FREQUENCY AND TIME GENERATION AND CONTROL

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ABSTRACT

FEI designs, develops and manufactures high precision quartz crystal oscillators, cesium beam atomic resonators, and cesium beam atomic standards for time and frequency generation equipment for ground, airborne, and space use. In order to utilize our resources more efficiently, the problem that we face is lack of long term visibility of DOD and NASA needs, and the enormous variety of hardware that we have to custom design for each individual program.

It is also becoming quite apparent that with the lack of significant R & D funds available from Government, advances in technology are slow, and in FEI's opinion, will not be able to meet near-future requirements such as GPS user equipment, Seektalk, and other programs. Because of the high risk factors involved, and the commercial applications of this product being too far off in the future, private capital for research and development is difficult if not impossible to obtain. More specific analysis and FEI's recommendation to overcome these difficulties will be objectively presented herein.

INTRODUCTION

FEI is a vertically integrated corporation, supplying frequency and time control components, sub-systems and systems for the military and aerospace users from the raw quartz to a finished timing system, and from the fabrication technology of the cesium resonators to the finished cesium atomic clock. It has been the Company's experience and history over the past eighteen years of its existence that the majority of its engineering talent has been applied to making modifications for each particular system of existing technologies rather than to further the state of the art and concentrate its talents on future needs and cost reduction. The Company has produced over twenty different types of distribution amplifiers; fourteen types of quartz standards; eighteen different oven controlled oscillators for the aerospace industry; and thirty-five different temperature compensated crystal oscillators, for the missile and space industry.

INSTRUMENTS AND SYSTEMS

The large variety of instruments and systems as exemplified by the equipment shown in Figures 1 thru 34, indicate the enormous amount of man hours that have been expended to hand-tailor similar functions for each particular user on pretty much of a crash basis. A careful analysis indicates that better planning and coordination between various DOD and NASA users, and the discipline to design and plan functional equipments that can be used over and over again in systems will reduce lead time costs enormously and at the same time make available the necessary engineering talent for use in the further development and the design of high reliability equipment at lower cost.

SIMILAR FUNCTIONAL MODULES

Similar functional modules that require significant redesign and repackaging in order to meet the particular specification requirements of specific systems are very expensive and time consuming to produce. There has been minimal standardization of products, which FEI feels is needed in spite of the past pitfalls of such standardization attempts which were buried in red tape and over-complications. Frequency and time generation and distribution equipment and systems need direction, standardization and long range planning in order to more effectively accomplish reliability, lower cost, and make available the desperately needed manpower to do the designs that will be required five to ten years hence.

OVEN CONTROLLED PRECISION OSCILLATORS

Oven controlled precision oscillators primarily for missile and satellite applications have been designed in hundreds of physical configurations as shown in Figures 5 thru 19. The basic functions of the oscillators, is to achieve low power (1 watt at room temperature), provide high stability ($1\text{-}5\times10^{-11}$/day) and survive launch vibrations. The enormous quantity of types of oscillators could be reduced by possibly two to three times by standardization and coordination between various users. FEI has found that out of a one hundred man engineering team, approximately seventy are expended on custom redesign for a specific system application. The exact frequency is not a limitation on a manufacturer such as FEI because we build our own resonators. However, the need for accommodating the various types of input and output control signals and physical configurations and the large variation in surface finishes all impose significant cost and risk factors in meeting a timely delivery schedule. As was the case for instruments and systems, FEI would welcome closer coordination between all aerospace users so that we can better service the industry and not expend all of our engineering talents for the large variety of designs that we are presently fulfilling.

OTHER CRYSTAL COMPONENTS

Temperature compensated crystal oscillators, crystal filters, and crystal discriminators for the missile and aerospace industry is another example of the enormous variation in shapes, form factors, and input voltages that must be designed into the equipment in order to meet the particular application of each user. In spite of having over one hundred different designs available for users to pick from, we find ourselves continuously custom designing to fit each application. Coordination between various users and the investment in developing a half dozen modules would most likely meet 90% of the needs of the users in the missile and aerospace field.

While FEI, and I am sure many others in the frequency and time control field, are working sixteen hour days to fulfill various different system applications, the planning for the future, and the research required for the advancement of the art is greatly lacking. We are so busy meeting our day to day needs in terms of engineering and production in quartz resonators that there is no time left for research and development for the future. Quartz resonators, I might add, have made very little progress from the precision resonators first developed at Bell Laboratories in the early 1950's. Even the various atomic standards have progressed very slowly from the mid-1960's.

CONCLUSION

It is FEI's recommendation that the following steps be taken immediately in order to service DOD, NASA, and eventually commercial users, in the next decade.

1. Establish a well planned and coordinated program to improve the basic raw material.
2. Finance research and development with continuity of multi-year programs for the development of high performance, high reliability, quartz resonators.
3. Invest in the necessary research and development for economically manufacturing the precision quartz resonator.
4. Develop economical, high reliablity, thermal controlled electronics and associated electronic circuitry to make use of the improved resonators, in order to meet the stringent future requirements of fast warmup, low g sensitivity, high stability, and high spectral purity sources of quartz oscillators and quartz standards.
5. Sponsor research in development a basic physics package to improve life and reliability, reduce manufacturing costs, and establish the capability for manufacturing the quantities of atomic standards that will be required in the next decade.
6. Coordinate and clearly outline the long range needs of ground, airborne, and space applications for frequency and time controlled components and systems in order to minimize the time and money expended by eliminating a multitude of different designs to accomplish the same function.

It is quite apparent, in FEI's view, that with the uncertainty in the production potential for DOD and NASA needs, private industry does not have the resources and the risk capital to do the basic research and development necessary to meet future needs. Therefore, it is imperative that the future specification requirements and the quantities needed be determined, and that the government sponsor basic and applied multi-year research programs if the industry is to meet the needs of the user in the next decade.

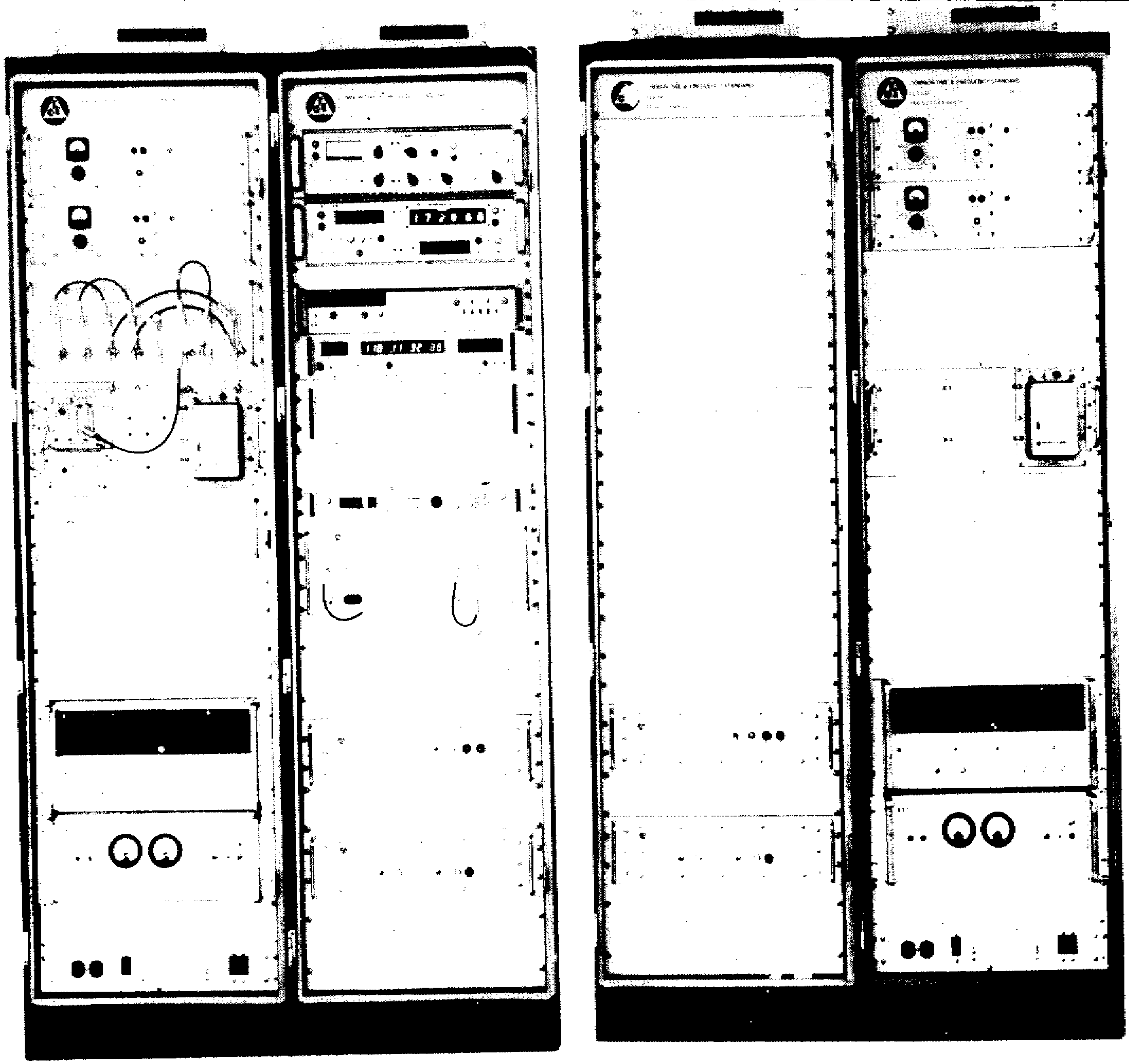

Figure 1. Common Time and Frequency Standard (CTFS)
Model FE-5054A
TDRSS Ground Station

