Revision of Japanese Appliance Energy Efficiency Standards
A New Top-Runner Approach

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1 - SYNOPSIS

This paper explain the summary of the new standards for energy efficiency of electricity appliances in household revised in this year.

2 - ABSTRACT

To help attain the 6% reduction in greenhouse gas emissions agreed to at COP3, the Japanese Energy Efficiency Standard was revised in March, 1999. The points of the revision were (1) to strengthen efficiency standards for electrical appliances and automobiles using the top-runner approach, and (2) to strengthen efficiency standards in factories and buildings. The stronger standards for appliances and autos use the efficiency of the most efficient domestically shipped models in each performance class as the efficiency levels, and is therefore called the top-runner approach. The seven items targeted are passenger cars, air conditioners, refrigerator-freezers, fluorescent lights, televisions and VCRs, copiers, and computers. For example, efficiency gains of 16% for televisions and 59% for VCR standby power are expected.

In this paper we report on the content of the new electrical appliance standards. Efficiency of Japanese electrical appliances meets high levels even on a worldwide scale, but even higher standards have been set, and because the standards also apply to imported goods they should also be of interest in Europe. Japanese efficiency standards set a lower limit for the average efficiency of each maker's shipments, differing from European and US standards, which set a lower limit on individual appliance efficiencies. Furthermore, the new philosophy represented by the top-runner approach should be considered when preparing future European efficiency standards.

3 - INTRODUCTION

In May, 1998, the Law Concerning the Rational Use of Energy, commonly known as the Energy Conservation Law (ECL) was revised. The ECL set forth (a) measures related to factories, (b) measures related to buildings, and (c) measures related to machinery and appliances. Individual standards regarding energy efficiency levels were set. Following the revision of the ECL the specific content of these standard levels was studied. The measures in the ECL for factories, buildings, and machinery and appliances are aimed at business operators, building owners, and manufacturers, respectively, each with their own performance obligations set forth. Although their legal binding power is weak, penalties have been established in case the standards are not met. For (a) factories and (c) machinery and appliances, penalties including advice and public notification, having been strengthened in the recent ECL revision. For (b) buildings, this kind of penalty has not been set, but in order to receive public

financing the standards must be attained.

Despite their weak legal power, all previous energy efficiency standards for (a) factories and (c) machinery and appliances have been met. It can be said that this is a peculiarity of Japan, but for (c) machinery and appliances, for example, domestic makers supply nearly all of the domestic demand so it is thought that penalties such as advice and public notification effectively contribute to enforcing the standards. In this paper we explain the revision of energy efficiency standards for household electrical appliances (air conditioners, fluorescent lights, televisions and VCRs, and copiers). Standards for refrigerators, refrigerator-freezers, and freezers have also been subject to revision. But, for refrigerators, as a prerequisite to revising efficiency standards, measurement methods are being reconsidered, and the new standards will be based on the new measurement methods. At present the new refrigerator efficiency standards values have not been set, so we do not report on them here.

4 - TOP-RUNNER APPROACH

Under (c) measures related to machinery and appliances, a lower limit was set on the average efficiency of each manufacturer's products shipped per year. When the standards were revised, the "top-runner approach" was used. The top-runner approach is one in which the most efficient products supplied domestically have their efficiency levels taken as the next efficiency standards, including future technological development. The standard values were set according to the principles below.

(A) Subject equipment includes the following nine categories (below called specified equipment): passenger automobiles, freight automobiles, air conditioners, fluorescent lights, televisions and VCRs, copiers, computers, and magnetic disk units. However, equipment with highly specialized uses, unconfirmed measurement or efficiency evaluation methods, or low market penetration rates are not subject to the standards.

(B) Energy efficiency levels are established by the following indices.

Automobile:	km/l
Air conditioner:	COP = cooling (heating) capacity (W)/cooling (heating) input power (W)
Fluorescent lighting:	lm/W
Television:	kWh/year
VCR:	W (stand-by power use)
Copier:	Wh/h
Computer:	W/MTOPS (MTOPS is mega operations per second)
Magnetic disk unit:	W/GB (GB is memory volume)

(C) Efficiency standard values are set for a number of categories established according to basic performance of equipment. Within each performance category the standard is set at or above the efficiency level of the most efficient product in the category. For each manufacturer the weighted average efficiency of all units shipped within a category must meet the standard for that category. The standard values and categories also apply to imported goods.

5 - ENERGY SAVINGS ON THE REVISED STANDARDS

Efficiency standards for the specified equipment must be attained in various target years. The energy savings effect of equipment shipped in the target years has been estimated and is shown in Table 1. In this estimate it was assumed that the type and performance of units shipped would be of the same market share as the present.

