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12 September 1985
English

RECYCLING SYSTEM FOR PLASTICS WASTE

US/CPR/83/245/11-02/32.1.H.
PEOPLE'S REPUBLIC OF CHINA

Mission report :

Prepared for the Government of the
People's Republic of China
by the United Nations Industrial Development Organization,

Based on the work of Georges Patfoort and
Alfons G. Buekens, experts in waste recycling

United Nations Industrial Development Organization
Vienna

This report has not been cleared with the United Nations Industrial Development Organization which does not, therefore, necessarily share the views presented.

EXPLANATORY NOTES

At the time of the visit U.S. dollars were exchanged at the following rate :

1 U.S. $ = 2.81 Yuan (¥)

The following abbreviations have been used throughout tne text

Abbreviation	Plastic material
ABS	= Poly (acrylonitrile-butadiene -styrene)
EVA	= Ethylene-vinylacetate
HIPS	= High Impact Polystyrene
PA	= Polyamide
PE	= Polyethylene
PMMA	= Poly methyl metacrylate
POM	= Polyoxymethylene
PP	= Polypropylene
PS	= Polystyrene
PVC	= Polyvinylchloride

ABSTRACT

During a brief tour in China the two experts have studied the recovery and utilization of wastes in Shanghai, with a particular emphasis on the recycling of plastic wastes. Agreement was reached to implement a plastic processing line at SRKUC (Shanghai), which would serve as a pilot-plant for the whole of China, with the purpose of adapting the FN-processing technology to the Chinese raw materials and technical and economic conditions.

In the course of the discussions and plant visits the pyrolysis of PMMA was also singled out as an important topic for further action. A separate project proposal for tackling the PMMA-pyrolysis problem is added to this report in Annexe VI.

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INTRODUCTION

This report deals with the data obtained, the observations made and the agreements reached during a 2 weeks mission in China of the two experts in Solid Waste Recovery.

The purpose of the project was to realize a recycling system for plastics waste adapted to the needs of the country integrated in a general programme of waste recovery.

Hence, a first task of the experts was to get acquainted with the local systems and customs in the field of waste recovery and recycling, including plastics and rubber. For that purpose the Chinese counterparts have organized a number of plant visits, the details of which are reported in a chronological order in one of the Annexes.

Secondly, a study was made of the technical requirements and needs in the field of plastics recycling. This task was greatly facilitated by the excellent technical knowledge of the Chinese counterparts and by the fact that the equipment they desired was originally invented by one of the experts.

Total agreement for the course to follow was reached during the discussion sessions scheduled towards the end of the visit. The results can be summarized as follows :

- the available budget would be used to
  (a) acquire the most essential parts of a FN mixed plastics processing-line. The non-essential parts of the line would be manufactured locally
  (b) send technical and commercial people to Belgium in order to obtain the necessary training for operating the equipment and to assess its financial benefits for the local (Chinese)operating conditions
- a R & D-agreement would be made between the Chinese counterparts and a Belgian public company, using a similar processing line for the recycling of mixed plastics
- further research would be initiated locally in order to adapt the line to the nature of the Chinese raw materials and market outlets. This would eventually lead to a more widespread use of the imported equipment throughout the whole nation on the basis of a suitable licensing agreement with the original manufacturer (FN)

In the course of the visit the Chirese counterparts put forward numerous questions regarding plastics recycling technology in general and the abatement of pollution in the processing plants in particular. The experts replied to these questions, but had to emphasize that the solution of most of the problems submitted would require important investments, which often would render unattractive the continuation of the present economic activity.

One of the most pressing questions of the Chinese counterparts was in the field of PMMA recycling, which at present is conducted with an exceptionally low yield.

Since this particular case could be solved by the experts on the basis of a limited amount of further study it is suggested that further work would be conducted in this field.

RECOMMENDATIONS.

1. Installation of a pilot recycling plant is recommended in view of the optimisation of the activities of the Shanghai company to increase the efficiency of the recycling of plastic Waste. Waste would be recycled to a much higher quality material and an increasing quantity of mixed waste would be processed which with present equipment is to be considered as useless material

2. Improvement of the operation of the PMMA plant would lead to an immediate and substantial increase of production an elimination of polluting side effects and a very important improvement in the quality of final products. The optimisation of the process is highly recommended.

PLASTIC WASTE RECYCLING PROBLEMS IN CHINA

1. Introduction

A large industrial city such as Shanghai(12,000,000 inhabitants) has great potentialities in the separate collection and recycling of waste containing all kinds of raw materials. The Shanghai Resource Recovery and Utilization company (SRRUC)recovers at present sixteen categories of waste materials, including more than a thousand subgrades. This includes ferrous metals, non ferrous metals, rubber, paper, rags , cotton, chemical fibre, animal bones, human hair, broken glass, glass bottles, old machine parts and accessories, chemical residues, waste oil and of course plastics. The total amount of waste material collected in 1983 was 1,660,000 Ton in which industrial wastes accounted for 85 per cent and post consumer waste for 15 per cent. The fraction of plastics is 12,000 Ton and that of rubber 8,600 Ton.

One can easely imagine the future potentialities of this comprehensive system of recovery if it were extended to the whole country. In accordance with western standards public attitudes and cost factors, the method of recovery of this waste material may seem incredible. We have to take into account the very high sense of responsibility of the Chinese authorities combined with a very wide prospective view in the problem of exhaustion of some raw materials and the limits in the resources of the planet.

Moreover, the appalling conditions under which raw materials in most developing countries are recuperated from dumps and tipping sites by flocs of women and children are completely eliminated in the Chinese system. Finally, the system is a source of clean employment and may help in supporting some principles of good housekeeping and thrift in a society rapidly evolving to increased consumption levels.

2. Tasks and Activities of the Experts

2.1. Statement of the problem

The task of the experts was particularly focused on the recycling possibilities of plastics and polymers.

But it is obvious that recycling activities of one material are interconnected with those of other materials. Plastic scrap, originating in industry or in the household is being supplied to selective collection centres or collected by identical brigades. Especially in the smaller arisings problems of mixed waste already exist to a large extent. The problem of their separation, their recovery by physical or chemical processes or their use in composite materials is one that has to be solved in the very near future otherwise the present system of selective collection will loose several of its assets and potentialities in waste recycling. Indeed, even the best waste recuperation system becomes completely useless when there is no acceptable outlet for the recovered fractions. Conversely, the existence of suitable outlets will maintain and stimulate the demand for secondary raw materials, rise their value and thus intensify their recovery.

