fig 14 (Bain) Mechanical oscillator mounted to girder system of the Live Room project

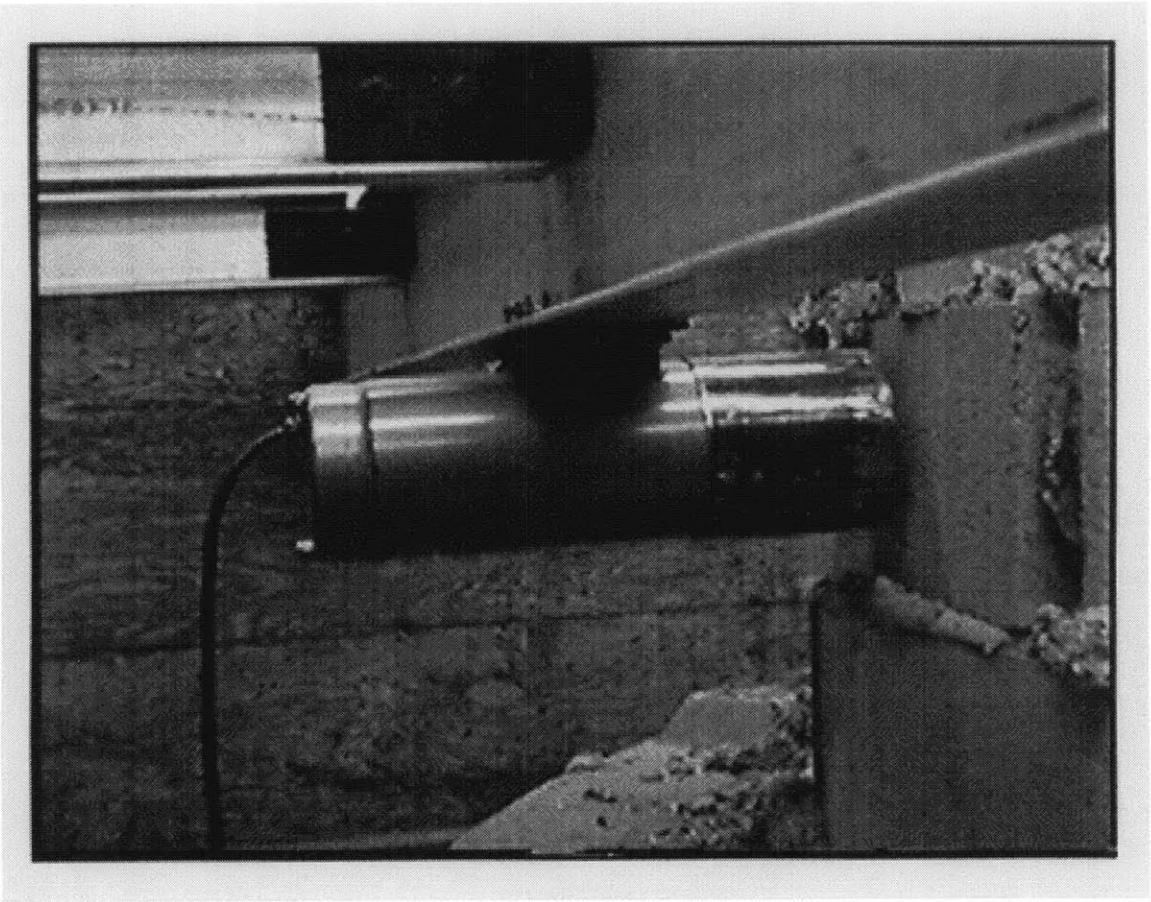


Fig 15 (Bain) Mechanical oscillator mounted to girder system of the Live Room project

