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ELECTRICAL ENERGY EFFICIENCY AND ENERGY CRITERIA IN HOME AXIAL FANS IN IRAN

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Abstract- Energy consumption in Iran is 3.5 times of the world average and electrical energy consumption in Iran is 5 times of the world average. So it is necessary to have the standard of energy consumption in particular of home energy and consuming tools. 42% of the total energy consumption in the world is related to the home sector. Fans with 9% of home consuming energy, after the refrigerators and air conditioning systems are the third energy consumers in this sector. Researchers conducted in other countries show that there has been a considerable reduction of energy consumption of fans when standard methods of fans tests have been applied. For this purpose, the standard and criteria of energy consumption in fans have been developed and communicated in accordance with the legal duties. The objective of developing these standards is to determine the method of energy consumption measuring and energy label of home centrifugal fans. This standard is applied on centrifugal fans from air giving out of 170 to 3500 cubic meter per hour. The index of energy consumption in various countries of the world has been defined based on CFM/W, M^3/min/Watt or M^3/S/Watt.

Keywords: Energy Labeling, Energy Saving, Electrical Energy.

I. INTRODUCTION

Energy label of home fans contains data upon which the consumers can compare different home fans with regard to the determined energy consumption index, energy output ranking (A to G), maximum of static pressure and maximum of air giving out.

In order to select the standard of the test of fan and test of aerodynamic performance measuring, the Iranian National Standard of ISIR 8464, and ISO 5801 ANSI/ASHRAE 51 have been used. The selection of the standard of consumption measuring and performance of fan is the ratio of produced air flow to the consuming energy (flow output) CFM/Watt, M^3/hr/Watt, M^3/min/Watt, M^3/S/Watt.

Studies conducted in other countries and the record of the project is as the following. The index of energy consumption in countries of the world has been defined based on CFM/W, M^3/min/Watt or M^3/S/Watt [2].

The USA, China and Taipei China have standards of minimum energy consumption for table fans and ceiling fans. In addition to the above mentioned cases, USA has the standards of minimum energy consumption for fans less than 500 CFM.

Table 1. Minimum of standards defined for air conditioning fans with by Energy Star [3]

Rate of air passing - P_e (CFM)	**Minimum standard of energy consumption (CFM/Watt)**
Kitchen hoods **500**	**2.8**
Bathroom air vent **10-80**	**1.4**
Room and Bathroom air vent **90-130**	**2.8**
Bathroom and Room air ventt **500-140**	**2.8**
Single or multi portal	**2.8**

Table 2. Some of the home air ventilators with Energy Star Standard Label [3]

Row	**Manufacturer**	**Rate of air flow (CFM)**	**Energy Consumption (W)**	**Energy consumption standard (CFM/Watt)**
1	Panasonic	50	13.6	3.7
2	Greenheck	51	18	4.5
3	Greenheck	53	38	1.4
4	Panasonic	60	13.7	4.38
5	Panasonic	70	17.6	4
6	Greenheck	70	20	3.5
7	Panasonic	70	20.2	3.64
8	Greenheck	70	45	1.6
9	King-air	80	24.2	3.2
10	Greenheck	88	29	3
11	Panasonic	90	20.9	4.3
12	King-air	90	28.9	3.11
13	Panasonic	110	24.5	4.49
14	Panasonic	110	26.7	4.12
15	Panasonic	150	39.6	3.78
16	Panasonic	190	42.4	4.48
17	Panasonic	190	42.6	4.46

- Terms and Definitions: In this standard, the following terms and definitions are used in addition to the terms and definitions defined in the Iranian National Standard No. 8464 [5, 6, 7].
- Flow rate in based static pressure: It is a part of static pressure which is considered to calculate the fan air ejecting. This pressure is for axial fans of 12.5 Pascal.

Table 3. Minimum standard defined for fan in Taipei China [4]

Type	Fan diameter (centimeter)	Energy consumption standard (M^3/min/Watt)
Auto revolving hanging fan	35	1.01
	40	1.07
Stand alone fan	30	0.81
	35	0.87
	40	0.92
	50	0.91
	60	0.87
Ceiling fan	60	0.87
	90	1.15
	120	1.46
	130	1.45
	140	1.45
	150	1.47
Table fan	18	0.64
	20	0.66
	23	0.66
	25	0.67
	30	0.79
	35	0.86
	40	0.91

1.