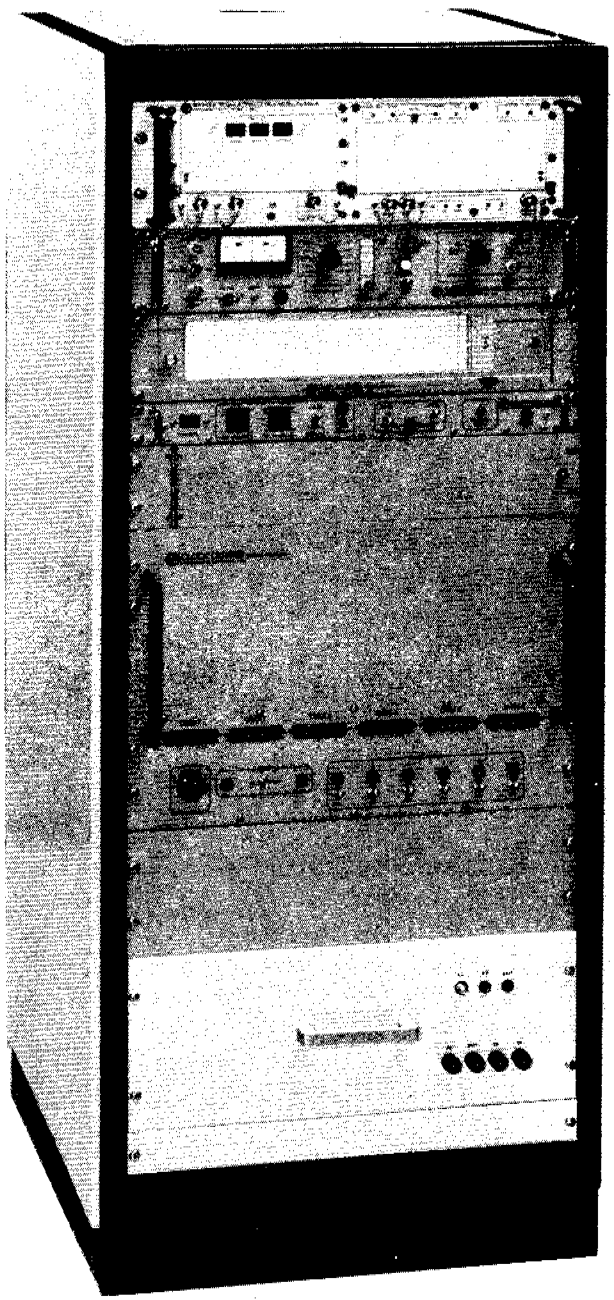

Figure 2. Frequency and Time Measuring System
Model FE-5070A
Seektalk

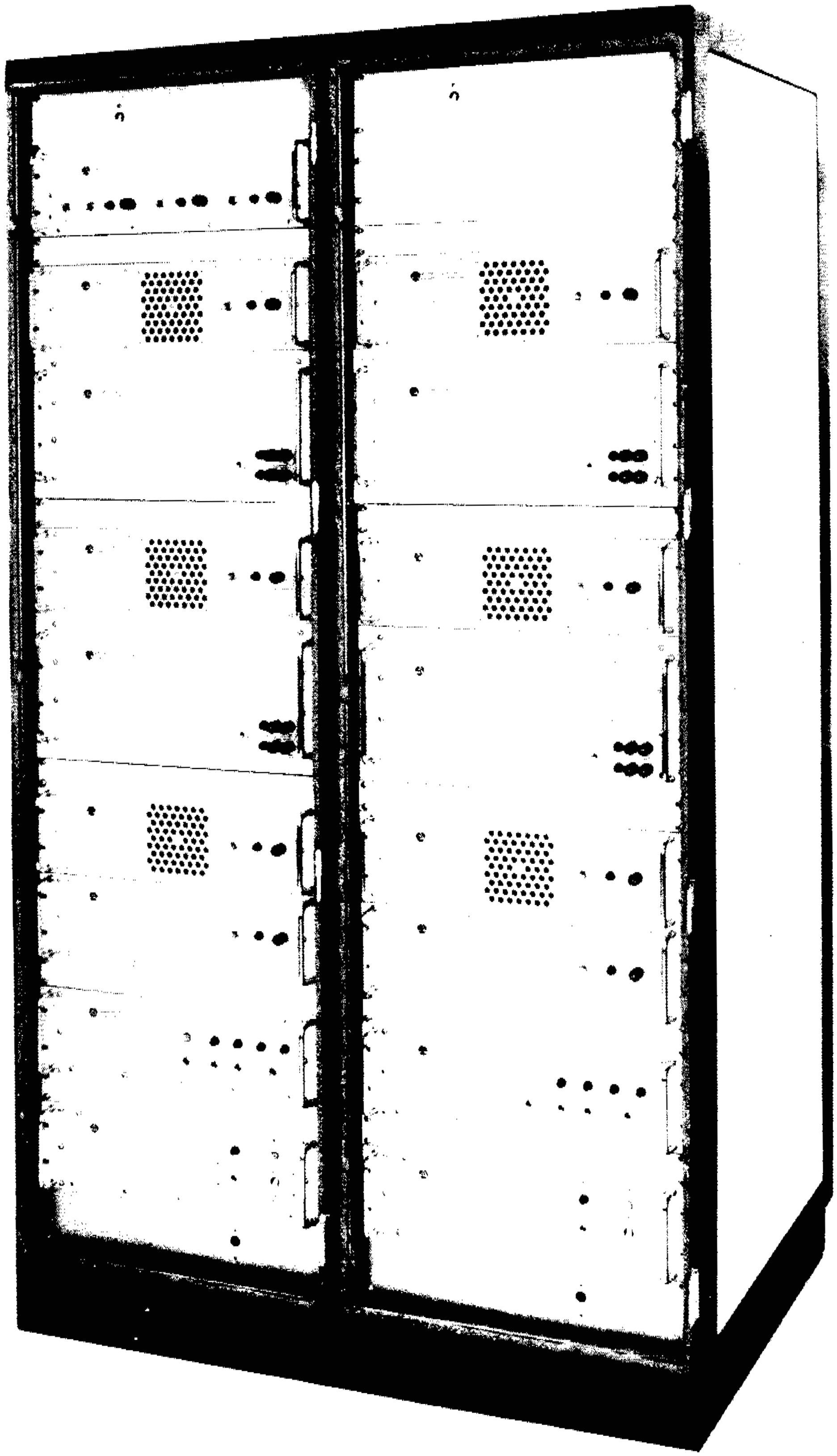

Figure 3. RF Switching Group
Model FE-7728A
HF Surveillance System

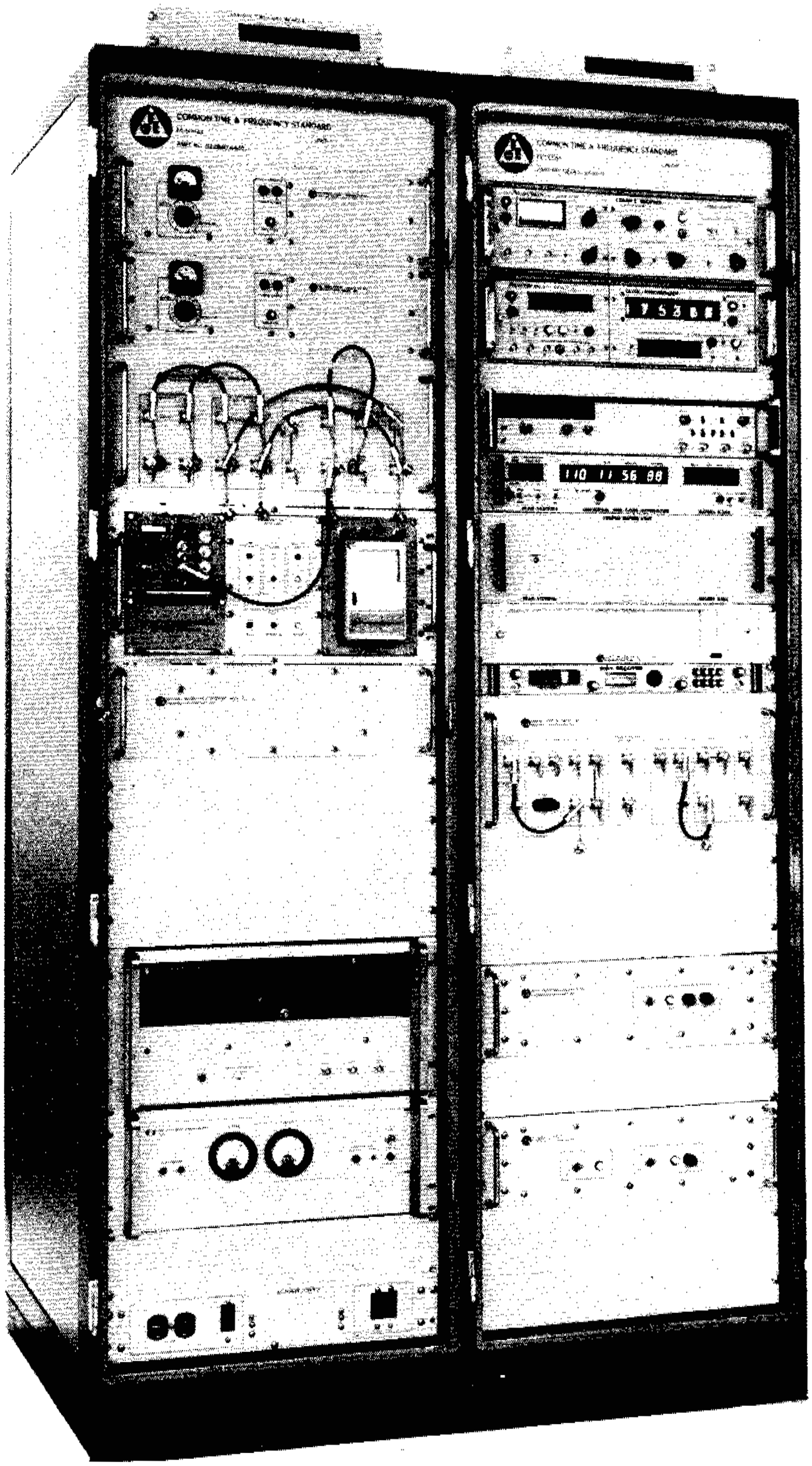

Figure 4. Common Time and Frequency Standard (CTFS)
Model FE-5054A
TDRSS Ground Station

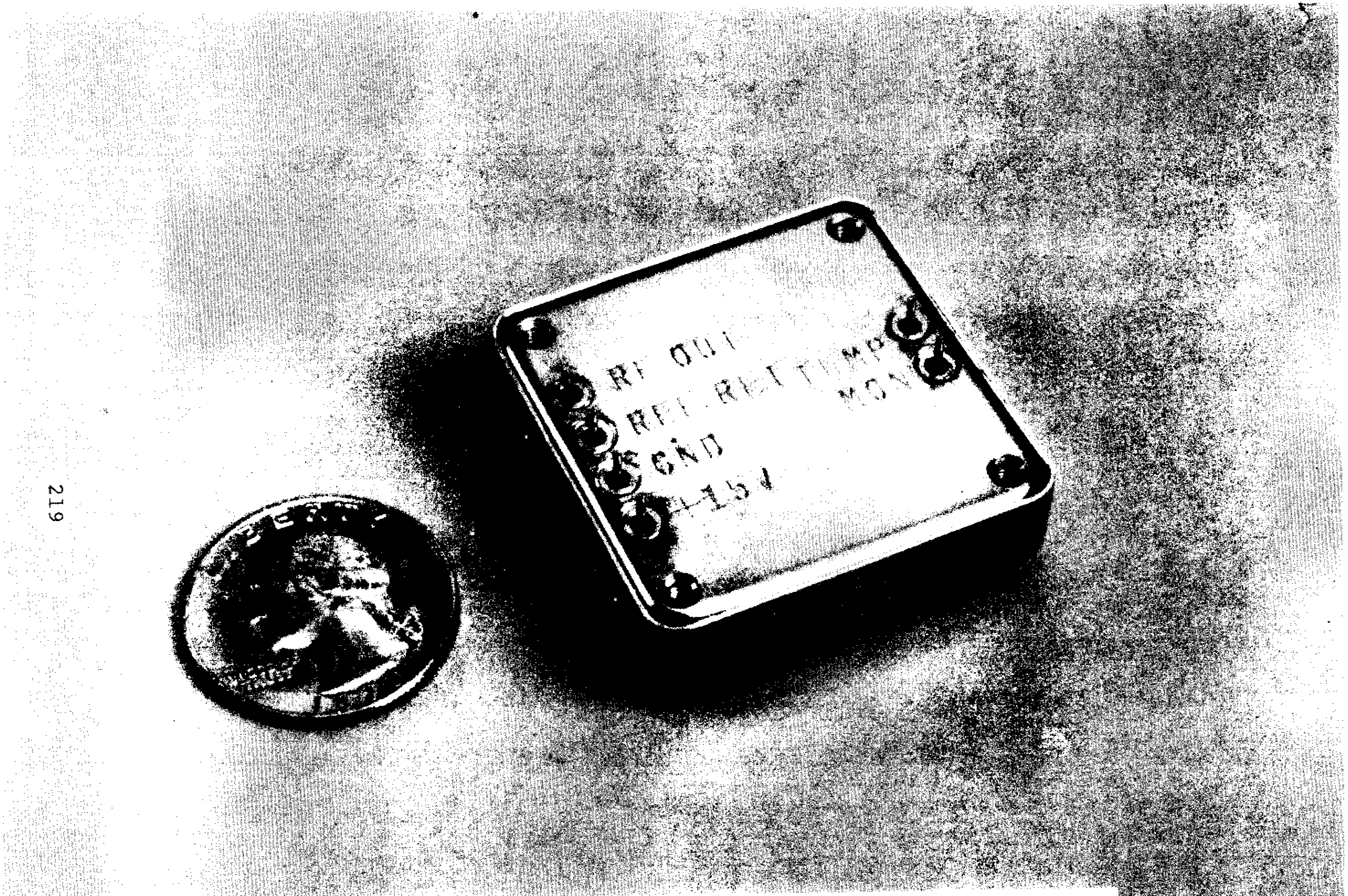

Figure 5. Temperature Controlled Crystal Oscillator (TCXO)
Model FE-8121B
Trident

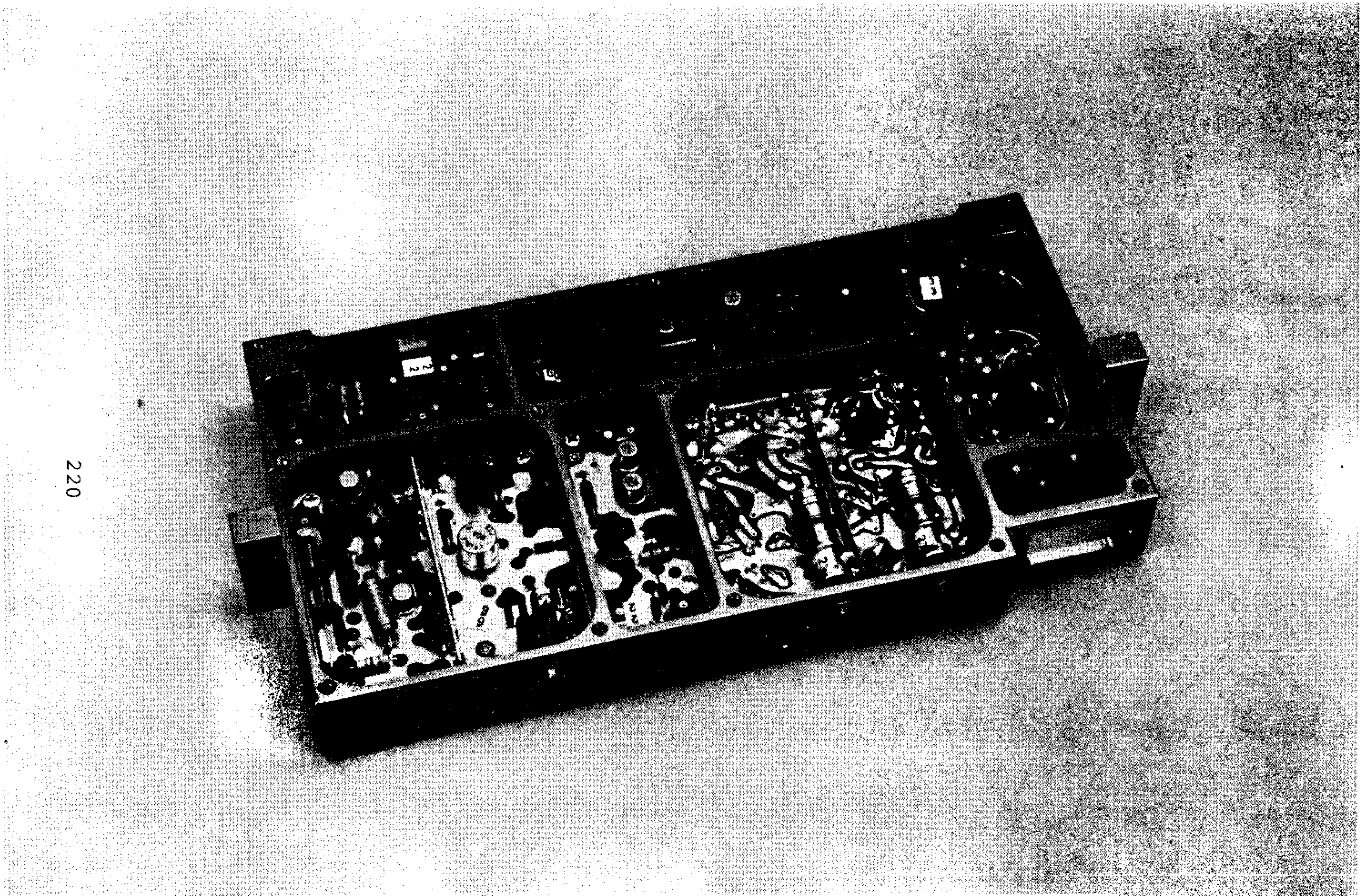

Figure 6. Double Local Oscillator
Model FE-2075A
Application Technology Satellite

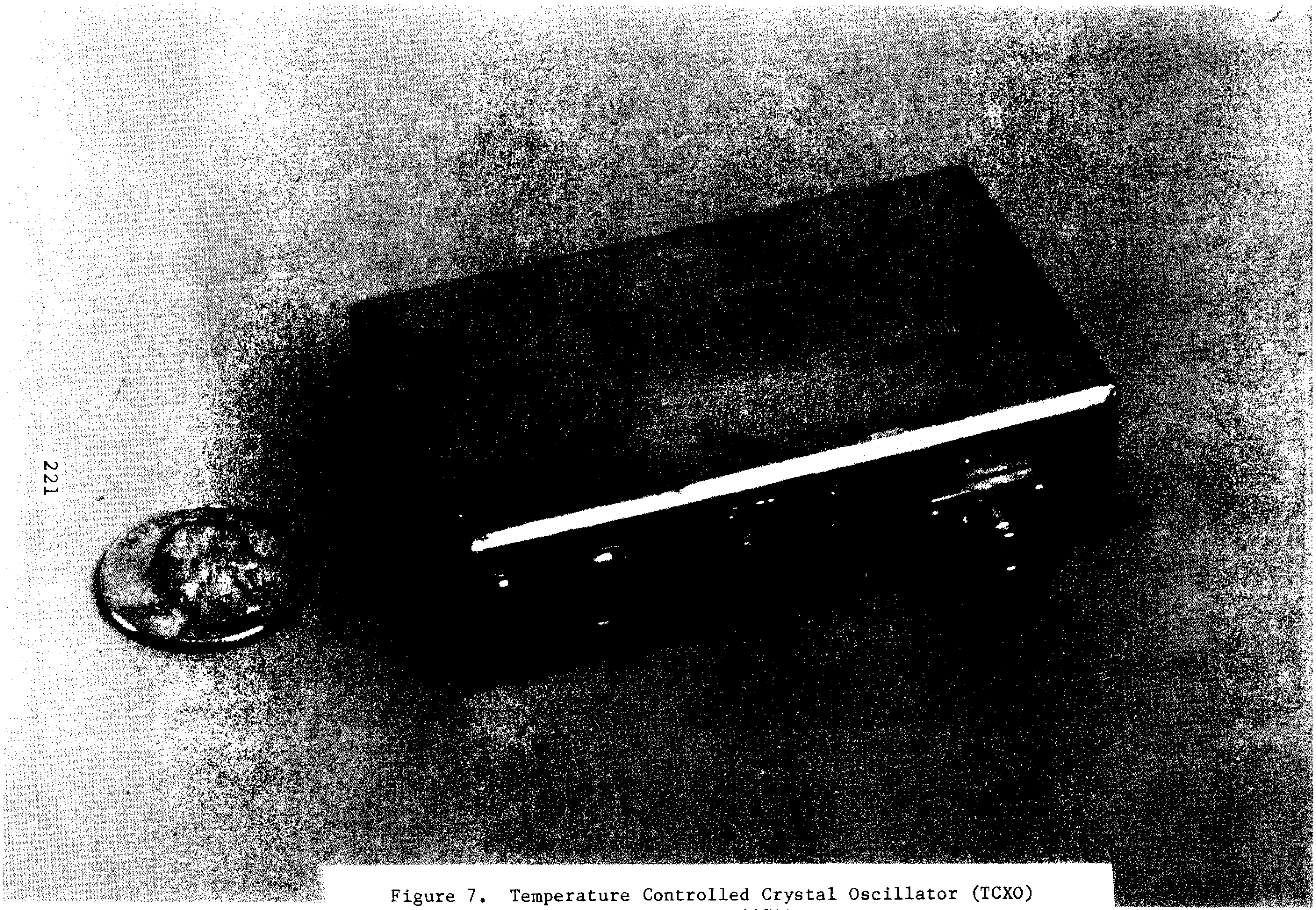

Figure 7. Temperature Controlled Crystal Oscillator (TCXO)
Model FE-8031A
Communications Satellite (777)