Target year is from 2003 to 2010 and differ from each appliance. The reason for it is that the difficulty of technical development for improvement of efficiency is differ from each appliance.

Table 1. Energy savings effect of revised standards and target year

Category	Energy savings effect	Target fiscal year
Automobile		
Gasoline vehicles	21.4%	2010
Passenger cars	22.8%	2010
Freight vehicles under 2.5t	13.2%	2010
Diesel vehicles	13.1%	2005
Passenger cars	14.9%	2005
Freight vehicles under 2.5t	6.5%	2005
Air conditioner		
Heat pump type	63.0%	2004(cooling year)
Cooling-only	14.0%	2007(cooling year)
Fluorescent lights	16.6%	2005
Television	16.4%	2003
VCR (stand-by power use)	58.7%	2003
Copier	30.1%	2006
Computer	56.0%	2005
Magnetic disk unit	72.0%	2005

6 - EFFICIENCY STANDARDS FOR AIR CONDITIONERS

In fiscal year 1997 the penetration of residential air conditioners was 1.8 units per household, with an average of 2.3 units per household for households that possessed any units. A trend of increasing penetration continues each year. In particular, the increase in heat pump air conditioners is striking, while there is a decreasing trend for cooling-only air conditioners.

Air conditioners subject to the standards are those with cooling capacities less than 28 kW, except for chilled water coolers, those without electric compression, and those used in transportation. This time multi-type air conditioners (in which a single outside unit with the compressor and condenser is connected to several inside units in different rooms) were added to the subject air conditioners. In FY1997 7.701 million subject air conditioners were shipped, corresponding to 98% of all units shipped.

The efficiency standards are set by categories according to basic function, type, and cooling capacity. The standard value is shown as the COP (cooling or heating capacity is divided by the input power) and for heat pump air conditioners this is the average of the cooling and heating COPs. Measurement methods are according to JIS B 8616 for package air conditioners and JIS 9612 for room air conditioners.

Tables 2 and 3 show the new efficiency standards. In comparison to the current standards, the new standard efficiencies have greatly increased. For example, the 3.2 kW separate type air conditioner generally used in households has current standard COPs of 2.97 for heat pumps and 3.09 for cooling-only types, while the new standard COPs are 5.27 (less than 2.5 kW) and 4.90 (2.5 to 3.2 kW) for heat pumps and 3.64 for cooling only types. Also, the separate type units exceeding 7.1 kW cooling capacity in commercial use increase from current COPs of 2.59 for heat pumps and 2.45 for cooling only types to new COPs of 3.17 and 2.91, respectively.

Table 2. Efficiency standards for heat pump air conditioners

units: COP

	Cooling Capacity Category				
	~ 2.5	~ 3.2	~ 4.0	~ 7.1	~28.0
Direct blow/window (one box) type	2.85				
Direct blow/separate type/wall mounted	5.27	4.90	3.65	3.17	3.10
Direct blow/others	3.96	3.96	3.20	3.12	3.06
Duct type	3.02			3.02	3.02
Multi type	4.12			3.23	3.07

Table 3. Efficiency standards for cooling-only air conditioners

units: COP

	Cooling Capacity Category				
	~ 2.5 kW	~ 3.2 kW	~ 4.0 kW	~ 7.1 kW	~28.0 kW
Direct blow/window (one box) type	2.67				
Direct blow/separate type/wall mounted	3.64	3.64	3.08	2.91	2.81
Direct blow/others	2.88			2.85	2.85
Duct type	2.72			2.71	2.71
Multi type	3.23			3.23	2.47

Air conditioners are composed of a heat exchanger, blower, and compressor. For the heat exchanger a slit fin type or pipes with grooves on the inner surface through which the coolant flows are used, and these forms have already been improved. Also, various improvements have been made to maximize the heat exchanger area. For the blower, a cross flow fan or turbo fan is used. The placement and shape of the fan and blade have been improved with the cross flow fan. For the compressor, rotary or scroll compressors are used and inverter-type (electronic, variable speed) compressors are generally in use. Thus, there is almost no margin left for technology improvements for air conditioners. Also, due to conversion from the conventionally used HCFC coolants to HFC coolants a 3 to 10% decrease in efficiency is expected. The high-efficiency air conditioners supplied to the current market are those that use many of these high-level technologies, and with increasing cost the type of machines are also many. Therefore, as the new standards are set, at the highest level of those currently on the market, further efficiency improvements due to technology development are not expected.