- Maximum static pressure: It is the maximum static pressure produced by fan in terms of Pascal.
- Air giving out: It is the volume passing of flowing air from fan in static pressure or total pressure in terms of cubic meter per hour.
- Maximum air giving out: It is the rate of fan ejecting in static pressure of zero in terms of cubic meter per hour.
- Revolving speed: It is the number of revolving of fan blade per minute.
- Nominal diameters: It is considered based on the diameter of fan propeller.
- Nominal power of engine: It is the power which has been mentioned on the fan engine body or by the manufacturer in terms of watt.
- Engine input power: It is the product of voltage by voltage in circulation by the power coefficient which is measured in different air giving out in a momentum form.

$$W_{in}=V\times I\times\cos\phi \tag{1}$$

which W_{in} is the engine input power in terms of Watt, V is the voltage in terms of volt, I is the consuming flow in terms of Ampere and $\cos\phi$ is the coefficient of power.
- Home fans: Fan is a set to replace air using a revolving propeller. A fan must at least have one input portal and one exiting portal. These portals may (or may not) have some components to be connected to a ductwork. These fans include axial fan of 170 cubic meters per hour and maximum air giving out of 3500 cubic meter per hour.
- Index of Energy Efficiency Ratio [8, 9]: It is the rate of fan air giving out in the flow rate in based static pressure to the input power of engine which is defined as follows:

$$E=\frac{Q_{spb}}{W_{in}} \tag{2}$$

where
E : Index of energy efficiency ratio
Q_{spb} : Air giving out of fan in based static pressure
W_{in} : Engine input power
- Air Fan: It is a set being used to replace air and uses a revolving propeller functioning by an engine. An air fan should have at least one input portal and one output portal. These portals may (or may not) have components to link with a ductwork.
- Obligations: Since the engine input power of a fan never remains fully fixes, so in order to have a real understanding, either the fluctuations of the measuring set should be absorbed or the read out figures should be averaged in an appropriate way.
- General conditions of test: The environmental conditions should be determined in accordance with the obligations of National Standard of Iran No, 8464 [5, 6].

II. TEST METHODS

- Energy efficiency ratio test to determine the engine input power: Measuring the engine input power should be conducted in accordance with the obligations of the Iranian National Standard No. 8464 and Paragraph 4-5 of the ANS/ASHRAE 51 of this standard [5, 6, 7].
- Test to determine the air giving out (ejecting) in based static pressure: The rate of fan air ejecting in based static pressure should be obtained in accordance with the obligations the Iranian National Standard No. 8464 of the curve of technical qualification.
- Measuring the energy efficiency ratio index: The index of energy efficiency ratio should be measured in accordance with this standard.
- Test to determine air giving out: Measuring air ejecting should be performed in accordance with the obligations Iranian National Standard No. 8464.
- Test to determine the maximum static pressure: The maximum static pressure of fan should be obtained in accordance with the obligations of Iranian National Standard No. 8464 in zero air giving out from the curve of fan qualifications.
- Test to determine maximum air giving out: The maximum air giving out of fan should be in accordance the Iranian National Standard No. 8464 at the zero pressure point from the curve of technical qualification.
- Test to determine the revolving speed: The speed of revolving of fan propeller is obtained in accordance with the obligations of Iranian National Standard No. 8464.
- Method of calculation and instruction of energy label [8]: Energy label of home fans contains data upon which the consumers can compare different home fans with regard to the determined energy consumption index, energy efficiency ratio ranking (A to G), maximum of static pressure and maximum of air ejecting.

III. METHODOLOGY

In order to select the standard of the test of fan and test of aerodynamic performance measuring, the Iranian National Standard of ISIR 8464, and ISO 5801 ANSI/ASHRAE 51 have been used. The selection of the standard of consumption measuring and performance of fan is the ratio of produced air flow to the consuming energy (flow output) CFM/Watt, M^3/hr/Watt, M^3/min/Watt, M^3/S/Watt.

