Development of Environment-Friendly Cable "Eco-Ace"

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ABSTRACT In recent years, depletion of ozone layer, global warming, environmental pollution, and other environmental problems have been aggravated, and have been greatly attracting public attention. As a result, awareness to environmental preservation has increased and countermeasures have begun to be taken at all levels.

We at Furukawa Electric give consideration to preservation of earth environment, and aim at realizing a society which enables sustainable development in conformity to the "Furukawa Electric Basic Environment Policy". The environment-friendly cable "Eco-Ace" has been developed as a part of it. "Eco-Ace" is a product developed by thoroughly reviewing conventional type cables from the viewpoint of "environment-friendliness". In particular, the product does not affect the surrounding environment and achieves high safety and excellent recyclability because special emphasis is placed on using no material containing any substance that may exert load to the environment and on using materials that can be recycled. In this report, discussion will be made on the development of low-voltage and high-voltage electric wires and cables, and their accessories of, in particular, power and control systems in the product group of environment-friendly cable "Eco-Ace".

1. INTRODUCTION

As a negative side of the advancement of modern civilization, aggravated environmental problems such as depletion of ozone layer, global warming, environmental pollution, etc. have greatly aroused people's concern. It has been pointed out that the orientation to mass production and mass consumption which is intensified as the civilization and science advance gives rise to energy extravagance, resource impoverishment, etc., and endangers the "sustainable development" of the society. With these on the background, in recent years, increased awareness to the environment is observed at all levels of the world, country, company, civic organization, and individual.

The worldwide campaign for taking countermeasures against environmental problems has extended even to Japan, and resulted in reorganization of laws such as Waste Disposal and Public Cleansing Law, Electric Appliance Recycling Law, etc.

For companies, it has already become a social obligation not to pursue expansion of business or profits only as before but to establish a concept to the environment and to incorporate this concept into the corporate activities and products.

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Furukawa Electric carries out corporate activities with preservation of earth environment taken into account and with an aim to realize the society that enables sustainable development in conformity to the "Furukawa Electric Basic Environment Policy". This report discusses the development of environment-friendly cable "Eco-Ace" as part of such activities.

2. WHAT IS "ENVIRONMENT-FRIENDLY" ELECTRIC WIRE AND CABLE?

What is the "environment-friendly" electric wire and cable? To grasp this, we must first think of the life cycle of electric wire and cable. To generally summarize, it can be said that the life cycle of electric wire and cable comprises four stages: (1) raw material, (2) processing to product, (3) application, and (4) disposal. The influences of this cycle on the environment are consumption of resources, use of energy, and discharge of hazardous substance. Of these, with respect to consumption of resources and use of energy, efforts are made to save resources and energy by reviewing the manufacturing process, promoting increased efficiency, etc. through cycle (1) and (2). For cycle (3), there would be no significant influence on the environment. We thought that it is cycle (4) that attention must be given to.

Table 1 shows the actual situation [1)] of cable covering material disposal in the cable industry.

Table 1 indicates that almost all cables are disposed of by landfilling. What is concerned about disposal by landfilling is deposition, dissolution, and leaching of low molecular weight components, additives, or decomposed substances by degradation with time in the electric wire and cable materials. If any of these substances exerts load to the environment, there is a danger of seriously affecting the surrounding environment. One answer to this is to eliminate the environment load substances in the product.

Table 1 also indicates that the ratio of reutilization of cable covering material such as insulation and sheath, that is, the recycling ratio, is not high. From the viewpoint of effective utilization of resources, recyclability becomes important. Examples of recycling include thermal recycling in which heat is utilized, material recycling in which product material is reused, etc. In thermal recycling, it is essential that the material does not generate any harmful substance when combusted and at the same time generates less smoke. In material recycling, it would be desirable to use thermoplastic materials from the viewpoint of ease of reformability. Thus, recyclable materials should meet the requirements of either type of recycling.

