(005W)

Excerpt from "NEC Total Engineering of Electrical Communication"
No.22, Feb. 1954

IIII: Vacuum Tube (p.p.: 66-80)- 11 Pages

4.1. Summary

It is our pleasure to see that many of NEC branches have grown with flower, and brought present success in our vacuum tube business after 20 years from its birth. In the following sections, we intend to explain process of growth and present situation in each area, but first, wish to describe our general philosophy here as: quality mind, new technology, process of progress changed by world situation, mind for future growth, etc.

We have started our challenge for vacuum tube production in 1931, and was solely for voltage amplifier tubes and power amplifier tubes for repeater in wired communication system. And then started trial production of transmitting tubes from 1933. It included water-cooled type, air-cooled type and mercury-vapor rectifiers for wireless equipment in HF broadcast transmitters and VHF transmitters. Thus all of such equipment demanded extremely high quality. The foreign partners we worked together at that time were Western Electric Co., STC Co., etc. which were top rated companies in the world, and the vacuum tubes we have challenged were based on their products. Therefore our mind against quality was:

a. High reliability
b. Uniform performance
c. Long life

This policy has never been changed more than past 20 years, and will never be changed in the future either. As the result, price of our products were quite high in the past, and maybe similar trend be seen at the present, too. A long time ago, when cost of a radio tube was approx. 1 yen, a repeater tube was 25 yen. But the fact told us that it should be paid off for such application i.e. high quality and long life tubes. Unfortunately, quality of our products have dropped considerably during the war particularly at the end, but this was because all materials were in short supply, and therefore could not keep our quality standard. We spent every effort to maintain our reputation.

By talking this way, people may think that we are too conservative and only try sure thing. But fact is totally reversed, and we have been very aggressive against new technology, and in introducing new technique, researching new theory and apply the result for new products, etc. were always running about top among the industry. In early days, we have adopted oil diffusion pump as the forerunner, and more recently, completed kovar sealing, succeeded sealing with arc welding for large transmitting tube, introducing powdered glass stem, etc. were few examples. A 50kW transmitting tube for short wave was the first one in the world. After the war, we have started study in micro wave tube, metallic reflex klystron, planar tube, etc., and built our own footsteps. We succeeded production of MT tubes in the earliest among Japanese companies as well known fact. Recently, we have completed preparation for sub-MT tube production, and again surpassed others. As to applying quality control, we were again fastest, and it has assisted birth of new products quickly as described earlier.

Our 20 years has passed, but during this period, world had greatly changed as Manchurian incidence to WWII, and finally reached recovering stage of present. Our situation in tube production has passed various epoch. We will list several of them looking back our trail:

First, when we started up this business, our work space was only one corner of an experimental room in the engineering department. Little later, it was assigned as in research section, but still no individual organization existed, and some engineers assigned for vacuum tube research were in research group, and others were in trial section, etc. Under those conditions, however, **TW-504-A** tube for 10kW short wave transmitter has completed.

In 1934 vacuum tube group has born in research section, staff associated with tubes were all together, but still only less than 50 staff. In this condition, **TW-502-A** tube installed in 100kW transmitter was born. In 1936 we finally upgraded to individual vacuum tube section, and at the same time, moved into new Tamagawa factory. It was still a small section at first, but gradually expanded, and research, design, production, etc. were organized as separate groups. At the end of 1940, research department has born, research work has concentrated into the department, and design and production work were reorganized in the factory. In 1942, matching the war time demand, a large organization, vacuum tube factory was organized, and inflated to 3,000 people including student assistants. In April 1943, we lost half of activity in the factory because of fire. But fortunately, it was recovered in 2 months with assistance of army and other factories. From early 1945 bombing by U.S. aircraft has getting severe, and moving to Ohtsu branch factory, and shift part of activity to Niigata has started, and when Tamagawa factory has become almost empty, the war has ended. After the war, facilities have gradually returned, and started as the first production division. At that time, first order to reopened factory was from U.S. occupation forces, and was large transmitting tubes for high powered broadcast transmitters. And next, communication tubes to reactivate damaged wired communication system were required, and at the same time, quality improvement of the products were highly demanded. For the reason, U.S. military headquarter has dispatched QC staff and educated us. And we have accelerated improvement of quality of our products. We presume that it was the first case of establishing quality control organization in Japan. In February 1947 inspection division has born to organize QC activity, performed product inspection by the independent organization. After this, research and design staff have separated from the factory and formed vacuum tube engineering section, merged into engineering division and today's organization has materialized.