Type of multi-nozzle chamber plate bed with 40 to 2900 CFM bed capacity and dimensions of testable fans of suction fan with 50 centimeter diameter and for blowing fans up to 28 centimeter diameter have been prepared. The plate bed to check the fan test is presented in Figure 1.

Figure 1. Plate bed to check the fan test [8, 10]

In order to collect data and evaluate the results, the FANlab program being prepared by LABVIEW software has been used which has the following features:

- Ability to obtain and reserve types of statistical data on fan under investigation (general and technical characteristics)
- Ability to calculate the qualifications of blowing fans (exit chamber) and sucking fans (input chamber)
- Ability to read the quantities needed from the electronic sensors of bed automatically (temperature, pressure, etc)
- Ability to perform automatic calculation and with a high preciseness of fan qualifications from the input quantities
- Ability to have a graphical display of the details of test to facilitate using the program of presentation of curves of qualifications after testing
- Ability to reserve the results of text in EXCEL

The type of the output of the software is presented in Figure 2.

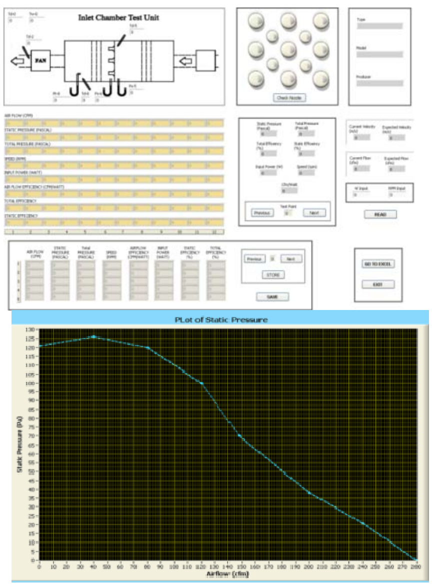

Figure 2. Software to test the fans FANlab [8, 10]

To take the test, first, a list of the products of some local large and creditable companies which produce more than 90% of local productions was prepared. Then some fan pivots and centrifugal types were selected which were confirmed by the Iranian Organization for Standard and Industrial Researches.

IV. RESULTS OF THE TEST

The results of the test of each fan by FANlab program include the following 7 diagrams:

- Statistical pressure in terms of flow discharge
- Total pressure in terms of flow discharge
- Consuming power in terms of flow discharge
- (CFM/Watt) M^3/hr/Watt in terms of flow discharge
- Total output in terms of flow discharge
- Statistical output in terms of flow discharge
- Revolving speed in terms of flow discharge

A sample of them is presented in Figure 3.

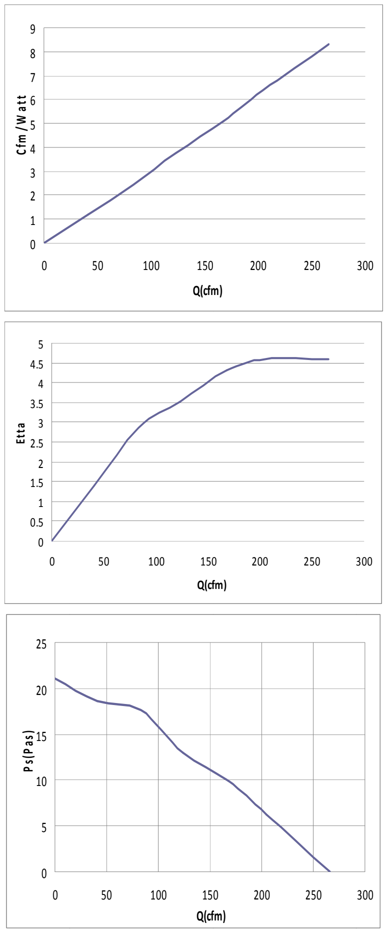

Figure 3. Curves of sample qualifications from axial fan in lab [8, 10]

In order to determine the rank of energy consumption of fans, the following three important parameters should be determined:

The standard of the comparison of consumption of (CFM/Watt) M^3/hr/Watt, the base point of measuring the point axial fan consumption with statistical pressure of 12 Pa, limit of maximum and minimum of consumption ranking are obtained by using the tested data of local fans and the data of creditable foreign fans.