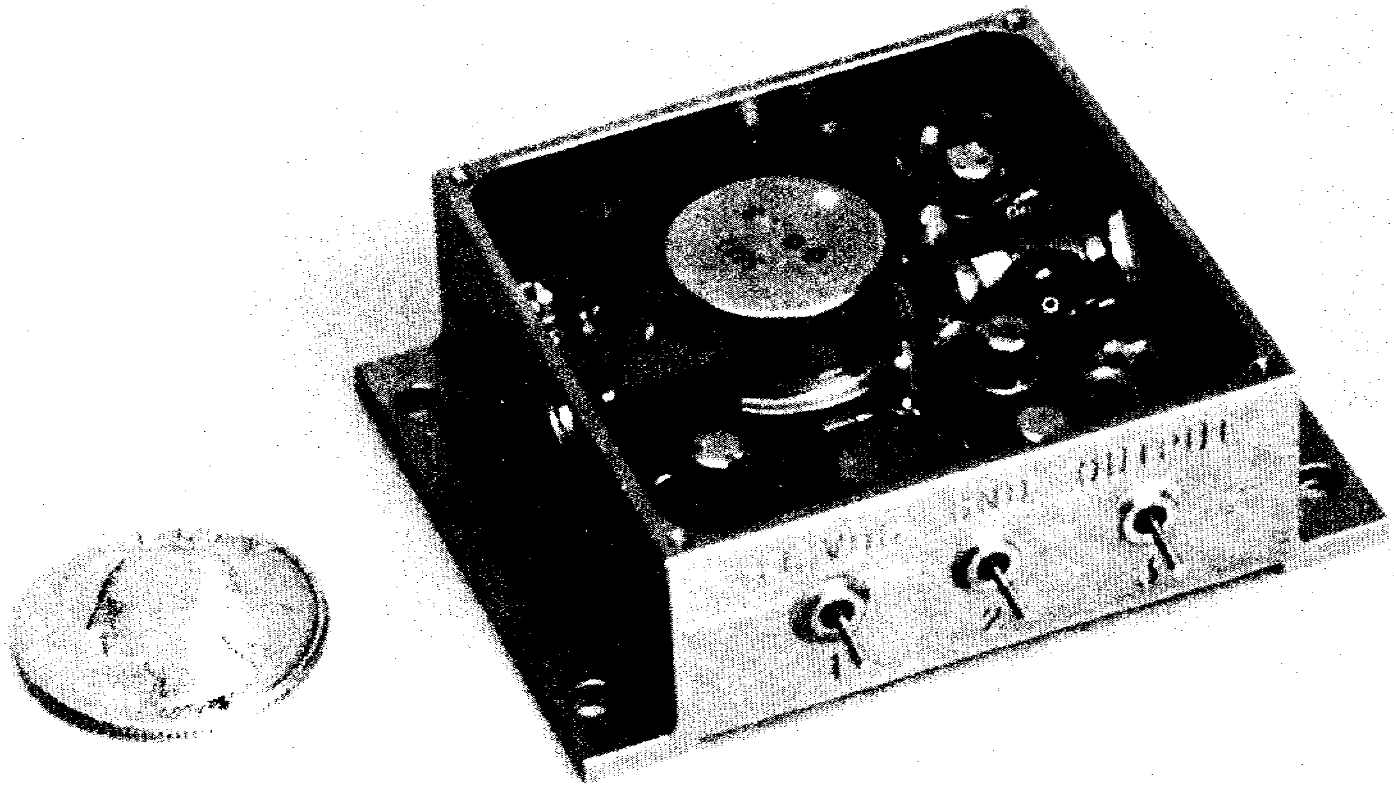

Figure 8. Temperature Controlled Crystal Oscillator (TCXO)
Top View, Model FE-8119A
Pioneer-Venus

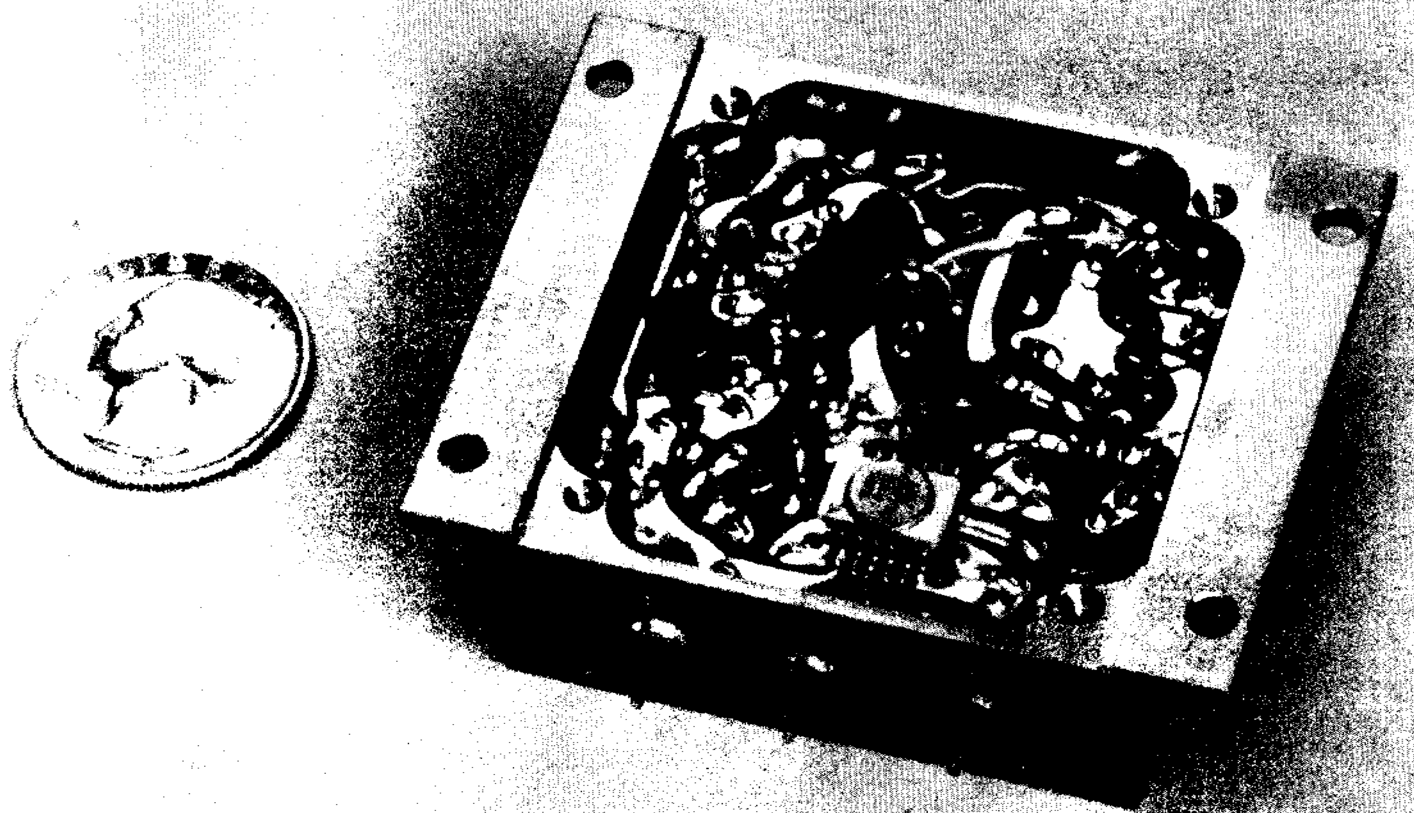

Figure 9. Temperature Controlled Crystal Oscillator (TCXO)
Bottom View, Model FE-8119A
Pioneer-Venus

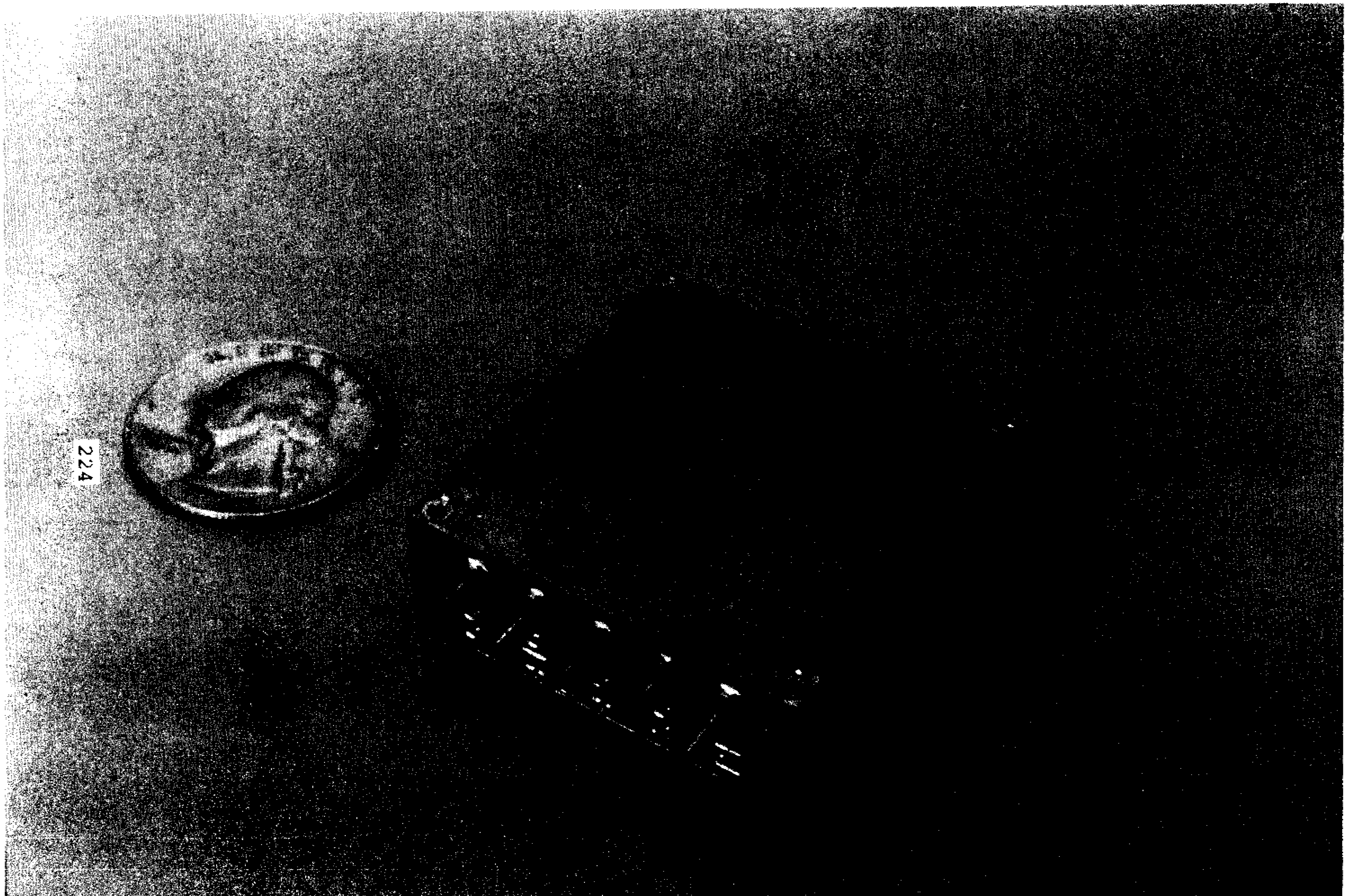

Figure 10. Temperature Controlled Crystal Oscillator (TCXO)

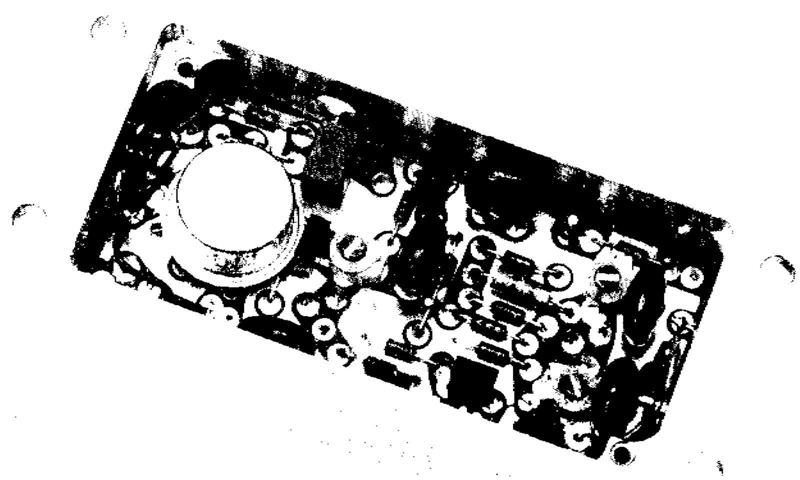

Figure 11. Temperature Controlled Crystal Oscillator (OCXO)
Model FE-8137B
Patriot Missile

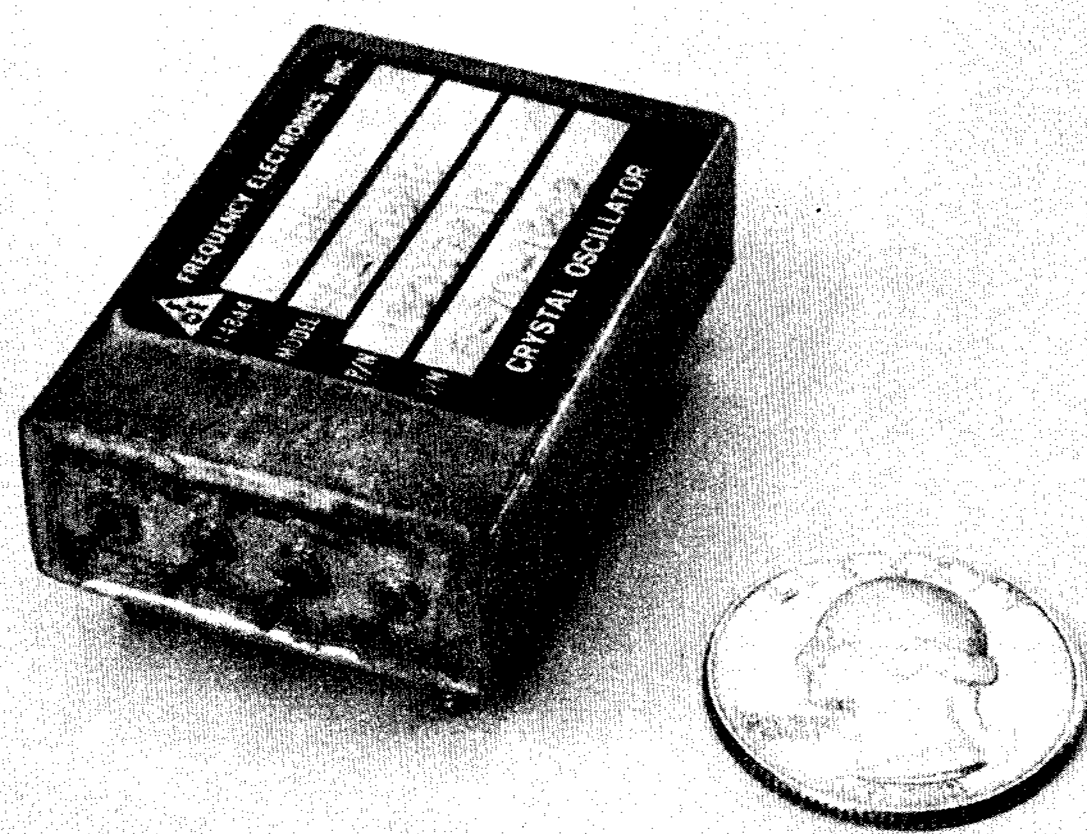

Figure 12. Temperature Controlled Crystal Oscillator (TCXO)
Model FE-8034B
Pioneer 10 and Pioneer 11