7 – EFFICIENCY STANDARDS FOR LIGHTING

Unlike in other developed countries, fluorescent lamps dominate incandescent bulbs in the lighting market in Japan. According to the survey done by the Illuminating Engineering Institute of Japan (IEIJ, 1993), fluorescent lamps occupy about 60% of the number of light bulbs in the residential sector. Moreover, incandescent bulbs are mainly used in places where lighting time is relatively short such as toilets, bathrooms or halls. This is why only fluorescent lamps are selected as subject to efficiency standards.

Efficiency is defined as lumens per watt (lm/W) for an appliance. Lumens is the total flux discharged from all lamps of each appliance and wattage is the total electricity consumed per unit time by the appliance. The effect of reflectors is not taken into account, because actually used flux varies with the situation or purpose of lighting (for example, indirect lighting is not efficient but is effective to create a good atmosphere). As shown in Table 4, appliances are classified according to the lamp, total watts, ballast type and main usage. Appliances with an electronic ballast are 20%-70% more efficient than those with a magnetic ballast, however, electronic ballasts cost about 10 times more than magnetic ones. It takes typically 10 years to recover the initial surplus cost by annual electricity savings. This is why some appliances are classified according to ballast type.

Table 4. Classification and target efficiency of lighting appliances

No.	Type of fluorescent lamp used by appliance	Total watts	Ballast type	Main usage	Electricity consumption in 1997*	New standards (lm/W)
1	110W rapid starter (Straight tube)	-	-	• Supermarket • Factory	459 GWh (6.4%)	79.0
2	40W high frequency (Straight tube)	-	-	• Office building • Large store	340 GWh (4.8%)	86.5
3	40W rapid starter (Straight tube)	-	-	• Office building • Large store	2,410 GWh (33.8%)	71.0
4	40W starter (Straight tube)	-	-	• Small store • Temporal building	655 GWh (9.2%)	60.5
5	20W starter (Straight tube)	-	Electronic (Inverter)	• Residential	591 GWh (8.3%)	77.0
6	20W starter (Straight tube)	-	Magnetic			49.0
7	Circle tube	> 72W	-		2,269 GWh	81.0
8	(combination of	62W - 72W	-		(31.8%)	82.0
9	20W, 30W, 32W	< 62W	Electronic			75.5
10	and 40W)	< 62W	Magnetic			59.0
11	Compact fluorescent	-	-	• Lighting stand	23 GWh	62.5
12	Straight tube	-	-		(0.3%)	61.5
	Others	-	-		390 GWh (5.4%)	-

