(003W-1)

Excerpt from “50 Year History of Tokyo Electric Company”

(1940) in Japanese

Radio Equipment (p.p.:424-454)

Part I: Receiving Tubes (p.p.:424-437)- 17 pages

Foreword

In recent scientific field in Japan, nothing should surpass radio technology in view of its surprising development and most effective application. Looking at the radio broadcast having nearly 5 million listeners at the present, or wireless communication between land and ocean, it is really amazing situation.

However, if we search source of such development, they are solely as a result of technology of vacuum tubes, and therefore, more than 20 years of our vacuum tube production history must be long remembered as a glorious memorial tower.

1) Dawn of vacuum tube industry

In 1904 Diode vacuum tube has found by **Fleming**, and Triode has invented by **deForest** in 1907. And then hard valve concept has followed by Langmuir in 1913 which contributed much to the development of vacuum tube industry. But major advancement came after WWI, and research of vacuum tube occupied a major field of national military interest. In view of this, our company started research project of vacuum tube in 1916 based on our experience of vacuum technology gained by light bulb production. And in 1917 succeeded manufacturing nation’s first vacuum tube named **Audion**.

In 1919 we produced so-called **French type** tube with a cylindrical anode for army as his standard product, and about the same time, produced a transmitting tube with

Tungsten spiral anode to post office. In 1920 we manufactured navy type tube by his request, and also supplied type **D Pliotron** in 1921. The name Pliotron stood for our transmitting tubes.

After 1920 demand of vacuum tubes increased, and the production technology finally got out of prototype stage, but the catastrophic earthquake occurred in 1922 which has destroyed our research and production facility completely, and many of our experienced research staff and documents have lost by the accident. But our effort afterward as a challenge given by heaven finally surpassed the difficulty.

The first Japanese radio broadcast started in 1925, and production of vacuum tubes has become real stage of advancement.

2) Progress of Receiving Tubes

a. Radio Broadcast and Receiving Tubes

The word Radio sounded as a big charm among general public when the radio broadcast has started in U.S. in 1920. Many R & D projects were held in various fields of Japan as well. In our company, **UV-200** (soft valve) and **UV-201**(hard valve) were manufactured for radio amateur, and marketed under the trade name “Cymotron”. Cymo stood for wave in Greek, and therefore meant as “component for wave”. This name Cymotron was used only for transmitting tubes after March, 1932, and all of receiving tubes were called “Mazda Tube” thereafter.

UV-200 and **UV-201** tubes described above were using pure Tungsten filament, but in 1924 we have succeeded production of Thoriated Tungsten filament, and marketed **UV-199** and **UV-201A** with it. This has received enthusiastic welcome of the radio fan.

In 1925 the first radio broadcast station in Shibaura, Tokyo has open, and radio was on the trail of huge success, and situation of our vacuum tube factory was out of description. Our effort of tube production, day and night, could never fulfill demand,

and never caught up such a demand even building new facility, etc.

Shortly after that, appearance of tubes for A.C. power supply was a big event.

b. Appearance of A.C. Radio

As the first interest when the radio broadcast has started was popularize radio to general public i.e. increasing number of radio sets regardless of crystal or tube model , and therefore, crystal sets were more popular as of lower cost, but gradually, demand of tube radio was increased, and therefore demand for tubes have greatly increased. But in the beginning, tube radio needed battery which is extremely inconvenient for handling , and gave general impression as “radio is troublesome and easily breakable thing”.

Soon afterward, a research has conducted to use household A.C. power line in Europe, and as the result, tubes for A.C. power line were developed. In our company, the same research has carried out, and in September 1928, **UX-112A** with oxide-coated filament was made, and in December of the same year, **UX-226** has followed. And in February of 1929, first rectifier tube **KX-112A** and in October in the same year, first indirect-heated tube **UY-227** has introduced, and finally, radios became operable with A.C. power line.

About this time, our company has set a firm policy as radio should only be popularized by A.C. power operated, planned lecture/presentation events and published documents for general public emphasizing advantage of A.C. powered radio.

