PRTR Estimation Manual

21. Fiber-Reinforced Plastic Manufacturing Industry

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The Japan Reinforced Plastic Society

Contents

1. Introduction

A fiber-reinforced plastic is a composite material, comprising of a radical thermoset resin such as unsaturated polyester and vinyl ester resins as the matrix phase, and glass fibers and the like as the reinforcement phase, and the manufacturing the same requires the Notification of Releases and Transfers under the Law Concerning Reporting, etc. of Releases to the Environment of Specific Chemical Substances and Promoting Improvements in Their Management (PRTR Law).

Of the 354 Class I Designated Chemical Substances designated as requiring the notification, seven chemical substances have been identified, that are believed to be contained in this composite material.

2. Chemical Substances Requiring Notification

For the fiber-reinforced plastic fabricators who manufacture either FRP or non-FRP products comprising unsaturated polyester resins and/or vinyl ester resins as its matrix, the chemical substances that come to fall under the subject of the PRTR Law are shown in Table 1 and Table 2. In the field of this composite material, seven chemical substances fall under subject to the Class I Designated Chemical Substances and one chemical substance subject to the Class II Designated Chemical Substances (for this, only MSDS presentation is required).

Estimation formulae for the transfers and releases have been constructed mainly for the styrene (hereinafter abbreviated as SM) which is the important major raw material as an cross-linking agent for the unsaturated polyester resins and vinyl ester resins. For methyl methacrylate (hereinafter abbreviated as MMA) and toluene, formulae are constructed in a similar manner to the above formula for SM. For MMA, however, it is assumed that it is included only in gelcoat.

In view of the fact that dichloromethane which used to be employed mainly as washing solvent is seldom used in recent years among FRP fabricators, it was excluded from this study. 2,3-epoxypropyl methacrylate (hereinafter abbreviated as GMA) is used to react with carboxylic group of unsaturated alkyd, and as a result almost no free GMA is believed to be produced, it was also excluded from this study. Di-n-butyl phthalate and bis(2-ethylhexyl)phthalate are used as dilution agents of cross-linking agents for this resin, and the estimation for these substances is believed to be handled by the cross-linking agent manufactures. As a result, they are also excluded from this study, and any inquiry should be directed to the respective manufactures.

Table 1 Class I Designated Chemical Substances (7 species)

Cabinet Order No.	Name of chemical substance	Use Classification	CAS No.
145	Dichloromethane (also known as methylene chloride)	Dilution agent and washing agent	75-09-2
177	Styrene	Cross linking agent	100-42-5
227	Toluene	Dilution agent and washing agent	108-88-3
270	Di-n-butyl phthalate	Dilution agent for cross linking agents	84-74-2
272	Bis(2-ethyl-hexyl) phthalate	Dilution agent for cross linking agents	117-81-7
316	2,3-epoxy-propyl methacrylate	Cross linking agent	106-91-2
320	Methyl methacrylate	Cross linking agent	80-62-6

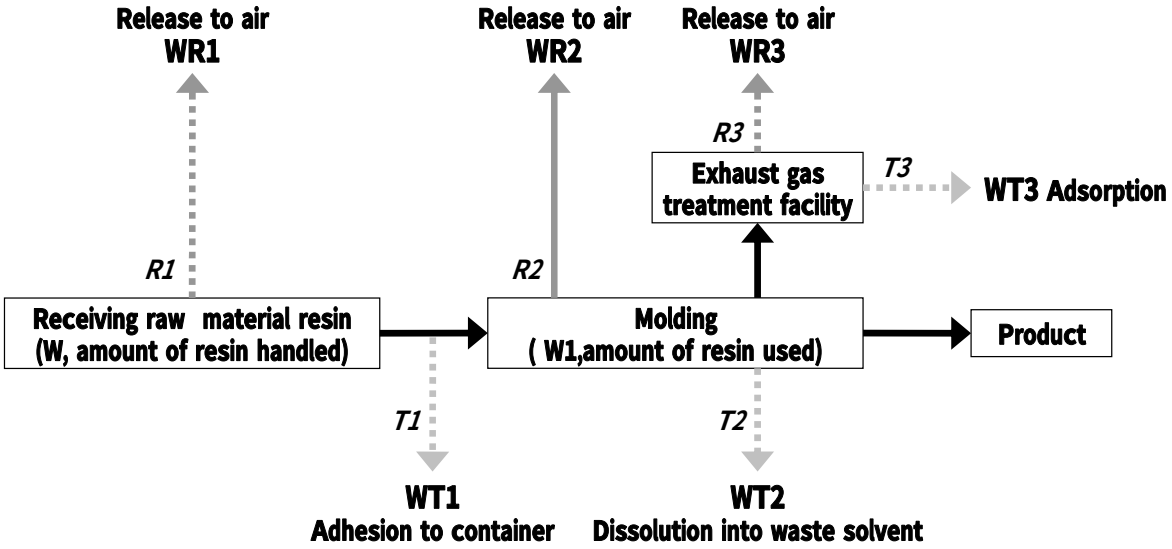
Table 2 Class II Designated Chemical Substances (1 species)

Cabinet Order No.	Name of chemical substance	Use Classification	CAS No.
37	Vinyl benzene	Cross linking agent	1321-74-0

3. Fabrication Process Flow Chart and Its Transfer and Release Representations

Conceptual diagram for the amounts transferred and released is shown in Figure 1, flow chart by type of process for open-mold molding process is shown in Figure 2, and conceptual diagram of closed molding process by type is shown in Figure 3.