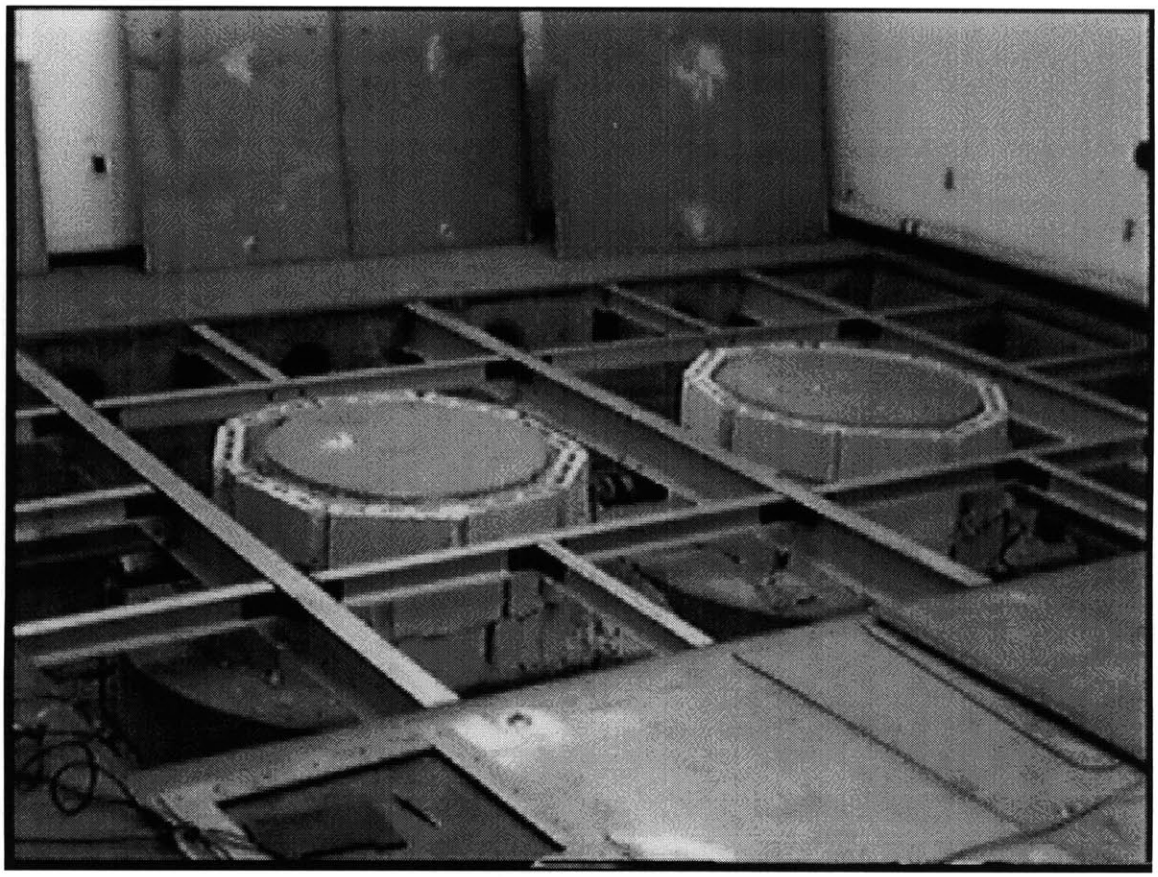


Fig 16 (Bain) Exposed girder system of the Live Room with two vibration isolation pads, floor plates removed