Using the results of the tests of air fans being produced inside the country, the limit of minimum and maximum of flow output can be determined. Using the mathematical relations, we draw the average line passing through all points and by drawing two parallel lines for the highest and lowest quantities, the limit of flow output is determined.

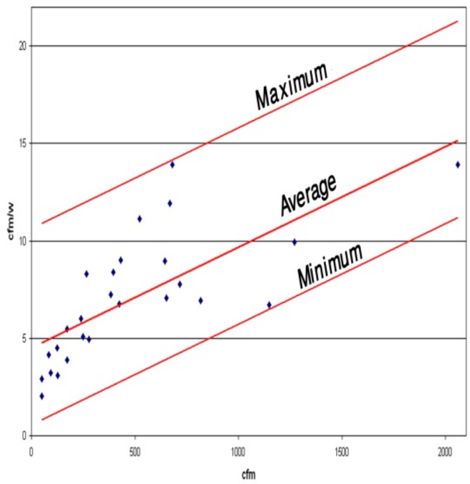

Figure 4. The primary estimation of the limit of flow output (axial air fans) [8]

But with a view in Figure 4 the main problems become clear:
- Due to the vastness of the scope of quantities of horizontal pivot, the linear estimation performed has a low preciseness.
- The maximum limit obtained in the regions with a lower air passing shows a very high figure.

The most prevailing way to solve this problem is to draw the horizontal pivot of the above diagram in the logarithmic specifications. So, the above diagram in the direction of the horizontal quantity of base becomes logarithmic and the vertical pivot which is the base of comparison remains intact. Then the distribution of quantities will find a more smooth shape (Figure 5). Such a diagram is called half-logarithm diagram in which the distances of points are changed in logarithmic form.

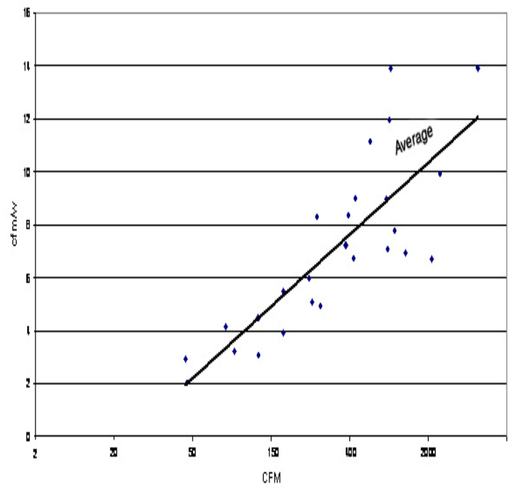

Figure 5. The primary estimation of the limit of flow output in semi-logarithmic form [8]

In order to solve the second problem, it is suggested that the slope of lines of maximum and minimum to be determined by using the existing quantities of maximum and minimum in the diagram. Thus, the highest and lowest existing quantities will be transferred to the Table.

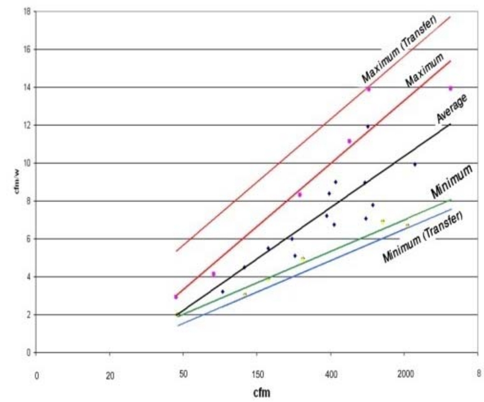

Figure 6. Methodology of ranking [8]

After testing a great number of fans in labs confirmed by the Iranian Institute of Standard and Industrial Researches, the results of the tests were as follows:

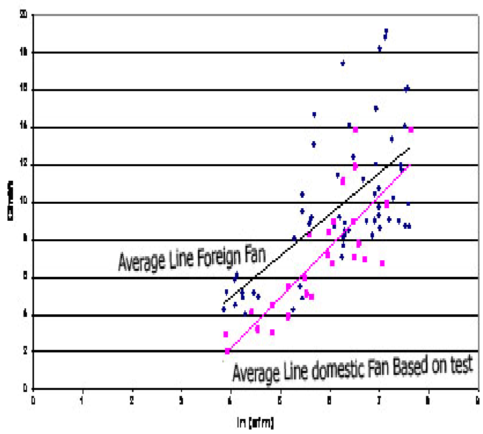

Figure 7. Diagram of comparing the output of the flow of Iranian and foreign axial fans [8, 10]