We believe that the major reason for present-day success of radio is greatly owing to realization of tubes for A.C. operation.

c. Advent of Multi-Electrode Tubes

The improvement of radio has never ended, and A.C. operated tubes keep progress,

and finally, age of multi-electrode tubes has arrived. In 1930 a screen-grid type tube **UY-224** which demonstrates a great performance in high-frequency amplifier was introduced as a forerunner of tetrode tube, thus most of household radio used screen-grid tetrode, and seemed bringing its height of glory together with indirectly heated tube as detector.

However, there was a drawback in ordinary tetrode tube which creates modulation distortion, cross-modulation, etc. in some situation, and variable-mu tube was designed as a solution. In 1932 **UY-235** has marketed for the purpose.

In the other hand, the output tube available up to that time was only triodes, but as higher powered tube was demanded, so-called Pentode which has output sensitivity of 30 times higher than triode, **UY-247** has introduced. And then a smaller version named **UY-47B** has followed, and next year, high-frequency amplifier tube **UZ-57** and **UZ-58** replacing **UY-224** and **UY-235** were marketed. Audio amplifier showed tremendous improvement by them because only one stage of audio amplifier gave sufficient volume and sensitivity as it needed two stages before.

Also a new technology made smaller and more rigid tubes possible which was a result of introduction of smaller ST styled bulb and use of mica spacer.

In other hand, demand of tube for high powered class-B amplifier has created, and **UY-46** to suit the purpose has marketed.

And this time, answering demand for much less voltage variation for such high-Powered equipment, mercury vapor rectifier tube **HX-82** has introduced for use with **UY-46**. And further, a larger version, **UX-83**, has marketed and welcomed by the users.

At the end of 1933, power amplifier pentode **UZ-43** and rectifier **KZ-25Z5** were introduced and made so-called transformer-less receiver possible.

d. Popularization of Radio and Receiving Tubes

In the history of vacuum tube production and advancement, we hardly note better year than 1934. In this year, **UX-12A, UX-26B, UY-27A, UY-24B, UY-47B**, etc. were marketed, and as a rectifier, **KX-12B** has introduced. They have replaced older **UX-112A, UX-226, UY-227, UY-224, UY-247B** and **KX-112B** with new and smaller ST styled glass bulb, gained more rugged construction by using mica, and played an important role for smaller sized and more popularized radio possible.

Also, the filament voltage of older tubes were mainly 2.5 volt, but 6.3 volt model has gradually adopted in Japan, too. **Ut-6A7** was one of the many examples.

Looking at the recently designed tubes, you may notice that many of them show higher efficiency i.e. one tube serves more than 2 purposes, triode and pentode show higher efficiency than earlier types, and one tube contains more than 2 units such as twin-diode/triode, twin-diode/pentode, etc.

e. Recent Battery Tubes

Although battery tubes looked as if all disappeared as a result of introduction of A.C. operated tubes, but still various progress was shown in this field, too. One example is for military application like airplane use, etc. and showing unusual progress, but its detail will not be described here.

From about 1932, demand for battery operated radio is revived, and therefore new type of tubes have appeared again. They are for use in areas where A.C. power is not available, or for portable radio. For those purposes, so-called economical type was demanded instead of old and high power consumption types. We have manufactured the following types for the purpose:

UX-109 (Feb., 1932), **UX-110** (Apr., 1933), **UX-230** (Nov., 1931), **UX-232** (Nov., 1931) and **UX-233** (Apr., 1932).

Among them, **UX-109** (triode for det./amp.) and **UX-110** (power amp.) are for operation with dry battery for both A and B source, and filament operates at 1.0 through

1.3 V, and they are also low battery consumption.

UX-230 , **UX-232** and **UX-233** tubes are for battery set operable in the area where no power line is available during daytime, and therefore contributed for popularizing use in this purpose. This type of battery sets are for storage battery operation, and recharge after use is required, and therefore 2V of filament voltage is adopted.

3) Recent Receiving Tubes

It should be noted that recent progress in radio receiver is largely owing to innovation of small-sized multi-electrode tubes. However, not only them, diodes and triodes are also showing big improvement, and desired tubes having high conductance with relatively small filament power are available.

We are unable to ignore presence of all-metal tubes although there may not be essential to domestic market. Also transformer-less receiver may become popular as it consumes less power which matches our national policy, and therefore many new type of tubes have marketed. We will overview recent receiving tubes:

Diode Tubes

Diode tubes are mainly used for rectifier of A.C. power or detector. For detector, many types are combined with amplifier tube. Typical diode tubes are: **KX-5Z3, KX-12F, 12X-K1, 24Z-K2, KX-80, HX-82, HX-83, KY-84** (for rectifier), and **Kt-6H6A** (for detector).