Based on these, we thought that the "environment-friendly" electric wire and cable should satisfy the following two requirements.

(A) Non-use of material containing substance that would exert load to the environment.
(B) Use of material that can be recycled.

Requirement (A) can be met by not using any substance and material which are identified or suspected to exert load to the environment at the present stage.

Requirement (B) can be met by using the substance which does not generate substance causing problems at the time of thermal recycling and is the thermoplastic material which can meet the material recycling.

Table 1 Actual situation of cable covering material disposal in the Japanese cable industry

Covering material	Leading six cable manufacturers					Nugget Council disposal rate (total of 59 out of 91 companies. All by landfilling)
	Amount used	Disposal		Recycling		
		Landfill	Inciner-ation	Reuse	Thermal decompo-sition	
Rubber	630	50	1	0	0	1208
PVC	6500	290	0	580	0	3358
PE	3700	160	0	130	0	846
XLPE	1850	220	95	0	10	
Total	12680	720	96	710	10	5412
		816		720		

(Unit: t/month)

Table 2 Combination gas of various materials

Generated gas (mg/g)	PE	PVC	Nylon 66	Poly-acrylic amide	Poly-acrylo-nitrile	Poly-urethane	Poly-phenylene sulfide
HCl	-	286	-	-	-	-	-
CO_2	738	657	590	796	556	666	1796
CO	210	177	205	157	108	173	161
COS	-	-	-	-	-	-	2.5
SO_2	-	-	-	-	-	-	423
N_2O	-	-	-	-	-	-	-
NH_3	-	-	9.8	17	-	-	-
HCN	-	-	31	18	56	3.3	-
CH_4	72	-	40	16	5.9	21	-
C_2H_4	185	-	94	10	-	43	-
C_2H_2	34	11	15	8.5	7.4	14	2.1
Gasification ratio (%)	62.5	69.3	60.7	63.3	37.7	51.4	85.1

3. DEVELOPMENT OF "ECO-ACE" LOW-VOLTAGE ELECTRIC WIRE AND CABLE

3.1 Selection of Material

From the two requirements described above, raw materials to be used for electric wire and cable covering material were selected.

For the base material that does not exert load to the environment, polyolefin-based resin was selected.

The polyolefin-based resin does not contain any harmful low molecular weight component or heavy metals, and does not generate any substance causing problems when combusted. Table 2 shows components of combustion product gas of polyethylene (PE), which is one of the polyolefin-based resins. [2] Table 2 indicates that polyethylene does not generate any harmful gas such as hydrogen cyanide or hydrogen chloride.

Because polyolefin-based resin is thermoplastic, it can meet the material recycling. In addition, when compared with halogen containing resin, polyolefin-based resin generates less smoke.

For the electric wire and cable covering material, flame retardance exceeding a certain level is required. The flame retardance required for general electric wires is the capability to self-extinguish within 60 seconds in the flame retardance test prescribed in JIS C 3005.

There are two techniques for providing flame retardance to polyolefin-based resin: (1) flame retardance achieved by halogen (addition of halogen-based flame retardant, halogenation of resin, etc.) and (2) flame retardance achieved by metal hydroxides. Of these, flame retardance achieved by halogen is assumed to exert load to the environment because hazardous substances including hydrogen halide is generated at the time of combustion. As against this, the substances generated when metal hydroxide is heated are water and metal oxides only, which are assumed to be stable and safe. Consequently, flame retardance achieved by metal hydroxides exerts low load to the environment and is suitable for the flame retardant of this product. In addition, the metal hydroxides have effects to suppress the smoke generation rate of the material with the metal hydroxides added. Therefore, a flame retardant technique by metal hydroxides is adopted.