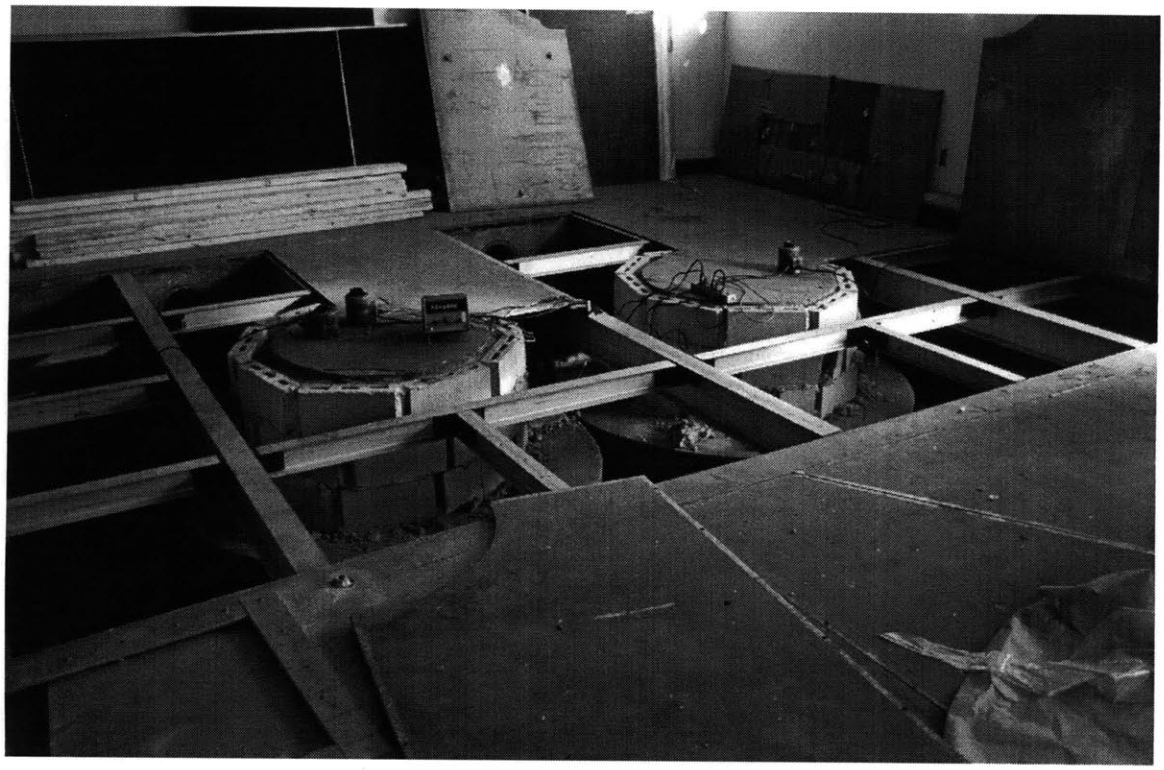


Fig 17 (Bain) Installation and frequency testing of the Live Room

Fig 18 (Bain) Floor panels replaced with two isolation pads in the center and control wire

Fig 19 (Bain) Detail of vibration isolation pad

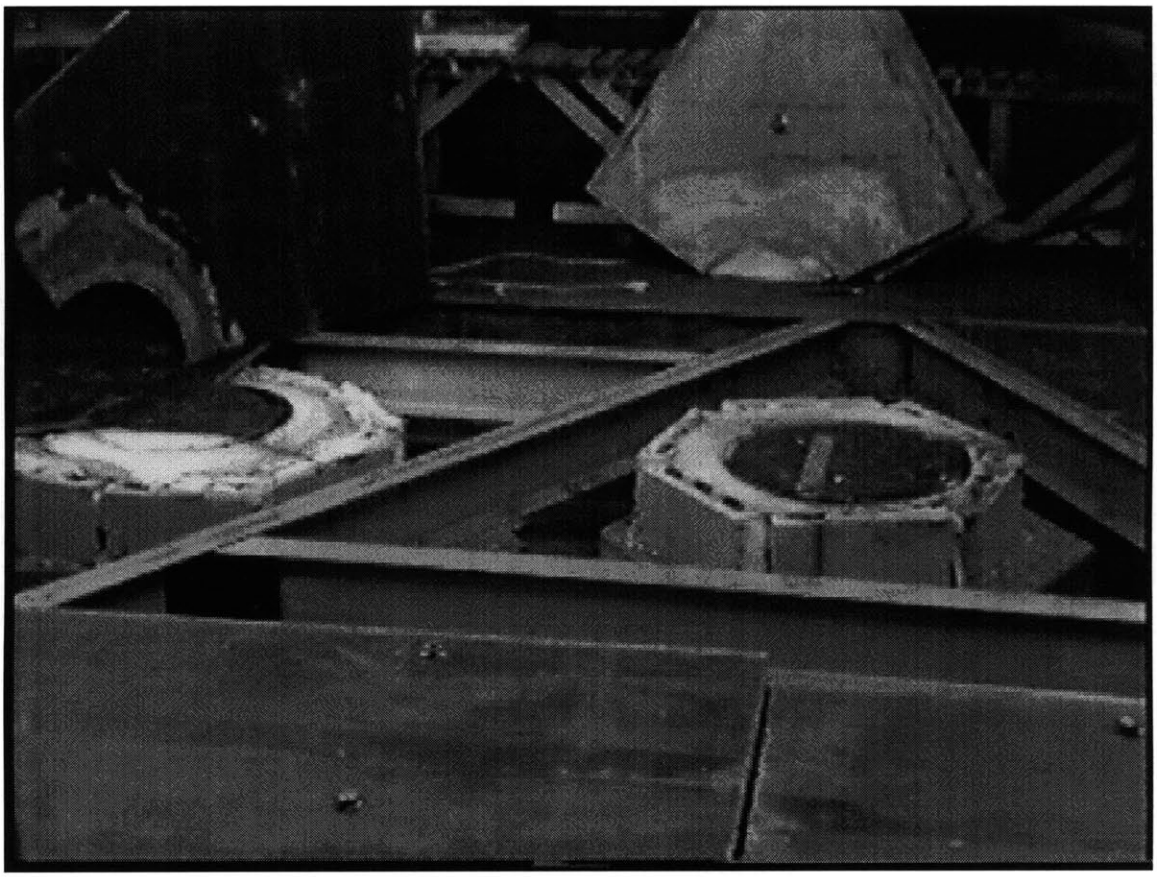


Fig 20 (Bain) Floor panels removed on secondary floor section

Fig 21 (Bain) Secondary floor section with floor panels replaced showing five isolation pads