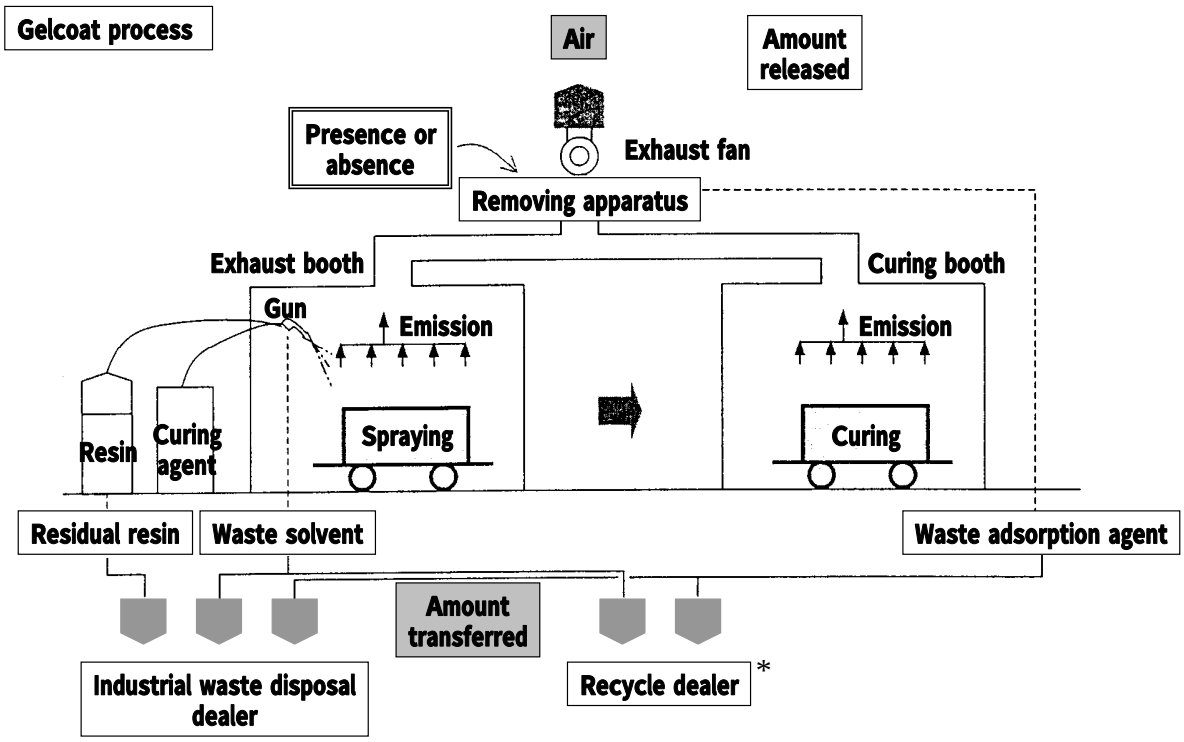
Fig. 1 Conceptual diagram of the amounts transferred and released



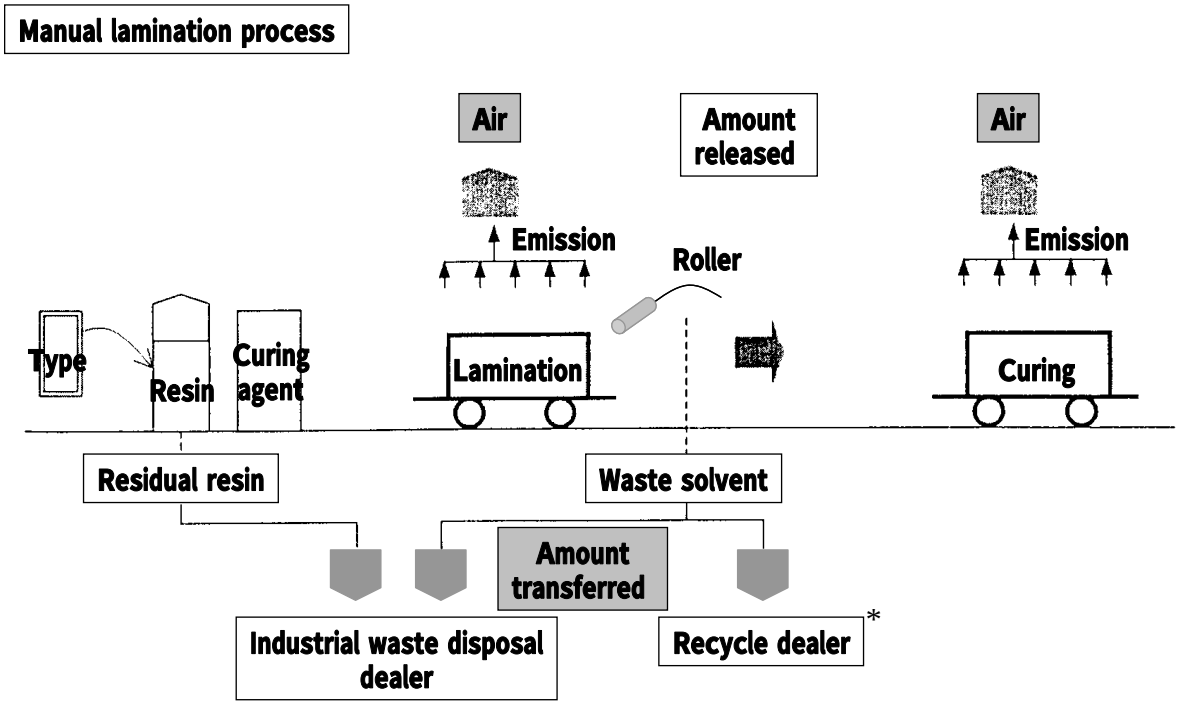
WR1、WR2、WR3	Amount released
WT1、WT2、WT3	Amount transferred
R1、R2、R3	Emission factor
T1、T2、T3	Emission factor