So if a plastics processing line treating this mixed kind of plastic waste with a good efficiency would be installed, the need of China with respect to this technology would be very important. For this reason, an agreement between the local Company SRRUC and an external Western partner would be desirable in view of an exchange of technology and the development and construction of a recycling line adapted to the local needs.

2.2. Organisation of activities

The stay of the two Unido Experts in Shanghai was very short. However, the organisation of activities by the management of the Shanghai Resource Recovery and Utilisation company (SRRUC) was remarkably efficient and flawless. So a maximum of information could be collected, lectures, meetings and discussions organised, and the required data gathered together to reach sound technological conclusions.

The material-labour ratio

It would be most inefficient to install a plastic recycling line in Shanghai that would be a true copy of those which are already operating in Europe at present.

Two determining arguments will be brought forward and illustrated with examples. One hour of labour in Western Europe represents the value of 15-20 kilogram of PVC. In China one kilogram of PVC represents nearly 4 hours of labour. So the ratio of the value of raw material to labour may vary with a factor of 60 to 80. This modifies completely any concept based upon the efficiency and the output of a process for European conditions.

The value of waste

A second argument lies in the fact that in most cases waste material, and especially household waste has no value in Europe. On the contrary one has to pay a steadily rising fee for its collection and ultimate disposal. Moreover, a large part of the waste is mixed so that expenses would be encurred to separate them. The Shanghai Resource Recycling and Utilization Company runs more than 400 collecting centers in the Shanghai area to which the population spontaneously brings in the waste material. The latter has already attained a high grade of preselection and is being paid for on the basis of its weight. Each center has a paper baling press to compress some of the materials. The later are transported to the factories, generally by simple means (cart, bicycle, ...). Further selection is of course much simplified by this pre-selection. Once more the ratio of the raw material to labour cost plays an important role in the profitability of the process.

Waste separation

As far as the plastics are concerned, the relatively straight-forward structure of the market facilitates the selection. In Europe composite and sophisticated articles, such as complex fibres, multiple extrusion items, multicolor products, fibre composites, multilayer synthetic leather, old shoes and copolymers makes a really comprehensive selection illusive. Furthermore, because of the use of a variety of additives and fillers even the general purpose plastics are no more recognisable by simple inspection and are not separable by usual physical methods.

In China one can usually still separate the different families of plastics after visual inspection. However there remains a variable quantity that is mixed or polluted by small quantities of other materials. Separation of completely mixed domestic waste, an acute problem in Europe, will probably not be of immediate interest in China.

Pollution and working conditions

To understand the further development of the discussions we have to emphasize the very high sense of responsibility of the Chinese authorities and population regarding the problems of ecology, air and water pollution, occupational safety, and maintenance of the equipment in suitable working conditions.

The present situation in the recycling plants visited is such that no adequate solution can be given with relation to many of the problems which were submitted to the experts. The experts gave of course as much advise as possible but they know that the improvements they proposed are only temporary and inadequate having in mind the obsolete and out of date processes used. Most of the time the improvements would necessitate investments that are completely unjustified, because they are not in a harmonious proportion with the present value of the existing assets.

Some of the processes used have been given up recently because of pollution or adverse working conditions. Other processes will undoubtedly follow in a very near future.

One can only approve of such decisions and admire the courage that is needed to take such humanitarian resolutions under difficult economic circumstances.

The pilot plant

In every case and especially under the present circumstances the decision not to install a ready to use plastic recycling line can only be approved of. This line, developed in Europe and exclusively taking into account Western living styles, social circumstances and economic situations is less suitable under Chinese economic and working conditions.

So the installation of a pilot plant to develop an adapted process, designed for local raw materials and operating conditions is certainly justified.

Furthermore, following arguments militate in favour of a prospective view for the development of an own specific technology adapted to the local requirements

- the extremely rapid development of the local economy and the subsequent changes in social conditions would render obsolete in a very short time a Western style line even if it could be adapted temporarily
- it is foreseen that the material/labour value ratio will evolve rapidly changing the conditions of efficient operation of any process
- the strictness of safety and sanitary regulations is augmenting rapidly
- air, water and soil pollution problems are increasing rapidly due to steady industrialisation so that some polluting processes will have to be eliminated.

All arguments are in favour of a pilot plant where local technology can develop and mature to an own appropriate process.

Once this obvious option is taken the next matter of discussion concerns the best adapted and most essential indispensable equipment needed for the pilot plant to allow a first research programme to be started. There is also the condition that the equipment is adapted as well to present needs as to future development.

In November '84 the Chinese Authorities organised an "International resource recovery and utilisation seminar" in Shanghai in order to be prepared for further discussion and study and to have at their disposal the necessary data and arguments regarding technology for future use. Companies all over the world that produce plastic recycling equipment have been consulted and study forums have been organised to test the efficiency of the different processes proposed. One of the delegation was visiting Belgium in '82, whereas one of the experts (Prof. Patfoort) was invited to demonstrate the Belgian realisations of industrial waste recycling in Andenne and the Intradel plant in preparation near Liege.

After this methodical preparation by the Chinese counterparts it is evident that the present discussions at Shanghai took place with full knowledge of the facts.

Industrial and domestic plastic waste

In Europe, as in China, one can divide plastic waste into two main categories : industrial and domestic waste. Normally the former category is not or only slightly mixed or contaminated. In case the latter category has been selected or separated it is assimilated to industrial waste. Two main problems are of fundamental importance in recycling :

- preparing the waste products of different form and shape (film, foam, big items), so that they can be accepted by a recycling machine. Often size reduction and densification and cleaning and drying are necessary
- plastifying and pelletising

The experts explained the different possible methods of separation, size reduction, plastification and pelletising.

Choice of equipment

Following the Chinese Technologist assisting to the meeting the two prevailing arguments determining the characteristics of the desirable equipment are the following :

- at present there is already a quantity of mixed plastic that is difficult or cannot be separated. This quantity will eventually augment in the future with the increased use of plastics in households and in packaging. These plastics generally present difficult separating problems and a method has to be found for reuse of these high value materials
- in the future items made of recycled material will come back a second or more times in the recycling cycle. Each time a plastic is processed the material is submitted to a thermal stress that depends on temperature and time. These stresses are additive and induce various degradation phenomena. It is essential that the residence time at high temperature of the plastics in the machine is reduced to a minimum.