By looking at actual products, we can find various processes. In the beginning, it was mostly triode tubes for wired communication, and then water-cooled tubes, air-cooled tubes and mercury vapor rectifiers. X-Ray tubes were one of others born around that time. And then short wave/ in high power age has followed, and in the other hand, pentode communication tube development associated with unloaded cable took place. As pressure by war comes, high powered pentode series in transmitting tubes was demanded, and mass production of pulse transmitting tubes and CRT were ordered by invention of wireless locator. At that time, our factory has continued expansion to answer the military demand. After the war, as vacuum tubes were one of the most needed items in recovery process, much fund has spent for it, and production of large transmitting tubes and communication tubes have recovered quickly. Next, one of the industrial application, high frequency heating, has realized, and shown active situation. And to fulfill market demand, active movement was required as; development of MT and sub-MT tubes, mass production of CRT to accommodate TV broadcasting, etc. In the other hand, development of micro wave tubes were accelerated. The application of vacuum tubes to industrial field has further increased, and expected to be a big market in the future. Therefore preparation for such movement has also carried on.

The details of these products should be covered in the following articles, but the writer wishes to add one thing here: The vacuum tubes should have a great future as its application increased, and for such usage, our motto as "high reliability", "uniform performance" and "long life" are strongly demanded, and therefore intend to pay continued effort in keeping quality and developing new products.

By Hidehiko Nishio

4.2. Transmitting Tubes and Thyratrons

In 1932 our chief engineer Dr. Shoji Kobayashi visited Europe for technical investigation, and especially spent one year at French laboratory L.C.T. under I.S.E. for studying production technique of vacuum tubes, and returned to Japan in 1933. We started producing transmitting tubes since 1933 utilizing the result.

4.2.1. Products before the war

(i) TW-502-A

The representative product during the cradle age must be a water-cooled triode having 120kW of output, **TW-502-A**. Therefore we can say that our transmitting tube production has started with high powered tube. This was a double-end type, filament was of pure tungsten, single phase with coaxial-shaped terminal. On the grid and filament terminals, radiator made by silmin are installed which was very modern design for that time. The anode voltage of 20,000V was a record breaking value, and we are still holding high technology since then. This tube was used in final stage amplifier and modulator of 100kW broadcast transmitter, but its production has discontinued at the present.

Tube Type	Anode kV	Output kW	Note
TW-502-A	20,000	120	Double End
TW-504-D	10,000	15	Double-End
TW-506-D	10,000	10	Double-End
TW-510-A	10,000	10	Single-End
TW-512-B	6,000	3	Double-End
TW-516-A	20,000	40	Single-End
TW-530-B	14,000	60	Double-End
TW-553-B	14,000	60	Double-End
TW-558-A	16,000	120	Double-End
TW-559-A	16,000	25	Double-End
TW-575-A	6,000	2.5	Single-End

Table 4.2.1.

Early Transmitting Tubes (Larger)

Tube Type	Output W	Note
TB-508-C	50	UV-211
TB-509-B	250	—
TC-517-A	750	251A (WE)
TC-522-A	1,500	279A (WE)
MC-526-A	100	UX-860
MC-527-A	70	UV-814
MC-528-A	250	UV-812
MC-529-A	500	UV-861
MD-546-C	250	Pentode
MC-580-A	1,500	Pentode
MC-582-A	500	Pentode
TC-1507	5	Triode.670MC

Table 4.2.2.

Early Transmitting Tubes (Smaller)

(ii) QC-715-C

This tube was made for rectified power supply of the above mentioned transmitter. The average anode current: 15A, maximum PIV: 20kV, with large indirect heated oxide coated cathode, and was a record making product completed after great effort of our engineering staff. This tube has still been used as power supply of 50kW short wave transmitter for overseas as described later.

Tube Type	Max Anode Curr. A	Max Anode PIV V	Note
QC-700-C	0.5	7,500	—
QC-701-C	1.0	15,000	—
QC-702-C	0.7	20,000	—
QC-704-C	1.7	20,000	—
QC-709-C	0.3	5,000	—
QC-710-C	4.0	20,000	951-B
QC-714-C	2.0	20,000	—
QC-715-C	15.0	20,000	—
QC-716-C	1.0	7,500	—
QC-717-C	0.8	20,000	—

Table 4.2.3.

Early Rectifier Tubes

(iii) TW-504-D

This was a water-cooled transmitting tube of 15kW output which was popular to early experts in wireless field. As letter D shows, it was fourth modified model since its first design. It had good reputation for high stability and long life.