Fig. 2 Open-mold molding process flow chart by type of process

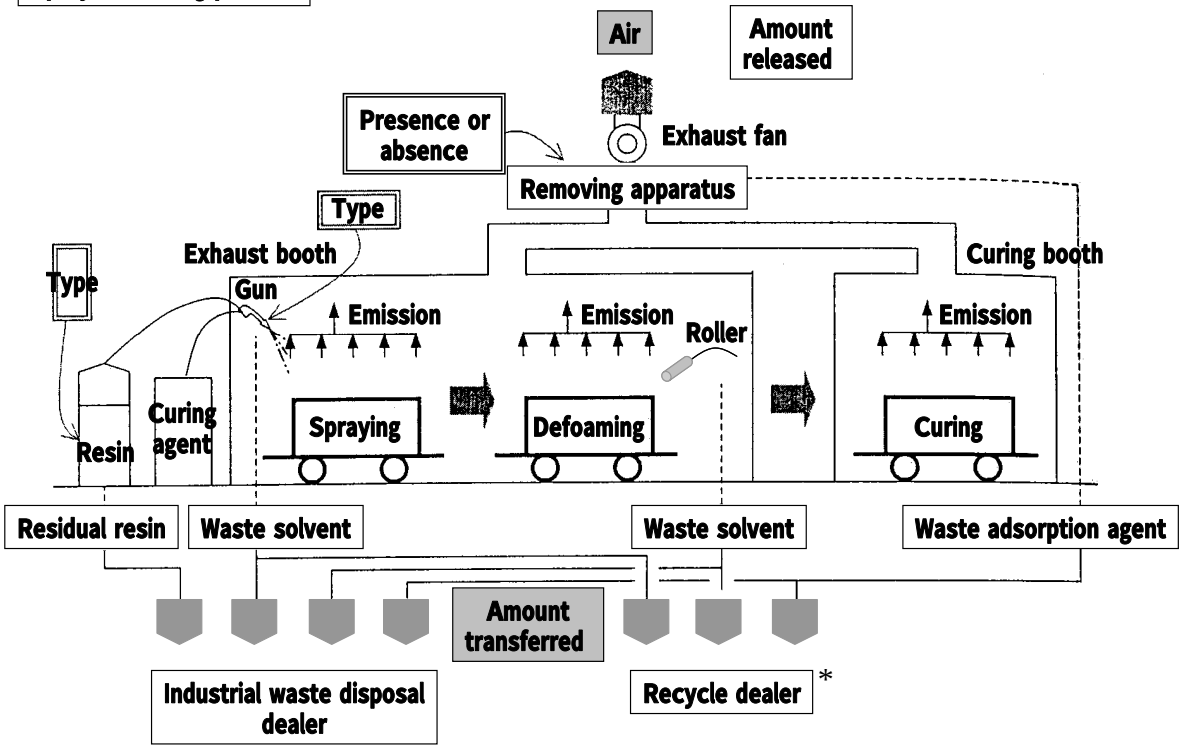
A: Open-mold molding



*: In case sold to recycle dealers as valuable, no notification is required.



Spray laminating process



Bonding process

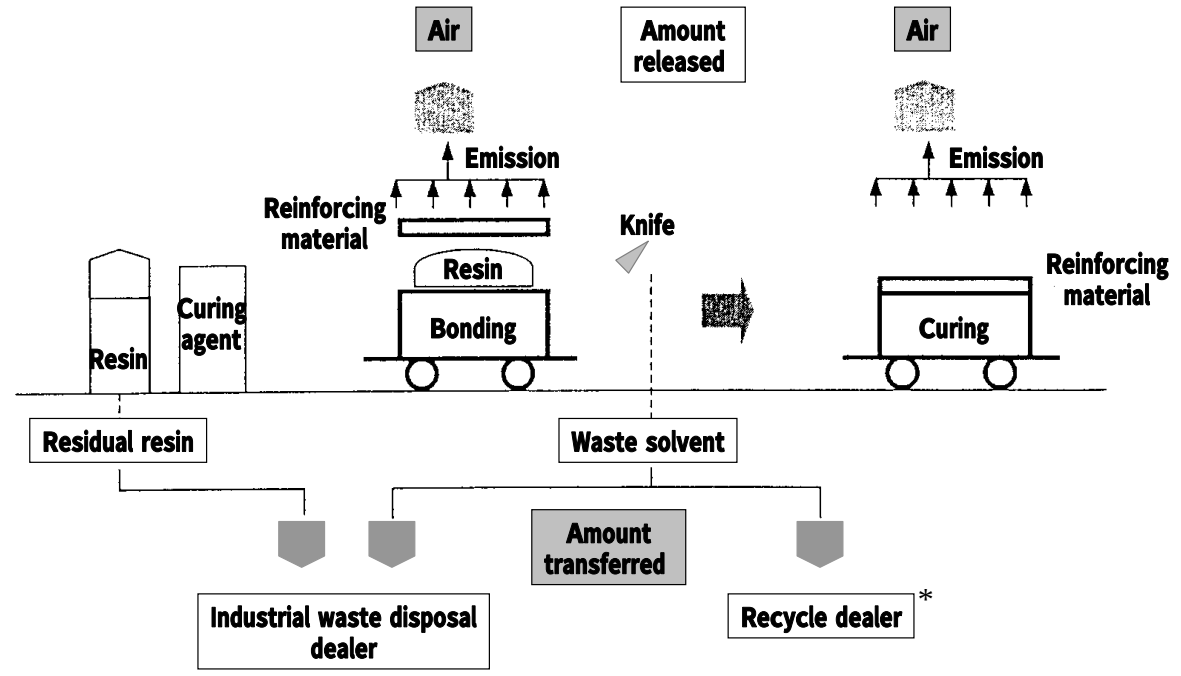
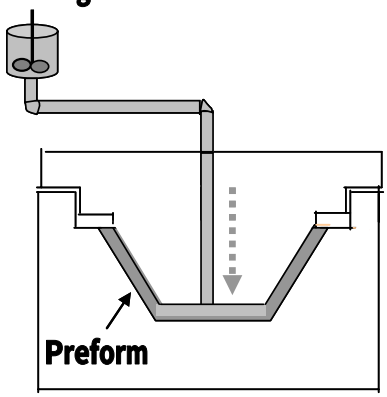
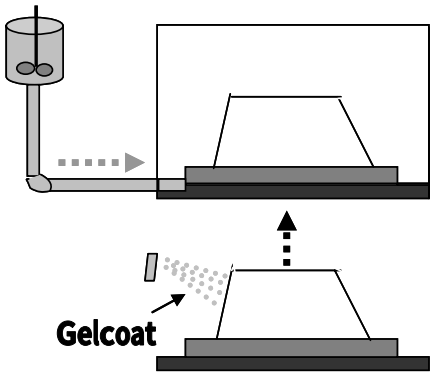


Fig. 3 Flow chart for estimating amounts of chemical substances under the Law for PRTR and Promotion of Chemical Management, by molding type

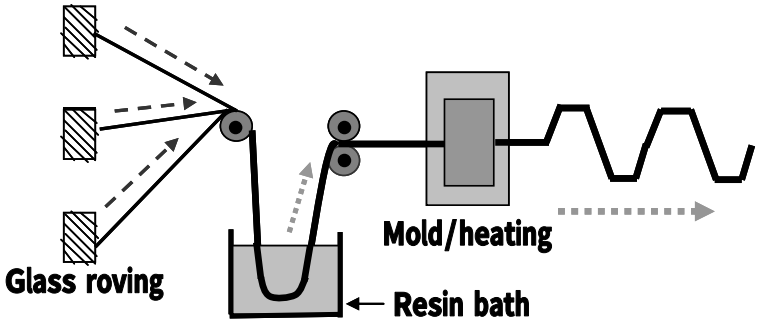
B: Closed molding-1



B-18: Resin transfer molding



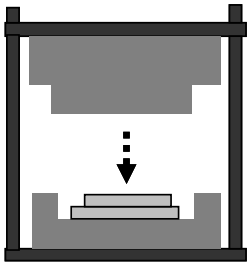
B-19: Cast molding



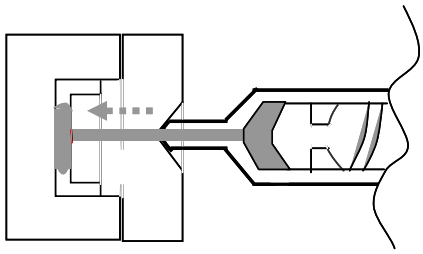
B-20: Pultrusion molding

B-21: Continuous molding

C: Closed molding-2



C-24 : SMC press molding



C-25 : BMC injection molding

4. Concept for Estimating Amounts Transferred and Released

4.1. Definition of Terms

- **All units are in "ton".**
- Annual amount of resin handled: annual amount of resin purchased + resin stock amount at the beginning of term – resin stock amount at the end of the term
- Annual gelcoat amount handled: annual gelcoat amount purchased + gelcoat stock amount at the beginning of term – gelcoat stock amount at the end of term
- Annual SMC amount handled: annual SMC amount purchased + SMC stock amount at the beginning of term – SMC stock amount at the end of term
- Annual BMC amount handled: annual BMC amount purchased + BMC stock amount at the beginning of term – BMC stock amount at the end of term
- Annual amount of resin used: annual amount of resin handled – amount adhered to containers (can or drum)

