CHAPTER 1.

OVERVIEW
1. Automobile Recycling - Current State and Issues

1.1. Amount of ELVs and State of Recycling

Five million vehicles reach the end of their life cycles every year in Japan. Of these, 500,000 to 1,000,000 are exported as used cars. The remaining 4 to 4.5 million are disassembled and recycled. Of the latter group, less than 1% come from vehicles illegally abandoned at roadsides. This is well under the 5 to 7% reported in the member states of the EU etc.

Automobiles illegally abandoned in Japan are being disposed of by the Association for Cooperation in Abandoned Car Disposal, established by the Japan Automobile Manufacturers Association (JAMA) and related industries in cooperation with the police and local governments. Over 99% of end-of-life vehicles (ELVs) therefore end up being reclaimed and processed. The reclaimed ELVs are disassembled by the dismantlers for their parts which are then supplied to the market as used parts or disposed of. The Ministry of Health and Welfare (MHW) has established guidelines for the disposal of gasoline, oil, and other liquids, batteries, and other hazardous materials. These are therefore first drained or removed, then the ELVs compacted to body scrap. The body scrap is marketed as scrap metal while including glass, seats, and the like and is recycled by the shredder industry.

The shredder industry uses large-sized hammermills called “shredder machines” to pulverize the body scrap, uses mechanical separators or workers to separate the scrap, and recovers the metals. At the same time, the glass and scrap plastic are sorted as ASR and disposed of in landfills.

This recycling system has spread rapidly since the first shredder went into operation in Japan in 1970. At the present time, 75 to 80% of automobiles, by weight, is recycled.

In recent years, however, the shredder industry has seen its economic foundation rapidly eaten away by plummeting prices of scrap iron & steel, the main source of its income, and continually rising costs for disposal of ASR at landfills - accounting for a large part of its expenses. Body scrap is being treated less and less as a valuable recyclable and more and more as industrial waste.

In particular, the cost of disposal of ASR in landfills will only rise, not fall, due to civil suits and the resultant difficulty in finding new controlled landfill sites.

1.2. Toughening of Standards for Disposal of ASR at Landfills

ASR had been disposed of as glass, scrap plastic, and other refuse basically free from harmful substances in simple controlled landfill sites without water treatment facilities. In 1990, however, an incident occurred in Teshima, Kagawa prefecture where about 510,000 tons of industrial waste including ASR was found to have been illegally dumped. This incident grew into a massive government suit.

The case was publicized on a nationwide basis through the television and other
mass media and has become a landmark case in litigation against illegal dumping in Japan.

The MHW and the Environmental Agency subsequently launched surveys into the disposal of ASR. As a result, the government strengthened environmental standards for water pollution in 1993 and amended the Waste Disposal and Public Cleansing Law in 1994. It decided to change the disposal of ASR from the old burial in simple landfills to burial in managed landfills separated from the surrounding water table and treating the wastewater starting from April 1996. Disposal in managed landfills is more expensive than disposal in simple landfills, so costs soared further.

1.3. **JAMA Approach to Processing of ASR**

In view of the above situation, JAMA decided to initiate a special four-year research program starting from fiscal 1996 to study alternatives to disposal of ASR in landfills.

Specifically, it studied and developed new technology for processing ASR and conducted demonstrations at an actual scale plant. It also disassembled and studied ELVs. By developing recycling technology and disseminating its findings on a broad basis, it has contributed to the suitable disposal of ASR and the broader promotion of recycling.

On the other hand, government and industrial efforts to promote automobile recycling have proceeded in synchronization with global endeavors. Germany established a law for promotion of recycling in its economy and suitable waste disposal in 1994 with the aim of increasing recycling. As part of this, the German government and industry held discussions over the recycling of automobiles. This led to the establishment of regulations for the disposal of ELVs in 1998.

In Japan, the Ministry of International Trade and Industry (MITI) put together a "recycling initiative", released in 1997, calling for the related industries to voluntarily work to recycle automobiles rather than establishing further government regulation.