** Sales base*

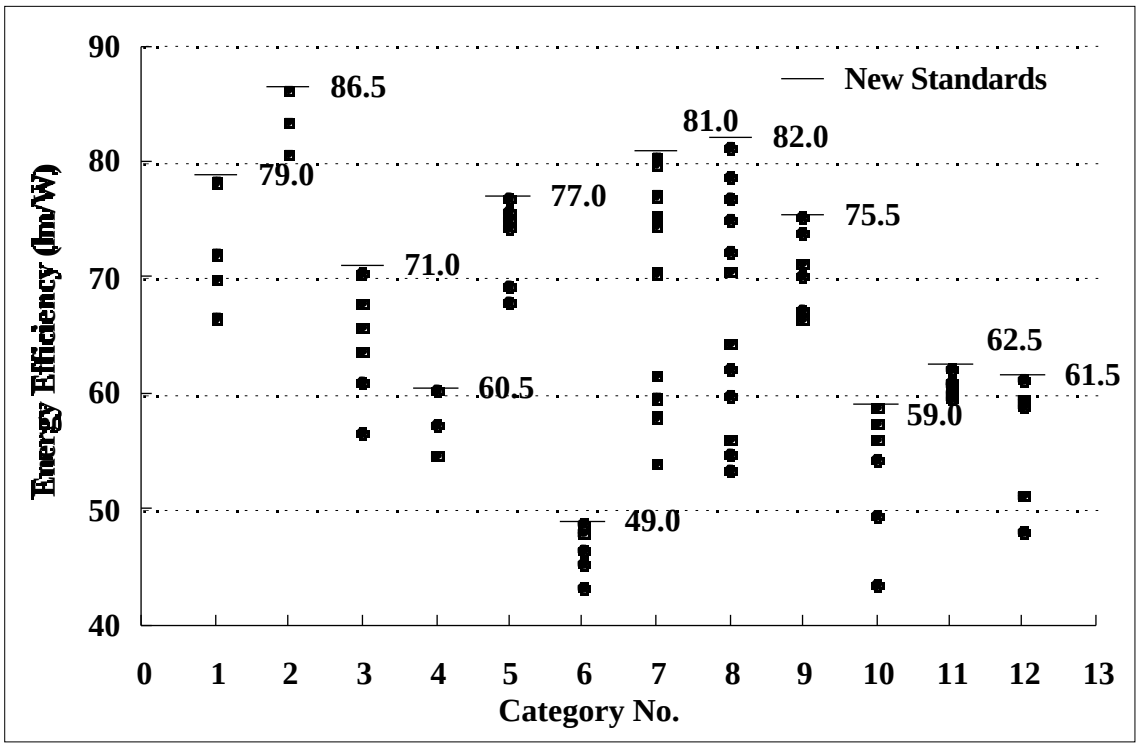

Figure 1. *Efficiency of current products and target efficiency of lighting appliances*

The efficiency of current products and the target efficiency are shown in Fig. 1. Basically, the targets are set to the levels of the top-runners and a little improvement is considered for some categories. This improvement is estimated assuming that lamps that can be used only with an electronic ballast penetrate to 5% for commercial use and 10% for residential use in 2005 (target year). The figure shows that the efficiency of category 3 (40W rapid starter) and category 7 and 8 (circle tube with total wattage more than 62W) should be greatly improved.

The weighted average of the efficiency (shipment base) is estimated to be 63.1 lm/W in 1997. If the weight remains unchanged, the efficiency will be improved to 73.6 lm/W (16.6% gain from the 1997 level) in 2005.

8 – EFFICIENCY STANDARDS FOR TELEVISION AND VCR(VIDEO CASSETTE RECORDER)

8.1 Television

Next to the air conditioner, refrigerator, and lighting, television consumes the fourth largest share of electricity among appliances in the residential sector in Japan (MITI, 1998). On average, each household has 2.2 televisions and both the numbers and the average wattage per appliance have been increasing. This is because the market shifts to larger sizes and televisions that have a built-in BS (Broadcast Satellite) tuner and/or a built-in VCR. More recently, flat type picture tubes were developed and they consume 17-55 kWh/year more electricity than normal types. Future average efficiency of television will decline due to these trends, if a stricter efficiency standard is not be enforced.

Efficiency is defined by annually consumed electricity per appliance. It is estimated by the following equation.

$$E = \{(P_O - P_A) \leftrightarrow t_1 + P_S \leftrightarrow t_2\}/1000$$

where E : Annually consumed electricity (kWh/year)
P_O : Consumed watts in working time (W)
P_A : Saved watts by power saving functions (W)
P_S : Consumed watts in idle time (W)
t_1 : Estimated average of working time (4.5 hours per day)
t_2 : Estimated average of idle (stand-by) time (19.5 hours per day)

Because the efficiency varies with the size, a linear equation is assumed between
efficiency and size (measured as the diagonal of the picture tube). Moreover, televisions are classified according to the type of picture tube, existence of a built-in VCR, and the number of added functions, as shown in Table 5. An example of how this equation is set is shown in Fig. 2 (the case of 4:3 aspect ratio, less than 100 deg. deviated angle and no functions). For categories in which the number of models is limited, the same slope as that of a similar category is applied and the constant values are changed to fit the efficiencies of the top-runners. Moreover, the added margin for the built-in VCR is unified to be 28 kWh/year for all categories.

The weighted average of the efficiency (shipment base) is estimated to be about 140 kWh/year in 1997. If the weight remains unchanged, the efficiency will be improved to 117 kWh/year (16.4% gain from the 1997 level) in 2003 (target year). However, it will be very difficult to achieve this improvement if current market trends (penetration of televisions with larger sizes, more functions and flat type picture tubes) continues.

Table 5. Classification and equation of target efficiency for televisions

Scanning Method	Aspect ratio of picture tube		Functions	Equation of new standard (kWh/year)	Plus margin for flat type picture tube
Normal	4:3	Deviated angle: less than 100 deg.	No	EM = 2.5S+32*	10
			Built-in VCR	EM = 2.5S+60	10
		Deviated angle: more than 100 deg.	No	EM = 5.1S-4	25
			Built-in VCR	EM = 5.1S+24	25
	16:9		No	EM = 5.1S-11	10
			Built-in VCR	EM = 5.1S+17	10
			1 function	EM = 5.1S+6	10
			2 functions	EM = 5.1S+13	10
			3 functions or more	EM = 5.1S+59	10
Double speed	16:9		Hi-Vision	EM = 5.5S+72	-
	16:9/4:3		non Hi-Vision	EM = 5.5S+41	-