Figure 1 shows the relationship between flame retardant mechanism of metal hydroxide (example is magnesium hydroxide) and combustion cycle of palstic. [3)]

In general, when plastic material is heated, as shown in Figure 1, the plastic material ignites and combusts through fusion, then, decomposition and gasification. To achieve fusion then decomposition and gasification, about 0.4 kJ/g and 0.8 kJ/g heat energies are required, respectively, but once combustion begins, the plastic material itself emits a great volume of thermal energy (about 46 kJ/g in terms of PE), forms a combustion cycle, and continues combustion even without firing source.

In the flame retardant mechanism by metal hydroxide, the addition itself of metal hydroxide dilutes combustibles, as shown in Figure 1. The metal hydroxide decomposes by heating and causes endothermic reactions. During this decomposition, water vapor and combustion products are formed. The water vapor dilutes combustible gas and the combustion products serve as a heat-insulating layer. These compositely act on in the combustion cycle, and display flame retardant effects.

However, the flame retardant effects of metal hydroxides are small. For example, the heat absorption rate of magnesium hydroxide at the time of decomposition is -0.75 kJ/g, far small as compared to the heat generation rate of polyolefin-based resin at the time of combustion. Consequently, in order to provide the flame retardance to polyolefin-based resin, a large volume of metal hydroxide must be compounded. However, compounding metal hydroxide in a large quantity degrades mechanical properties of the material. Therefore, new compositions were developed with particular attention placed on the balance between material mechanical properties and flame retardance.

When metal hydroxide is compounded to polyolefin-based resin, phosphorus-based flame retardant is frequently used for the flame retardant assistant. However, since the phosphorus-based flame retardant markedly increases the smoke generation rate, it was determined unsuited for the development of this product and was not used.

To the cable covering material, additives necessary for satisfying properties as cable material are compounded in addition to the flame retardant assistant. For the additives used for the developed composition, those assumed not to exert load to the environment were used.

Table 3 shows the properties of the cable covering material.

Table 3 indicates that the developed material not only satisfies the properties required for cable covering material but also provides excellent brittle temperature as compared to those of conventional covering materials. Because the temperature rating becomes 75°C, higher than 60°C of the conventional case, a continuous current rating of 1.3 times is achieved (installed at 40°C ambient temperature, in air), providing a possibility of downsizing.

In addition to this, development was also carried out on the materials for cable branches as in the case of selection of the cable covering material, and the material which provides properties equivalent to those of conventional ones and yet achieves greater safety and higher recyclability was developed.

3.2 Cable Characteristics

Table 4 shows the characteristics of "Eco-Ace" low-voltage wire and cable.

The visibility distance *S* (m) at the time of smoke generation was found by the following formula using the cable smoke generation rate in conformity to the formula given by Fire Handbook. [2)]

$$S = \frac{2.7}{C_s}$$

$$C_s = \frac{1}{L} \ln\left(\frac{I_0}{I}\right)$$

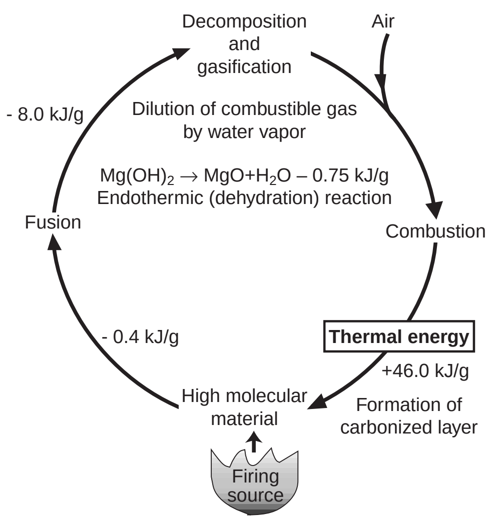

Figure 1 Flame retardant mechanism and combustion cycle of metal hydroxide

Table 3 Properties of covering material for low-voltage Eco-Ace cables

	Standard	Unit	"Eco-Ace" covering material
Tensile strength	JIS C 3005	MPa	13
Elongation	JIS C 3005	%	650
Tensile strength after aging 90°C×4 days	JIS C 3005	%	85
Elongation after aging 90°C×4 days	JIS C 3005	%	93
Brittleness temperature	JIS C 3005	°C	- 50 or lower
Amount of acidic gases evolved	JCS 397	mg/g	0
Oxygen index	JIS K 7201		26
Temperature rating		°C	75

where,
C_s: Absorbance coefficient
I: Measured transmittance
I_0: Initial transmittance
L: Length of optical path (m)

The present developed product not only provides flame retardance equivalent to that of conventional products but also generates no harmful substance such as hydrogen halide.