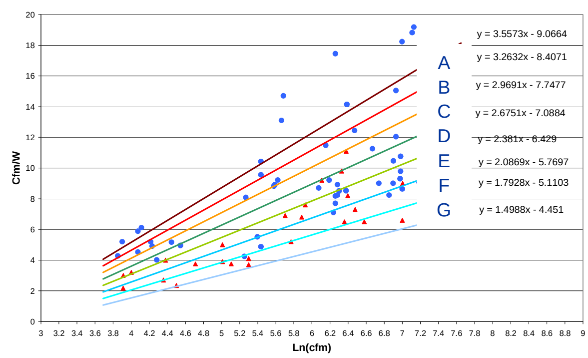

Figure 8. Comparing the rank of energy consumption of Iranian (triangle) and foreign (circle) axial fans [8]

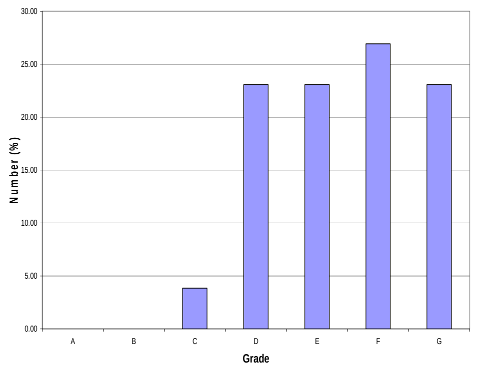

Figure 9. Diagram of percentage of axial fans tested on the obtained ranking [8]

V. METHOD OF CALCULATION OF ENERGY LABEL

In order to determine the rank of energy efficiency ratio, the maximum of air giving out (ejecting), maximum of static pressure and the speed of fan revolving, the following stages should be done:

1. Measuring the input power of engine (momentum power) in the based static pressure in accordance with the Paragraph 1-1-7 of this standard in terms of watt
2. Measuring the fan air ejecting in based static pressure in accordance with the Paragraph 2-1-7 of this standard in terms of cubic meter per hour
3. Calculation of the energy efficiency ratio index by using the Paragraph 3-1-7
4. Determining the group of energy efficiency ratio (energy ranking) by using the stage 3 and Table 1 to 4
5. Determining the maximum of fan air ejecting by using Paragraph 4-7 and 9-3 in terms of cubic meter per hour
6. Determining the maximum of fan static pressure by using Paragraph 307 in terms of Pascal
7. Determining the speed of fan propeller revolving speed by using the Paragraph 5-7 in terms of cycle per minute
8. Determining the nominal diameter of engine by using the Paragraph 7-3 in terms of millimeter
9. Determining the nominal power of engine by using Paragraph 8-3 in terms of watt

Table 4. Ranking the home axial fans [8, 9]

Ranking	Energy Efficiency Ratio index (M^3/hr/W)
A	$E > 5.54 \text{ Ln}E - 17.22$
B	$5.04 \text{ Ln}E - 15.84 \leq E < 5.54 \text{ Ln}E - 17.22$
C	$4.55 \text{ Ln}E - 14.45 \leq E < 5.04 \text{ Ln}E - 15.84$
D	$4.05 \text{ Ln}E - 13.07 \leq E < 4.55 \text{ Ln}E - 14.45$
E	$3.55 \text{ Ln}E - 11.68 \leq E < 4.05 \text{ Ln}E - 13.07$

Data included in the energy label includes the following items (Figures 1 and 2) [8, 9]:

1. Standard sign and name of label
2. Energy Efficiency Ratio (energy ranking) (Refer to Paragraph 8-1)
3. The digit quantity of energy efficiency ratio (E) (Refer to Paragraph 8-1)
4. Maximum of fan air ejecting (Refer to Paragraph 8-1)
5. Maximum of static pressure (Refer to Paragraph 8-1)
6. Revolving speed (Refer to Paragraph 8-1)
7. Nominal diameter (Refer to Paragraph 8-1)
8. Nominal power of engine (Refer to Paragraph 8-1)
9. Name of the manufacturer
10. Type of fan
11. Model of fan