(iv) TC-517-A and TC-522-A

These were also popular air-cooled transmitting tubes. The former was 750W output, and the latter was 1.5kW, and both of them had thoriated tungsten filament. These unique construction were by special design of Western Electric Co., having excellent frequency characteristics and usable up to 22Mc. These tubes had high reputation as long lived air-cooled tubes, and are still used in our transmitters today.

(v) TW-530-B

In 1937 a 50kW short wave transmitter for overseas broadcast was installed in Nazaki, Saitama by International Wireless Co. This was the world highest powered short wave transmitter made by us, and this **TW-530-B** used as last stage amplifier was of course the world largest short wave power tube at that time.

For stable amplification up to 22MC, reducing inductance at grid input portion, making dimension of its operating area smaller for reducing grid temperature in order to minimize grid emission, etc. were applied. As the result, anode dissipation per unit surface area has increased, and difficult problems i.e. cooling of glass part of grid/anode and filament/anode, etc. have finally resolved. This type was both-ended water-cooled type, and glass portion was forced air-cooled. This tube is still used actively for overseas broadcasting.

(vi) MD-546-C

In 1938 an air-cooled pentode with 250W output has completed. This tube was used in final stage tube with first suppressor grid modulation. This was for our shipboard wireless transmitter. This tube was not only for the first suppressor grid modulation, but also record making as 250W crystal oscillator. As its driving power was extremely small, large oscillation output could be obtained without damaging crystal vibration element in the grid circuit. One item noteworthy in the history of pentode transmitting tube development.

(vii) MC-580-A

Following completion of **MD-546-C**, we marketed **MC-582-A** (500W output), and in 1940 introduced **MC-580-A** with 1.5kW output. By those pentodes, wireless equipment having 2kW output was realized in much smaller size. The former was being used in Nakano station of national police station and Kemigawa station of national communication station for some time, but after introduction of movement for unifying tube type numbers, this tube was replaced with **6P70** which was an improved model.

(viii) TW-558-A

In 1940 **TW-558A** which was our second 120kW output class tube has completed. This was the newest designed tube at that time, filament was 3-phase heating to reduce A.C. hum with tri-axial terminal, smooth shaped both-end type. The best layout was adopted to reduce A.C. hum after ample research. And our first 100kW broadcast station in Taiwan using this tube has installed with Doherty modulation system as the forerunner. This transmitter has still been working today. But new production of this tube has terminated, and **8T21** tube as the successor is under production now.

(ix) TC-1507

In 1944 Japan's first UHF multi-channel telephone system with 670MHz has installed in Japan National Railway's Aomori-Hakodate line by us. For the final stage of this system, our **TC-1507** tube was used, and no competitive product existed which can produce 5W of output at this frequency. This tube was with thoriated tungsten filament, and anode and grid leads were at both ends and designed as operated at the center position of lecher tuning circuit. This tube has still been in use today, and marked the first in UHF transmitting tube.

(x) TR-593-A, TR-594-A, TR-1501

During the war, we developed high peak powered forced air-cooled tubes for wave finder or wave locator. **TR-593-A** had peak output of 10kW, **TR-594-A** was 50kW, **TR-1501** was 30kW. Those were first examples using copper anode and thoriated tungsten filament, and anode voltage was high 10,000V. After paying great effort for obtaining high vacuum, considerably long life was obtained which was unusual for pulse use. This result made basis for use of thoriated tungsten filament to large powered transmitting tubes today.

4.2.2. Products after the war Excluded---Ed.

4.2.3. Thyratron

(i) Products before the war

Our first thyratron was **XB-712-C**, argon gas filled type produced in 1935. This tube was used for relay, voltage control, saw-tooth wave generator, etc. After this, several mercury-vapor type thyratrons were made. Among those, record making model was **XC-732-A**. This tube was used in 100kW transmitter installed in Taiwan in 1940 as described in transmitter tube section. It was used for shutting down the power source within several cycles if the last stage tube had internal flash. The surge current in this case should reach 100A, and therefore thyratron action must withstand against it, thus record making item at that time. The representative products from 1933 through 1945 are shown in **table 4.2.6**.

XB-767-A was argon filled type made in 1944. It was tetrode construction differed from older type, and anode, grid and cathode were all in rectangular frame, and the frame was divided into 2 sections shielding anode and control grid by screen grid. Feature of tetrode type is low control grid current, and therefore can be used in high impedance grid circuit, and also have steep starting characteristics. Also starting characteristics can be changed by varying screen grid potential. At the present, an improved type **XB-785-A** is in production.