The smoke generation from the cable is extremely small, and it is clear that about 16 times visibility distance is secured as compared to conventional cables. In general, the visibility distance required for evacuation at the time of fire is said to be about 15 m for the visitor to the building, suggesting high safety of this new product at the time of fire.

3.3 Product Line-ups of "Eco-Ace" Low-voltage Wire and Cable

Table 5 shows product line-ups of "Eco-Ace" low-voltage wires and cables.

Photo 1 shows "Eco-Ace" low-voltage wires and cables and Photo 2 "Eco-Ace" EM-BH branches.

3.4 Recycle of Non-separated Cable Refuse

In the future when the collection system of separated refuse is organized, which is problematic at present, recycling of cables as a whole including covering materials (sheath and insulation) and auxiliary materials (tape and filling material) becomes meaningful. Therefore, the following investigation was carried out.

Figure 2 shows the weight ratio of constitutional materials other than conductor for a 600-V EM-CEE 3 x 14 mm^2 (Ecological Material - polyEthylene insulated polyEthylene sheathed Control cable) Eco-Ace cable.

Assuming that the materials other than sheath material are non-flame-retardant and the weight ratio of the flame retarding agent of the sheath material is 50%, then, the flame retarding agent in the constitutional materials other than conductor of the cable accounts for 21% (this varies with the cable construction, size, and the weight ratio of flame retarding agent in the sheath material).

It is anticipated in this case, that mixing the entire constitutional materials for recycling excluding the conductor will result in a flame-retardance which is excessively low. Therefore, investigations were made on the cases when the new sheath material was mixed with the recycled

Table 4 Characteristics of low-voltage Eco-Ace cables

Items	Standard	Unit	Eco-Ace	Conventional cable
Flame retardance test	JIS C 3005		Accepted	Accepted
Amount of acidic gases evolved	JCS 397	mg/g	0	250 - 320
Smoke density: transmittance	IEC 1034	%	92	25
Visibility distance when smoke is generated	Computed from cable smoke generation rate	m	97	6

Table 5 Low-voltage Eco-Ace cable products

Type	Cable designation
Low-voltage power cable	600 V EM-CE, 600 V EM-CET
Low-voltage flat cable	600 V EM-EEF
Control and instrumentation cable	EM-CEE, EM-CEE-S
Insulated electric wire	EM-IE
Fire resistant cable	FT-8-C
Cable with branch	EM-BH