  When purchasing in lorry tank or carrier container, annual amount of resin used = annual amount of resin handled.
- Annual gelcoat amount used: annual gelcoat amount handled – amount adhered to containers (can or drum)

  SM amount released will be estimated based on this annual resin and gelcoat amounts used
- Annual SMC amount used = annual SMC amount handled
- Annual BMC amount used = annual BMC amount handled
- Since SM content is expressed in mass %, "mass % ÷ 100" should be used in the estimation formula.

4.2. Concept for Amounts Transferred and Released

4.2.1. Concept for Amount Transferred

In estimating the amount transferred during the course of manufacturing process which starts from receiving the purchased resin and ends with the product shipment, this study was conducted assuming the following five items as necessary conditions.

(1) When the resins or gelcoats are purchased in the form of container (drum or can) and used for the manufacturing, the resin amount adhering to the container is considered as the amount transferred. In determining the ratio of the resin amount adhering to container, comments were solicited from fabricators and resin manufacturers (for this, a survey in the form of questionnaire was conducted), and they were used as a guide.

(2) Depending on the processing methods, there are some stages of process which require solvent washing during the processing. Since it was difficult to exactly estimate the amount of resin and gelcoat that goes into the waste solvent, it was assumed for the time being 1/9 of the amount adhering to the container go into the waste.

(3) In cases where resins are purchased in lorry tank or carrier container, the transfer amount that goes to disposal as residual resin in container or as waste solvent, was assumed to be zero.

(4) In cases where the molding process is equipped with an exhaust gas treatment facility, the amount that was prevented from releasing to the air by the facility was counted as the amount transferred.
(5) In estimating the amount transferred [kg/yr], an estimation formula was constructed to allow it be calculated once the annual amount of resin handled [ton/yr] and the annual gelcoat amount handled [ton/yr] are known.

4.2.2. Concept for Amount Released

In estimating the amount released during the manufacturing process which starts from receiving the purchased resin and ends with the product shipment, this study was conducted assuming the following four items as necessary conditions.

(1) The amount released to air from the vent of resin storage tank (This question was referred to the resin manufacturers) was included.
(2) The amount released from the molding process (lamination, curing, etc.) was included.
(3) For the case of carrier container delivery, the amount released was assumed to be zero.
(4) In estimating the amount released [kg/yr], while the annual amount of resin used [ton/yr] and the annual gelcoat amount used are the basis for the estimation, estimation formulae were constructed such that all estimation can be made from the annual amount of resin handled [ton/yr].

4.3. Classification According to Various Conditions

4.3.1. Classification According to Molding Method and Facility

Considering the molding methods, facility conditions, compound preparation conditions, non-FRP resin preparation conditions and others, the processes were classified into a total of 27 types which comprised 17 types of open-mold molding (series A), 6 types of closed molding-1 (series B), 2 types of closed molding-2 (series C) and 2 types of compound preparation process (series D).

Series A: Open-Mold Molding

A-1: conventional type of resin is used and the lamination is done manually
A-2: low volatile type of resin is used and the lamination is done manually
A-3: spray lamination process without exhaust gas treatment facility, using conventional type of resin
A-4: spray lamination process without exhaust gas treatment facility, using low volatile type of resin
A-5: spray lamination process with exhaust gas treatment facility, using conventional type of resin
A-6: spray lamination process with exhaust gas treatment facility, using low volatile type of resin
A-7: spray lamination process using conventional type of resin, while preventing the resin from becoming mist form
A-8: spray lamination process using low volatile type of resin, while preventing the

resin from becoming mist form

A-9: filament winding process using conventional type of resin

A-10: filament winding process using low volatile type of resin

A-11: gelcoat process without exhaust gas treatment facility

A-12: gelcoat process with exhaust gas treatment facility

A-13: gelcoat process wherein MMA (methyl methacrylate) is contained

A-14: lamination process wherein lamination is done manually using conventional type of resin and curing is done with covering by sheet after completing the impregnation step

A-15: spray lamination process using conventional type of resin where curing is done with covering by sheet after completing the impregnation step

A-16: lamination process where lamination is done manually using conventional type of resin and curing is done with covering by sheet without the impregnation step

(In cases of manufacturing non-FRP type decorative laminate, this process condition should be employed for the estimation.)

A-17: spray lamination process using conventional type of resin where curing is done with covering by sheet without the impregnation step

Series B: Closed Molding-1

B-18: resin transfer molding

B-19: cast molding

B-20: pultrusion molding

B-21: continuous molding

B-22: MMD (matched metal die)

B-23: centrifuge molding

(In cases of Rejikon molding (cast molding) and button molding (centrifuge molding), both of which belonging to non-FRP field, this condition of closed molding-1 should be employed for the estimation.)

Series C: Closed Molding-2

C-24: SMC (sheet molding compound) press molding

C-25: BMC (bulk molding compound) injection molding

Series D: Compound Preparation Process

D-26: SMC (sheet molding compound) preparation

D-27: BMC (bulk molding compound) preparation

Clear artificial marble type BMC (the type in which glass powder, aluminum hydroxide and the like are used as filler) which belongs outside the field of conventional BMC is also included in this BMC preparation process.

4.3.2. Properties and Assumptions on Resin and Gelcoat

1) The low volatile type of resin is a type such as wax added type, or a type in which volatilities are decreased by some kind of means, and the volatile amount per unit surface area should be less than 50% of that of the conventional type of resin when measured under the same condition.
2) In cases where mainly open-mold molding is involved, and if seasonal types of resin are used through the year, that is if resin types for winter season, for spring-and-autumn season, for summer season, etc. are used in accordance with the season, assumption was made that all the amount of resin used were the type for spring-and-autumn season, and the annual amounts transferred and released were calculated based on the SM content of this particular type of resin.
3) It was assumed that MMA is contained only in gelcoat.