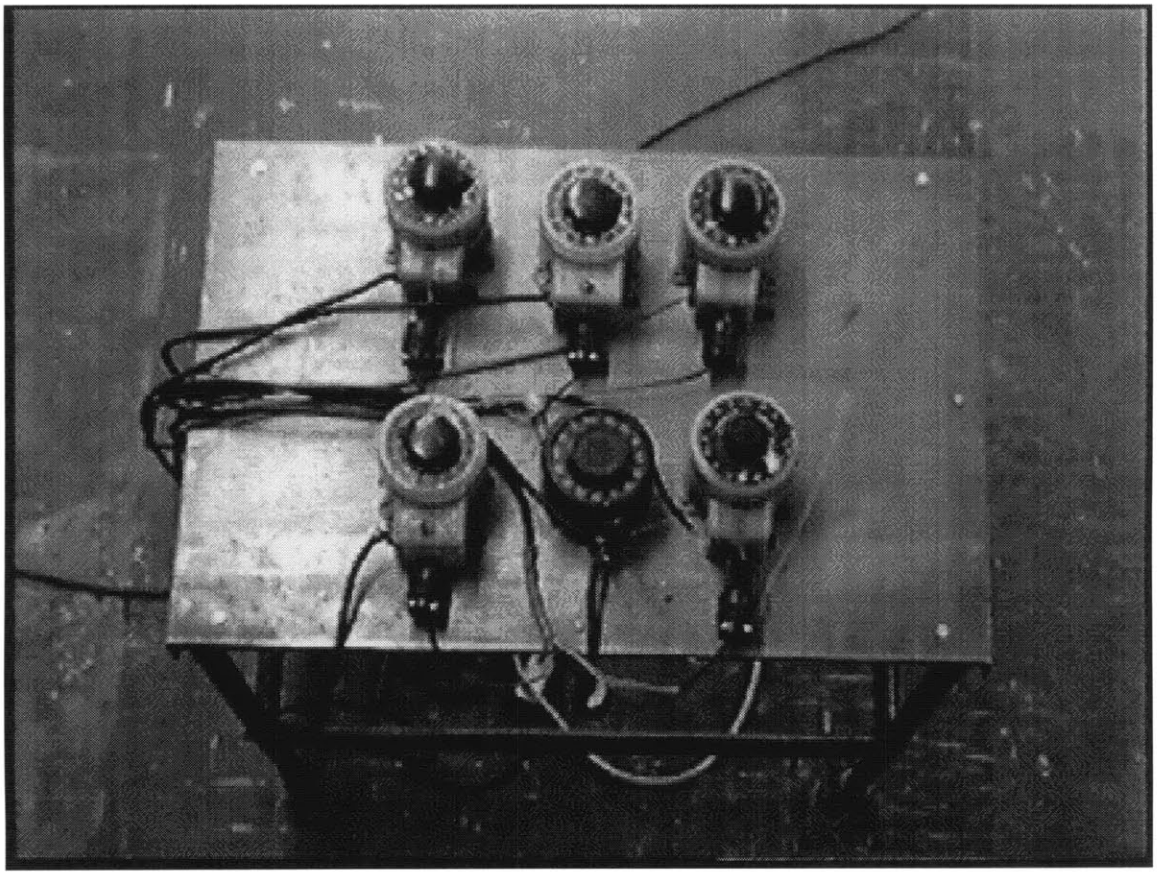


Fig 22 (Bain) The Live Room control table showing six rheostats