Triode Tubes

As early types of triode were for general purpose, and mutual conductance was low.

But they were improved recently, and development for both voltage and power amplifier tubes were advanced, and mutual conductance value reaches 1 to several milli-mho level. They are in one way born to compensate drawback of multi-electrode tubes, and for example, **UX-2A3**, a power amplifier triode, exhibits excellent performance at the operating condition as μ: 4.2, rp: 800Ω & Gm: 5.25mS. And **UY-6301** suited for microphone amplifier shows 7.7mS of Gm at 9mA of plate current, 100 of μ and 13kΩ of rp, and low noise.

Class-B amplifier tubes are normally used without bias, and therefore need to have high μ, but in this case, push-pull connection is required, and therefore twin triode tubes in one bulb are marketed.

The representative triodes are: **UX-2A3** (power amp.), **UX-12A** (audio amp.), **UX-30** (detect, amp., osc.), **UX-45** (power amp.), **UY-56/ UY-76** (detect, amp. & osc.), **UZ-19** (power amp.), **UT-6A6/ UT-53** (class-B amp.), **UY-6301** (low-noise/ high-gain amp.), etc..

Tetrode Tubes

Tetrode tube consists of space-charge grid type, screen-grid type, variable μ type and 2 grid type for power amplifier.

The space-charge grid type does not seem to show progress except special application like measuring extra-low input signal, and for portable receiver. This is because recent triode exhibits progress in design and higher Gm at low anode voltage became possible.

The screen-grid type tetrode has gradually replaced to pentode as a characteristic disadvantage due to secondary emission.

There are still some tetrode tubes in the market such as: **UY-24B** (H.F. amp., det. & A. F. amp.), **UX-32** (H.F. amp. & det.), **UY-46** (power amp.), **UX-111** (det. & A.F. amp.) etc., and especially **UX-111B** is designed for dry battery operation, and therefore

best suited for portable receiver.

Beam Power Amplifiers

The tetrode tube was considered unsuited for power amplifier as it has a drawback due to secondary emission, and therefore range of usable anode voltage is limited, but owing to innovation in engineering, it was found that secondary electron emission can be suppressed without suppressor grid, and beam power amplifier has born as a highlight of recent small tube development.

In the beam power amplifier, screen-grid current is minimized by matching control and screen grid pitch toward flow of electron. And also electric potential between screen-grid and anode become more uniform than pentode, shoulder on the anode characteristic curve becomes more steep which results in better voltage utilization of anode, and also less amount of third-order harmonics is expected.

Pentode Tubes

The pentode tube was first designed for power amplifier, and then this concept has adopted to H. F. amplifier i.e. as screen-grid pentode and variable μ pentode.

Pentode tube surpasses tetrode type for higher rp and lower capacitance between anode and control grid.

By recent development of television, demand of high Gm pentode arose. For this purpose, **UZ-6302** has introduced with a surprising Gm of 10millimho at 12mA of anode current.

The power amplifier pentode tend to show higher third-harmonics compared with the triode, but requires much lower input voltage, and therefore gives great advantage in receiver design.

The typical pentodes are: **UZ-2A5** (power amp.), **UY-33** (power amp.), **UZ-42** (power amp.), **UY-47B** (power amp.), **UZ-57** (H.F. & L.F. amp., det.), **UZ-58** (H.F. var. μ amp.), **UZ-77** (H.F. & L.F., det.), **UZ-78** (H.F. var. μ amp.), **UY-133** (power amp.), **UX-134** (H.F. amp.), **UZ-6302** (TV amp.), etc.

Heptode Tubes

The heptode tube has 5 grids between cathode and anode, and is used as the first detector (frequency converter) in the super heterodyne receiver. There are **Ut-2A7,** and **Ut-6A7**, etc. as example.

The 1st and 2nd grids form local oscillator circuit. Electrons generated from cathode is modulated by the local oscillation frequency and reaches 3rd (acceleration) grid, but as 4th grid is at a negative potential, forms space-charge layer and create fictitious cathode, and electron exited from it is further modulated by 4th grid (by input signal), and finally accelerated by 5th grid and reaches anode. Thus anode current contains intermediate frequency component proportional to variation in input signal and local oscillation frequency.