4.4. Condition Setting for Estimating the Amount Transferred and Released

4.4.1. Condition Setting for Estimating the Amount Transferred

For estimating the amount transferred, the following conditions 1) to 5) were set.

1) Items counted as the amount transferred (three items)
   (a)The amount that is adhering to containers such as cans and drums (Not applicable to lorry tank or carrier container delivery)
   (b)The amount that is contained in waste solvent
   (c)In cases where exhaust gas treatment and removing apparatus is present, the amount removed is equal to the difference between the cases where removing apparatus is present and absent.
2) Transferred amount factor for the resin amount adhering to container (can and drum)
   (a)The amount of content of can (18 L) and drum (200 L) were assumed to be constant at 20 kg and 200 kg, respectively.
   (b)The proportion factor for resin amount adhering to can (18 L) was assumed to be 1.0% by weight (observed value).
   (c)The proportion factor for resin amount adhering to drum (200 L) was assumed to be 0.5% by weight (observed value).
   (d)The ratio of the amount delivered in can compared to drum was assumed to be 1: 4 (observed value).

From these conditions the transferred amount factor is calculated to be 0.6%. As a result, the following relation is obtained for this case:

Annual amount of resin used (ton/yr) = 994/1000 x Annual amount of resin handled (ton/yr).

3) Transferred amount factor for the gelcoat adhering to container (can and drum)
   (a)All containers were assumed to be of a can (18 L), and its amount of content to be constant at 20 kg.
   (b)The adhering resin amount factor for can (18 L) was assumed to be 3.0% by weight (observed value).

From these conditions, the transferred amount factor is calculated to be 3.0%. As a result, the following relation is obtained for this case:

Annual amount of gelcoat used (ton/yr) = 97/100 x Annual amount of gelcoat handled (ton/yr).

4) Amount contained in waste solvent

It was assumed that the ratio of the amount that is adhering to container (can and drum) to that that goes into waste solvent is uniformly at 9: 1 (constant, ratio by weight) for both resin and gelcoat. As a result, the following relation is obtained for this case:

Amount contained in waste solvent = 1/9 x Amount adhering to container (constant).

In this connection, therefore, when a resin is delivered in lorry tank or carrier container, there is none that is contained in waste solvent.

5) In cases where exhaust gas treatment and removing apparatus is present, the amount removed, which is equal to the difference of the amount released between the cases where removing apparatus is present and absent, is applicable to the cases of three molding conditions including A-5, A-6 and A-12 (all are open-mold molding) (See Table 3).

4.4.2. Condition Setting for Estimating Amount Released

Condition setting for estimating the amount released is same as that described in section 4. 3. 2.

All emission factors shown in this manual were set following the description by the American Composites Manufacturers Association (former the Composites Fabricators Association)

The American Composites Manufacturers Association can be accessed by:

www.cfa-hq.org → Legislative & Regulatory

→General discussion on emission factors for open molding

→Estimating Emissions from Open Molding of Composites

4.5. Estimation Formula

4.5.1. Estimation Formula for SM

4.5.1.1. Estimation Formula of Amount Transferred

(1) Gelcoat process with exhaust gas treatment facility (A-12)

SM transferred [kg/yr]

= (1+1/9) × 3/100 × annual amount of gelcoat handled [ton/yr]

× 1000 × SM content + (α - β) × 97/100 × annual amount of gelcoat handled [ton/yr]

--- Formula-1

1/9: portion corresponding to the amount transferred that went into waste solvent

α : emission factor for cases where exhaust gas treatment facility is not present

β : emission factor for cases where exhaust gas treatment facility is present

Both are to be obtained from Table 3.

(2) Gelcoat process without exhaust gas treatment facility (A-11)

SM transferred [kg/yr]

= (1+1/9) × 3/100 × annual amount of gelcoat handled [ton/yr]

× 1000 × SM content

--- Formula-2

3/100: transfer factor for gelcoat

1/9: portion corresponding to the amount transferred that went into waste solvent

(3) Spray lamination process wherein resins are purchased in drums or cans and exhaust gas treatment facility is present (A-5 or A-6)

SM transferred [kg/yr]

= (1+1/9)×6/1000×annual amount of resin handled [ton/yr] × 1000

× SM content + (γ - δ) × 994/1000 × annual amount of resin handled [ton/yr]

--- Formula-3

1/9: portion corresponding to the amount transferred that went into waste solvent

γ : emission factor for cases where exhaust gas treatment facility is not present

δ : emission factor for cases where exhaust gas treatment facility is present

Both are to be obtained from Table 3.

(4) Spray lamination process wherein resins are purchased in lorry tank or carrier container and exhaust gas treatment facility is present (A-5 or A-6)

SM transferred [kg/yr] = (γ - δ) × annual amount of resin handled [ton/yr]

--- Formula-4

γ : emission factor for cases where exhaust gas treatment facility is not present

δ : emission factor for cases where exhaust gas treatment facility is present

Both are to be obtained from Table 3.

(5) Spray lamination process wherein resins are purchased in drum or can and exhaust gas treatment facility is not present

SM transferred [kg/yr] = (1+1/9) × 6/1000 × annual amount of resin handled [ton/yr]

--- Formula-5

1/9: portion corresponding to the amount transferred that went into waste solvent

(6) Spray lamination process wherein resins are purchased in lorry tank or carrier container and exhaust gas treatment facility is not present

SM transferred [kg/yr] = 0 (none)

--- Formula-6

SM amount can be estimated using the above conditions combining (1) ～ (6) appropriately.

4.5.1.2. Estimation Formula of Amount Released

1) Series A (Open-mold molding)

(1) Gel coat application process

SM released [kg/yr]

= gelcoat emission factor [kg/ton] (from Table 3)
× annual amount of gelcoat used [ton/yr]
= gelcoat emission factor [kg/ton] × 97/100
× annual amount of gelcoat handled [ton/yr]

--- Formula-7

SM emission factor for the amount released from gelcoat can be determined from Table 3 once the presence of exhaust gas treatment facility and its SM content are known.

(2) Lamination process wherein resin is purchased in drum or can

SM released [kg/yr]
= emission factor for respective processing condition [kg/ton] (from Table 3)
× annual amount of resin used [ton/yr]
= emission factor for respective processing condition [kg/ton] × 994/1000
× annual amount of resin handled [ton/yr]

--- Formula-8

Emission factor [kg/ton] for respective processing condition can be determined from Table 3 once the process of molding, presence of exhaust gas treatment facility, type of resin (conventional or low volatile type) , and SM content are known.