(ii) Products after the war Excluded---Ed.

Tube Type	Gas	Anode		
		Curr. A	PIV V	Max V
XB-712-C	Argon	0.07	200	300
XC-726-B	Mercury	0.4	5,000	5,000
XC-727-B	Mercury	0.8	1,000	2,000
XC-728-A	Mercury	0.2	2,000	5,000
XC-732-A	Mercury	1.5	20,000	20,000
XB-767-A	Argon	0.1	350	700

Table 4.2.6

Early Thyratrons

4.3. Small Tubes for Communication

Small tubes are general definition of tubes covering detect, rectify, voltage and power amplify, frequency conversion, etc. having less than 20W of anode dissipation. Within the category, we have separated production of major part to newly established New NEC, and our company is concentrated in tubes for communication purpose. The communication tubes include tubes for measuring instrument, part of sound system and industrial use, etc.

4.3.1. Wired Communication Tubes

This category has the longest history and tradition, and hold the main stream of NEC's small communication tubes. Its history, products and their performance and process of improvement have described in NEC Nos.10-12, and 16, but the summary is shown here for convenience:

Variation in Wired Communication Tubes and their Progress

Classification	Tube Type	Date of Start Prod.	Note
Type D Triode Eb = 130V If = 1.0A	101-D, 101-G 102-D, 102-G 104-D, 104-G	1931-1933	1) Coupled type filament with Pt core has replaced with non-coupled type with Ni core after 1939 2) Spherical bulb has replaced with dome type after Aug. 1948 3) G tubes are identical in characteristics to D, but improved for better insulation and lower noise
Type F Triode Eb = 130V If = 0.5A	101-F 102-F 104-F	1934-1935	
Type HO Triode Eb = 250V If = 0.5A	HO-101-F (TB-616-A) HO-102-F (TB-612-B) HO-104-F (TB-608-B)	1935-1937	1) In use since 1937 at repeater stations between Tokyo and Nagoya as first unloaded cable line 2) From 1940 changed from pare to dome bulb
Type CZ Pentode Eb = 250V If = 1.0A	CZ-501-D (MC-656-C) CZ-502-D (MC-657-C) CZ-504-D (MB-655-A)	1938-1939	Predecessor of CZ-501-D was first assigned as MC-622-B (2.5V/1A, 1.5mS), then changed to to MC-656-A. This was used in high-output/wide range repeater between Tokyo-Osaka broadcast system, improved as MC-656-C in 1938, and in 1939 finally assigned as CZ-501-D
Type CY Pentode Eb = 250V If = 0.5A	CY-501-F (MC-656-B)	1939	CY-501-F was changed from MC-622-C (2.5V/0.5A) which was improved model of MC-622-B. In 1939 assigned as Post office standard as Type C pentode
Pentode for coax. cable Eb = 250V Ef = 6.3V	CZ-511 (MC-658-A) CZ-514 (MC-660-A)	1940-1941	MC-658-A was first designed as TV amplifier, modified in many ways after the war together with MC-660-A, and renamed as CZ-511 and CZ-514
Type CZ Red Tube Eb = 250V Ef = 6.3V	CZ-501-V (MC-656-D) CZ-504-V (MB-655-D)	Nov., 1950	Same characteristics as CZ-501D and CZ-504D and only Ef is 6.3V, use red bakelite base. Refer to NEC No.9: Red communication tubes for wireless application
Type of Eb = 130V Pentode Ef = 10V	310A 311A	1950-1951	Identical to WE310A and 311A. Same characteristics as CZ-501D and CZ-504D. Refer to NEC No.13; about 310A, 311A

Note: Among those, three Type D triodes and CZ-503D, total of 4 types are no longer in production. Therefore total of 19 types are remaining as standard wired communication tubes.

Table 4.3.1

(i) Variation and Improvement of Wired Communication Tubes

Please see **Table 4.3.1.** ---- Ed.

(ii) Process of improvement

The improvement process has planned since early 1946, and especially on **CZ-501-D** and **CZ-504D** which are lifeline of main communication system. The major items of process are: Shown in **Table 4.3.2.** ---- Ed.