The plastifying machine

To the opinion of the local technologist the only plastic recycling machine fullfilling these two conditions is the plastifying machine of the F.N. Company in Belgium. The Chinese delegation in Belgium (1982) was present during experiments to make polymer alloys with very high P.V.C. content mixed with other high melting point materials. These mixtures had never been accepted for testing with any other machine. The experts explained the scientific basis of this rather unusual behaviour of polymeric material in this equipment.

The second argument was also to the advantage of the F.N. plastifier : the"hot"residence time in extruders of the order of the minute and even several minutes in other plastifier machines. In the F.N. machine this residence time is reduced to 10-20 seconds. It is immediately evident that the number of recycling cycles compatible with a good material quality is augmented in the same ratio.

So it was decided by the Chinese technologists that as well for present as for future development this equipment would fullfill the requirements of the pilot plant for the purpose of plastifying recycling.

Auxiliary equipment

As far as size reduction, cleaning and drying, transportation and packaging is concerned, local technology should prevail, It is the task of pilot plant to develop a complex line with auxiliary equipment, adopted to local needs but with lower investment costs. Chinese industry is already manufacturing similar equipment such as cutters, rotating separators, drying equipment, so that this solution is viable.

Micronising

Although the local counterparts are perfectly capable of providing a plastics cutter, it seems necessary to include in the project the acquisition of a microniser of a very new design. It has a rapid rotating action and a pulverising effect on hard materials such as glass and thermosets, which may be mixed with the plastics and incorporated in the final product, more or less like a filler. Hence this microniser is an essential and even inevitable tool in the recycling line; its action cannot be substituted by manual work or other mechanical equipment. This microniser also reduces the plastic material to very fine and dense particles and permits to

eliminate any contamination that could damage the plastifier screw. The plastifier is provided with a sieve and followed by a hot pelletiser that reduces the thermal stress on the material.

Conclusions

In anticipation, plans were developed for the completion of the line and investment funds are foreseen. For a final determination of the line and a more detailed analysis of materials to be processed and site plans are necessary and should be prepared by the counterparts, in collaboration with one of the experts. Still, testing with manual feeding can begin as soon as the machine would be installed at Shanghai. It is concluded that the selected plastics and also the high value engineering plastics can be processed on the FN-machine with the required efficiency and much shorter residence time than is possible on classical or competing equipment.
The problem of PMMA (poly methyl metac rylate), that can be selected easily and has a high commercial value will be dealt with separately, the solution to this problem depending on a completely different process.

2.3. The PMMA Problem

Right from the beginning of the visit the Chinese counterparts had expressed keen interest in the experts' opinions, comments and advice on various practical topics, which are directly and indirectly related to the recycling of plastics.

A list of four important problems was presented on Friday, 23 August , and illustrated and commented upon during the various plant visits. The experts have replied to all the questions of the counterparts during the various discussion sessions.

One topic was singled out for further actions i.e. the PMMA pyrolysis.

The pyrolysis of PMMA is conducted according to a local process which for various reasons is highly inefficient and cumbersome. The extremely low yield of the process, currently about 48 %, in the opinion of the experts could at least be raised to the Western value of 80 % and possibly to an even higher yield.

In a view of further study a number of detailed data on plant engineering and operation as well as actual product samples were collected.

The local PMMA problem could be solved on the basis of the next programme for one of the experts

1. survey of relevant scientific and patent literature
2. experimental confirmation of the monomer yields at various operating temperatures, in the range of 350 to 550 °C, and for various addition rates of diluent
3. Preparation of a report on these findings
4. Preliminary design of a new pyrolysis plant, featuring continuous operation.
5. submitting the design data to SRRUC and help in finalizing the new plant lay-out and construction.

The experts are confident that the problems experienced at SRRUC can be solved on the basis of the process flow sheet and operating procedure proposed by the Unido experts.

Please find a project proposal relative to this work in Annex VI.

Conclusions

The PMMA-unit described in Annex V attains a pyrolysis yield of only 48 %, against 80 % for even the simplest Western units. The development of a new continuous process based on the existing expertise would allow SRRUC to construct a new pyrolysis plant locally and attain much higher product yields.

The preparatory work required is described in a project proposal (Annex VI)

Acknowledgement

The experts like to express their deep gratitude to the Secretary and Manager and Staff of the Shanghai Resource Recovery and Utilization Company for the excellent preparation of the programme, the most pleasant atmosphere in which the mission took place and the exceptional hospitality they have shown.

Further aid is acknowledged from Mr. Sissingh, the S.I.D.F.A. at Beijing, and the Services of the Chinese Ministry , which took care of the organisation of the arrival, departure and accomodation at Beijing.

Background Information

Since 1971 intensive research has been performed in the CRIF laboratories in Liège, Belgium, on polymeric alloys. These alloys are essentially very finely divided emulsions obtained by intensive mixing of polymers in the molten state and stabilized by cooling.

To obtain a high quality mix of a very viscous polymeric liquid with a very short residence time in the heated state, a special device has to be used.

A theory of polymer mixing was worked out and a device invented by Prof. Patfoort and developed to a pilot machine in the CRIF laboratories.

Since the energy crisis, the study of the fabrication of polymeric alloys from mixed plastics waste was emphasized. Since 1977, the licence was taken over by the F.N. Industry in Herstal (Belgium), and the process was developed to a complete plastics recycling line also suitable for single component granulation with minimum residence time of the material in the machines, an absolute necessity for repeated recycling.

A Chinese delegation with a delegate from the Worldbank and Mr. Youssef from UNIDO visited Belgium on 13 May 1983. The study tour included a visit to the pilot plant of the F.N. Industry in Herstal, the municipal waste recovery plant in Liège that became fully operational in November 1983 (this plant is the EEG pilot unit), and the factory for industrial waste recovery in Andenne (all types of plastics waste).

Results of recent practical experiences are as follows:

- Polymer alloys can be obtained easily with the existing machines as well as from domestic and from industrial waste. Of course, the properties of the alloys are dependent from the composition and the origin of the components;

- A detailed study has to be made in relation with transport, selection, availability and quality of the plastics waste to determine the feasibility of the operation in each case;

- As an example, it takes two years for a factory like the visited Andenne type, to write itself off working with industrial waste. In the case of domestic waste a lot of non-technological operational factors have to be taken into account.

For this purpose, SCRUM (Shanghai Company of Recycling and Utilizing of Materials) requests the visit of two experts to discuss the problems regarding the establishment of a pilot plant for recycling and utilization of plastics waste.