(3) Lamination process wherein rein is purchased in lorry tank

SM released [kg/yr]
= emission factor for respective processing conditions [kg/ton] (from Table 3)
× annual amount of resin handled [ton/yr] + 1/10000
× annual amount of resin handled [ton/yr] × 1000

--- Formula 9

1/10000: emission factor for vent from resin storage tank (observed value)

(4) Lamination process wherein resin is purchased in carrier container

SM released [kg/yr]
= emission factor for respective processing conditions [kg/ton] (from Table 3)
× annual amount of resin handled [ton/yr]

--- Formula 10

2) Series B (Closed molding -1)

(1) Wherein resin is purchased in drum or can

SM released [kg/yr]
= 2/100 × annual amount of resin used [ton/yr] × 1000 × SM content
= 2/100 × 994/1000 × annual amount of resin handled [ton/yr] × 1000 × SM content

--- Formula 11

2/100: emission factor

(2) Wherein resin is purchased in lorry tank

SM released [kg/yr]
= 2/100 × annual amount of resin handled [ton/yr] × 1000 ×SM content

+ 1/10000 × annual amount of resin handled [ton/yr] × 1000

--- Formula 12

2/100: emission factor

1/10000: emission factor for vent from resin storage tank (observed value)

(3) Wherein resin is purchased in carrier container

SM released [kg/yr]

= 1/100 × annual amount of resin handled [ton/yr] × 1000 × SM content

--- Formula 13

1/100: emission factor

If gelcoat process is concomitantly used, the following amount:

gelcoat emission factor [kg/ton] (from Table 3)

× annual amount of gelcoat used [ton/yr]

= gelcoat emission factor [kg/ton] × 97/100

× annual amount of gelcoat handled [ton/yr] (Formula-7)

is to be added to the above SM amount released.

3) Series C (Closed molding -2)

(1) SMC molding

SM released [kg/yr]

= 2/1000 × annual amount of SMC handled [ton/yr] × 1000

--- Formula 14

2/100: emission factor

(2) BMC molding

SM released [kg/yr] = 1/1000 × annual amount of BMC handled [ton/yr] × 1000

--- Formula 15

1/1000: emission factor

4) Series D (Compound preparation step)

(1) SMC compound preparation

SM released [kg/yr] = 17/10000 × annual amount of SMC prepared [ton/yr] × 1000

--- Formula 16

17/10000: emission factor

(2) BMC compound preparation

SM released [kg/yr] = 8.8/10000 × annual amount of BMC prepared [ton/yr] × 1000

--- Formula 17

8.8/10000: emission factor

4.5.2. Estimation Formula of Amount Transferred and Released for MMA

This is applicable only for the case where a gelcoat process is concomitantly used and the gelcoat contains MMA.

MMA transferred [kg/yr]

= (1+1/9) × 3/100 × annual amount of gelcoat handled [ton/yr] × 1000 × MMA content

--- Formula-18

1/9: portion corresponding to the amount transferred that went into waste solvent

MMA released [kg/yr]

= gelcoat emission factor [kg/ton] (from Table 4) × annual amount of gelcoat used [ton/yr]

= gelcoat emission factor [kg/ton] × 97/100 × annual amount of gelcoat handled [ton/yr]

--- Formula-19

MMA emission factor for the amount released from gelcoat can be determined from Table 4 once its MMA content is known.

4.5.3. Estimation Formula of Amount Transferred and Released for Toluene

(A) Estimation formula of amount transferred

(1) Wherein resin is purchased in drum or can

Toluene transferred [kg/yr]

= (1+1/9) × 6/1000 × annual amount of resin handled [ton/yr] × 1000 × Toluene content

--- Formula-20

1/9: portion corresponding to the amount transferred that went into waste solvent

(2) Wherein resin is purchased in carrier container or lorry tank

Toluene transferred [kg/yr] = 0 (none)

--- Formula-21

(B) Estimation formula of amount released

(1) Wherein resin is purchased in container

Toluene released [kg/yr]

= annual amount of resin used [ton/yr] × 1000 × Toluene content

= 994/1000 × annual amount of resin handled [ton/yr] × 1000 × Toluene content

--- Formula-22

(2) Wherein resin is purchased in carrier container or lorry tank

Toluene released [kg/yr]

= annual amount of resin handled [ton/yr] × 1000 × Toluene content

--- Formula-23

Table 3 Emission factor to air of styrene monomer (SM) contained in lamination resin and gelcoat in open-mold molding (series A)
(Expressed in kg of SM amount released per 1 ton of resin or gelcoat used.)

Unit: kg of SM/1 ton of lamination resin or gelcoat

SM content in lamination resin or gelcoat [mass%][1]			25	30	35	40	45	50	55
Manual lamination		Conventional type of resin	28	34	42	55	68	81	94
		Low volatile type of resin[2]	21	23	26	28	30	32	37
Mechanical lamination	Spray method provided with no exhaust gas treatment facility	Conventional type of resin	38	46	63	95	127	159	191
		Low volatile type of resin[2]	23	28	39	58	79	99	119
	Spray method provided with exhaust gas treatment facility[3]	Conventional type of resin	29	35	49	73	98	123	147
		Low volatile type of resin[2]	18	22	30	45	60	76	91
	Wherein resin is impregnated from short distance so as the resin not to become mist form[4]	Conventional type of resin	24	29	35	42	49	56	63
		Low volatile type of resin[2]	15	19	21	26	31	35	39
Filament winding molding process[8]		Conventional type of resin	41	50	60	72	85	97	109
		Low volatile type of resin[2]	27	32	39	47	55	63	71
Gelcoat coating and curing[7]		Wherein exhaust gas treatment facility is not provided.	100	120	151	198	244	291	338
		Wherein exhaust gas treatment facility is provided[3]	73	88	110	144	178	206	246
Wherein curing is conducted with covering by sheet following impregnation process.			Emission factor for Conventional type of resin x 0.80 or 0.85[5]						
Wherein curing is conducted with covering by sheet without impregnation process.			Emission factor for Conventional type of resin x 0.50 or 0.55[6]						

(Source: the Composites Fabricators Association, as of April 7, 1999)