The target for recycling in Japan is 85% by the year 2002 and 95% by the year 2015. Japan has further established as its own distinctive goal - the reduction of the volume of ASR buried to 2/3 by the year 2002 and to 1/5 by the year 2015. The means for achieving these targets is being left to the related parties to figure out on their own. The state of achievement is being monitored and encouragement given by a study group established for the improvement of the effectiveness of the recycling initiative in MITI.

1.4. **Current Recycling Rate of Automobiles**

The levels of recycling in the current automobile recycling system are shown in Fig. 1.1.

At the present time, 75 to 80% of the weight of automobiles are recycled through
the different stages of dismantling, shredding, ASR sorting and processing. The remaining 20 to 25% is disposed of as ASR in landfills.

The problem, as mentioned above, is the establishment of a new route for recycling to take the place of disposal of ASR in landfills. Therefore, development of new recycling technology such as thermal recycling has become necessary.

The composition of ASR differs when obtained by pulverization with household electrical appliances and other large articles. Here, an example of the analysis of the composition of ASR obtained by pulverizing the scrap obtained from automobiles alone (100%) after removal of the engine, chassis, batteries, oil, etc. is shown in Fig. 1.2.

60% of the ASR is organic and 40% inorganic. The ASR contains about 3% of the particularly valuable copper metal. This is

2. ASR Thermal Recycling Technology - Current State and Problems

2.1. Conditions for Achievement of 95% Recycling Rate as Seen From Composition of ASR

The composition of ASR differs when obtained by pulverization with household electrical appliances and other large articles. Here, an example of the analysis of the composition of ASR obtained by pulverizing the scrap obtained from automobiles alone (100%) after removal of the engine, chassis, batteries, oil, etc. is shown in Fig. 1.2.

60% of the ASR is organic and 40% inorganic. The ASR contains about 3% of the particularly valuable copper metal. This is
mostly derived from the copper in the wire harnesses used in automobiles. The organics include a large amount of plastics and other substances with high caloric contents. ASR as a whole has a calorific content of around 19 MJ/kg or about the same as coal.

ASR currently constitutes 20 to 25% of the weight of the original automobiles. Even if all of the organics were completely incinerated, 8 to 10% ash (inorganics) would remain.

Even if everything other than the ash were recycled, the recycling rate would be 90 to 92%. This would not be enough to reach the 95% targeted for the year 2015. Therefore, this ash has to be recycled in some form or another to achieve the targeted figure.

### 2.2. State of Development of Thermal Recycling Technology of Refuse

Figure 1.3 shows an example of the thermal recycling technology. The technology for incineration of refuse may be classified into direct burning technology for complete burning all at once in an oxidizing atmosphere and thermal decomposition and dry distillation and gasification technology for dry distillation to divide the refuse into dry distillation gas and dry distillation residue and then incineration.

In direct burning, two of the main technologies used for incineration of plastics and other industrial waste with high calorific content have been the rotary kiln system and the fluidized bed system. These systems are currently being used extensively, but disposal of the incineration ash in controlled landfill sites has been becoming increasingly difficult with each passing year due to the lack of new sites and the problem of the dioxins in the ash. Therefore, the "molten slag technology" offering the possibility