ANNEX II

LIST OF THE MOST PROMINENT CHINESE COUNTERPARTS, WHO ASSISTED TO THE FINAL DISCUSSIONS ON THE PROJECT ON AUGUST 27

Li Bingzhang	Manager	SRRUC
Guo Yongkang	Deputy Section Chief	Foreign Economic Relations Shanghai Supplying & Marketing Cooperative
Zhang Dexing	Deputy Section Chief	SRRUC
Yuan Yong ling	Manager	Nashi District Branch, SRRUC
Guo Bangda	Technician	Nashi District Branch, SRRUC
Liu Paoping	Deputy Director Technician	Xinguang Plastic Factory, Nashi District Branch
Ye Liuying	Deputy Director Assistent Engineer	Xinguang Plastic Factory, Nashi District Branch
Lin Xuenong	Manager	Zhapei District Branch, SRRUC
Hu Deyu	Deputy Manager	Zhapei District Branch, SRRUC
Li Weigi	Technician	Zhapei District Branch, SRRUC
Huang Jianging	Chemical Engineer	SRRUC
Zhang Guochang	Interpreter	SRRUC
Chen Oiuying	Interpreter	SRRUC
Zhang Yiansiao	Interpreter	SRRUC

LIST OF THE PRINCIPAL CHINESE MANAGERS, WHO HOSTED VARIOUS PLANT VISITS

Yuang Yongling	Manager	Nashi District Branch SRRUC
Dai Oinghua	Manager	Nashi District Branch SRRUC
Guo Bangda	Technician	Nashi District Branch SRRUC
Liu Baoping	Deputy Director Technician	Xinguang Plastics Factory
Ye Liu ying	Deputy Director Assistant Engineer	Xinguang Plastics Factory
Jiang Fuging	Director	Xinlian Plastic Products Manufacturer
Lin Xuekong	Manager	Zhabei District Branch, SRRUC
Liu	Director	Huguang Plastic Products Manufacturer
Zhu Changsheng	Deputy Director	Ligong Plastic Products Manufacturer
Li Weigi	Technician	Zhabei District Branch SRRUC
Sun Yongsie	Manager	Recycling Center of Zhabei District
Hu Zhanhuei	Manager	Rubber, plastics & Miscellaneous Department, SRRUC

PROPOSED PROGRAMME FOR THE STUDY VISIT OF THE BELGIAN EXPERTS IN SHANGHAI

Aug. 23 Friday	
10:20	Experts arriving in Shanghai The leader of Shanghai Resource Recovery & Utilization Company meeting the experts at the airport
12:00--13:30	Luncheon
16:00--17:00	The leader of SRRUC briefing on the recycling practice in Shanghai at the hotel
	Discussing the proposed programme
18:00	Welcome banquet
Aug. 24 Saturday	
8:30--11:30	Site-visit to Xingguang Plastics Factory
12:00--13:00	Working lunch
13:15--17:00	Visiting Xinlian Plastic Products Manufacturer Visiting the Naishi Waste Plastics Supplying Station
Evening	Open
Aug. 25 Sunday	
8:30--11:30	Visiting Yan'an Dong Road & Sichuan Rd. Waste Purchasing Station
12:00--13:30	Lunch
13:30--16:30	Touring Shanghai's Town God's temple--Yuyuan Garden & Jade-Buddha Temple
19:00	Performance
Aug. 26 Monday	
8:30--11:30	Visiting the Huguang Plastic Products Manufacturer
11:30--13:00	Working lunch
13:30--16:30	Visiting the Rubber, Plastics & Miscellaneous Scraps Business Department, SRRUC
Evening	Open
Aug. 27 Tuesday	
8:30--11:30	Prof. Patfoort working in Xinguan

	Plastics Factory
	Dr. Beukens visiting the Recycling Center of Zhabei District
12:00--13:00	Working lunch
13:30--16:30	Prof. Patfoort same as forenoon
	Dr. Beukens visiting the Nanshi Paper Stock Supplying Station
Evening	Open
Aug. 28 Wednesday	
8:30--11:30	Prof. Patfoort working in Xinguang Plastics Factory
	Dr. Beukens visiting the subordinate unit
11:30--13:00	Working lunch
13:30--16:30	Discussion with the leader of SRRUC on the existing problems in waste plastics recycling with suggestions for follow-up works to carry out the UNIDO Co-operating Project
Evening	Open

ANNEX IV

AGREEMENT PROPOSAL BETWEEN SRRUC, FN AND UNIDO (DRAFT)

Following agreement proposal was submitted to the management of the Shanghaï Company, to the FN Company and to Unido.

The Shanghaï Material Recovery and Utilisation Company wants to set up a pilot plant and laboratory to develop the technology of recycling and recovery of plastics.

In view of this development they want to install a short screw plastifier from the F.N. company in Belgium.

Materials and mixtures will be tested, technicians exchanged and an agreement would be important between the Chinese and Belgian pilot plant "Intradel" in Liège to exchange their experience and future developments.

However the Shanghaï Material Recovery and Utilisation Company is aware of the intellectual property of the machine to the F.N company where the machine has been developed and agrees not to publish common results without previous agreement and not to copy, duplicate or sell machines of the F.N. type nor give information to other companies to facilitate their fabrication or commercialisation. A licence for realisation of machines and recycling lines in China would be desirable in the future and could be discussed later on between the two companies.

Unido would agree to provide the facilities of communication between the two companies and to assure the good working of their agreements.

CHRONOLOGICAL REPORT ON THE MISSION

Monday, 19 August

- Arrival at UNIDO Headquarters in Vienna
- Briefing by Mr. May and Mr. Youssef. Contacts with Mr. Van Hellemont about the Belgian involvment in the project
- Consultation of Files on former projects in the People's Republic of China and on Operating Conditions and Practical Information regarding this country.