1) Since the SM content is expressed in mass%, estimation should be made using "mass% ÷ 100" in the estimation formula. For SM content falling between two listed values, emission factor should be calculated by proportional allotment. This SM content is a value which includes the SM post-added by molders. However, it is a value before other additives such as powder, filler, glass and the like are added. If there are seasonal types of lamination resin or gelcoat (that is, if the SM content varies), calculation should be made assuming spring and autumn types of resin are used throughout the year.
2) Low volatile type of resin represents the resin which contains paraffin and the resin of low odor. Resins other than these types should be regarded as conventional types of resin.
3) Common to both lamination resin and gelcoat, note that the difference between the cases with and without exhaust gas treatment facility will go into the transferred amount. For example, when a resin for lamination and of conventional type is used and the SM content is 40 mass%, the transferred amount will be (95 - 73) kg/ton.
4) Resin spray without air (Air-less resin spray) and the like (providing the resin not becoming mist form) are envisaged.
5) For the case of hand lay-up lamination, 0.80, and for machine-led lamination, 0.85 should be employed, respectively.
6) For the case of hand lay-up lamination, 0.50, and for machine-led lamination, 0.55 should be employed, respectively.
7) Emission factors for gelcoat coating and curing wherein non-atomized coating or brush type coating is applied are:
[SM content / Emission factor] 25/56 30/76 35/96 40/117 45/137 50/158 55/178
For details on non-atomized coating application data, refer to "Emission Factors for Non-Atomized Application of Gel Coats used in the Open Molding of Composites", EECS (Engineering Environmental Consulting Services) Report (July 17, 2001).
8) Emission factors for filament winding molding process are obtained from "Dow Filament Winding Emission Study".

Table 4 Emission factor to air of methyl methacrylate (MMA) for gelcoat lamination and curing processes (series A)

MMA content in gelcoat [mass%][1)]	1	5	10	15	20
MMA amount released to air per 1 ton of gelcoat (kg)	6.75	33.75	67.5	101.25	135

(Source: the Composites Fabricators Association, as of April 7, 1999)

1) This MMA content is a value which includes the MMA post-added by molders. However, it is a value before other additives such as powder, filler, glass and the like are added.

Since the MMA content is expressed in mass%, calculation should be made using “mass% ÷ 100” in the estimation formula. For MMA content falling between the two adjacent values listed, emission factor should be calculated by proportional allotment.

Examples of How to Calculate Using the Formula

Example 1

Condition Setting:

[1] Open mold molding (series A)
[2] Gelcoat coating (exhaust gas treatment facility is present)
[3] Annual amount of gelcoat -- 12 ton
[4] SM content of gelcoat -- 50 mass%
[5] Manual lamination
[6] Conventional type of resin is used for lamination
[7] Lamination resin is purchased in drum or can
[8] Annual amount of lamination resin handled -- 120 ton (for lamination only)
[9] SM content of lamination resin -- 45 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Gelcoat [kg/yr] -- from Formula-1 and Table 3
10/9 × 3/100 × 12 × 1000 × 50/100 + (291-206) × 97/100 × 12
= 200 + 989 = 1,190 kg/yr
2) SM Amount Transferred from Lamination Resin [kg/yr] -- from Formula-5
10/9 × 6/1000 × 120 × 1000 × 45/100 = 360 kg/yr
3) Total Amount of SM Transferred = 1,550 kg/yr

Estimation of Amount Released

4) SM Amount Released from Gelcoat [kg/yr] -- from Formula-7 and Table 3
206 (from Table 3) × 97/100 × 12 = 2,400 kg/yr
5) SM Amount Released from Lamination Resin [kg/yr] -- from Formula-8
68 (from Table 3) × 994/1000 × 120 = 8,100 kg/yr
6) Total Amount of SM Released = 10,500 kg/yr

Example 2

Condition Setting:

[1] Open mold molding (series A)
[2] Gelcoat coating (exhaust gas treatment facility is present)
[3] Annual amount of gelcoat -- 12 ton
[4] SM content of gelcoat -- 50 mass%
[5] Machine-driven lamination/spray method (exhaust gas treatment facility is present)
[6] Low volatile type of resin is used for lamination
[7] Lamination resin is purchased in drum or can
[8] Annual amount of lamination resin handled -- 120 ton (for lamination only)
[9] SM content of lamination resin -- 45 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Gelcoat [kg/yr] -- from Formula-1 and Table 3
10/9 × 3/100 × 12 × 1000 × 50/100 + (291-206) × 97/100 × 12
= 200 + 989 = 1,190 kg/yr

2) SM Amount Transferred from Lamination Resin [kg/yr]
-- from Formula-3 and Table 3

10/9 × 6/1000 × 120 × 1000 × 45/100 + (79-60) × 994/1000 × 120
= 360 + 2,266 = 2,630kg/yr

3) Total Amount of SM Transferred = 3,820kg/yr

Estimation of Amount Released

4) SM Amount Released from Gelcoat [kg/yr] -- from Formula-7 and Table 3
206 (from Table 3) × 97/100 × 12 = 2,400 kg/yr

5) SM Amount Released from Lamination Resin [kg/yr] -- from Formula-8
60 (from Table 3) × 994/1000 × 120 = 7,160 kg/yr

6) Total Amount of SM Released = 9,560 kg/yr

Example 3

Condition Setting:

[1] Open mold molding (series A)
[2] Gelcoat coating (exhaust gas treatment facility is not present)
[3] Annual amount of gelcoat -- 12 ton
[4] SM content of gelcoat -- 45 mass%
[5] MMA is contained by 10 mass% in Gelcoat
[6] Machine-driven lamination/spray impregnation from short distance using air-less gun
[7] Curing is executed with covering by sheet after impregnation step has completed
[8] Conventional type of resin is used for lamination
[9] Lamination resin is purchased in lorry tank
[10] Annual amount of resin handled -- 120 ton (for lamination only)
[11] SM content of lamination resin -- 45 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Gelcoat [kg/yr] -- from Formula-2
10/9 × 3/100 × 12 × 1000 × 45/100 = 180 kg/yr

2) SM Amount Transferred from Lamination Resin [kg/yr] -- from Formula-6
0 kg/yr

3) Total Amount of SM Transferred = 180 kg/yr

4) MMA Transferred from Gelcoat [kg/yr] -- from Formula-18
10/9 × 3/100 × 12 × 1000 × 10/100 = 40 kg/yr

Estimation of Amount Released

5) SM Amount Released from Gelcoat [kg/yr] -- from Formula-7 and Table 3
244 (from Table 3) × 97/100 × 12 = 2,840 kg/yr

6) SM Amount Released from Lamination Resin [kg/yr] -- from Formula-9 and Table 3
49 × 0.85 (both from Table 3) × 120 + 1/10000 × 120 × 1000
= 4,998 + 12 = 5,010 kg/yr

7) Total Amount of SM Released = 7,850 kg/yr

8) MMA Amount Released from Gelcoat [kg/yr] -- from formula-19 and Table 4

67.50 (from Table 4) × 97/100 × 12 = 790 kg/yr

Example 4

Condition Setting:

[1] Open mold molding (series A)
[2] Gelcoat coating (exhaust gas treatment facility is not present)
[3] Annual amount of gelcoat handled -- 12 ton
[4] SM content of gelcoat -- 50 mass%
[5] Machine-driven lamination/spray method (exhaust gas treatment facility is not present)
[6] Curing is executed with covering by sheet without impregnation step
[7] Conventional type of resin is used for lamination
[8] Lamination resin is purchased in drum or can
[9] Annual amount of resin handled -- 120 ton (for lamination only)
[10] SM content of lamination resin -- 45 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Gelcoat [kg/yr] -- from Formula-2
10/9 × 3/100 × 12 × 1000 × 50/100 = 200 kg/yr
2) SM Amount Transferred from Lamination Resin [kg/yr] -- from Formula-5
10/9 × 6/1000 × 120 × 1000 × 45/100 = 360 kg/yr
3) Total Amount of SM Transferred = 560 kg/yr

Estimation of Amount Released

4) SM Amount Released from Gelcoat [kg/yr] -- from Formula-7 and Table 3
291 (from Table 3) × 97/100 × 12 = 3,390 kg/yr
5) SM Amount Released from Lamination Resin [kg/yr] -- from Formula-8 and Table 3
127 × 0.55 (both are from Table 3) × 994/1000 × 120 = 8,330 kg/yr
6) Total Amount of SM Released = 11,700 kg/yr

Example 5

Condition Setting:

[1] Open mold molding (series A)
[2] Without gelcoat coating
[3] Manual lamination
[4] Low volatile type of resin is used for lamination
[5] Lamination resin is purchased in container
[6] Annual amount of resin handled -- 120 ton
[7] SM content of lamination resin -- 40 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Gelcoat [kg/yr] -- from Formula-5
10/9 × 6/1000 × 120 × 1000 × 40/100 = 320 kg/yr

Estimation of Amount Released

2) SM Amount Released from Lamination Resin [kg/yr] -- from Formula-8 and Table 3

28 (from Table 3) × 994/1000 × 120 = 3,340 kg/yr

Example 6

Condition Setting:

[1] Open mold molding (series A)
[2] Without gelcoat coating
[3] Filament winding molding
[4] Conventional type of resin is used
[5] Resin is purchased in container
[6] Annual amount of resin handled -- 120 ton
[7] SM content of resin -- 35 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Lamination Resin [kg/yr] -- from Formula-6

0 kg/yr

Estimation of Amount Released

2) SM Amount Released from Lamination Resin [kg/yr] -- from Formula-10 and Table 3

60 (from Table 3) × 120 = 7,200 kg/yr

Example 7

Condition Setting:

[1] Closed molding-1 (series B)
[2] Gelcoat coating (exhaust gas treatment facility is present)
[3] Annual amount of gelcoat handled -- 12 ton
[4] SM content of gelcoat -- 50 mass%
[5] Resin transfer molding
[6] Lamination resin is purchased in drum or can
[7] Annual amount of resin handled -- 120 ton (for lamination only)
[8] SM content of lamination resin -- 45 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Gelcoat [kg/yr] -- from Formula-1 and Table 3

10/9 × 3/100 × 12 × 1000 × 50/100 + (291 – 206) × 97/100 × 12

= 200 + 989 = 1,190 kg/yr

2) SM Amount Transferred from Lamination Resin [kg/yr] -- from Formula-5

10/9 × 6/1000 × 120 × 1000 × 45/100 = 360 kg/yr

3) Total Amount of SM Transferred = 1,550 kg/yr

Estimation of Amount Released

4) SM Amount Released from Gelcoat [kg/yr] -- from Formula-7 and Table 3

206 (from Table 3) × 97/100 × 12 = 2,400 kg/yr

5) SM Amount Released from Lamination Resin [kg/yr] -- from Formula-11

1/100 × 994/1000 × 120 × 1000 × 45/100 = 540 kg/yr

6) Total Amount of SM Released = 2,940 kg/yr

Example 8

Condition Setting:

[1] Closed molding-1 (series B)

[2] Without gelcoat coating

[3] Continuous molding

[4] Resin is purchased in lorry tank

[5] Annual amount of resin handled -- 120 ton

[6] SM content of resin -- 35 mass%

Estimation of Amount Transferred

1) SM Amount Transferred from Resin [kg/yr] -- from Formula-6

0 kg/yr

Estimation of Amount Released

2) SM Amount Released from Resin [kg/yr] -- from Formula-12

$1/100 \times 120 \times 1000 \times 35/100 + 1/10000 \times 120 \times 1000 = 420 + 12 = 430$ kg/yr

Example 9

Condition Setting:

[1] Closed molding-2 (series C)

[2] SMC molding

[3] Purchased as SMC

[4] Annual amount of SMC handled -- 120 ton

Estimation of Amount Transferred:

SM amount transferred is 0 kg/yr since purchasing is executed as SMC

Estimation of Amount Released: from Formula 14

$2/1000 \times 120 \times 1000 = 240$ kg/yr

Example 10

Condition Setting:

[1] Closed molding-2 (series C)

[2] BMC molding

[3] Purchased as BMC

[4] Annual amount of BMC purchased -- 120 ton

Estimation of Amount Transferred:

SM amount transferred is 0 kg/yr since purchasing is executed as BMC

Estimation of Amount Released: from Formula 15

$1/1000 \times 120 \times 1000 = 120$ kg/yr

Example 11

Condition Setting:

[1] Compound preparation process (series D)

[2] SMC preparation
[3] Annual amount of SMC prepared -- 120 ton

Estimation of Amount Transferred:

SM amount transferred is 0 kg/yr when Formula-6 is applied to this case

Estimation of Amount Released: from Formula 16

17/10000 × 120 × 1000 = 200 kg/yr

Example 12

Condition Setting:

[1] Compound preparation process (series D)
[2] BMC preparation
[3] Annual amount of BMC prepared -- 120 ton

Estimation of Amount Transferred:

SM amount transferred is 0 kg/yr when Formula-6 is applied to this case

Estimation of Amount Released: from Formula 17

8.8/10000 × 120 × 1000 = 110 kg/yr

Example 13

Condition Setting:

[1] Pre-preg forming
[2] Resin dissolved in toluene is used
[3] Resin is purchased in drum or can
[4] Annual amount of resin handled -- 120 ton
[5] Toluene content -- 30 mass%

Estimation of Amount of Toluene Transferred: from Formula 20

10/9 × 6/1000 × 120 × 1000 × 30/100 = 240 kg/yr

Estimation of Amount of Toluene Released: from Formula 22

994/1000 × 120 × 1000 × 30/100 = 35,800 kg/yr.