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<td>Refuse</td>
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<td>Molten iron catalyst residue melting apparatus</td>
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Fig. 1.3. Thermal Recycling Technology for Refuse
of detoxification of incineration ash and recycling of resources has been
developed. Effort is being made to develop methods for recycling of the
incineration ash together with combustion apparatuses.
Further, the dry distillation and gasification technology is effective for reducing the
production of dioxins from the combustion stage. Domestic and foreign plant
manufacturers are working to develop this as the next generation technology for
incineration of refuse.
Here, the flow of processing in dry distillation and gasification apparatuses of the
fluidized bed system, thermal decomposition drum system, and later explained
JAMA system will be shown.
The direct melting furnace is based on the technology of the vertical shaft furnace
shaped cupola which has been used for melting iron & steel materials in the
casting industry. It incinerates the refuse together with coke and limestone, melts
the inorganics at the coke bed portion formed at the bottom, and discharges the
result from the furnace bottom as slag. There is also a type which uses gas
instead of coke as the heating source and has ceramic balls filled at the bottom to
form a melting zone.
Other technologies being used are the "kiln melting technology" and "surface
melting technology".
The "kiln melting technology" uses a water cooling jacket type rotary kiln to heat to
an internal temperature of over 1200°C so as to promote the conversion of ash to
molten slag in the kiln. The furnace walls are coated by this molten slag.
The "surface melting technology" heats the surface of the ash by a burner to a
temperature over the melting temperature of the ash to convert the ash to molten
slag. By forming a layer of molten slag on the surface of the top part of the ash,
the furnace floor is prevented from contacting the molten slag directly and
therefore the durability is improved.

2.3. Incineration of ASR - Experiments and Problems

JAMA had experimented with incineration of ASR from 1992 to 1994 - before it
began tackling technical development in earnest in 1996.
The findings are summarized in Fig. 1.4. The test furnaces of the fluidized bed
system, surface melting system, and thermal decomposition and gasification
system are shown from the top down. The concentrations of the dioxins in the
exhaust gas are shown in the tables at the right.
First, JAMA used an experimental fluidized bed type incineration furnace
(capacity 1 ton/h) for the test. As a result, it found that while there were no
problems with heavy metals, NOx, and other environmental load substances
stipulated in the Air Pollution Prevention Law, there was a problem with a high
dioxin concentration.
The experiment was conducted based on the "3T" guidelines of the MHW, that is,
taking full consideration of the temperature, time, and turbulence, specifically,
holding the furnace at over 800°C for more than 2 seconds. Despite the
experiment being conducted at settings exceeding this, the prescribed concentration of dioxins was far exceeded. This showed that the concentration of dioxins increased around the bag filter and suggested that resynthesis occurred in the process of incineration of the exhaust gas.

Next, JAMA conducted an experiment by a surface melting type incineration and melting furnace enabling the incineration temperature to be raised to 1200°C and thereby enabling conversion of the inorganics to molten slag at the same time as incineration. As a result, it was confirmed again that the concentration of dioxins was higher at the portion after the exhaust gas was cooled than right after the incineration furnace, that is, that resynthesis was occurring.

The mechanism for the synthesis of the dioxins in the cooling process of the combustion exhaust gas is reported to be the de novo synthesis or oxychlorination reaction shown in Fig. 1.5. The dioxins are synthesized at 250 to 500°C in the presence of a catalyst. The catalyst plays an important role at this time. In particular, copper chloride is known to act as a powerful catalyst.

ASR contains PVC covered copper wire from the wire harness. Copper chloride is reported to be formed in the incineration furnace. (1) (2) That is, the copper oxide formed in the high temperature part of the furnace changes to copper chloride in the low temperature part of the furnace. In an incineration and melting furnace, the copper melts and evaporates to react with the hydrogen chloride in the process of movement in the exhaust gas and therefore becomes a cause of the formation of copper chloride.
To confirm this, JAMA prepared simulated ASR mimicking the properties of ASR in a surface melting furnace and conducted experiments on the relationship with the concentration of dioxins using the content of copper as a parameter. The results are shown in Fig. 1.6. A clear correlation appeared and backed up this hypothesis.

The reason why the concentration of dioxins was lowest with the thermal decomposition, gasification, and melting technology shown in Fig. 1.4 is that, first, the dioxins are thermally decomposed in the less than 600°C reducing atmosphere in the dry distillation and gasification process, so the metal copper is held in the dry distillation residue without being oxidized and does not travel to the gas system.

The metal copper and grit are removed from the dry distillation residue in the refining process. The residue is then supplied to the incineration and melting furnace as powdery thermally decomposed carbon containing ash and is incinerated and melted along with the thermal decomposition gas.