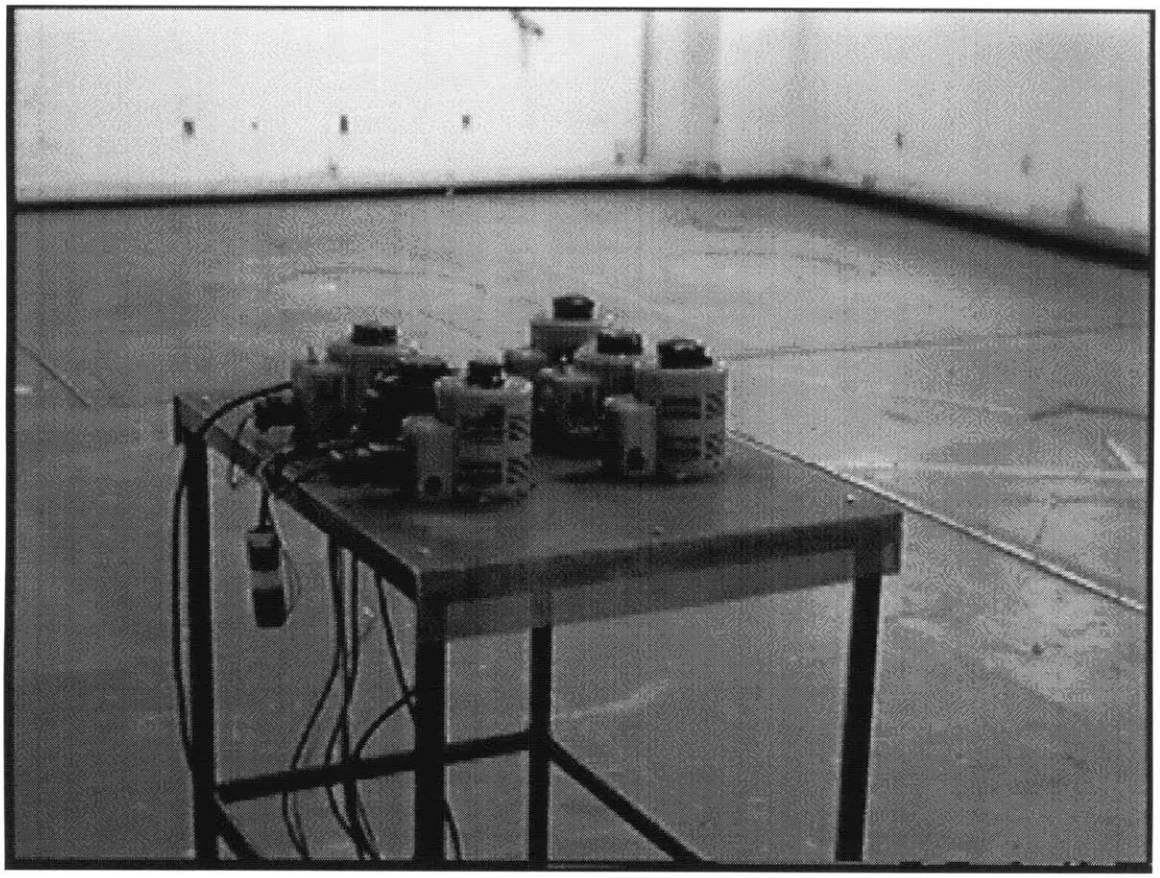


Fig 22 (Bain) Control table

Fig 23 (Bain) The Live Room