Tuesday, 20 August

- Discussion with Mr. Youssef regarding the available means alloted to the project and the possible uses of these funds, amongst other things, regarding
  1) the training of Chinese technicians in Belgium
  2) the economic evaluation of the process by Chinese experts
  3) the dispatching by air mail of Chinese samples to the Intradel processing plant
- Leave to Beijing

Wednesday, 21 August

- Arrival at Beijing Airport. Experts welcomed by Representatives of the competent Chinese Ministry, the direct counterparts, Shanghai Resource Recovery and Utilization Company ,further abridged to SRRUC not being represented in Beijing
- Installation at the Hua Du Hotel

Thursday, 22 August

- Received at the UNDP offices by Mr. A. Sissingh, SIDFA, who confirmed the keen local interest in the project and the efficiency of local counterparts

Friday, 23 August

- Flight to Shanghai-Welcomed by the Manager of SRRUC, Mr. Li Bingzhang, accompanied by technical staff and interpreters
- Installation at the Peace Hotel
- Luncheon together with the SRRUC-team
- Presentation of the proposed programme. After expression of their keen interest in a rapid realization of the pilot-plant program and of some disappointment regarding the brevity of the experts' visit the following items were submitted for consideration by the experts :
  1) the low yields attained in the recovery of PPMA
  2) the quality problems (ageing, darkening of the colour) of recycled plastics
  3) the sorting of mixed plastics
  4) the environmental problems associated with the processing of nylon and phenol-formaldehyde resins.

The experts agreed to analyse these problems and propose a further course of action.

Welcome Banquet at the Friendship Shop

The original program, as prepared by the Chinese counterparts, is given in Annex III. This program was slightly adapted later, in order to introduce more room for group's work and discussion.

Saturday, 24 August

Visit to the Xingguang plastics recycling factory. Installed power : 420 kvA, but total requirements are higher. Two firetube boilers, generating low pressure steam with coal as a fuel.

Preliminary Discussion on the local production of plastics, the generation of waste plastics, the internal recycling in the factories and by plastics processors, as well as the recycling activities of SRRUC. Essentially all industrial plastic wastes and a sizeable amount of postconsumer wastes is being recycled, in part by SRRUC for industrial wastes and solely by them for postconsumer wastes. The main difficulties identified are :

- the characterization and manual sorting of the plastic wastes
- the recovery of relatively minor quantities of ill-known engineering plastics
- the recycling of thermosets (at present burnt in the open air).

Three sources of raw materials have been identified :

- plastic wastes, arising in factories
- plastic wastes, arising during conversion of plastics
- plastic wastes, delivered to the collection centres of SRRUC by private individuals, small shops and workshops

During the visit to the plant the following activities were observed :

1. PVC recycling

- the PVC-scrap processed was mainly of industrial origin and supplied in relatively modest unit quantities (in baskets, bags, sacks, etc), but to a minor extent also consisted of hand sorted, multi-coloured PVC-film, packaged in PVC-bags. The scrap was plasticized using three 400 mm double-roll mills, operating at 160 - 180 °C. Each unit is capable of plasticizing about 20 kg of waste in one quarter of an hour. A paste of additives, composed of plasticiser, lubricant, colorant and stabilizer is added in the process, which yields a strip of more or less even coloured soft PVC. The latter is cut to smaller strips (with a cross-section of 25 x 5 mm) by means of a rotating blade.

The latter are reprocessed by means of locally made extruders featuring a screw (L/D between 10:1 and 15:1) with an improved profile and a set of manually operated strainers. Finally the resulting strips are granulated by another set of extruders, yielding pellets of a relatively uneven shape after cutting to pieces of the air cooled extrudate.

Observations and comments

The experts have to recognize that considerable care is taken for the identification, sorting and grading of the material, · of which is washed with water or alkali solutions and dried. Moreove ged material is also rejected.

On the other hand it seems that the technology used puts a considerable thermal strain on the product, which has to be reheated several times before its conversion to a granulate, which is still fairly uneven in form, the cooling and cutting previsions being far from adequate.

Especially in case of repeated recycling a number of side-effects, such as ageing, darkening and inefficient stabilization seems inevitable, mainly because of the nature of the process used.

2. PVC Flooring

- The conversion of the PVC to flooring tiles was not in operation during our visit.

3. Nylon Recycling

- The plant also featured a manual sorting operation, in which nylon textile cuttings were cleaned from impurities, such as cotton and other extraneous materials.

The material was then processed in 4 open-end extruders, yielding a flat lump of black, solidified nylon. The operation is accompanied by the liberation of fumes, which probably consist of evaporated moisture, together with minor amounts of decomposition products.

The nylon cuttings are extruded by means of two huge vertical preheating and melting vessels. The melted material is pressurized by means of a cogwheel pump delivering a single strand of extruded material. One line is watercooled, the other cooled by blowing air on the extrudate.

Observations

Here again the process used is ill-adapted to the necessity of limiting hydrolysis and degradation of the nylon. It seems desirable to dry the nylon, prior to its submission to a treatment at high temperature. This would not only reduce its loss in mechanical properties but also curtail the pollution of the working atmosphere by vapours.

4. PMMA pyrolysis and polymerisation

The plant converts the cast-quality of PMMA to monomer by a batch pyrolysis process. The PMMA of Chinese origin, or imported from the U.S.A., is chopped or cut to pieces and charged in a cauldron, lined up in a battery of eight. Each cauldron is heated by a separate coal fire. The temperature of the fire and inside the cauldron is not measured. The material is melted and heated, so that monomer vapours are distilled off and condensed by tubular coolers. The condensed product is collected in small, individual vessels for intermediate storage, from which they are discharged to a large, central vessel. Both are located, for safety reasons, outside the pyrolysis building.

The crude monomer is subsequently batch distilled in a steam jacketed boiler, fitted with a packed rectification column (Ø = 25 cm). Some low boiling impurities are removed. The monomer is agitated with saturated brine to coagulate some suspended material.

A second distillation takes place at a reduced pressure, so that the boiling point is lowered to 61 °C. After elimination of the residual moisture the monomer is distilled off and its quality is verified by means of gas chromatography.

As a next step the purified monomer is prepolymerized in a stirred tank reactor operating at about 90-94 °C, until the desired viscosity is attained. The reactant content is then cooled.

After colouring the material and removal of enclosed air bubbles the material is again polymerized in between two sheets of glass (moulds of 60 x 75 cm). A set of moulds is vibrated in a water cooling bath, until the polymerisation is complete.

Finally the plastes of PMMA are stress relieved by reheating and released.

Observations

The engineering and operation of these locally made units show a good craftmanship and ability, but still lead to utterly disappointing results. Hence, considerable emphasis was placed on the local desire to have these problems examined by the experts.

The main problem is the low yield, attained by the process. Charging 100 kg of PMMA

75 kg of pyrolysis oil

60 kg of crude monomer

48 kg of pure monomer are obtained.

In the opinion of the experts this yield could normally be doubled.