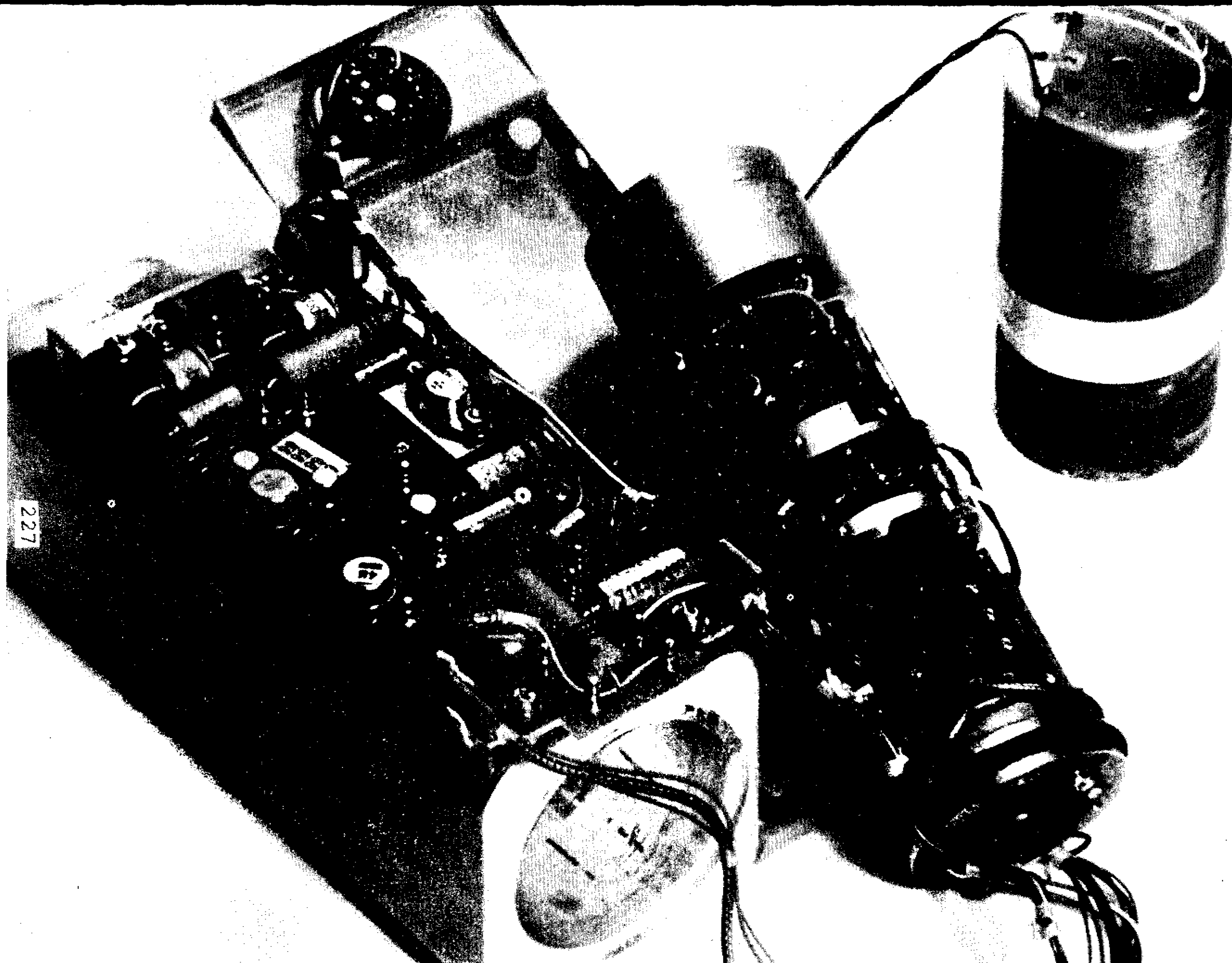

Figure 13. Oven Controlled Crystal Oscillator (OCXO)
Model FE-2037B-5.2
OSO Program

Figure 14. Low Power Precision Oscillator
Model Fe-10A-MOD-L
Timation I and Timation II

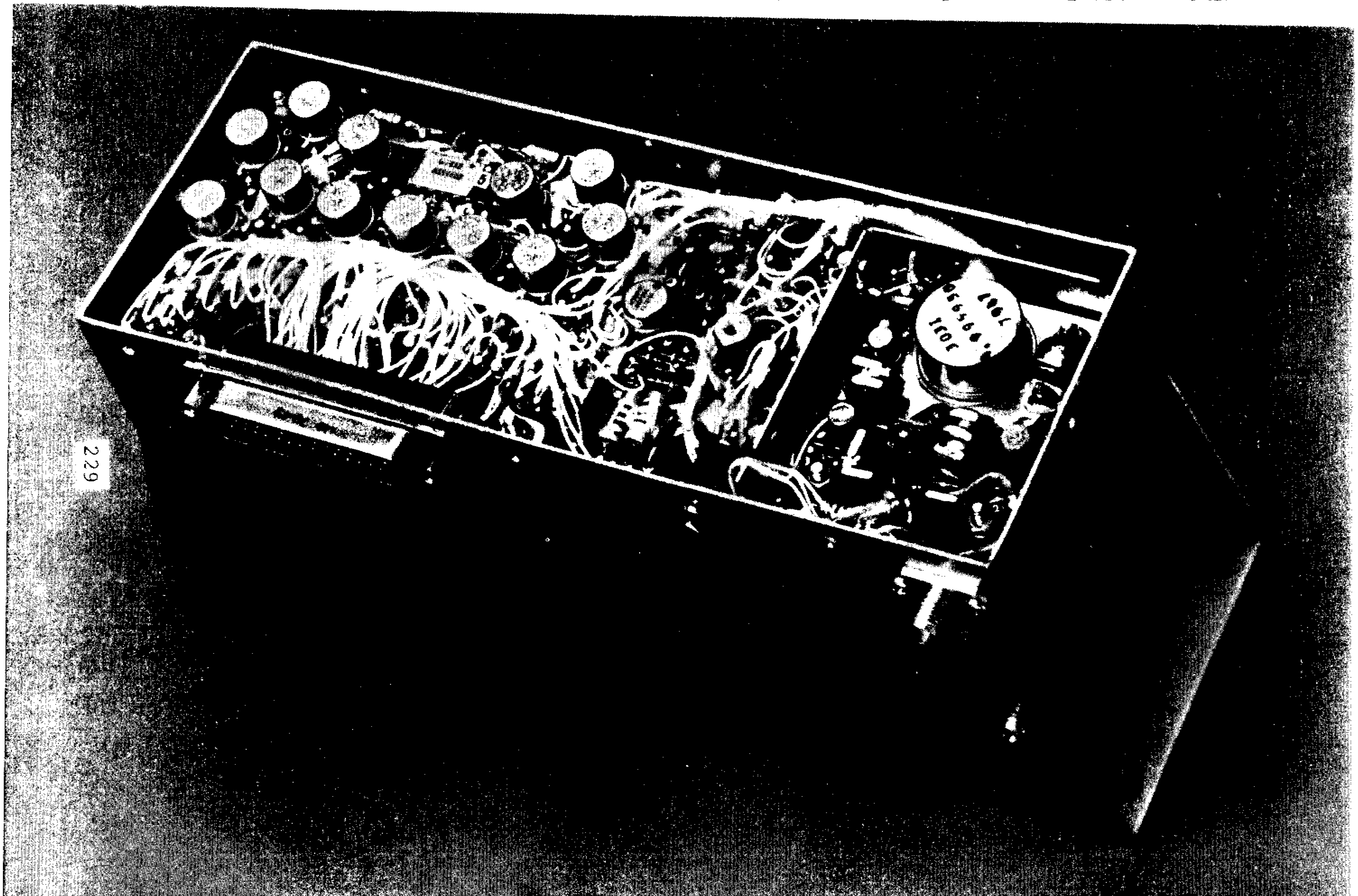

Figure 15. Oven Controlled Crystal Oscillator (OCXO)
Model FE-2158A
HS 350

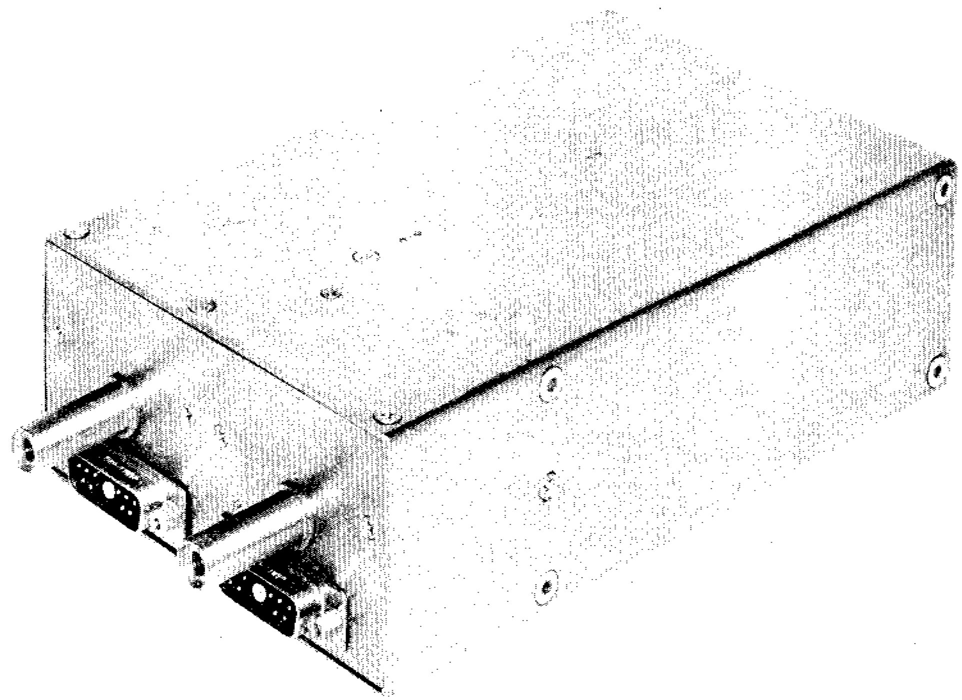

Figure 16. Ultra-Stable Oscillator (OUS)
Model FE-2108A
TIROS N

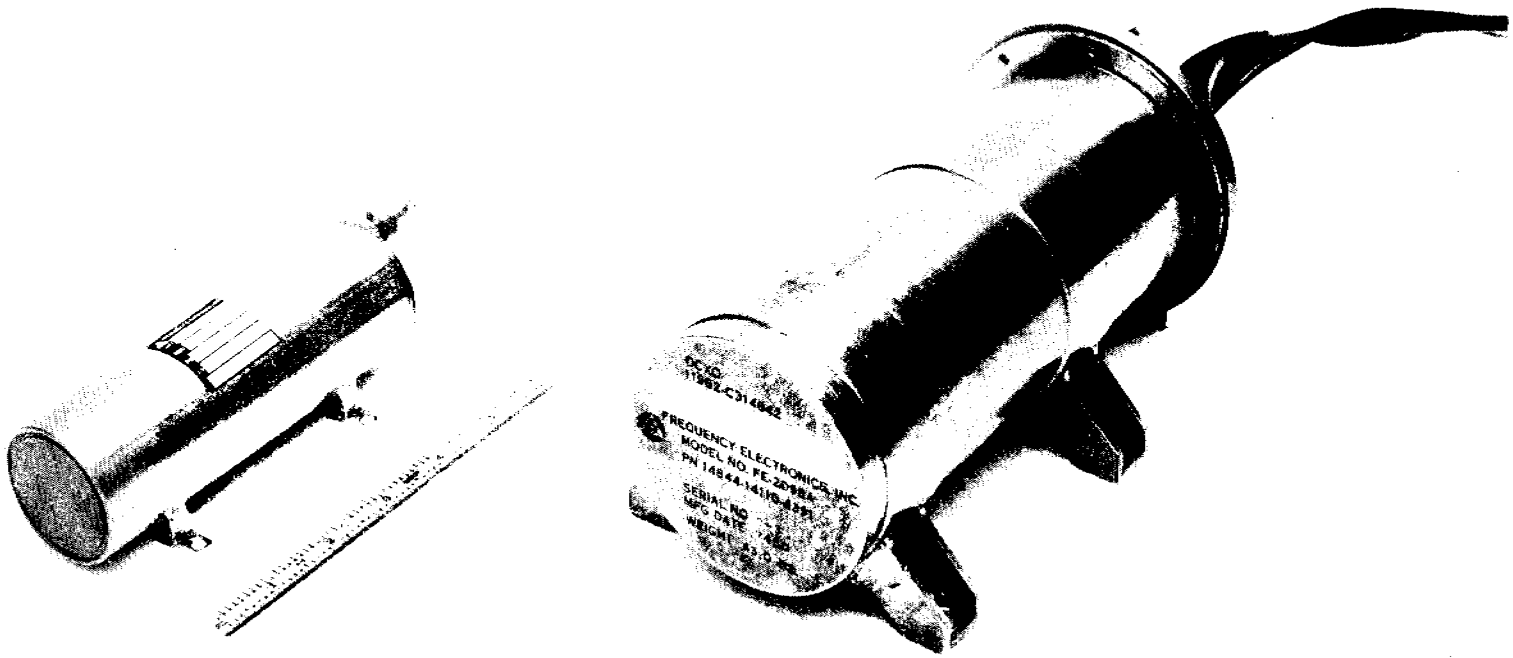

Figure 17. Stable Oscillator (OCXO) Model FE-2161A GALILEO Probe Program vs. Oven Controlled Crystal Oscillator (OCXO) Model FE-2098A FLTSATCOM