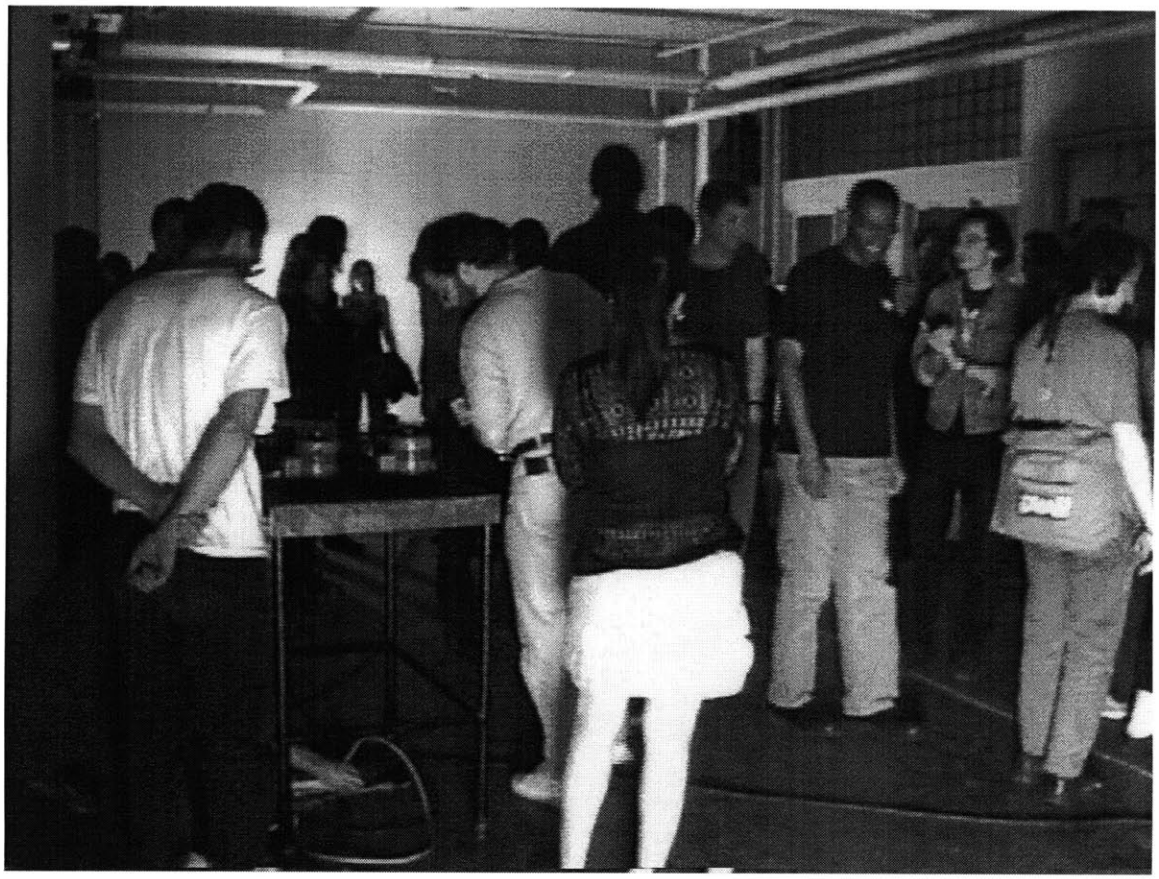
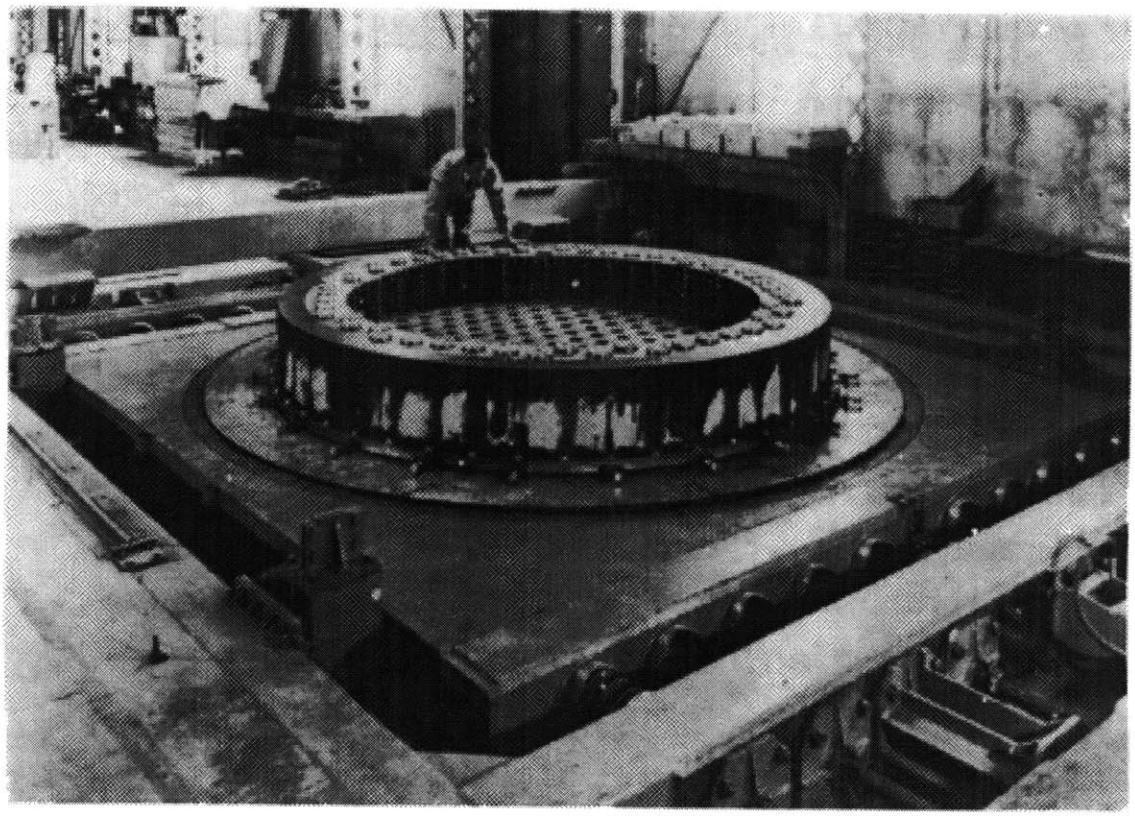