Moreover there are a number of operating problems, some of which are rather serious :

1) the cauldron is overheated by the coal fire in an uncontrollable way. Each month its bottom has to be replaced

2) part of the material is carbonized, forming a layer on the bottom of several cm. This further impairs heat transfer and leads to further overheating of the bottom and the charge

3) the temperature distribution and residence time in the cauldron are uneven and uncontrollable, which leads to the occurence of side reactions and lower yields

4) the excessively low yields render the distillation more complex than necessary and lower the final purity of the product

5) in case the operating temperature during prepolymerisation is not observed useless "blow material" is formed

6) the release of the PMMA plate from the glass mould is sometimes problematic

7) the intrusion of water or the appearance of bubbles is too frequent.

On the basis of their observations the experts have proposed a course of action, involving a redesign of the pyrolysis unit after collecting supplemental data on PMMA pyrolysis. The course of action was accepted by the local counterparts, who are prepared to finance all equipment provided the Unido experts deliver the necessary technology and know-how.

Since this topic completely deviates from the main object of this study a separate proposal will be submitted for approval to Unido and SRRUC.

Afternoon - Visit to Xinlian Plastic Products Manufacturer

This factory converts various raw materials, namely

PMMA	10-12	tonnes/month
PS	5	tonnes/month
ABS	3-5	tonnes/month
nylon	2-3	tonnes/month

to fashionable buttons for uniforms, dresses, etc. Part of the production is metallized elsewhere. The factory has an installed power capacity of 630 kVA and uses tap water for cooling (in closed circuit), with one cooling tower .

The PMMA-buttons are manufactured according to the following process :

1) punching of PMMA-plate
2) polishing the back-side
3) stamping of the design
4) polishing the front-side

The PA-buttons are made in the following sequence :

1) drying of the PA
2) injection moulding of sets of generally 6-8 buttons
3) drilling holes in the buttons
4) drying by means of appropriate solutions.
5) inspection.

Observations

All buttons inspected had a very attractive appearance. The injection moulding of nylon, PS and ABS still makes use of plunger-type injection machines, made in China. This type of equipment is obsolete and fairly improductive. The amount of rejects is impressive, possible because of an inadequate design of the moulds or of insufficient post-pressing.

The machining of the buttons is extensive, and labourintensive.

Although this factory does not meet current Western standards of productivity there seems no urgent need for modifying operating methods or renewing equipment, because the over-all standards of quality and workmanship are excellent.

The working conditions were clean and fairly pleasant.

Nanshi Waste Plastics Supplying Station

This Waste Plastic Supplying Station started its operations in 1964. Originally it recovered only 500 tonnes/year but at present it would process 12,000 tonnes/year, a quantity which seems enormous indeed.

Of these materials 60 % originates in industry, 40 % domestically.

In 1964 only 3 types of plastics were treated : PVC, PE, PS. At present there are 10 types, namely the former + PP, HIPS, ABS, POM, PMMA , EVA, PA. Engineering plastics generally remain within the factories.

The activity of the station consists of

- the reception and grouping of plastics of industrial and domestic origin
- the storage of imported virgin plastics
- the manual sorting of industrial plastic waste (sprues and runners) according to their colour
- the manual sorting of mixed domestic waste plastics.

The material is regranulated in a separate, but nearby shop (not visited). Amongst the final outlets two applications were cited :

- foamed ceiling tiles from fire-proofed PE (?) (In the opinion of the experts the material resembled more to rubber)
- shuttles for weaving mills
- PVC drainage pipe.

The relative quantities of recovered materials are :

PVC (soft + rigid)	36 %
PE	20 %
PP	13 %
PS	7 %
ABS	7 %
PMMA	5 %
miscellaneous, including engineering plastics	12 %
	100 %

Observations

The hand sorting operations were observed and appeared to be relatively inefficient. According to the counterparts this operation is the most unpleasant and the least hygienic of all their activities. Advice was requested regarding the possibilities of mechanizing these operations.

It is increasingly difficult to identify the various available qualities with the eye, touch and possibly flame tests. The plastic materials of domestic origin show a definite decrease in quality. Industrial wastes, on the contrary, have very good, steady properties.

Despite the relatively low capacity of each sorter (180 kg/sorter, 8 h-day) the operation is, according to the experts, economically justified. Some measures could be taken to increase productivity :

- avoid colour mixing at the source
- sorting of domestic plastic waste at a conveyor belt instead of around a working table. Other measures could be taken to make the working atmosphere more pleasant and hygienic, although over-all standards seemed quite acceptable already.

One of the experts (A. Buekens) promised to send data on the identification and grading methods, published in literature and from his own, earlier reports.

Sunday, 25 August - Morning

Visit to the Yan'an Dong Road Waste Purchasing Station

Visit to the Sichuan Road Waste Purchasing Station

Yan'an Dong Road Station

This waste purchasing station employs 19 people under the Direction of a Deputee Manager, Mr. Tsu. The shop opens every day from 8 a.m. to 5 p.m., only 4 days per year excepted! The total turn-over amounts to 270,000 ¥/year, which corresponds to a quantity of salvaged materials totalling 135 tonnes/year (1984 figures). Most supplies are delivered on Sundays and in the time period preceding the Festival, the moment Chinese housewives thoroughly clean up their premises.

The waste purchasing station serves a Residential Area of over 10,000 households. In their order of importance the recovered materials are : (1) paper, (2) scrap iron & steel, (3) rugs & textiles (4) glass bottles.

The monthly amount of recovered plastics is 800 kg, which corresponds to a yearly salvage rate of about 1 kg per household.

The following contributions are paid per kg of accepted materials :

	¥/kg
Paper : newsprint	0.30
mixed paper	0.11
Plastics : average	0.20
PVC - industrial arisings	0.90
- household arisings	0.16
PE - white industrial trimmings	0.60
- mixed colours	0.40
PS - first class (mixed with ABS)	0.60
- second class	0.30
PMMA - industrial arisings	1.90
Rubber : 1st quality	0.467
2nd quality	0.36
3rd quality	0.20
Textiles : cotton	0.22
synthetic fibre	0.10
Animal bones	0.12
Glass bottles (reusable)	0.08
(broken)	0.04
Metals : raw iron	0.19
tin cans	0.22
steel plate	0.145
iron parts	0.05
copper (red)	4.7
(brass)	3.6
toothpaste tubes	0.01/tube
Clothes, dresses	according to the quality
Shoes	0.01/shoe

Furniture and wood can be supplied to a different company

Human hair is no longer accepted (although it probably is recuperated elsewhere).