Namely, heptode operates at no-load, its oscillation activity is stable and have high conversion conductance, but the other hand, high harmonics in the output and high noise level are its negative side.

Ut-2A7, Ut-6A7, UZ-1C6B (for battery operation), etc. are examples of frequency converter tubes.

Triode/ Pentodes

These are types that one each of triode and pentode unit contained in a glass bulb, and the typical example, **Ut-6F7** can be used in super heterodyne receiver as local

oscillator and first detector with one tube.

In this group, we also have our own type of tubes.

Twin-Diode/ Triodes

This type consists of a pair of diode and a triode, and use the former as detector, and the latter as amplifier. Typical products in this category are **UZ-2A6, UZ-55, UZ-75** and **UZ-85**. They all place a triode unit at the top and diodes at the bottom (in a shielded compartment) of a common cathode.

Twin-Diode/ Pentodes

This is the type replacing triode in the type described above with a pentode, and **Ut-2B7** and **Ut-6B7** are the typical examples. Usage of them has no big difference between Twin-diode/ triodes; use diodes as detector and feed its output to audio amplifier; use one each of diodes for detection and AVC; make only one tube for I.F. amp., detection and audio amp.,

etc.

All-Metal Tubes

The receiving tubes in our country reached a turning point at 1933, and as a result, smaller size and shock-free construction with ST bulb were realized, and after 1933-34, this trend has continued.

But about this time, there was a surprising fact occurred i.e. introduction of **Catkin tube** in UK. The concept of Catkin tube was differed tremendously because of using metal around glass envelope. It was sufficient to catch curiosity of people, but as it was

just placed anode outside the glass, and considered insufficient for defining as unbreakable, and although recognizing its advantage, still had to be rated as a transient product.

In our laboratory, we saw this as an important matter, and R & D project was in progress. And recently, the effort led to production of all-metal tube. This success must be evaluated as a conclusive result towards smaller and more rugged construction in progress of receiving tubes.

The construction of this type of tube is totally different from existing types. Using steel envelope instead of glass bulb, and it works as perfect shield at the same time, and therefore capacitance between grid and anode is reduced tremendously. Also shape of stem has totally changed, and lead wires have brought outside through eyelets consist of special metal called fernico and special glass having identical thermal expansion coefficient as fernico. This construction maintains vacuum seal perfectly.

By these features, realization of many advantages have resulted as follows, and made future of all-metal tube delighted:

a): excellent and uniform electric performance,

b): rugged construction maintains performance against shock,

c): smaller size,

d): suited for short wave application because of low internal capacitance

At the present, all-metal tubes produced by us are as follows, and the day in which these tubes appear in the marketplace under the name of Mazda should not be too long in a future:

US-6C5 (triode), **US-6J7** (H.F. pentode), **US-6K7** (variable-μ pentode), **US-6F6** (power pentode), **US-6H6** (twin diode), **US-6L7** (mixer), **US-6V6** (beam power tube), etc.

Tubes for Transformer-less Receiver

It was several years ago when so-called transformer-less tubes which do not need

transformer have introduced in U.S. The reason why it did not get popularity in Japan at that time was because low cost power transformer was readily available. But as materials became in short supply and controlled by the government because of war in China, it became very important to save precious material like copper and iron, and demand of transformer-less tubes became essential, and production of new tubes have accelerated.

The transformer-less tubes are not different in their operation like amplification, detection, rectification, etc., but only make their filaments connected in series, and heat them directly from 100V A.C. supply without using transformer. The heating current selected in this case was 150mA.

The existing tubes can be used for this purpose if filament current rating is identical, and in fact in U.S., such receivers are manufactured with existing tubes having 0.3A of heater rating. In this idea, no new type of tubes are required, but instead, it requires 30W of electric power regardless of actual need. This seems out of question in the city areas, but in rural areas where power consumption of less than 20W was desired for listeners because of fixed-rate power cost.

As to output power, it is desired to have minimum of 0.25W for household set. It may be said the higher power the better, but considering use of a popular magnetic type of speaker, more than 1W of power should not be necessary.