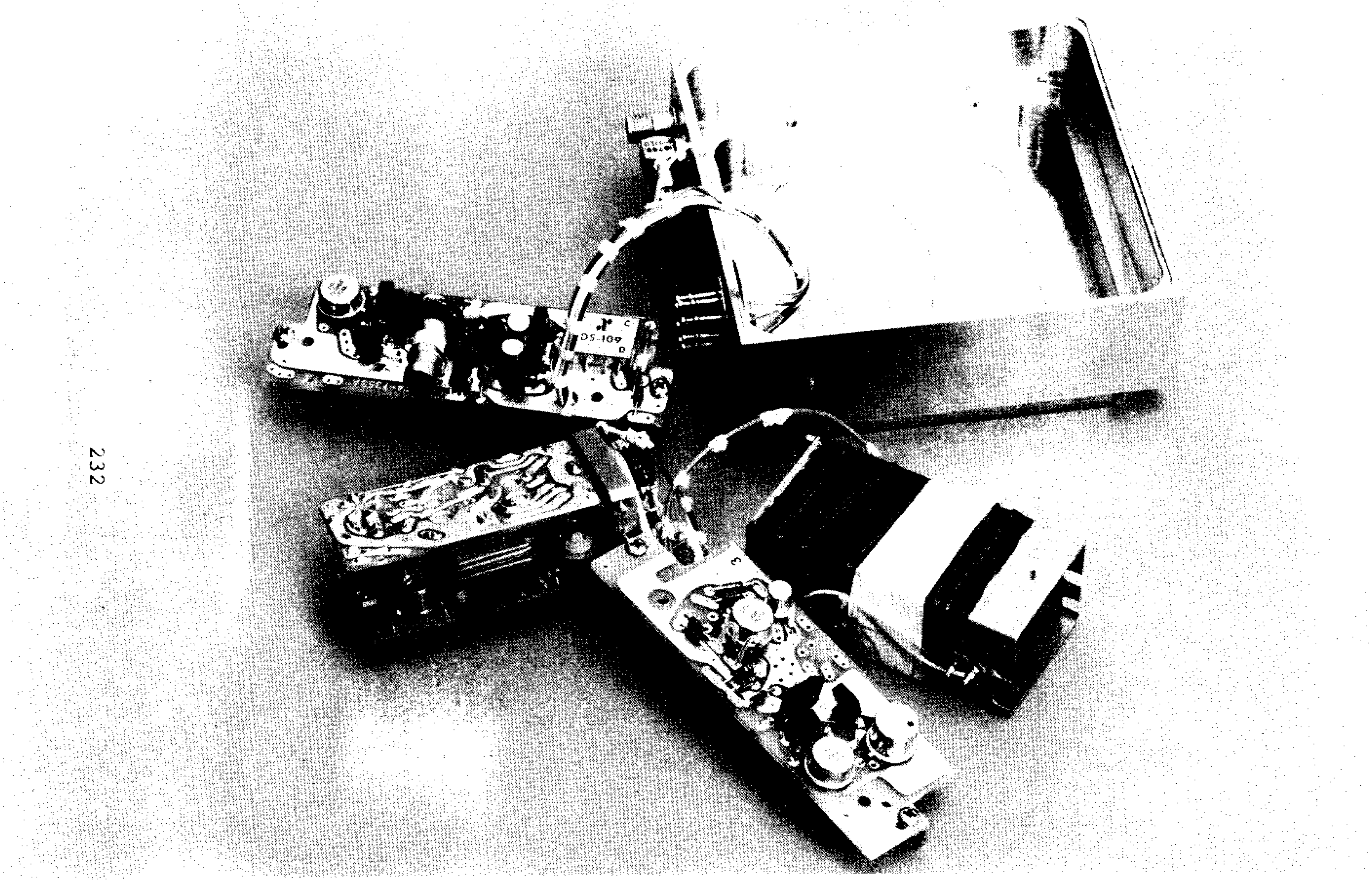

Figure 18. Fast Warmup Crystal Oscillator, SC Cut
Model FE-2163A

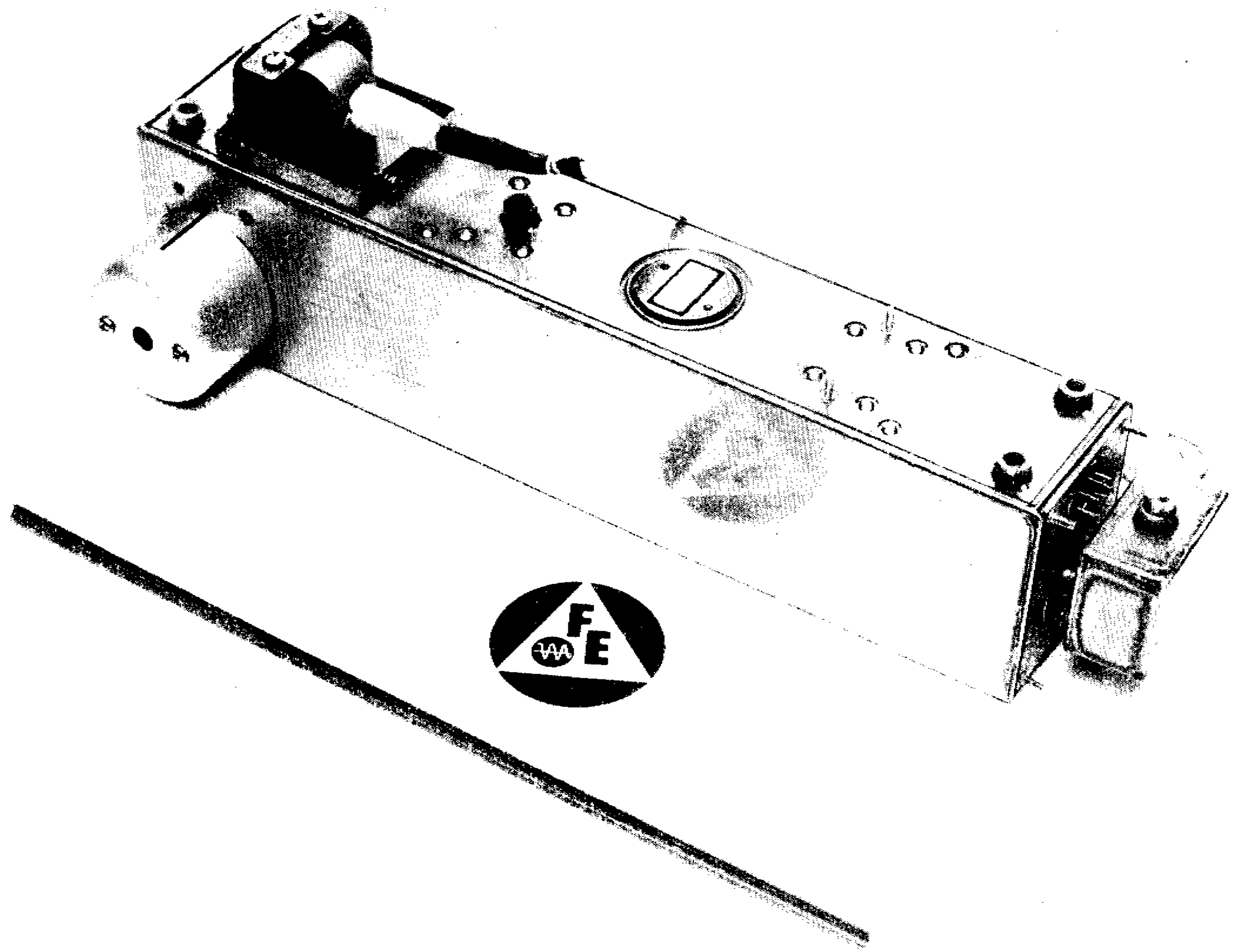

Figure 19. Lightweight Cesium Beam Tube Resonator
Model FE-6203A

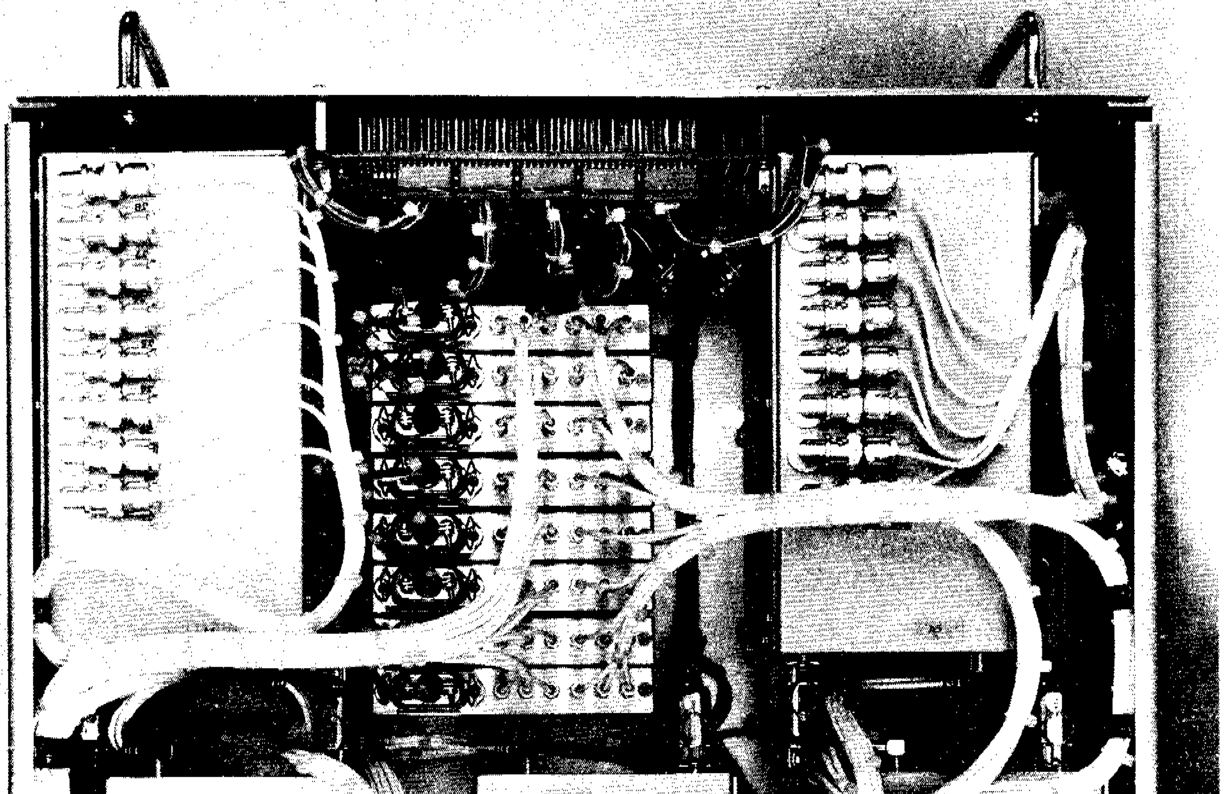

Figure 20. Automatic Test Equipment (ATE)
Switch Matrix, Top View
Model FE-7707A

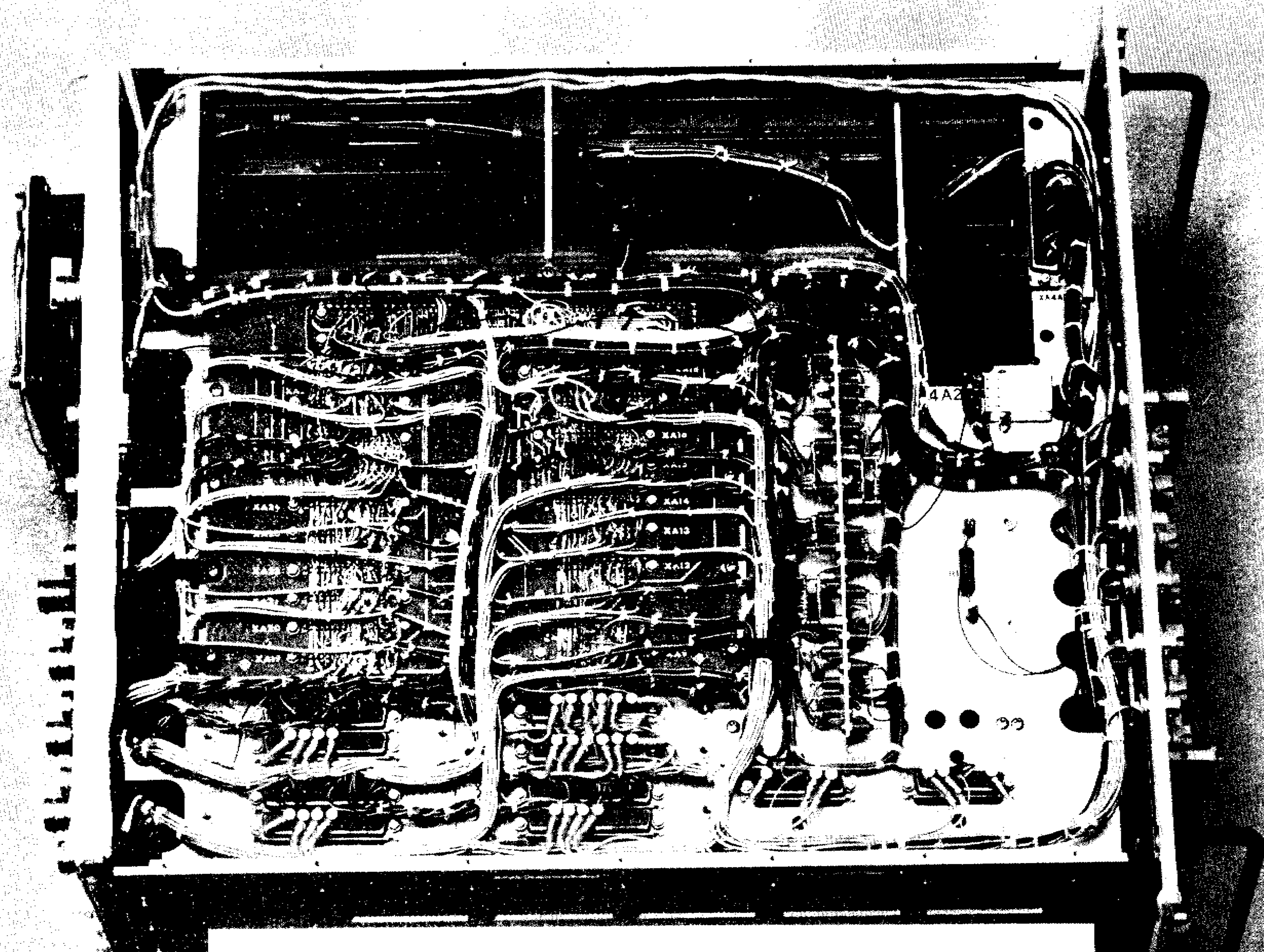

Figure 21. Selector Unit, Timing Standard, SA-2239/WLQ-4(V), Precise Time and Time Interval Switch (PTTIS), Bottom View
Model FE-5055A
Cutty Sark