** EM: Maximum of annually consumed electricity, S: Size of picture tube in inch (length of diagonal)*

Figure 2. *Efficiency of current products and target efficiency of television (4:3 aspect ratio, less than 100 deg. deviated angle and no functions)*

8.2 VCR

The most characteristic point of VCRs is that their efficiency is defined by the electricity consumption in idle time. This is because average working time of VCRs is less than 1 hour per day and 86% of electricity is consumed in idle time (in 1996). Typically, 1.0-1.5 W of electricity is consumed by the clock display continuously. A Japanese maker of electric appliances developed a VCR that has a switch to turn off the clock display and other indicators (Sharp Co., 1998). Savings of 3.4 W are available by turning off the display and the VCR consumes only 0.5 W in idle time. According to a questionnaire done by the Electronic Industries Association of Japan (EIAJ), 40% of households do not use the VCR clock. Considering this, average electricity consumption of VCRs with displays that can be turned off is estimated by the following equation. The multiplier 0.2 means that half of the people who do not use the VCR clock are assumed to actually turn off the display.

$$E = P_{d\ \mathrm{on}} - \left(P_{d\ \mathrm{on}} - P_{d\ \mathrm{off}}\right) \times 0.2$$

where E : Average electricity consumption in idling time (W)
$P_{d\,on}$: Electricity consumption when the sign is displayed
$P_{d\,off}$: Electricity consumption when the sign is not displayed

The efficiency of current products and the target efficiencies based on the top-runner approach are shown in Fig. 3. There is currently no VCR whose display can be turned off in the "Others" category. Therefore this target is set to the target efficiency of the "Normal VHS with BS Tuner" category minus the margin for the built-in BS Tuner. Setting a strict target for the "Others" category is very important because this category occupied 70% of shipments in 1997.

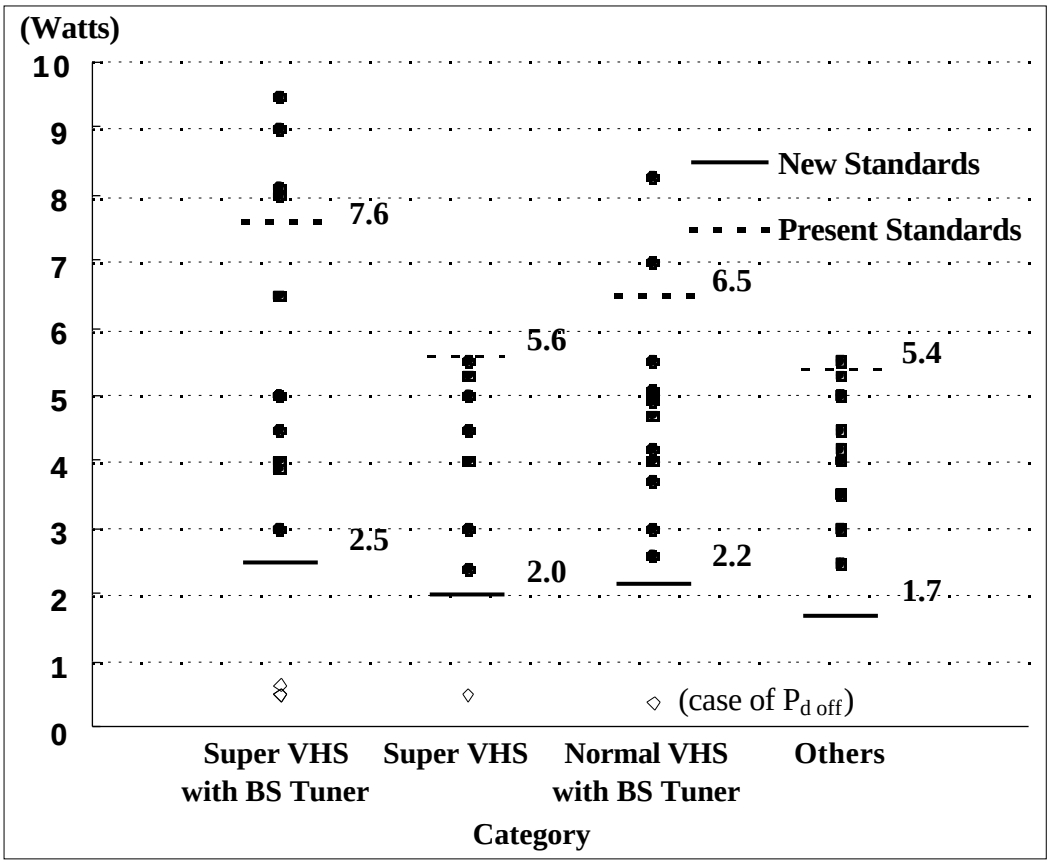

Figure 3. *Efficiency of current products and target efficiency of VCRs*

The weighted average efficiency (shipment base) is estimated to be about 4.55 W in 1997. If the weight remains unchanged, the efficiency will be improved to 1.88 W (58.7% gain from the 1997 level) in 2003 (target year).