For these consideration, our Mazda receiving tubes for transformer-less receiver has designed as having total power consumption of less than 20W, and their filament voltage is rated as 12V or twice of it. Following is the list of such tubes:

12Y-V1 (H.F. variable- μ pentode)

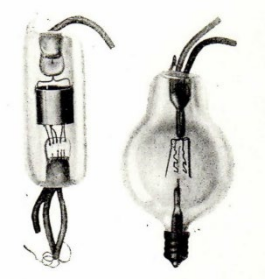
12Y-R1 (H.F. amp. & detector pentode)

12Z-P1 (power amp. pentode)

24Z-K2 (voltage- doubler rectifier)

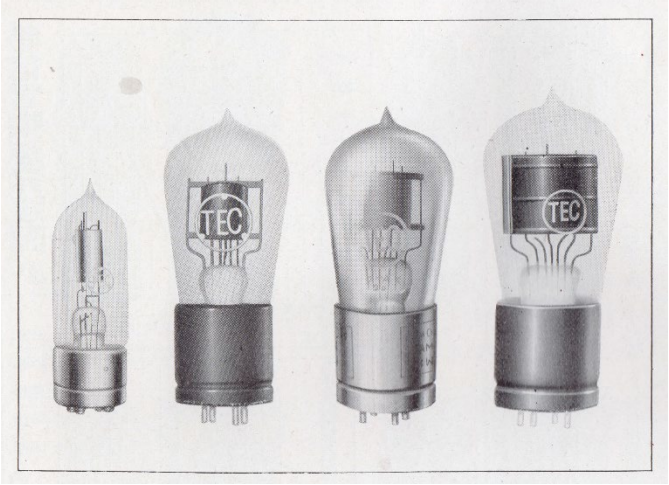
Note: these type numbers and ratings were certified by Japan Broadcast Society as a

standard of transformer-less receiver, and the first letter (s) indicates heater voltage, the second letter shows type of base, the third means kind of tube or usage, and the fourth shows order of manufacture. But for rectifier, the fourth letter means: odd number as half- wave type, and even number as full- wave or voltage- doubler type.



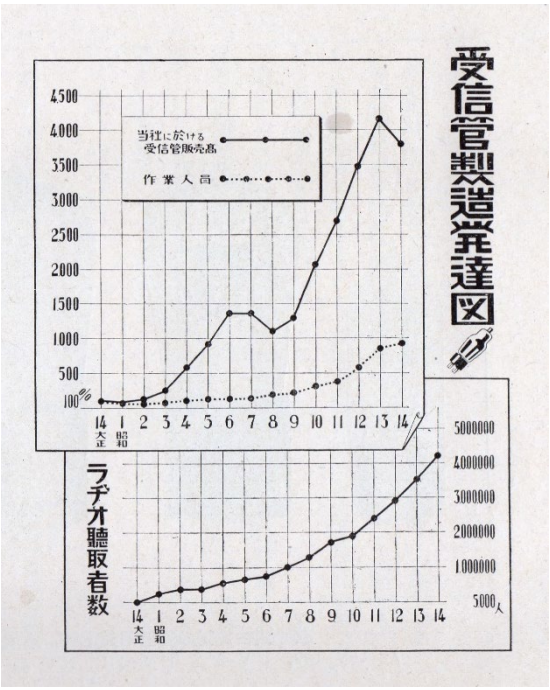
Pliotron　Audion

Earliest TEC vacuum tubes



UV-199　UV-200　UV-201　UV-201A

Tubes used when radio broadcast started



Above:

Receiving Tube Production in TEC

Solid line: No. of tubes sold

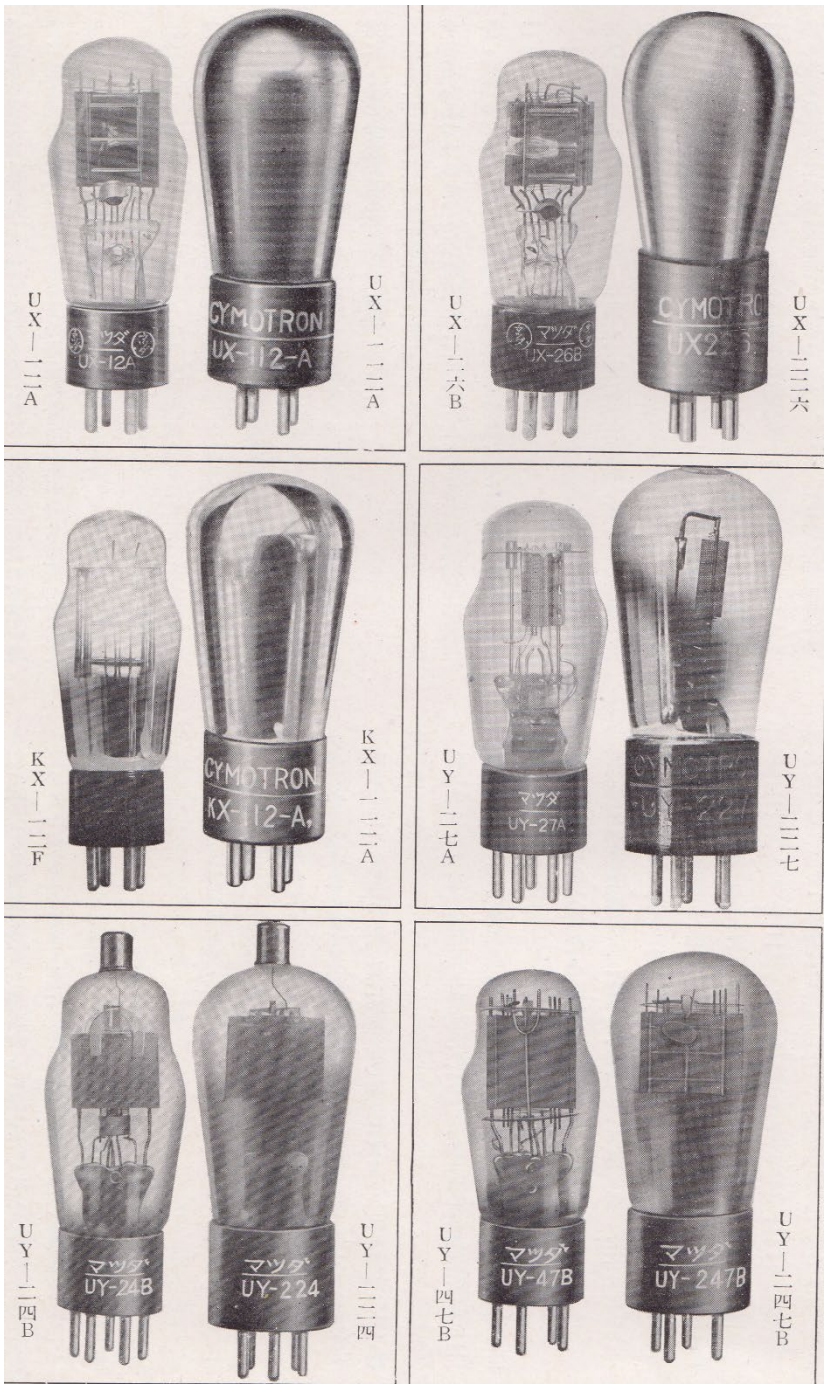
Dotted line: No. of workers

Below:

No. of Radio Listeners

Horizontal axis: Year 1925 to 1939

Comparison of newer (left) and older (right) types in typical receiving tubes



Left: UX-12A and UX-112A

Right: UX-26B and UX-226

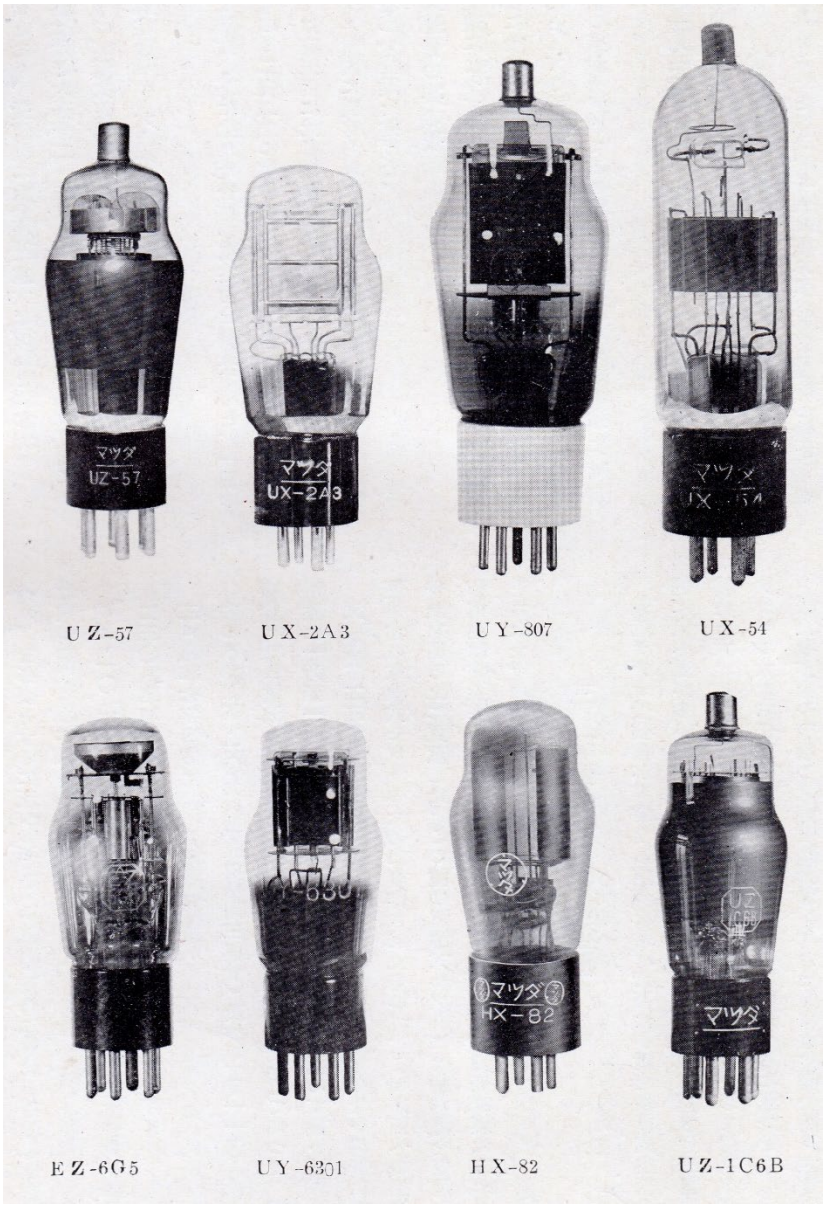
Left: KX-12F and KX-112A

Right: UY-27A and UY-227

Left: UY-24B and UY-224

Right: UY-47B and UY-247B

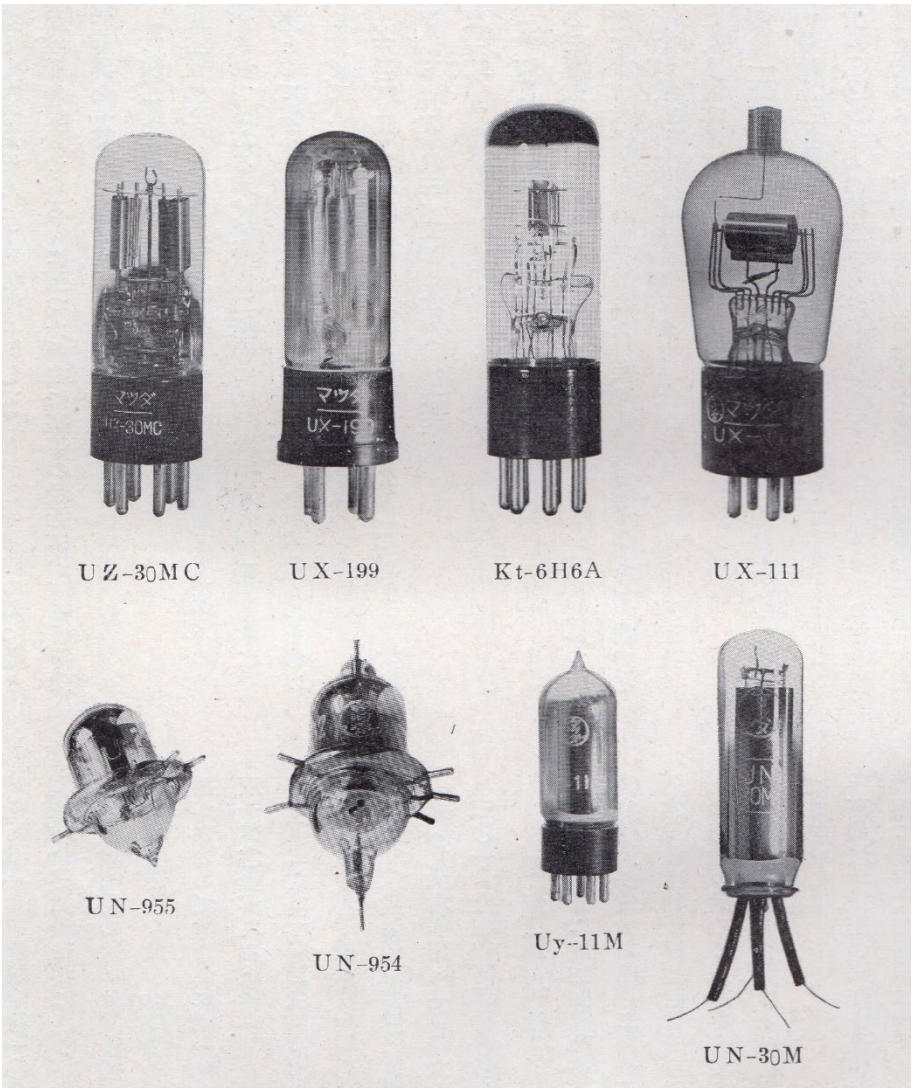
Example of Receiving Tubes: Part 1



UZ-57　　UX-2A3　　UY-807　　UX-54

EZ-6G5　　UY-6301　　HX-82　　UZ-1C6B

Example of Receiving Tubes: Part 2

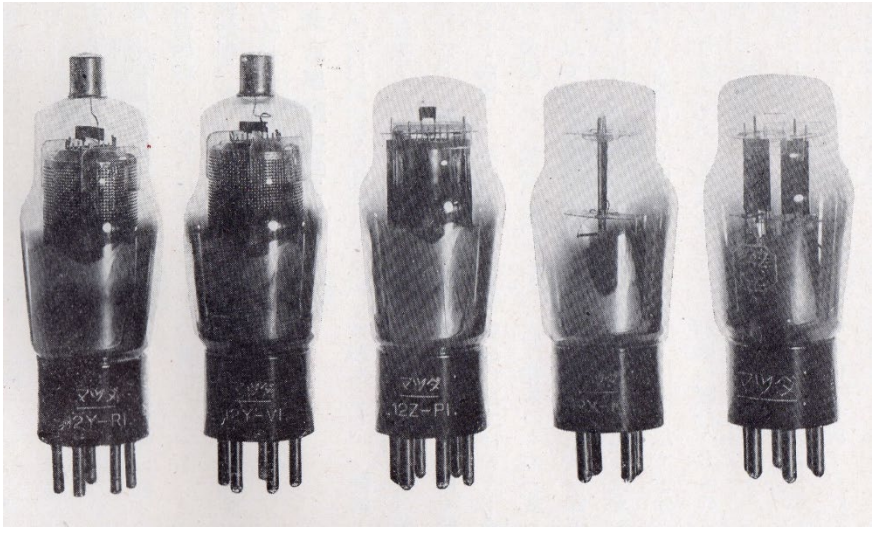


Type Number			
TEC (Mazda) Tubes generally bear 2 top letters. First letter shows Usage, and second shows Base.			
First Letter		Second Letter	
U	Triode or Multi-Electrode	X	4-Pin
E	Tuning Eye	Y	5-Pin
K	Vacuum Rectifier	y	Mini 5-Pin
H	Mercury Vapor Rectifier	Z	6-Pin
		T	Large 7-Pin
		t	Small 7-Pin
		F	B4 (French) 4-Pin
		N	Unbased or Special Base

Example of Receiving Tubes:　Part 3 (Metal Tube)

US-6F6　　US-6J7　　US-6J5　　US-6C5　　US-6H6

Example of Receiving Tubes:　Part 4 (Transformer- Less Tube)



12Y-R1　　12Y-V1　　12Z-P1　　12X-K1　　24Z-K2