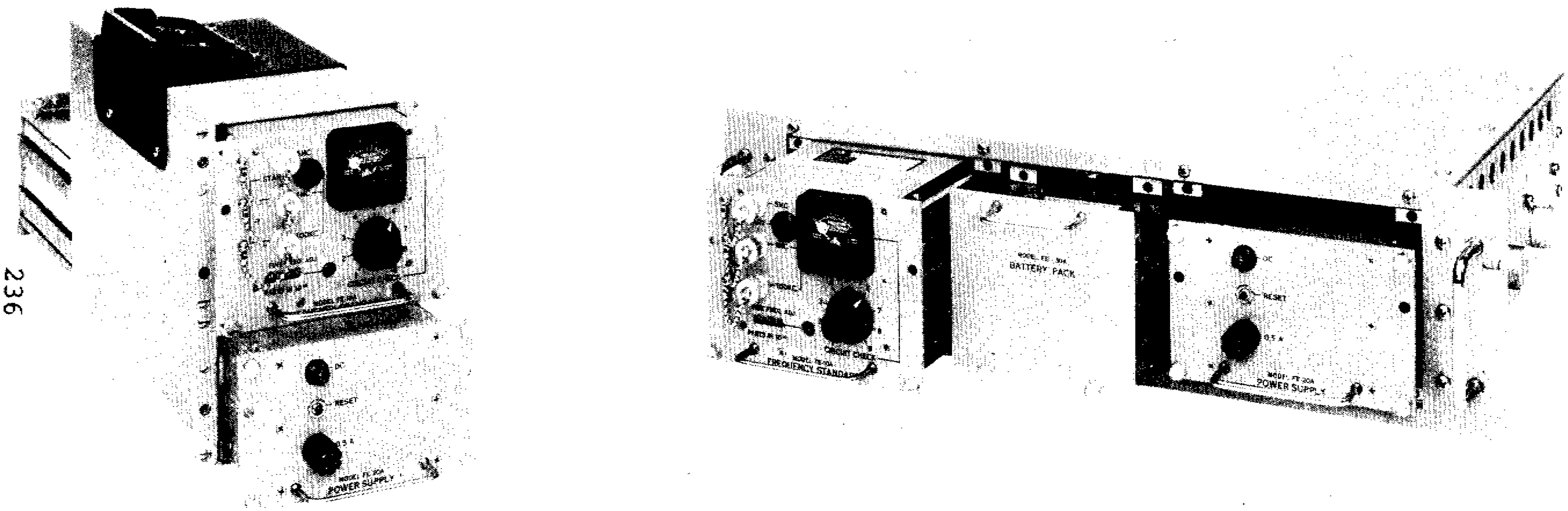

Figure 22. Frequency Standard
Model FE-1000Q
AN/URQ-10A

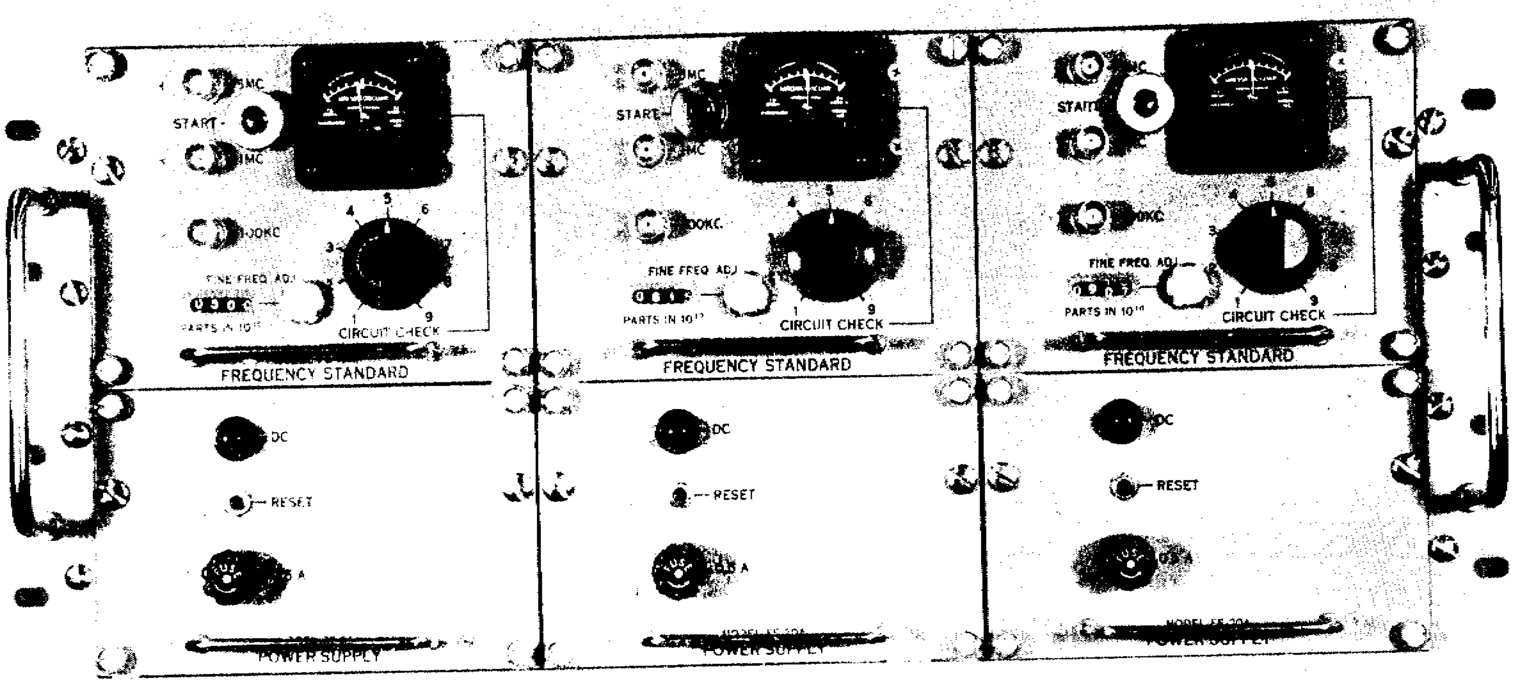

Figure 23. Three High Stability Frequency Standards
Model FE-1000Q
AN/URQ-10A

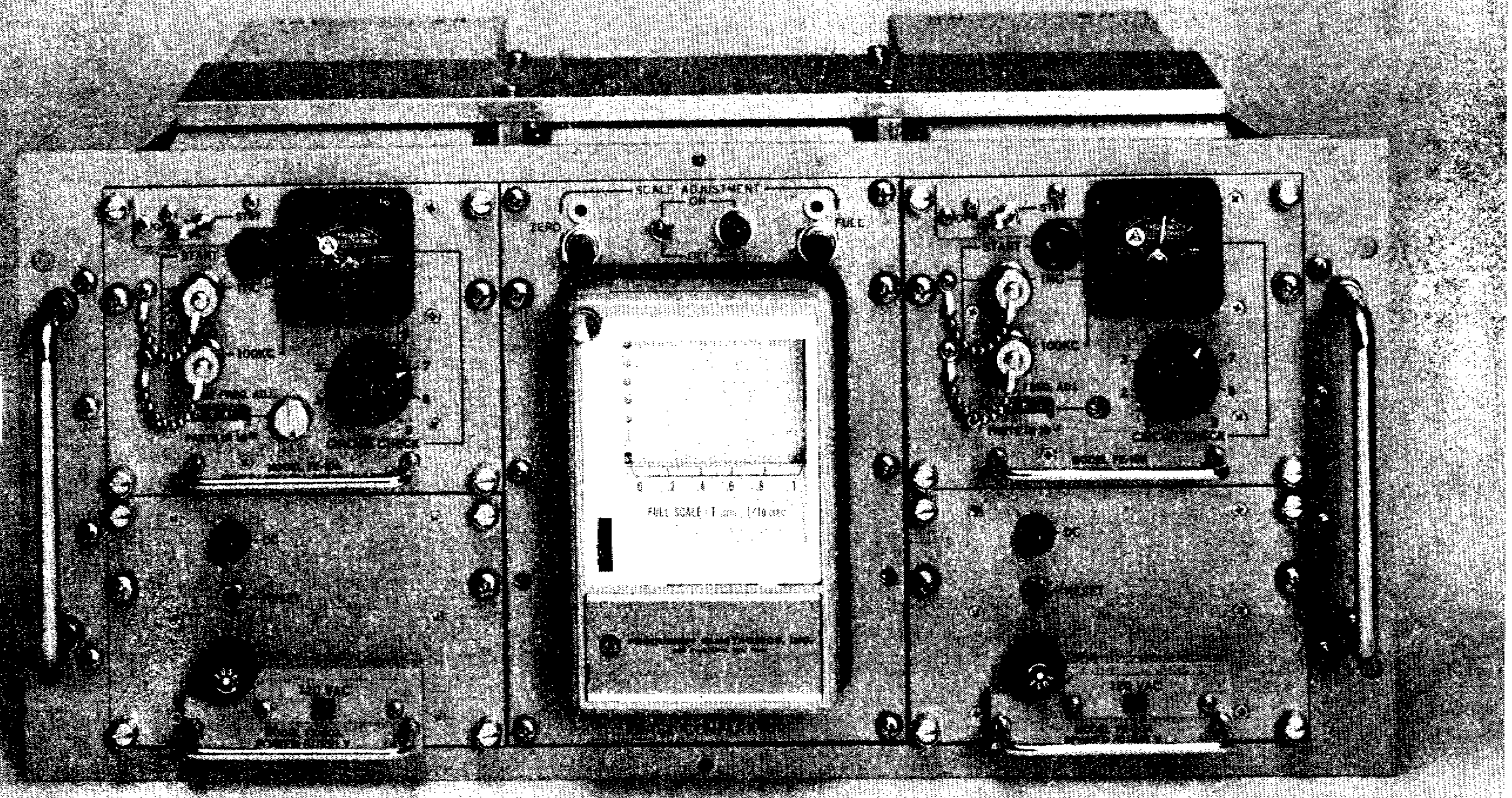

Figure 24. Frequency Generator Unit (FGU)
Model FE-5066A
NATO III

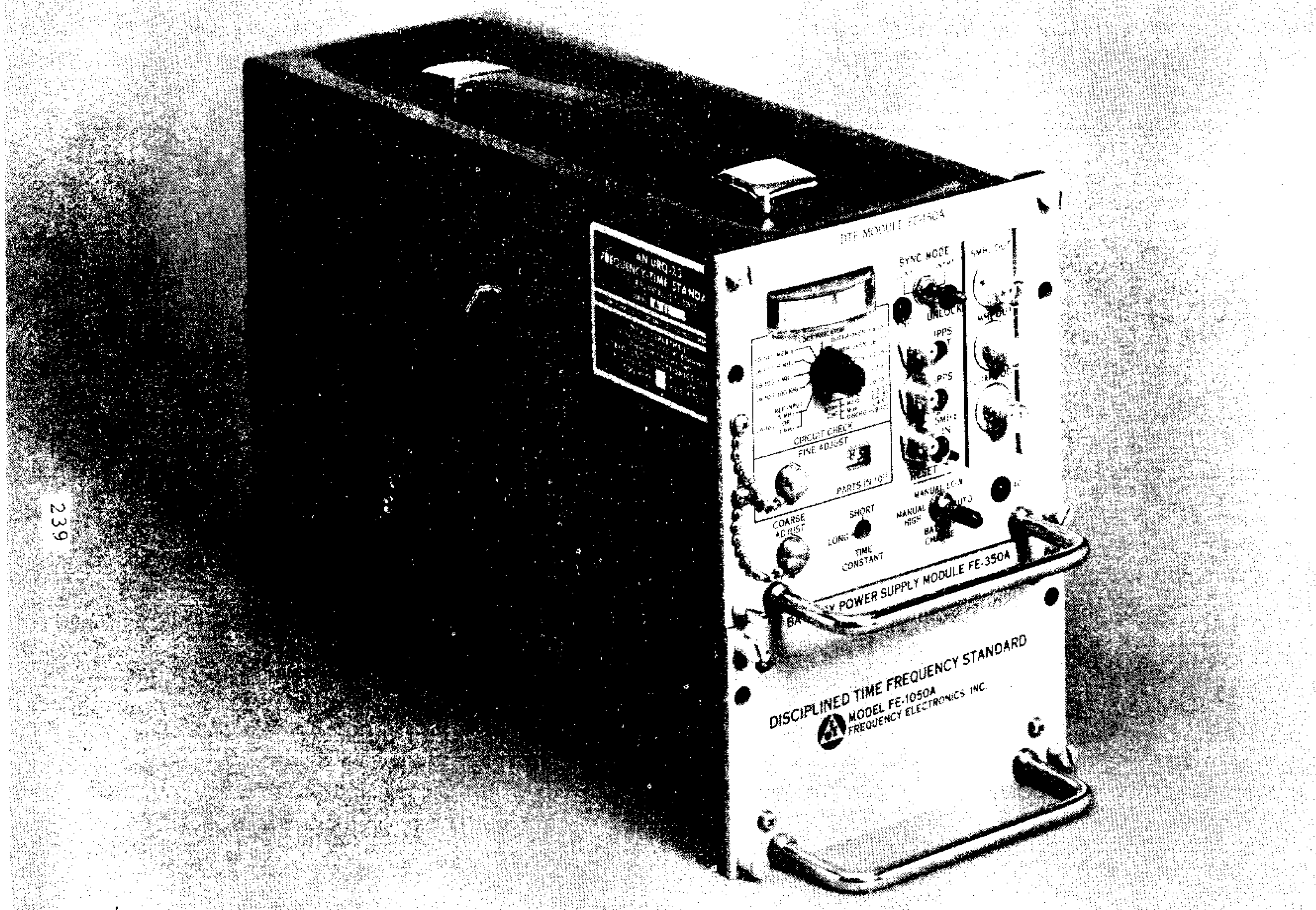

Figure 25. Disciplined Time Frequency Standard
Model FE-1050A
AN/URQ-23

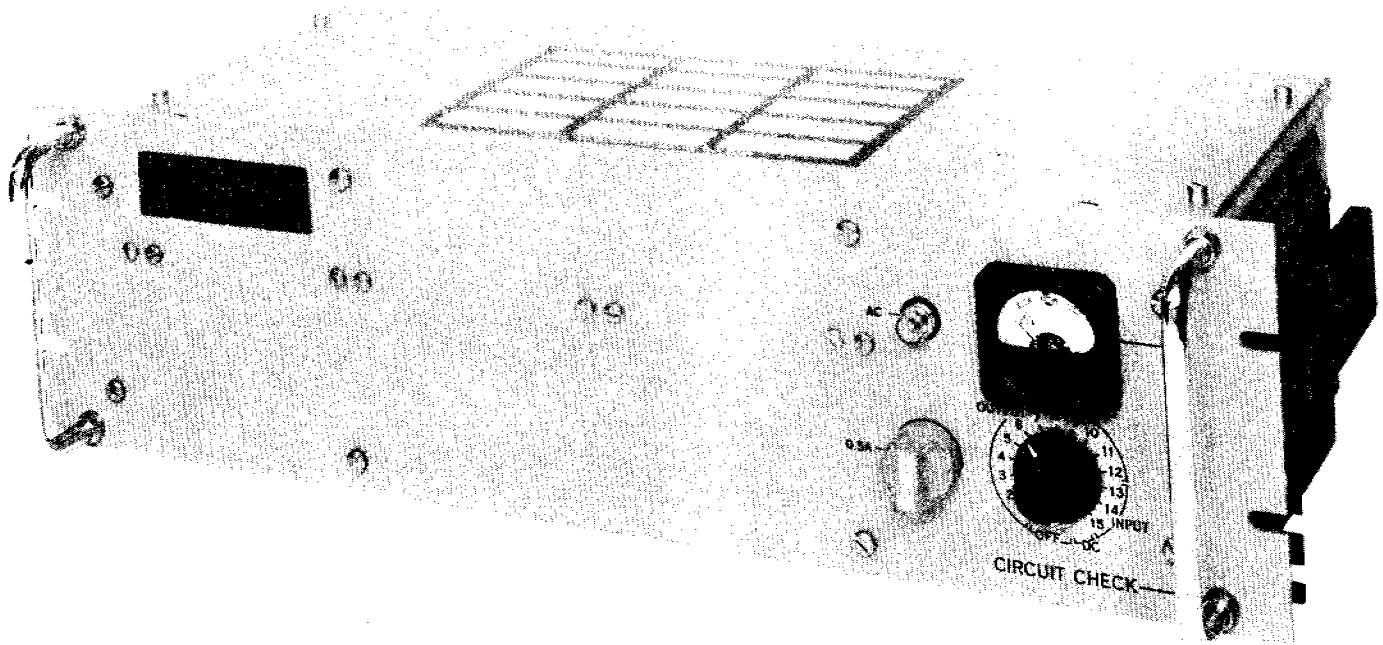

Figure 26. RF Amplifier (12 Channel)
Model FE-70Q
AM-2123A(V)/U