The paper is baled in a double action press. Glass bottles, bones, metals, plastics are packed in various types of sacks. The iron & steel fraction is supplied to Shanghai steel plant number 1 and 10, the plastics to the Nanshi Waste Plastics centre. Clothes are sold to the villages. Most of the material being offered seemed in a good shape. Apparently actual Chinese youths have become fashion-conscious, a tendency which was actively discouraged in former times!

It was stated that 15 % of the turnover is handed over as a "cash-flow" for the collection station. On a basis of 270,000 ¥/year, this would amount to some 40,000 ¥/year. In view of the limited operating cost (renting of the premises, depreciation of the rather elementary equipment) and the low wages (order of magnitude of 1.000 ¥/person,year) this collection station looks like a high-profit operation!

Sichuan Road Waste Purchasing Station

This second waste purchasing station was smaller in size and not very busy at the time of our visit (late Sunday morning). On the other hand it had excellent records, as followed from a number of placards and trophies, obtained for excellent service. We were greeted by the Shop Manager, who was a lad·· and showed around. A prominent article, stored under cover because of its smell, were chicken plumes.

Afternoon and evening Program (organised by Tl SBr)

A visit was paid to two important local Buddhist temples and the famous Yuyuan garden.

The Evening Program consisted of a boat excursion on the River Huang-Pu, which allowed to get an impression of harbour activities and heavy industry, situated along the river.

Monday, 26 August

Morning : visit to the Huguang Plastic Products Manufacturer

This factory can be characterized by the following figures :

- fixed assets of 400.000 ¥
- surface of 7,260 m^2
- 150 staff members.

It has two activities :

- waste materials, arising in the manufacturing of synthetic leather are handsorted, crushed and hot pressed in a multi-storyed press, in which the colour sorted material is heated for 5 minutes, then cooled for 20 minutes. Apparently the heating and cooling medium is distributed by means of the same manifold. The final product is a handsome, multi-coloured square PVC-panel of 1 m x 1 m, used for decorative purposes and flooring No filler is added, but stearic acid is used as a releasing agent
- the production of a phenol-formaldehyde polycondensate, to be mixed with cotton cuttings and trimmings, collected by the waste purchasing stations.

The polycondensate is manufactured in the aqueous phase using a reaction vessel, fitted with a condensor. The impregnation takes place in a series of tumblers.

The following problems were submitted for the attention of the experts :

- the production of PVC plates heavily relies on hand sorting. No methods are available for eliminating the fibres. During the pressing there is evolution of gaseous HCl. Moreover the manufacture of 1.5 m^2 of sheet would require an incredibly high amount of 7-10 kg of coal!!
- the production of phenol-formaldehyde polycondensates give rise to minor quantities of phenol containing wastewaters, which are considered to be unfit for discharge
- the emission of fumes leads to condensation on the ceiling and the dripping of condensate onto the workpeople, causing skin irritation as well as troubles of the respiratory system.

Observations of the experts

The experts have replied that

- the evolution of HCl can be diminished by a more accurate control and (especially) a lowering of the pressing temperature. Other measures include a regular removal of small pieces of PVC, that lay on the pressing tables, without actually being pressed.
- a more sophisticated ventilation system of the workshop in principle would solve the problem of condensation. This method is being applied, int.al., above papermaking machines. The cost of such a system would, however, be prohibitive in this context!
- regarding the phenol-formaldehyde impregnation units (2, in separate buildings) it was concluded that this technology is obsolete. Nowadays, only solid resin powders (possibly under a pre-pelletized form) are used. The filling with wood flour or textiles is conducted in automated roll mills.
- the phenol could be removed from the wastewater using a liquid/liquid extraction unit with aromatics (toluene,e.g.) as an extraction agent. Such a unit would yield a purified effluent, together with a phenol-solution in toluene. As an alternative active carbon adsorption can be used, or the (relatively small amount of) wastewater evaporated.

Afternoon program

visit to the Rubber, plastics & miscellaneous scrap department

relevant figures :

workforce of 517 people

40,000 m^2 of surface available

5,560 m^2 of warehouse

chief activity : recycling of waste tyres and other rubber scrap, including old rubber boots

the amount of materials reworked would attain 70,000 tonnes, part of which is reprocessed elsewhere (e.g. the rethreading of tyres)

the scrap rubber is cleaned, finely crushed in double roll mills with a corrugated hard surface; after addition of plasticiser (oil), the rubber powder is thermally devulcanized in autoclaves and compressed to sheets of rubber reclaim. The yearly production of 30,000 tonnes/year is reused in rubber industry

tyres are skinned and peeled, yielding sheets of (vulcanized) rubber, which are measured and cut to pieces of standard size. The later are eventually converted to protective soles, fittings for spinning & weaving mills, rail gaskets, etc (4,000 tonnes/year)

another 9,000 tonnes/year is used as a raw material in mining and other industrial enterprises.

other activities collection of PVC fil (300 tonnes), trimmings (170 tonnes), thermoset plastics (100 tonnes). All figures relate to 1984, the first year of operation

2 lines of a Chinese design convert cotton-based materials to non-woven of a superior, white quality.

late afternoon : split Program

Prof. Patfoort gives a lecture on the technological aspects of the short screw extruder

Prof. Buekens paid a visit to the Recycling Centre of Zhabei District.

In this centre iron and steel scrap is gathered from about 500 factories, as well as from some 60,000 households.

The annual capacity attains 10,000 tonnes, which corresponds with a turn-over of 15 million ¥ . The annual operating profit amounts to 1/3 of this figure !

The activities consist of :

- manual sorting and simple mechanical processing (with small shears, by flame cutting, etc)
- mechanized baling of swarf, turnings, punchings, etc by means of hydraulic presses.

Handling was based on manual conveying (carts), cranes with a fixed magnet & mechanical discharge, conveyor belts, etc.

Observations

The only unusual features were :

- the cutting of structures with a flame torch, with the aim of recovering reusable profiles, tubes and parts. The latter are sold in a small local shop (or elsewhere)
- the treatment of relatively small arisings in a labour-intensive manner.

No particular problems were submitted for the attention of the experts. The baling presses were relatively highly mechanized. It was stated they were made locally and no longer up-to-date, but no indications of malfunctioning or loss of efficiency were apparent.

Tuesday 27 August

Group discussions on the Unido-project at the Recycling Centre of Zhabei District.