Photo 1 Low-voltage Eco-Ace cable products

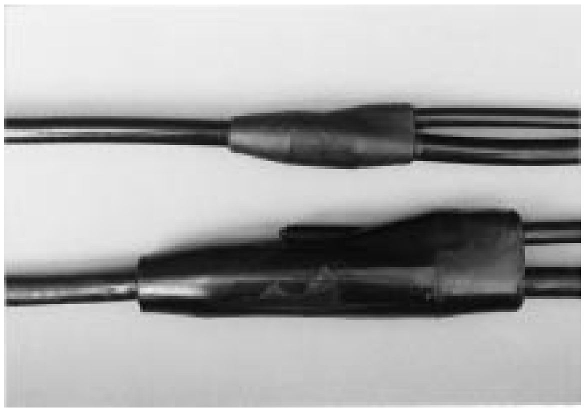

Photo 2 Eco-Ace EM-BH branch

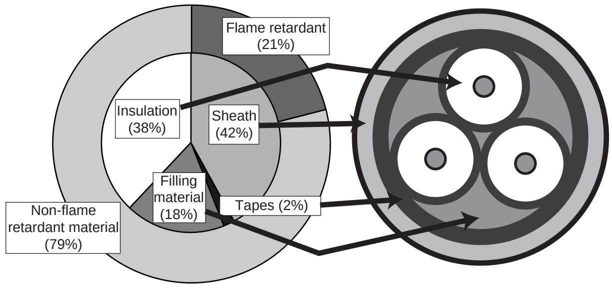

Figure 2 Weight ratio of constitutional materials other than conductor for an Eco-Ace cable (600-V EM-CEE 3 x 14 mm^2)

Table 6 Properties of recycle sheath material

	Unit	New sheath material A	Recycle sample B	Mixed sample A:B = 1:1	Mixed sample A:B = 3:1
Tensile strength	MPa	12	13	15	14
Elongation	%	610	630	670	688
Tensile strength after aging 90°C×4 days	%	85	110	90	85
Elongation after aging	%	101	65	79	93
Oxygen index		28	21	24	25

material collected from cables.

First of all, 600-V EM-CEE 3 x 14 mm² cables were manufactured. Auxiliary materials such as fillers and tapes were selected from those for conventional materials that are polyolefin-based and having a melting point of 140°C or lower. Then, from the manufactured cables, conductors were removed, and the remaining materials were crushed. This is called recycle sample. Then, a material with new sheath material and crushed product mixed at 1:1 and that at 3:1 were prepared. These are called mixed samples. The recycle sample and the mixed sample were kneaded at 160°C by a pressurizing type kneader followed by forming into a sheet. Table 6 shows the evaluation results of the sheet.

As is clear from Table 6, the recycle sample, as such, had a flame retardance lowered to a level unsuited for the use as sheath material. In addition, the elongation after aging greatly lowered. These are attributed to the improper amount of flame retarding agent and antioxidant in the recycle sample. Therefore, it is desirable to use a mixed sample, and when the cables are recycled in a plurality of times, the mixture ratio of new sheath material must be increased.

4. DEVELOPMENT OF "ECO-ACE" HIGH-VOLTAGE CABLE

4.1 Improved Damage Resistance of Cable

The cables for high-voltage application is likely to be subject to big side pressure on its sheath because the cable must be installed in conduits, etc. It has been identified that the cable may be damaged due to the level difference of conduits if the sheath material developed for the "Eco-Ace" low-voltage electric wires and cables is used for the sheath. Consequently, a new covering material has been developed from the viewpoints of --as is the case with the cable for low-voltage application-- (1) the substance that would exert load to the environment is not used and (2) the substance can be recycled. Polyolefin-based resin and metal hydroxide flame retarding agent were used for the material which is provided with an improved resistance for abrasion.

When polyolefin-based resin and metal hydroxide flame retarding agent are compounded, a large amount of metal hydroxide must be compounded as described earlier, and this works to lower mechanical properties. The fillers such as metal hydroxide exist in resin not dissolved but in the form of scattered particulates. When this kind of material is subjected to mechanical force, shearing frequently occurs, and this is a cause of lowering mechanical properties. This suggests that an improved adhesion between resin and metal hydroxide results in improved damage resistance. Therefore, adhesive polyolefin was compounded to improve the adhesion between resin and metal hydroxide.