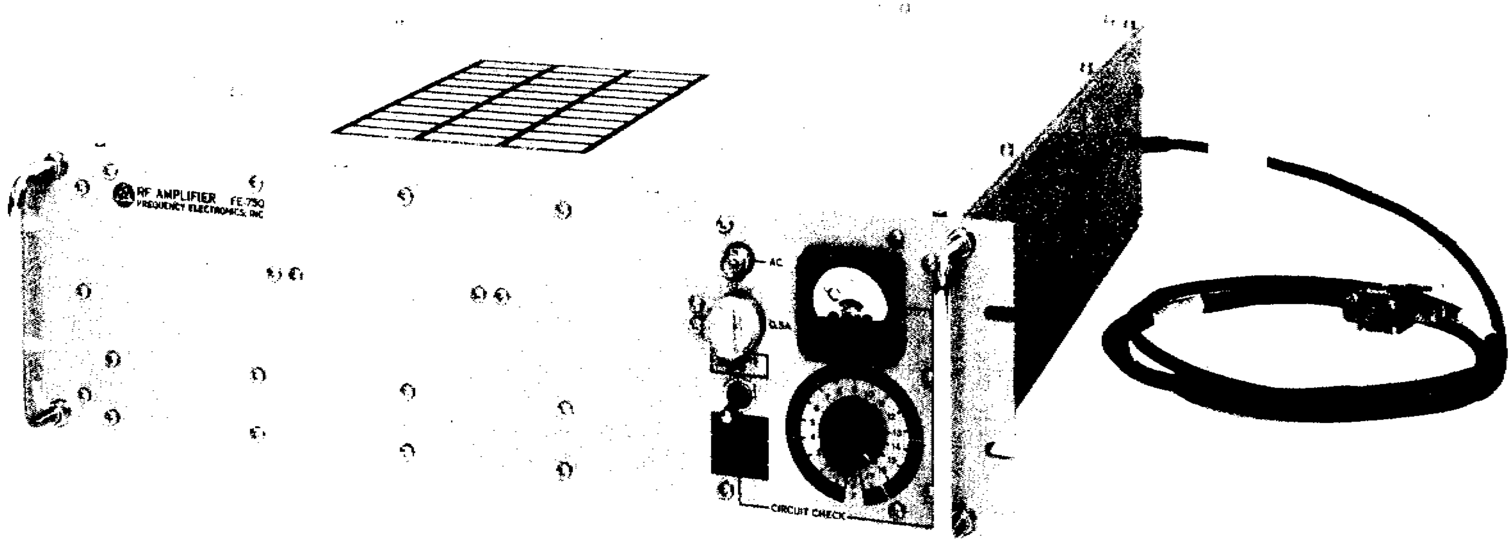

Figure 27. RF Amplifier (30 Channel)
Model FE-75Q

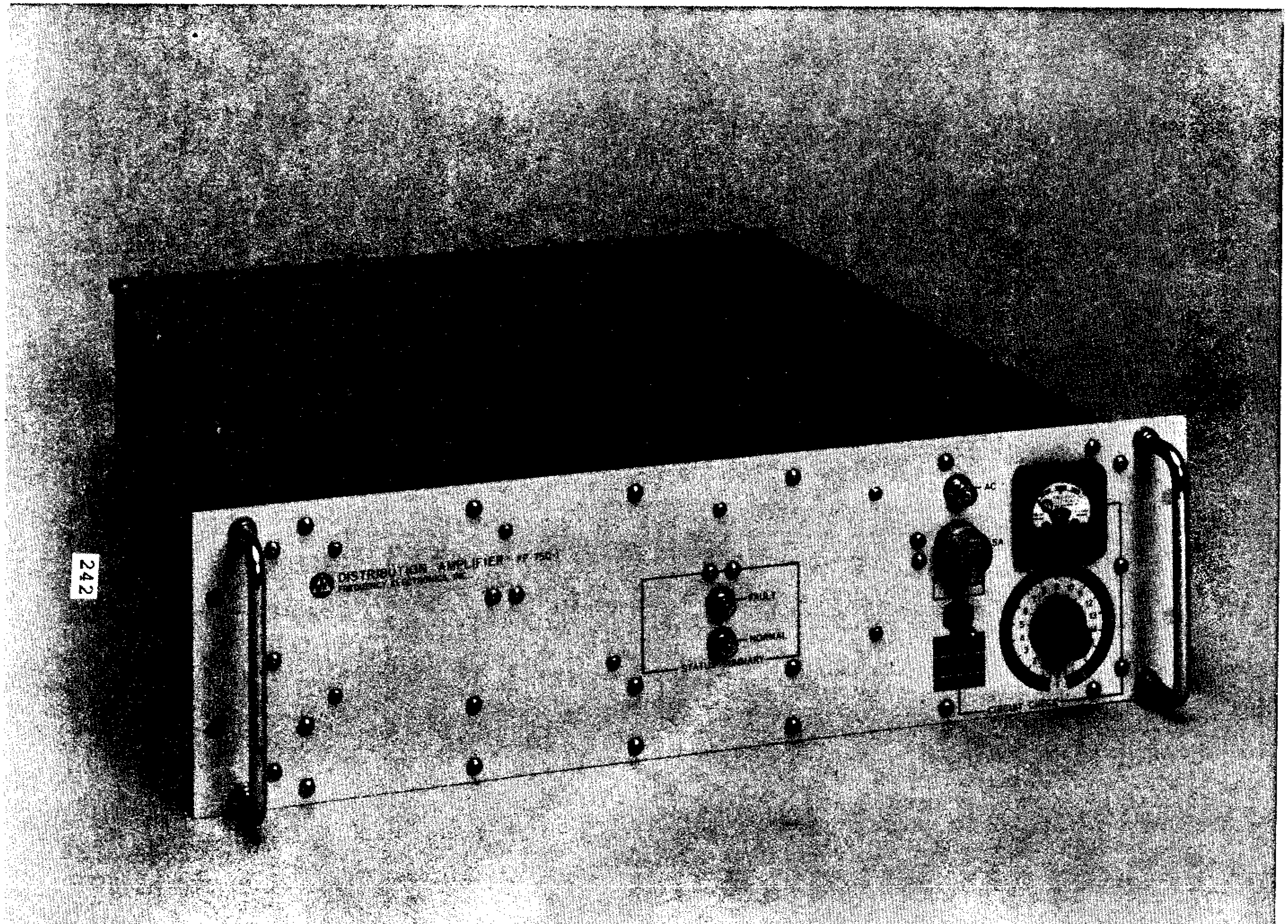

Figure 28. Distribution Amplifier (30 Channel)
Model FE-75Q-1

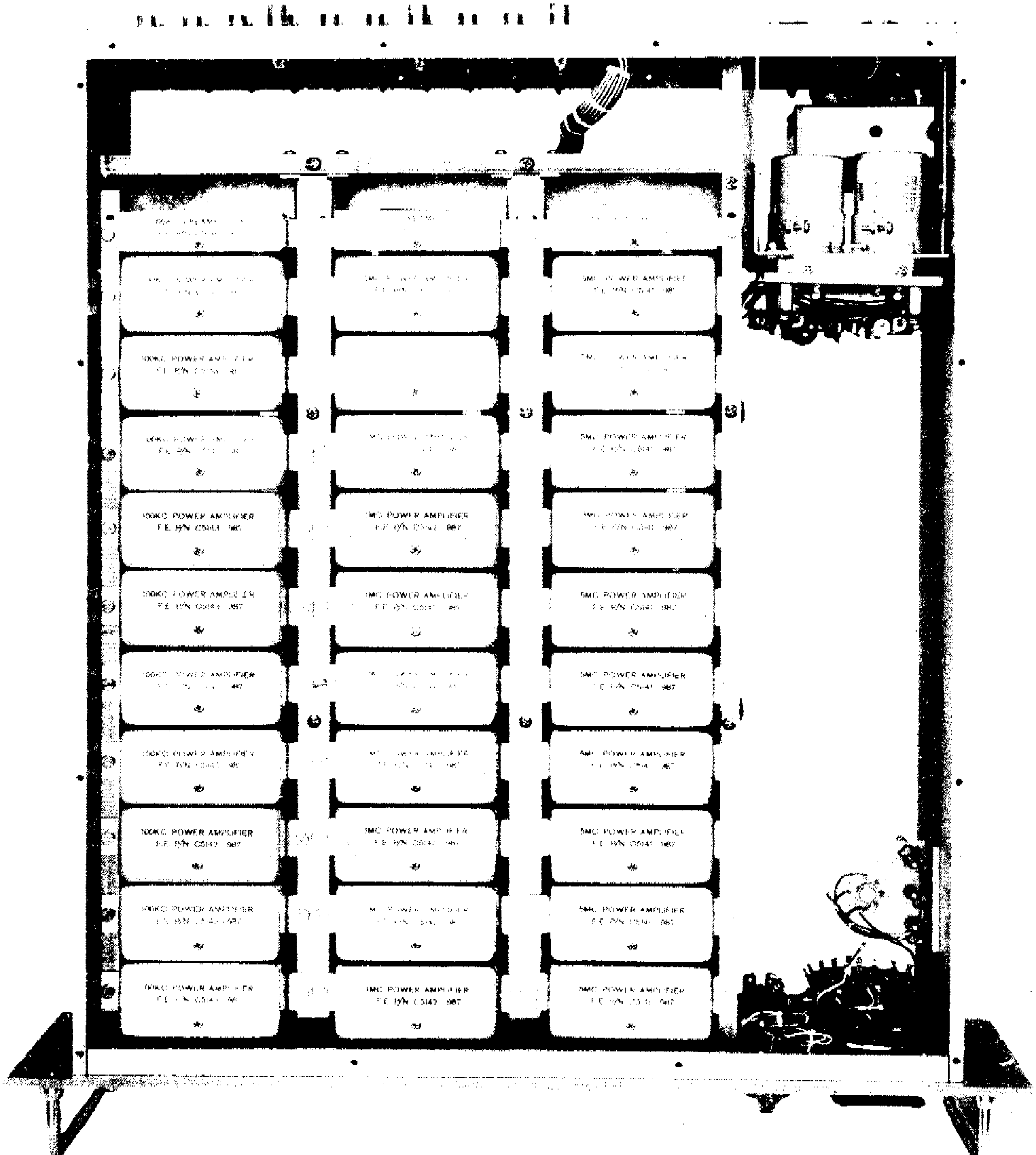

Figure 29. RF Amplifier (30 Channel)
Model FE-75Q

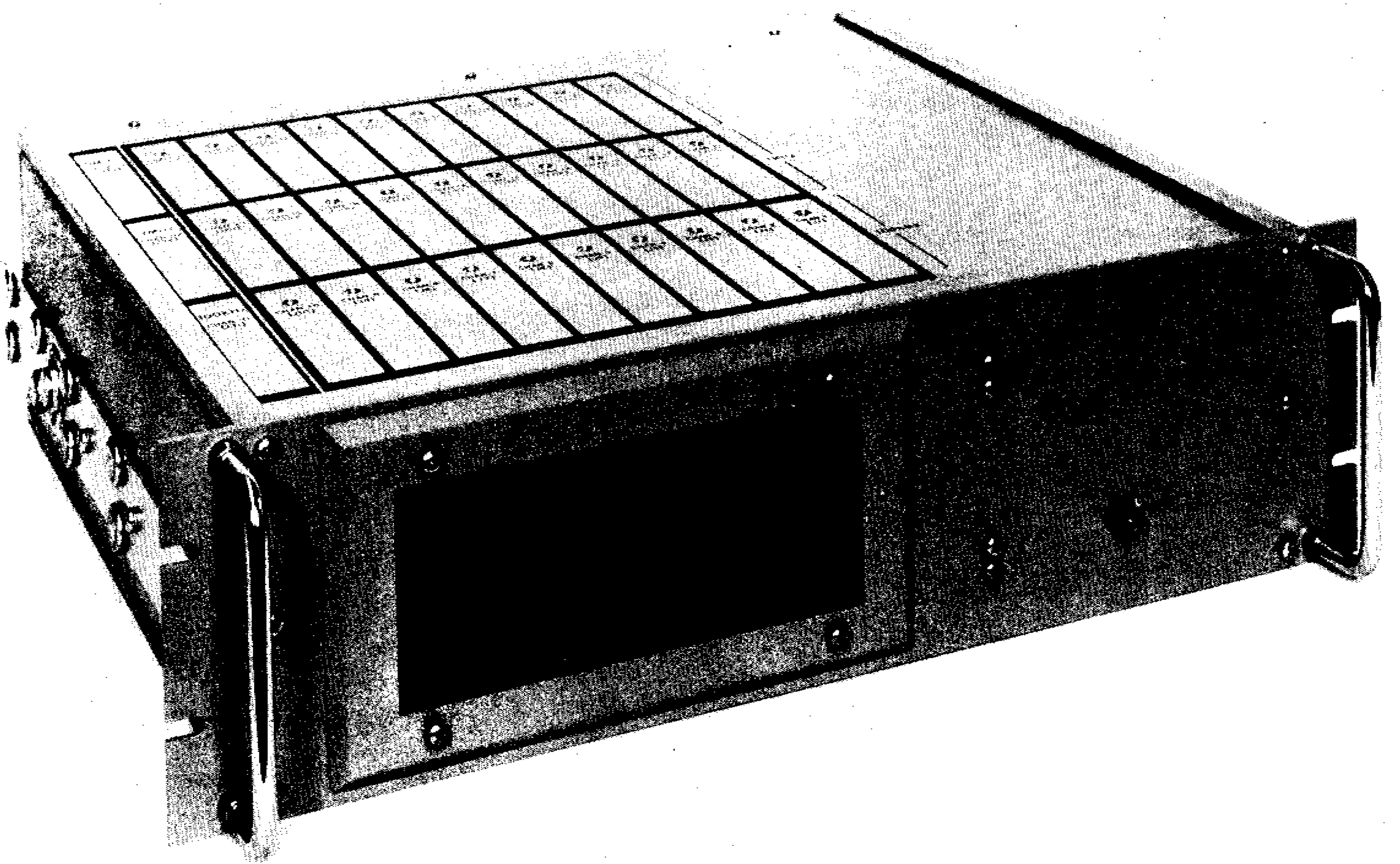

Figure 30. RF Amplifier (30 Channel)
Model FE-75A
TINKER

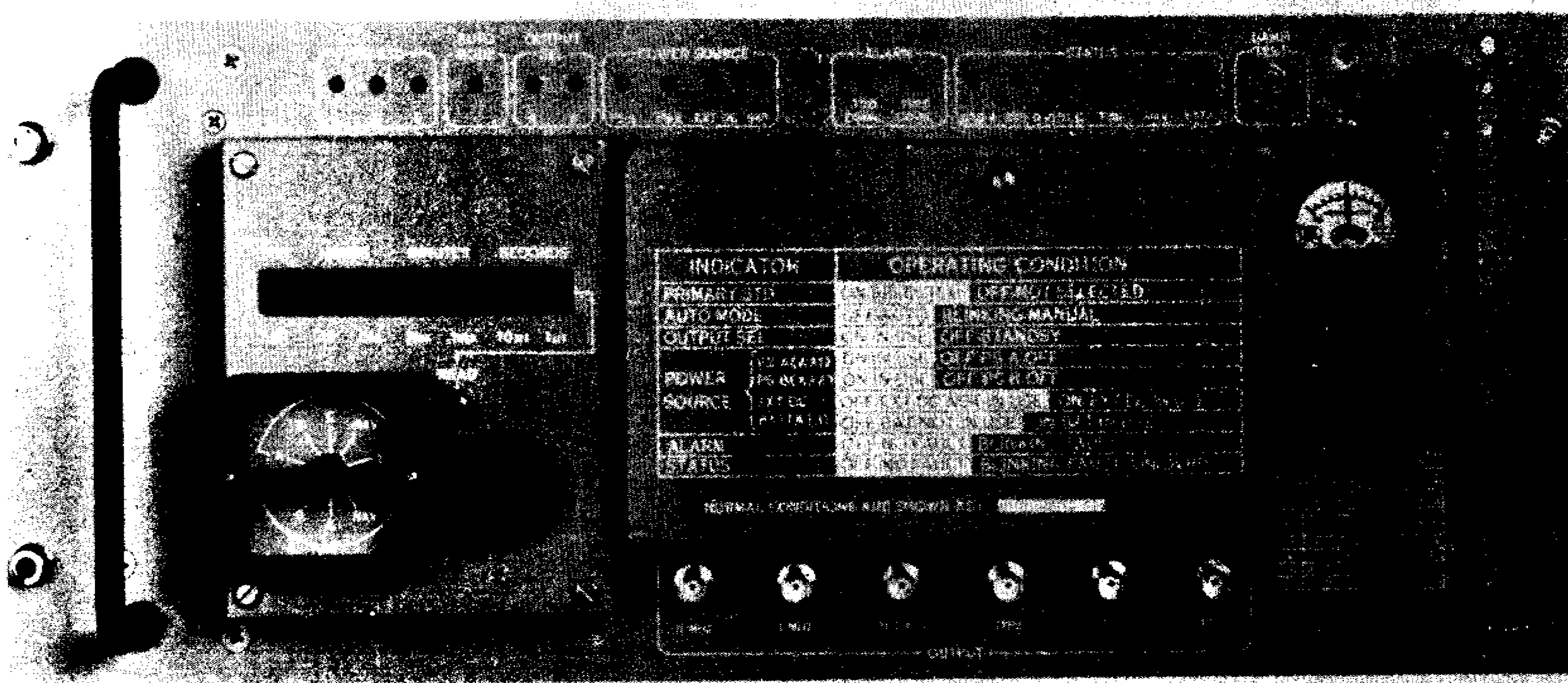

Figure 31. Selector Unit, Time Standard, SA-2239/WLQ-4(V),
Precise Time and Time Interval Switch (PTTIS), Front View
Model FE-5055A
Cutty Sark