Fig 24 (Bain) The Live Room presented to the Electronic Research Society, MIT

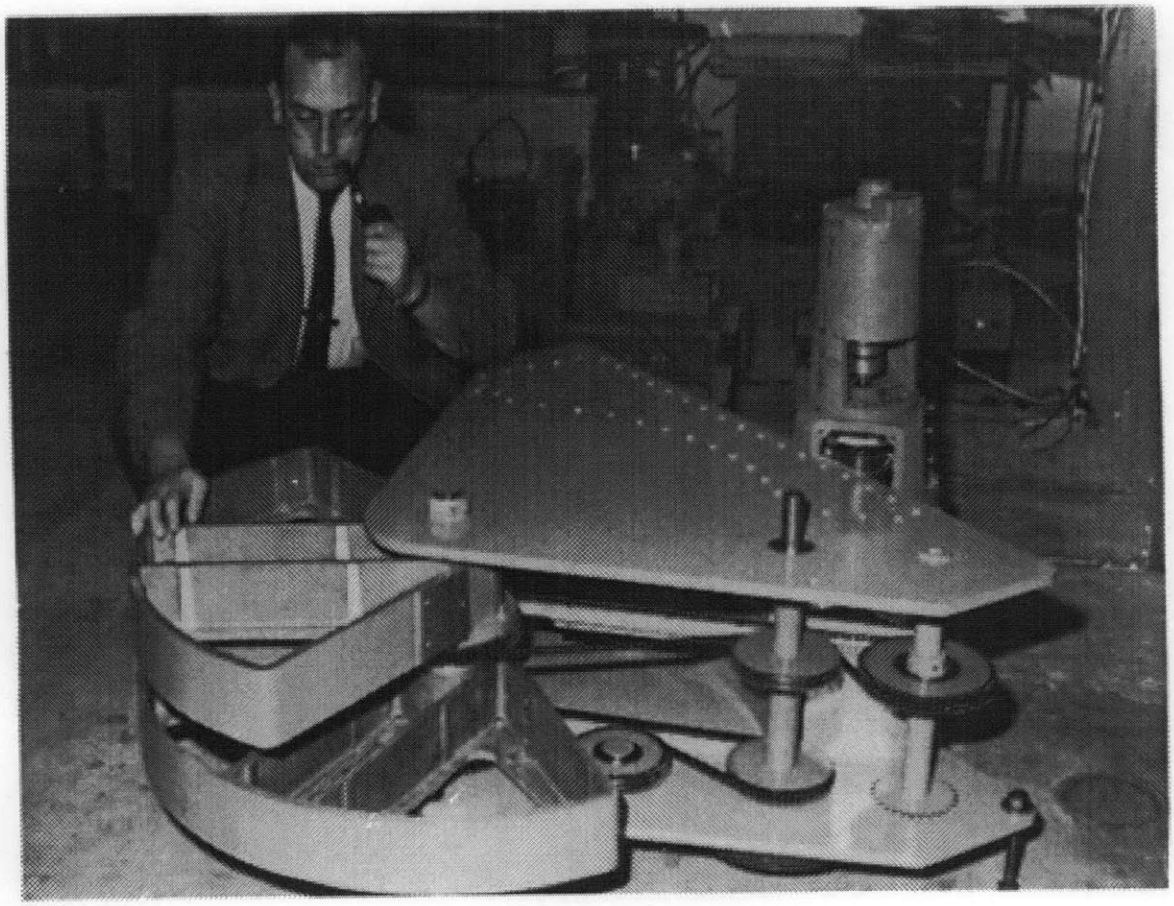
Appendix

Machines for seismic testing



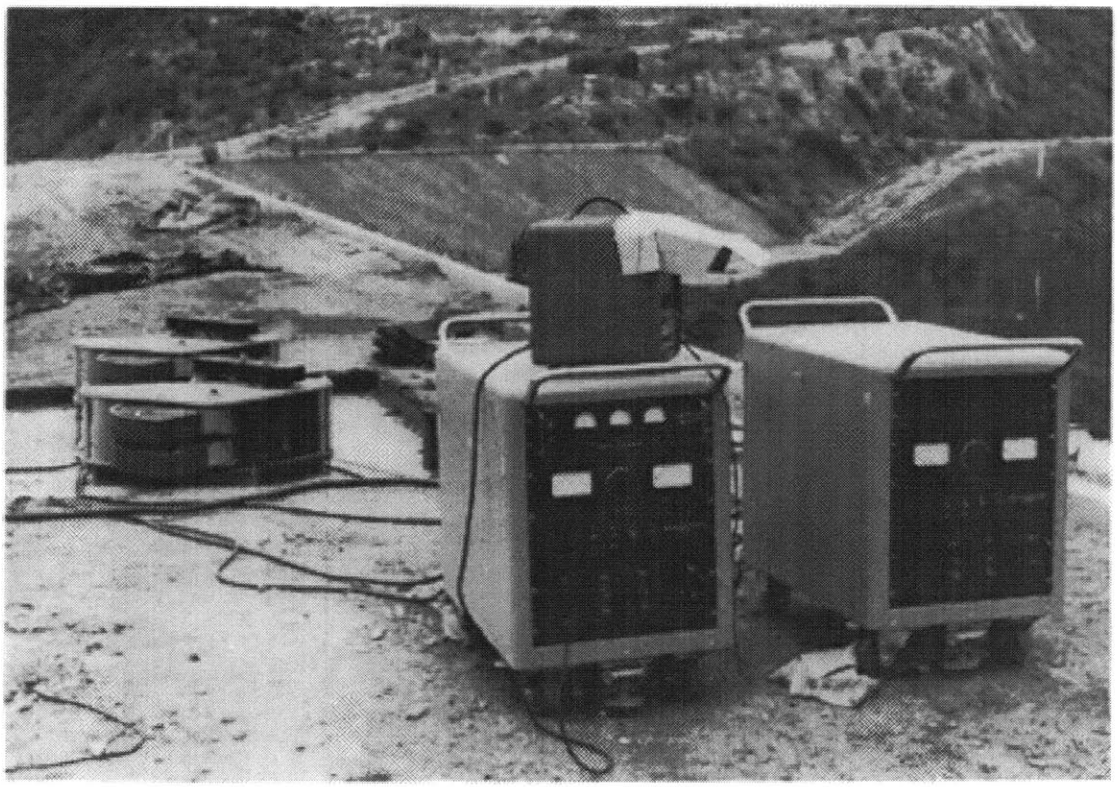
LARGE SEISMIC TEST TABLE OF THE JAPANESE BUILDING RESEARCH INSTITUTE.