Table 7 Properties of covering material for high-voltage Eco-Ace cables

	Standard	Unit	Eco-Ace	Conventional cable
D.C. voltage test on sheath	JEC 3403		25 kV for 1 min: Accepted	25 kV for 1 min: Accepted
Flame retardance test	JIS C 3005		Accepted	Accepted
Smoke density	ASTM E662		96	250 - 300
Amount of acidic gases evolved	JCS 397	mg/g	0	250 - 320
Damage resistance test			250 kg/m Accepted	250 kg/m Accepted

4.2 Cable Characteristics

The developed composition was used for the sheath in manufacturing 6-kV EM-CET 3 x 60 mm² (Ecological Material - Cross-Linked polyEthylene insulated polyEthylene sheathed Triplex type) power cables. Table 7 shows the cable characteristics. Photo 3 shows the scene of flame retardance test prescribed in JIS C 3005. Figure 3 illustrates the damage resistance test referred to in the table. This is a test to see damage in the cable when a specimen cable is placed with a load and pulled on a frame simulating conduit. When no damage is observed on the cable, the cable is accepted. Photo 4 shows the cable after the damage resistance test.

As is clear from Table 7 and Photo 4, the developed cable provides a satisfactory damage resistance that is sufficient to pass the 250-kg/m damage resistance test, which is comparable to conventional cables.

As described above, the "Eco-Ace" high-voltage cable has been developed, which is environment-friendly and is free of problem at the time of cable installation.

5. CONCLUSION

In order to address environmental problems in recent years, environment-friendly electric wires and cables were considered, and "Eco-Ace" was developed. And the following results were achieved.

(1) Environment-friendly electric wires and cables were defined as (A) electric wires and cables that do not use any substance that exerts load to the environ-

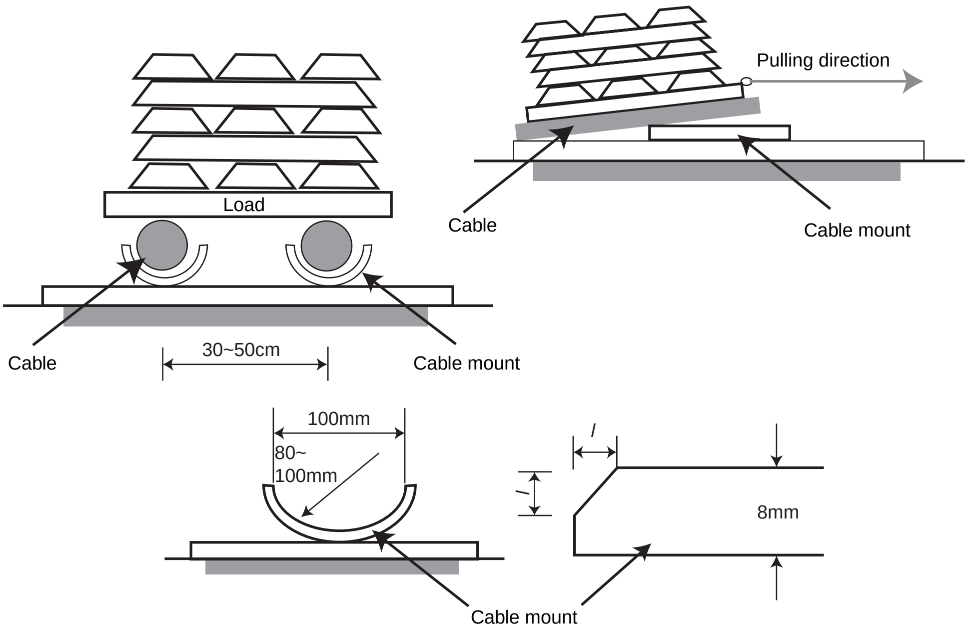

Figure 3 Damage resistance test

Photo 3 Flame retardance test (JIS C 3005)

Photo 4 Appearance of an cable after damage resistance test

ment and (B) wires and cables that use recyclable materials; and development of materials for such cables and wires was carried out.

(2) Using the developed covering material, environment-friendly and low smoke generation rate "Eco-Ace" low-voltage wires and cables were developed.

(3) "Eco-Ace" high-voltage cables with improved damage resistance were developed.

In the future, while supplying environment-friendly electric wires and cables with superb balance achieved in environment-friendliness, economy and functionality, we hope to cooperate with various people concerned to positively grapple with promotion of recycling.

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