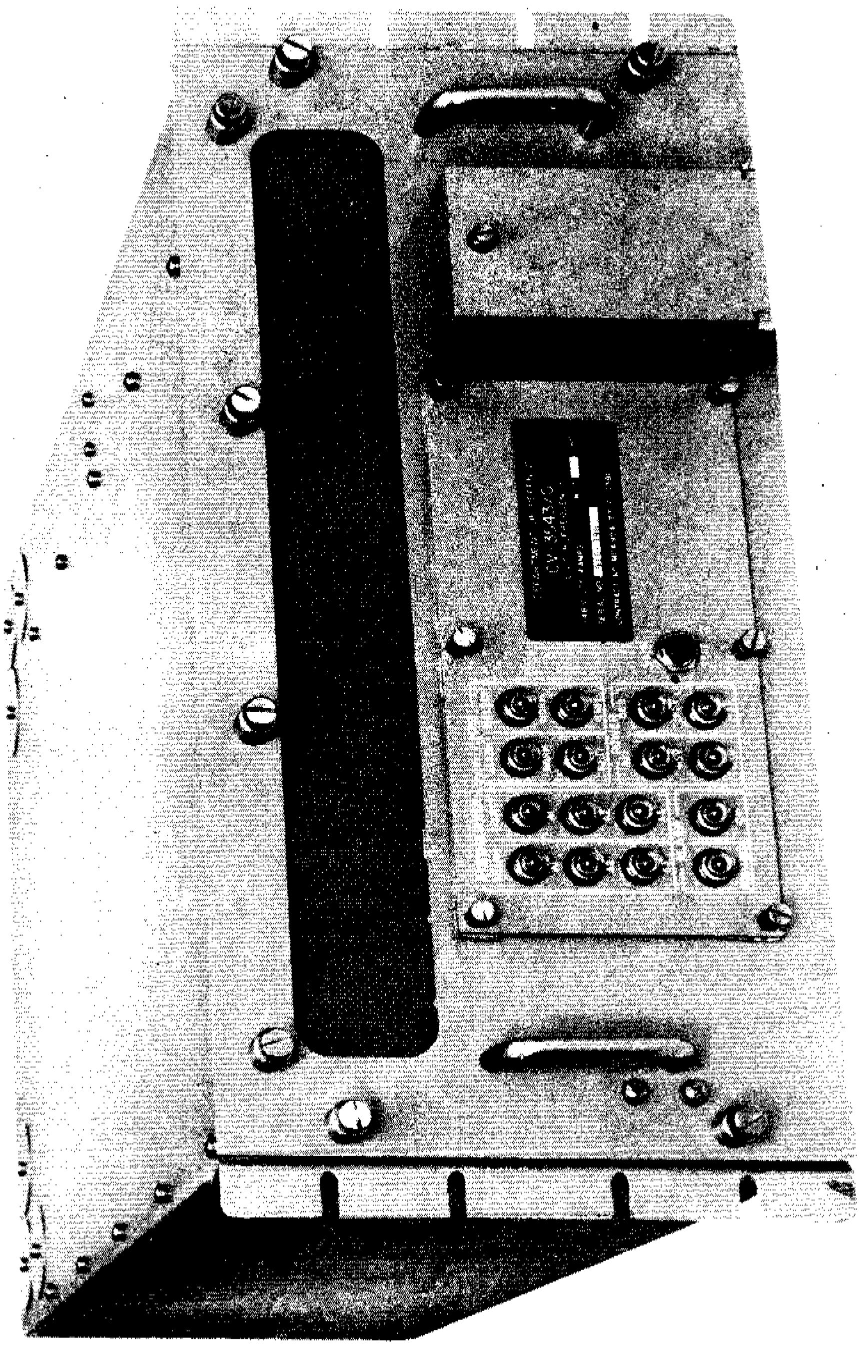

Figure 32. Frequency Divider
Model FE-7036A

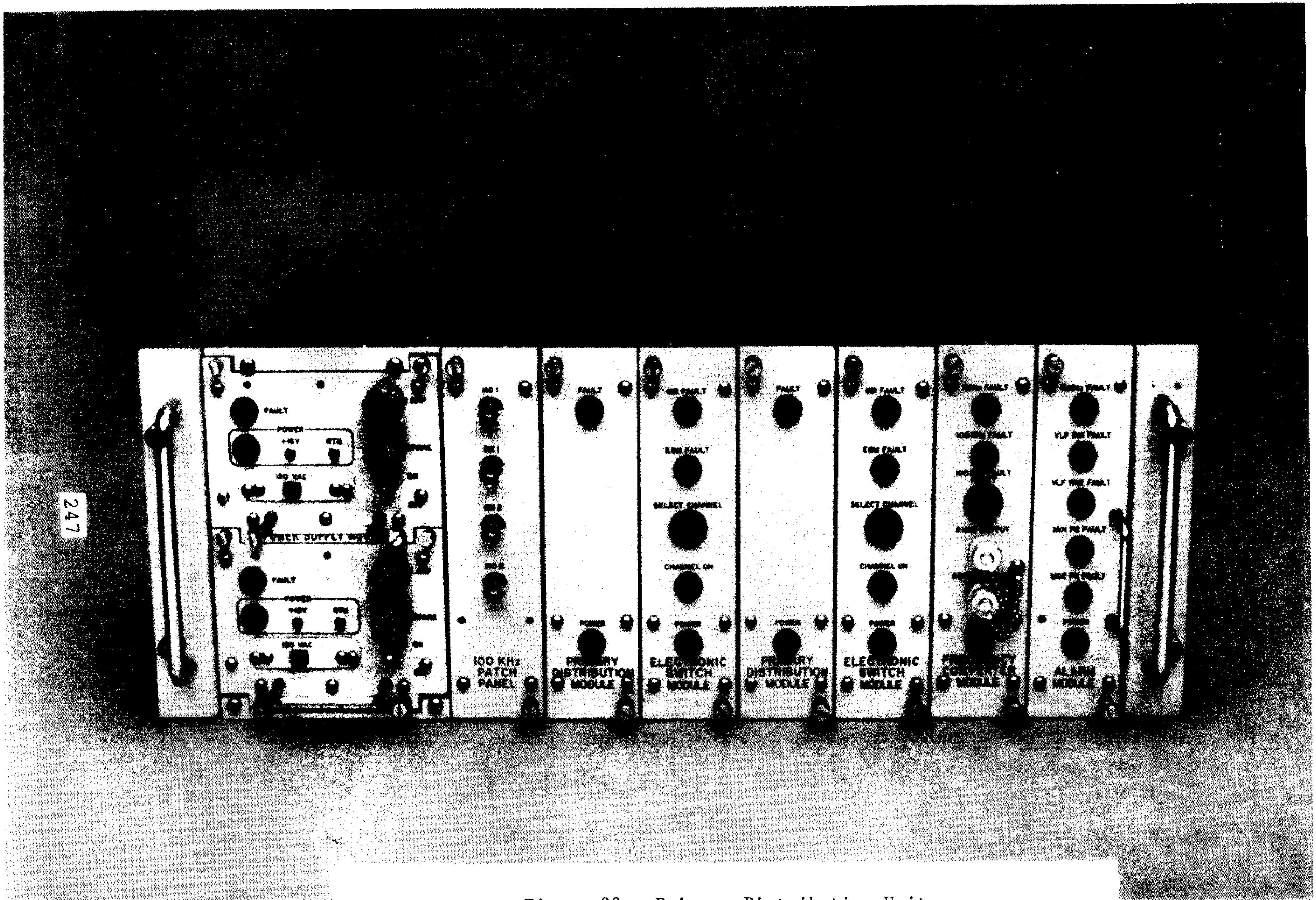

Figure 33. Primary Distribution Unit
Model FE-798A
NATO III

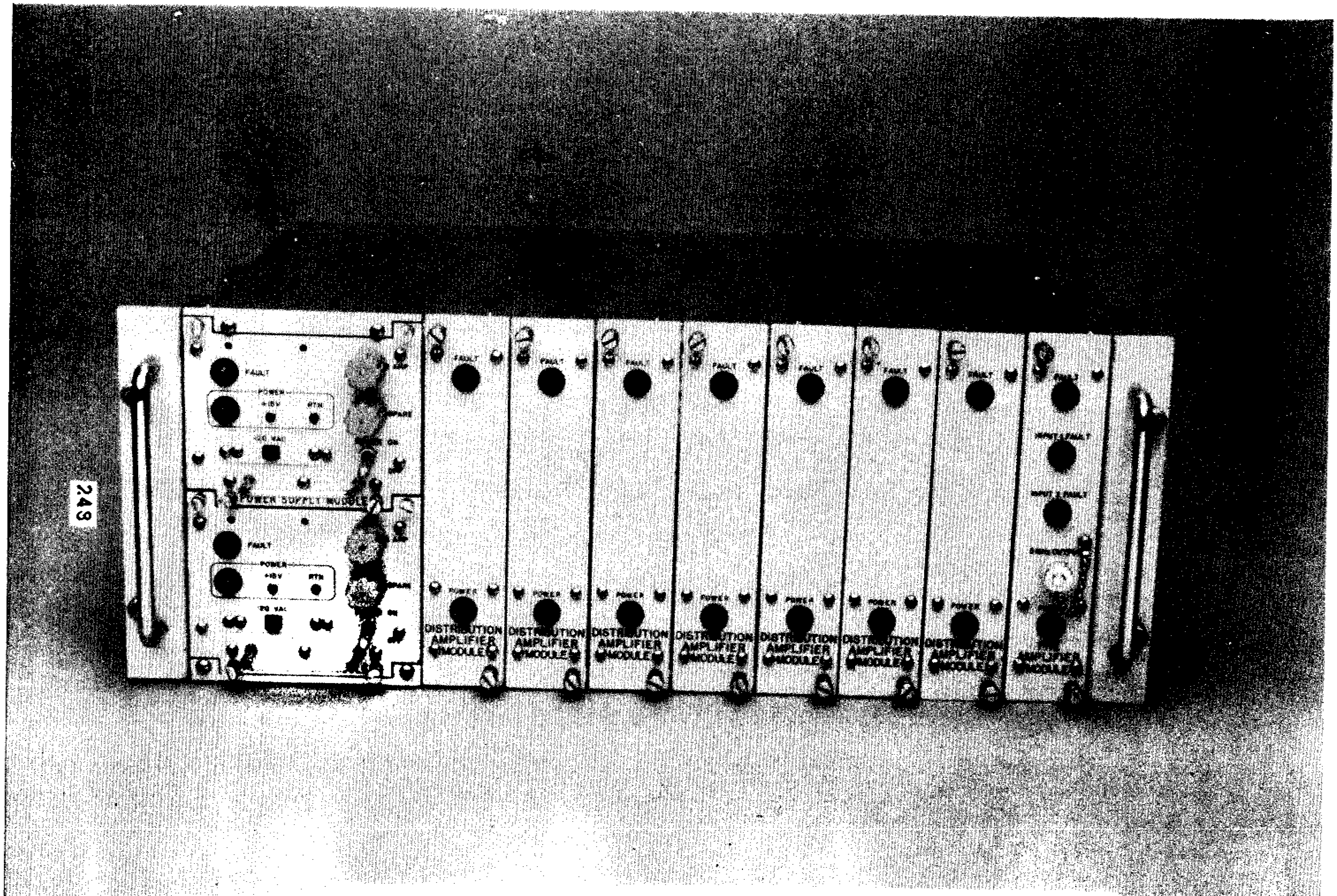

Figure 34. Secondary Distribution Unit

QUESTIONS AND ANSWERS

CHAIRMAN STOVER:

Are there any questions?

MR. JOSEPH MURPHY, Westinghouse

Could you give us some explanation as to why the quality of the synthetic quartz has declined over the years?

MR. BLOCH:

What has happened has been an inbreeding process. You see, most of the early synthetic quartz has been grown on natural seeds that were gathered from very large pieces of quality quartz which were available in abundance. As time progressed, the seeds for the new generation of quartz material has been grown on synthetic seeds, and there has been an inbreeding process.

The inbreeding process has really destroyed the manufacturability of the crystals. We throw out one out of four bars of premium material, and then we throw out 40 percent of the resonators due to imperfections in the materials due to softness or radiation.

But it is due to inbreeding processes. I think John Vig might be able to comment on this. He has been studying it for the Army and Nick Yannoni of the Air Force.

MR. VIG:

I think you are right. The manufacturers don't have an incentive to grow this quartz because 99.999 percent of all applications are met by the currently available quartz.

For every ultra precision resonator sold, there are probably a million low quality resonators sold. For very low cost units, there are probably 10,000,000 parts sold, so they don't have the incentive to grow quartz.

MR. BLOCH:

Total needs of DOD of this precision quartz, I think, is 4,000 pounds a year and that is a very small bucket compared to about a million pounds of quartz that are now manufactured worldwide each year.

MR. MURPHY:

One more question. How many resonators would you say you have made over the past 18 years?

MR. BLOCH:

We have been manufacturing resonators since 1968 so that it is 12 years. I would estimate about 30,000.

MR. MURPHY:

Is that synthetic quartz?

MR. BLOCH:

We are primarily servicing the aerospace industry so most of our units have been premium Q swept-synthetic quartz because we are looking for radiation hardness whenever we launch into space. I would say 80 percent of the resonators that we have made are made of premium Q. For your programs under 616 A, you absolutely insist that it be premium Q-swept material for Westinghouse.

DR. WINKLER:

Mr. Bloch has been tactful enough to be silent about the real reason why the synthetic quartz degraded over the years. It is that the government has become less competent. But seriously, I think that we owe you thanks for pointing out a real serious problem. In fact, this is precisely the kind of problem which caused us to make a major effort a couple of years ago to get a requirements analysis funded.

That is precisely the direction which I think we must take in order to streamline our efforts. Government today is fragmented because of a jungle of conflicting organizations, processes, laws, regulations, what have you.

I think Dr. Yannoni has pointed to some of the difficulty that the best thought-out plans inevitably after two years become modified.

Also many of the people who write specifications and requirements, have never done designing or developing themselves. So, they do not appreciate the fact that even the slightest change can cause untold disasters. Now, you cannot blame people for adding specifications because they simply do not have enough qualified people at hand today. I think we are coming to some real limitations:

how do you organize, what can we do about planning and procurement and development, a better standardization of building blocks; that, I think, is really a big problem.

Why don't you as a bidder, when he is faced with unreasonable trivial requirements like "I want to have five more lights and seven more screws and a connector at the bottom." Why don't you say, "Look, this is my standard equipment. You can have that for $2,499.95. Your special requirements will make the price $6,000 per unit. Take it or leave it."

MR. BLOCH:

We do it all the time, Dr. Winkler.

DR. WINKLER:

Well, I tell you, the unfortunate part of it is that the small user doesn't give a damn. He will have his own design, independent of cost. Yesterday I had the occasion to see a new aerospace application for a classified satellite. An extended TCXO was available which will meet all the requirements but has a height of .8 inches; but the spacecraft designer decided that all the slices are going to be .55 inches high, so we are going to spend another 100K redesigning a TCXO.

MR. BLOCH:

There is another point that this industry has faced over and over again. There was a meeting a couple of years ago where it was said, "We, the government, have the needs. Why doesn't private industry go ahead and develop reliable clocks for use that will be available?" I have explored this approach in great length. The future quantities needs are so small or so wild that it is very difficult to get private capital to commit to really meet the future needs.

When you are strictly a military supplier -- and we have tried hundreds of times with the distribution amplifiers -- saying, "Here is a standard product. Use it." No, we want the blue panel. We want an extra two lights. So, I think we need to talk with each other more to coordinate future needs.