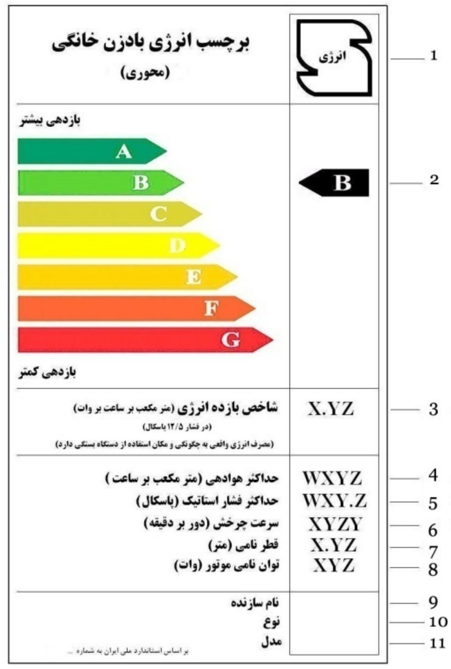

Figure 10. Energy label for axial fan [8, 9]

Methods of reducing the energy primary costs:
- Speed control
- Change in engine revolution
- Using the speech exchanger like gearbox
- Selecting an engine with a high output
- Reducing the propeller diameter
- Blades to regulate the input flow to fans
- Using reinforcing fans

Methods of reducing annual cost:
- Factors affecting the system such as ducts and portals
- Lubricating oils with high performance
- Compensating the free motion of internal revolving section , maintaining and services

Energy Consumption of Fans in Iran: According to the statistics, Fans have allocated about 9% of the total electrical energy consumption to themselves. So, with regard to the fact that the total energy consumption in Iran in the year 2006 was 147000 Giga Watt hours, the rate of estimated energy consumed by fans in 2006 will be 13230 Giga Watt.

Ability to increase the output of fans:
- According to the statistics, the output of foreign fans can be increased between 10 to 15%
- According to the tests, the output of Iranian fans is 75% of the foreign fans
- In average, the Iranian fans have a 16.6 percent ability to increase output.

VI. CONCLUSIONS

Estimation of the rate of saving in Iranian energy consumption as a result of raising the output of fans is less than 2100 CFM. The total consumption of Energy in Iran in the last year was 147000 Giga Watt Hours. Fans and sets consume about 9% of the total electricity; The Iranian fans hold 10 percent of the total market consumption. The fans with a discharge less than 2100 CFM form at least 30% of the consumption market. The free price of electricity in the Budge Law in 2007 is 642 Rials for per kilo watt hour [11]. With regard to the fact that the rate of increase of electricity consumption in the country is in average 6.8% annually, so, for the next five years, we will have the following Tables 7 and 8.

Table 7. Electricity Indexes

Description	Unit	Increase of 2006	Total	Total (2005)	Growth percentage 2005 to 2006
Per capita * power	Watt	59	663	604	7.9
Per capita * production	kWh	122	2743	2621	7.4
Per capita * consumption	kWh	143	2099	1956	3.7
Customers average consumption	kWh	364	7128	6764	4.5

Table 8. Rate of saving and its Rials value [8]

Year	Saving Rate (GWh)	Saving rate (BRLS)
The First	66	42
The Second	70.5	44.8
The Third	75.3	47.8
The Fourth	80.4	51
The Fifth	85.9	54.5
Total	312	242

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BIOGRAPHY

Reza Effatnejad was born in Abadan, Iran, 1969. He received the B.Sc. degree from K.N. Tossi University of Technology and the M.Sc. degree from University of Amirkabir and the Ph.D. degree from Iran University of Science and Technology all in Power Electrical Engineering (Tehran, Iran), in 1992, 1996 and 2002, respectively. Currently, he is an Assistant Professor of Power Electrical Engineering at Islamic Azad University, Karaj Branch (Karaj, Iran). He is also an academic member of Power Electrical Engineering at Islamic Azad University and teaches Power System Analysis, Power System Operation, and Electrical Machines. He has published more than 40 papers in journals and international conferences. Power and energy is the main field of his study.