Process of improving Type CZ wired communication tubes		
Item	**CZ-501-D**	**CZ-504-D**
Anode and other metal parts: Fe→Ni (N-tube)	After Sept.'46 partially, after Oct.'46 totally	
Stem : Pb glass→Ka glass (NK-tube)	Totally after Nov.'46	
Getter: Mg→Ba→Ba	After Sept.'46 partially, after Oct.'46 totally	
Mount system applied to assembly		Dec.'48
G1 support bar: 0.6→0.8mm dia.		Feb.'49
G2 support bar: 0.6→0.8mm dia.		Feb.'49
G1 support bar: Ni→Steel alloy	Nov.'50	Feb.'49
G1 wire: →adopt Gold plate	Mar.'53	Apr.'49
Cathode→adopt emboss system	Oct.'51	
Cathode→adopt special Ni material	June'51	Sept.'51
Grid support bar→adopt stopper system	June'51	Sept.'51
Adopt double mica for improving insulation	Feb.'53	
Adopt phenol resin for base cement	Oct.'49	
Adopt glue for undercoat of base & cap	Oct.'49	
Adopt anti-humidity paint on base top	Sept.'49	
Base cement→Silicon Resin	July,'52	

Table 4.3.2. Process of Improving Type CZ Wired Communication Tubes

(iii) Results after improvement

As result of above mentioned improvement, average life of the present products exceeded 100,000 hours compared with several thousand hours when the war has ended which is a dramatic improvements. See **Table 4.3.3**.

Station	Type No.	Sample No.	N.G. No.	Date Inspected	Est. Avg. Life
Kounosu	CZ-501-D	30	8	Aug.10,'51-July 31,'53	130,000
Takahagi	CZ-501-D	154	16	June 20,'52-Apr.22,'53	122,500
Mito	CZ-501-D	42	4	May 15,'52-Apr.22,'53	—
Mito	CZ-504D	3	0	Sept.15,'52-Apr.22,'28	—

Table 4.3.3.

(iv) Improvement plan on CZ tubes with reduced cathode temperature

When tubes are operated for a long time, Barium scattered from cathode tend to result in reduction of insulation and create grid emission, and therefore current CZ tubes are operated with I_f of 0.95A instead of designed 1.0A intentionally. Also as relation between lifetime **L** and cathode temperature T_k against emission is: $\log L \propto 1 / T_k$, and therefore reduction of T_k at the rated condition makes lifetime longer. Therefore improvement plan of CZ tubes with reduced cathode temperature are carried on since early 1952. Reduce E_f to 3.0V for **CZ-501-D** and 5.0V for **CZ-504D**. By this change, T_k should be reduced by 30°C on the former, and 25°C on the latter. The estimated lifetime of NEC's **CZ-501D** used currently is 130,000 hours by the accelerated life test conducted at NTT's Communication Research Lab., and 120,000 hours by our test, and these figures approximately matches the above mentioned actual operation results. In the other hand, if cathode temperature has reduced by 30°C, estimated lifetime should be approx. 400,000 hours i.e. amazing value equals about 45 years.

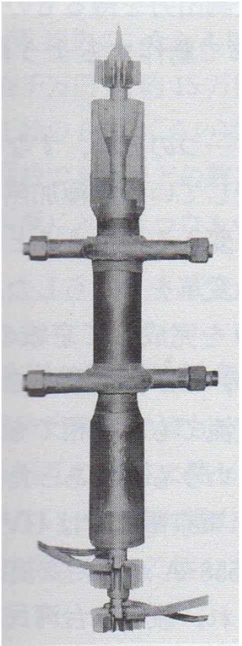
In the same way, present **CZ-504D** has lifetime of approx. 100,000 hours, and if cathode temperature has dropped by 25°C, then estimated lifetime will be approx. 220,000 hours. This estimate, of course, excludes all possibility of failure other than emission. We sincerely hope that current problem on power supply and maintenance at relay stations and improved communication tubes be in actual use soon.

(v) **Miniature Communication Tubes** Excluded---- Ed.

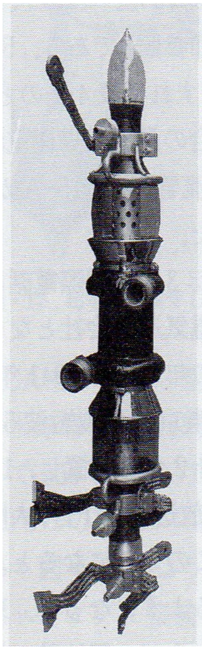
4.3.2. GT type Communication Tubes and Metal Tubes Excluded----- Ed.

4.3.3. Miniature type Communication Tubes Excluded----- Ed.

4.3.4. Sub-MT Tubes Excluded------ Ed.



TW-502-A
120kW Output
1934



TW-530-B
60kW Output
1937
For Short Wave

TW-558-A
120kW Output
1940

Note: Photos from “History of Vacuum Tubes” (Japanese Version) ------ Ed.