Wednesday 28 August

Group discussions on the Unido-project and the PMMA-pyrolysis proposal at the Xinlian plastic products factory.

End of the afternoon : Visit to the Nanshi Paper Stock Supply Station

During a fairly brief visit it was observed how the wastepaper was delivered, distributed over several parallel series of manual sorting lines, trommelled and baled. The main qualities set aside by manual sorting are books and comparable qualities of printing papers on one hand, contraries such as ribbons, plastic film and other extraneous matter on the other hand.

The trommel, used to screen off dirt and fines, may be regarded as a modern and technically efficient way to tackle this problem.

Some off-grade paper was reused on a basis of thorough manual control, combined with a subdivision using guillotine shears. The resulting piles of quality-sorted paper is bound together to notebooks and similar articles.

Thursday, 29 August

All important business being concluded the last day in Shanghai had a more informal character, with a morning walk in a famous garden, a Farewell Banquet, followed by transfer to the Airport.

Flight back to Beijing, where no hotel accomodation was available. The experts were lodged at the UN Office, nearby the Great Wall Hotel.

Friday 30 August

Discussion of the results of the mission with Mr. Sissingh, who had taken arrangements for confirming the flight back. Mr. Sissingh showed interest in the addition of a PMMA-project as an Annex to the mission.

No further activities for the rest of the day.

Saturday, 31 August

Discussion with Mr. Sissingh on the working conditions in China and their evolution over the last few years. Further advice by Mr. Sissingh regarding future contacts, mail and other matters of practical interest.

Flight back to Vienna

Sunday 1 September

No activities

Monday 2 September

Visit to Unido Headquarters

Reporting to Mr. Youssef, Mr. May, and Mr. Van Hellemont.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

PROJECT PROPOSAL

PART A - BASIC DATA

COUNTRY: China

PROJECT TITLE: Development of an improved PMMA Pyrolysis system

PROJECT No:

UNIDO CONTRIBUTION: US$ 31,000

SCHEDULED START:
as soon as possible

GOVERNMENT CONTRIBUTION
US$ 300,000

SCHEDULED COMPLETION :
6 months later

CURRENCY REQUIRED FOR UNIDO IMPUT:

ORIGIN AND DATE OF OFFICIAL REQUEST:

GOVERNMENT COUNTERPART ACENCY:
Shanghai Resource Recovery and Utilization

UNIDO SUBSTANTIVE BACKSTOPPING SECTION:

PROPOSAL SUBMITTED BY:

PROGRAMME COMPONENT CODE:

DATE OF SUBMISSION:

PART B - NARRATIVE

1. Background and Justification.

The PMMA pyrolysis unit, described in Annexe V has a monomer yield of the order of 48% only, whereas in similar W.European plants 80% is attained.

If means were found to improve the technology and increase the yield to normal values SRRUC would finance all required plant modification and construction activities.

Without the intervention of the UNIDO-experts they would not be in a position to acquire the technology and know-how necessary to upgrade this plant. It is proposed that UNIDO provides the means for performing the required preliminary study. Since it is almost certain that this work would lead to success, the Chinese counterparts are most anxious to have this study started as soon as possible.

2. Special Consideration.

The expertise required for upgrading the process, the technical equipment for optimizing the PMMA pyrolysis and the design experience for converting the experimental results into the design of a small continuous plant are available at the V.U.B., Laboratorium voor Chemische Ingenieurstechniek en Industriele Scheikunde, Brussels.

Prof. Buekens, head of this department, was appointed as a UNIDO- expert for this mission.

3. Objectives.

Determine the optimum temperature, residence time and steam dilution factor in order to attain the highest yield in monomer and the lowest loss in by-products.

Propose a preliminary design for a continuous PMMA-pyrolysis plant, for approval by SRRUC.

Advice SRRUC in the detailed engineering and construction of the plant, according to the new design.

Help SRRUC in starting-up the plant and optimization procedures.

4. Project Outputs.

A new design for the present PMMA-pyrolysis plant, which will be replaced at the end of the project.

The new design will markedly increase product yield and quality. The unit will be more convenient ans economic to operate.

5. Project Activities.

- Survey of the few date (BIOS/FIAT reports) published is the literature
- Experimental optimization of the product yield at a bench-scale pyrolysis plant

  Operation temperatures: 400, 450, 500, 550°C

  partial pressure: 0,1, 0,3, 1 bar
- Preparation of a report on the experimental investigation
- Design of a new pyrolysis plant

  taking into account product yield and mass and heat transfer consideration
- Proposing the plant design to SRRUC
- Follow-up in construction , start-up and optimization

6. Project Imputs.

A. Government Contribution

The contribution of China (SRRUC) is in the detailed engineering, construction and erection of the full-scale plant

The required investment is difficult to evaluate by the experts, because of a lack of knowledge of Chinese cost factors. In Belgium the construction cost of the new plant would amount to some 30.000 U.S. $, excluding peripheral equipment and extraneous costs.

The Government of China will, in the opinion of the experts, be willing to bear this high cost because of

-a very short pay-off time of the required investment

-the possibility of locally constructing almost all of the equipment required.

B. UNIDO Contribution.

UNIDO will provide adequate funds for carrying out the necessary activities to study the present design, gather the necessary data, prepare the experimental work and prepare a new design for a PMMA plant.

This will involve

- 3 months of home-based work for one of the experts
- the necessary budget for renting the required experimental facilities and obtained the product yields and composition under optimized conditions.
- 1 month of follow-up activities
- one visit to Shanghai

7. Proposed Evalution.

The results of the project will be easy to evaluate on the basis of the:

- bench-scale experimental results
- full-scale plant operating data

8. Envisaged Follow-up.

Although this project is self-contained and can be terminated within a reasonable time and budget it cannot be excluded that the Chinese counterparts would request to

- perform additional experimental work on other types of PMMA
- pay an additional visit to the new pyrolysis plant for further evaluation or expansion.

ANNEX I- PROJECT BUDGET.

UNIDO Constribution (Estimate)

(1)	Mission Cost to China	US $	4,000	
3	Months of expert	US $	18,000	(gross)
	Subcontract for the experimental work	US $	3,000	
1	Month of follow-up activities	US $	6,000	(gross)
		US $	31,000	

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The following references proved to be of value in the preparation of the mission:

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Reference

Part of the relevant data were extracted from the Proceedings of the "International Resource Recovery and Utilization Seminar " Shanghai China, November 1984