Therefore, the residue is burned in the incineration and melting furnace in the state with the copper component removed. The formation of copper chloride in the exhaust gas is suppressed, there is little synthesis of dioxins, and therefore an extremely low concentration of dioxins in the exhaust gas is achieved.

The above findings were confirmed in subsequent experiments by plant manufacturers. This is one of the important points to note in the thermal recycling of ASR.
3. **JAMA Plan for Development of ASR Recycling Technology**

3.1. **JAMA’s Development Concept**

Figure 1.7 gives an overview of the concept behind JAMA’s development of ASR recycling technology.

JAMA set three phases 1 to 3 for the development of technology for recycling ASR taking into account the problems and the conditions for achieving the targeted future 95% recycling rate unique to ASR found by previous experimental studies and the issues in technical development requiring urgent attention.

The theme of development in each of the phases was how to satisfy their individual requirements independently. JAMA planned to complete each phase and combine them into an overall system which would then enable the achievement of a 95% automobile recycling rate.

3.2. **Phase 1: Sorting, Compaction, and Solidification Technology**

In 1996, the year when the study was started, there was no sorting, compaction, and solidification systems for automobile ASR operating anywhere in the world. There were only a few plants in Japan using apparatuses developed for the purpose of compacting waste plastic.

Therefore, there was little information about ASR compaction and solidification
technology and almost no technical reports on ASR. Accordingly, for the study, JAMA built and operated a scale model size experimental apparatus for the particularly urgently required sorting, compaction, and solidification technology for ASR so as to find the problem points and devise measures and improvements to deal with them. The information was then fed back into the development of commercial systems.

### 3.3. Phase 2: Selection of Dry Distillation and Gasification Technology for Compacted Solidified ASR

One of the systems used in thermal recycling technology for ASR is direct dry distillation and gasification without compaction and solidification. The systems being developed by plant makers and other specialized manufacturers are mostly of this type. The reasons why JAMA is developing dry distillation and gasification technology using compacted solidified ASR are that preliminary experiments showed that dry distillation gas is extremely clean and can be used as fuel gas and that, in particular, the dioxins expected to be produced along with burning of the gas can be dealt with by just high temperature incineration. Further, the technology is of a scale which can be effectively utilized by shredder companies and other small businesses, is easy to operate, and is easy to obtain licensing for. Further, JAMA believed it better to avoid overlap with the technical development programs of the plant makers etc. and thought that by collecting and disclosing this basic data, it could better contribute to the development of the technology for recycling ASR.

### 3.4. Phase 3: Basic Research on Use of Residue

Achievement of a 95% recycling rate requires recycling of the inorganics in the dry distillation residue as well, as explained earlier. As technology applicable to this, the conversion of the incineration ash of municipal refuse into molten slag and recycling of this for aggregate materials for civil engineering or tile has been reported. While the standards for elution of heavy metals can be cleared by this, however, this technology still cannot be said to be generally applicable due to concerns over the content of heavy metals. In many cases, even the molten slag is disposed of in managed landfills. On the other hand, there are also examples of large-scale recycling of molten slag. The ferrous metal industry uses blast furnace slag as a cement aggregate material or gradually cools converter slag to form rock-shaped masses which it then pulverizes to adjust in size and then ships out as civil engineering materials. Therefore, JAMA focused on the carbon in the dry distillation residue and investigated the possibility of recycling it as a carbon material by concentration. Note that the ash mixed in as impurities at this time would be recycled as ferrous
metal slag in the case of use in the ferrous metal industry. Finally, when considering recycling at an independent plant, quality control of the molten slag becomes necessary. Learning of the existence of this technology, the U.S. has decided to participate through undertaking commissioned experiments to obtain information on the technology.

3.5. **Development Schedule**

Figure 1.8 shows the schedule of development. JAMA has been able to proceed with the development as scheduled. The findings obtained in each phase will be reported in Chapter 2 on.

![Fig. 1.8. Overall JAMA Plan for Development of ASR Processing Technology](image)

References