9 – EFFICIENCY STANDARDS FOR COPIERS

The number of domestically shipped copiers was 698,000 in 1992 and 1,124,000 in 1997 (Ministry of International Trade and Industry (MITI)), an increase by a factor of 1.6. MITI estimates that of the 4,323,000 units in place nationwide, 69% are analog machines and 21% are composite types, while digital machines and color copiers are increasing but still hold only a few percent .

The copiers subject to standards are the analog type comprising 69% of the existing stock. Nearly all copiers currently in use in general offices are analog type. Multi-function types are those that combine copiers with fax or printer functions. They also comprise a large share of the existing stock but they were not subjects of the standards due to their measurement methods being unstandardized. Digital and color copiers were also excluded from the standards due to small market shares.

Energy efficiency is estimated by hourly electricity consumption, obtained by the equation below, with Pattern A measured for one hour after being turned on, and Pattern B measured for the following hour (Fig. 4) .

Hourly electricity consumption = $(A + 7B) / 8$ (Wh/h)

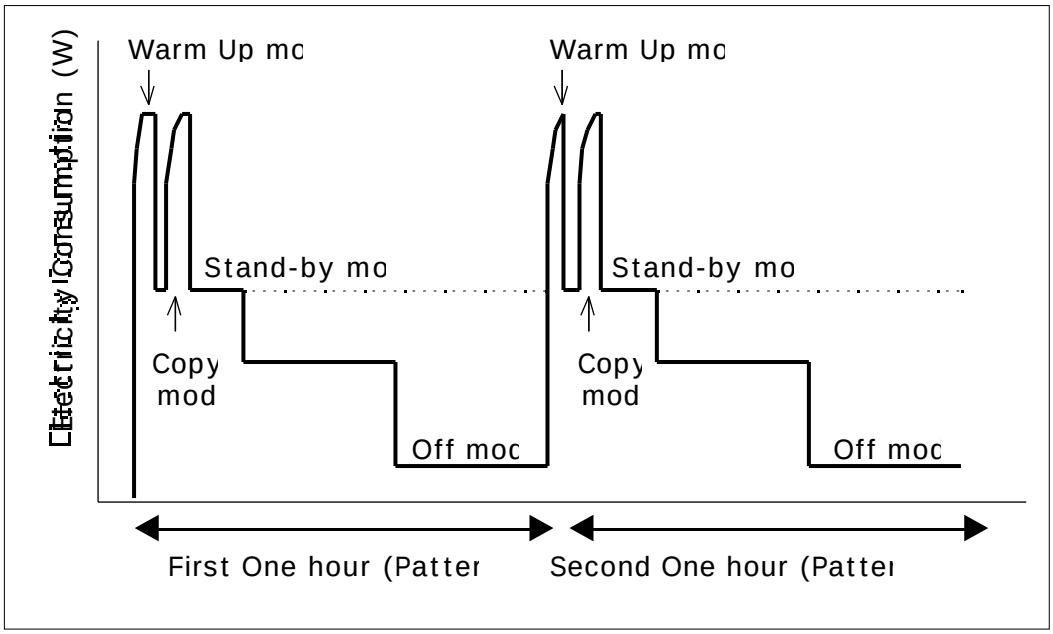

Figure 4. *Measurement patterns for copiers*

There is a trend for copier electricity use to increase with the number of copies per minute (CPM). Also, electricity use varies depending on the maximum paper size. This is because the fixer, which accounts for 60 to 70% of electricity use, varies with the number of copies and the maximum paper size. The current standard set efficiency levels for each copier speed at 1 CPM increments, but in the new standard efficiency levels are set for categories of 10 CPM increments.

Currently, most copiers are of the A3R type, and their electricity consumption is proportional to their CPM. Copiers of the A4 and B4 type are distributed at or below 20 CPM, and A3R type copiers are widely distributed between 10 and 90 CPM (Fig. 5) .