Fig 25 (Hudson)



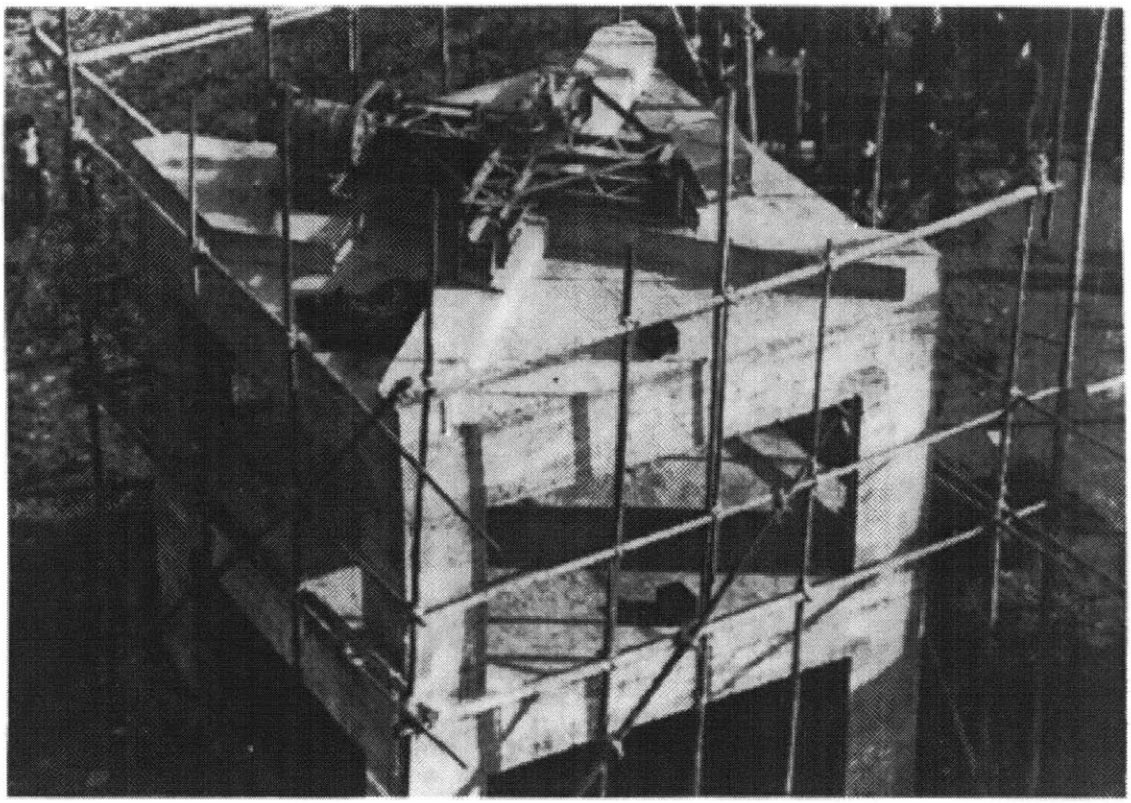
ROTATING WEIGHT VIBRATION EXCITER.

Fig 26 (Hudson)



SYNCHRONIZED ROTATING-WEIGHT VIBRATION EXCITERS AND SPEED CONTROL EQUIPMENT.

Fig 27 (Hudson)



LARGE BUILDING VIBRATOR OF THE JAPANESE BUILDING RESEARCH INSTITUTE.

Fig 28 (Hudson)

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