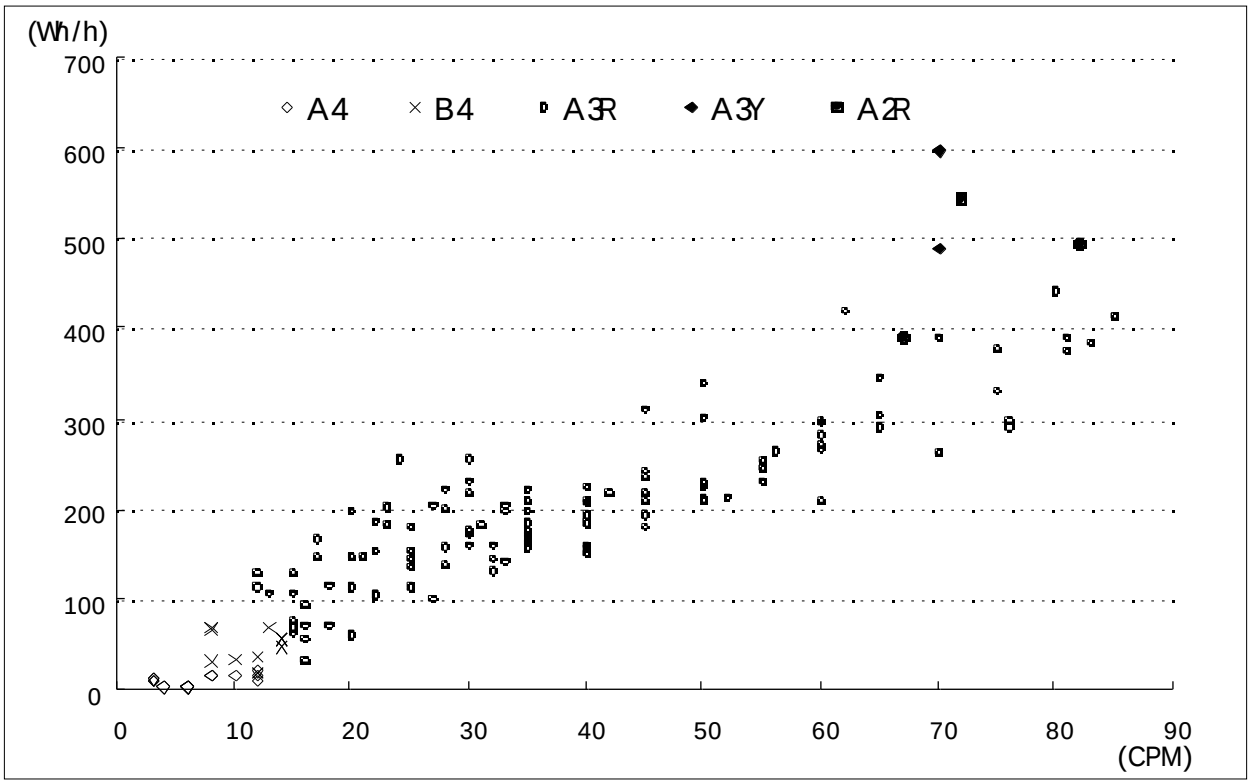

Figure 5. *Energy consumption of present copies (1997)*

For the 20 CPM and slower category, there are machines that use the surf method to attain very low stand-by electricity consumption. However, because one company holds the patent to the surf method, setting the standard at that obtained using the surf method would effectively give one company a monopoly in the 20 CPM and slower category. Therefore, for this category, only machines not using the surf method were considered, but to encourage future efforts in technology development the standard was set at electricity use of 5% below the current top-runner not using the surf method.

The new copier efficiency standards are set for each 10-CPM interval at the level of the type of machine using the least electricity (excluding those using the surf method), allowing for a few percent improvement due to future technology development. These revised standards are set for machines with maximum paper sizes of A4, B4, A3R, and A3Y. When compared to the present standard, the level for the most popular A3R type has been greatly improved (Fig. 6).

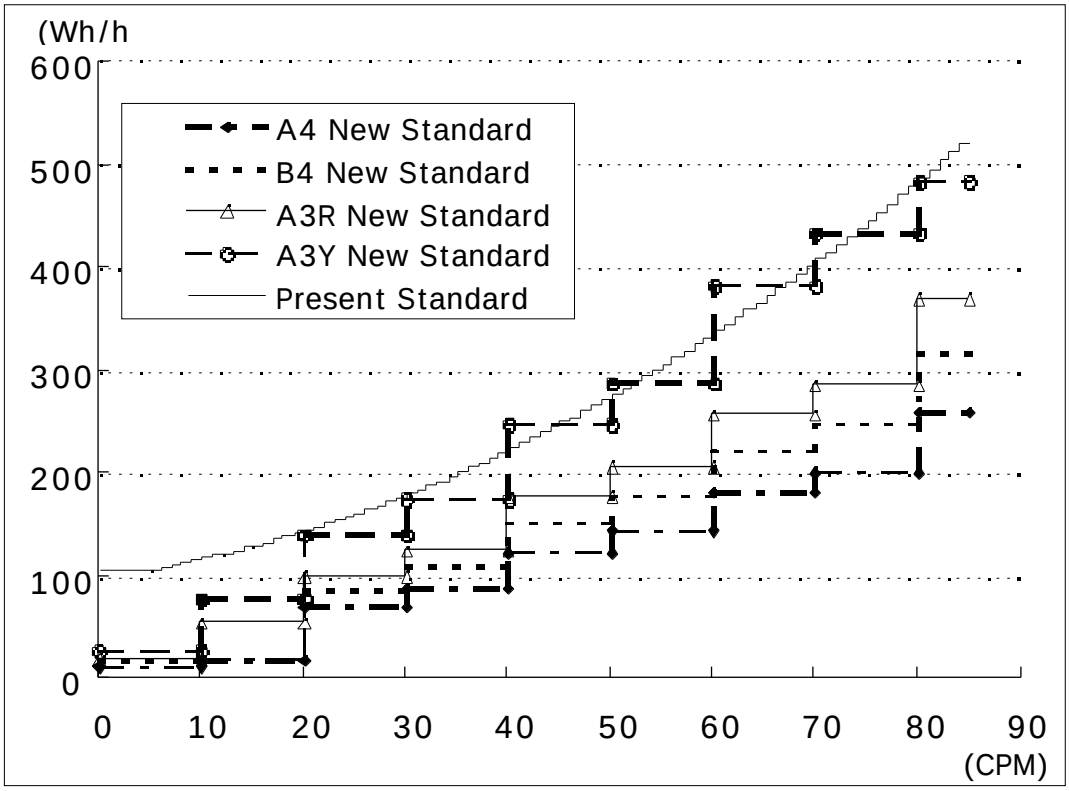

Figure 6. *New standards for copiers*

Regarding technology development for copiers, machines with shortened warm-up periods due to a thinner fixing roller, and machines that incorporate and off mode have appeared. As for fixing methods, those other than the generally used hot roller method have been proposed, but the hot roller method has won out for its comprehensive function. In contrast, the surf fixing method has entered the market, and from the perspective of energy efficiency it has superior functions, but it is not applicable to the medium- and high-speed copiers used in typical offices. Other technology developments, such as decreasing the light source wattage, increasing the sensitivity of the photosensitive material, and decreasing the toner melting point, have already been carried out.

Furthermore, because the standard value is set for categories of 10-CPM increments, copiers will have to meet the standards within their own categories. Generally, makers do not produce several types of machines with identical functions. This means that with the new standards, all products will have to meet the standards, and it will be difficult for makers to select products that have strategically received the bulk of technology development efforts. As a result, the new standards will bring forth a rigorous effort at technology development.

10 - DISCUSSION

Since the revision of the ECL in May, 1998, work on setting the new standard levels began. In the short period of about half a year the standard setting was finished. With these revised standards, the average efficiency will be brought up to the level of the current most efficient product. In other words, the premise is that what is currently thought to be the best technology will have to be used in all products, and makers are requested to pursue technology development and cost savings.

However, as seen here, for the top-runner approach, which sets up product categories according to model sizes, the issue of the lack of discouragement for the degradation in efficiency that accompanies increasing model size remains. Not only is raising of efficiency standards needed, but also planning and implementation of energy

efficiency policies such as support for further technology development, measures to increase the diffusion of efficient machines, as well as measures favorable to decreasing model sizes.

Nevertheless, because at the time of setting the new standard values the focus was on current mainstream products and rigorous efficiency standards were set, we expect that the overall energy savings effect will be great. There should be a major impact on future efficiency improvements.

In contrast, the use of the top-runner approach has already influenced makers' technology development. Since the standards have been summarized products exceeding these efficiency levels have been introduced. These were included at the final stage of the current revised standards and the standard levels were recalculated, but in the future models that exceed efficiency standards will probably be introduced before the target dates for those standards. In the future, the standards will need to be reconsidered if models with efficiencies greatly surpassing the standard are introduced or if products not subject to the these standards come to have a large market share. Even for those cases the top-runner approach can be used flexibly and quickly.

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