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Landfill Reclamation - Potential for Recycling/ Reuse and Results of the Evaluation of the Collier County, Florida MITE Demonstration

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INTRODUCTION

In October 1993, the US Environmental Protection Agency (EPA) issued the report "Evaluation of the Collier County Florida Landfill Mining Demonstration." This technology was developed by the Collier County Solid Waste Department and was evaluated as a part of EPA's Municipal Solid Waste Innovative Technology Evaluation (MITE) Program. The purpose of the MITE program is to objectively evaluate innovative solid waste management technologies and transfer the resulting information to municipalities and solid waste managers.

This paper details the demonstration and the subsequent evaluation of the landfill mining, or as it is often called, landfill reclamation technology. Included among the results of the numerous tests conducted during the evaluation period is a waste characterization that was performed on all separated streams and physical and chemical analyses of the soil fraction for comparison to Florida State Compost Regulations. The other separated fractions (ferrous and plastic) were evaluated for their recycling market potential. During one week of the demonstration, air quality measurements were taken for a full range of contaminants. After testing was completed, the data were used to estimate the capital and operating costs of the system, and the processing cost per ton.

EXPERIMENTAL METHOD

The MITE Program

The US EPA established the Municipal Solid Waste Innovative Technology Evaluation (MITE) Program to provide municipalities and the public sector with information on new and developing solid waste management technologies. The MITE program provides a framework within which technology developers have the opportunity to demonstrate the effectiveness of their technology or process in the field. Technology proposals are solicited once per year and are reviewed and selected by an Advisory Committee made up of local and State solid waste recycling coordinators. This ensures that public sector needs are given consideration when choosing evaluation technologies. The Advisory Committee, as well as the subsequent evaluations, are administered for EPA by the Solid Waste Association of North America (SWANA).

After selection the demonstration is planned according to the needs of the technology developer. EPA tries to tailor the evaluation to meet the technological and research needs of the developer, as well as meet the information need of local government and the public sector -- the potential purchasers or users/operators of the waste management technologies. Each project is conducted jointly; the technology developer is responsible for funding and directing the demonstration of the technology and EPA funds and directs the technical and economic evaluation.

At the completion of each evaluation, a report that contains the results of the technical and economic assessment is published. The report serves as a marketing tool for the private developer and is widely distributed by EPA in response to requests for information and for the purposes of technology transfer. The MITE program has completed five evaluations to date, and has six ongoing projects.

Landfill reclamation was submitted to the MITE program by the Collier County Solid Waste Department, and was selected in May 1991. Landfill reclamation uses basic excavation and solid waste processing operations to reclaim and recover landfilled materials. Collier County was one of the first public or private sector groups to develop and apply this technology.

Collier County Solid Waste Department

The Collier County Solid Waste Department had been mining a closed cell of the Naples Landfill for the purpose of recovering degraded material and cover soil for reuse as cover on the active part of the landfill. Their original system was basic in nature, consisting of a series of screening steps to separate the soil fraction which was then used on the active part of the landfill. Material not suitable for reuse as cover (material not passing through the screens, or "overs") was placed back in the landfill. The use of the reclaimed cover soil on the active portion of the landfill represented a cost savings to Collier County on the purchase of cover soil. With this demonstration, Collier County wished to further develop their system by recovering a greater portion of the soil fraction and recovering additional components, such as ferrous and aluminum metal for the purposes of recycling.

Since the inception of their operation, a number of other landfills have attempted similar projects. Landfill reclamation can be used to meet a number of fairly divergent objectives:

- Recovering cover soil and other potentially recyclable materials
- Decreasing the footprint of a landfill and the acreage that requires closure and post-closure care.[1]
- Using the high-energy-value material in a waste-to-energy combustor.
- Removing material from an unlined landfill in order to upgrade the site by lining and reusing the space or removing a groundwater contaminant source.

Collier County's goal of recovering additional material for recycling was an ambitious one, and one which necessitated further equipment. For this purpose the solid waste department approached equipment vendors for the rental of the necessary materials and equipment needed to accomplish the additional recovery objectives. Once the additional processing equipment was procured, the new process line was established for the demonstration and subsequent evaluation.

Landfill Reclamation Process Line

The system evaluated was designed by the Collier County Solid Waste Department with assistance from the University of South Florida.[2] Figure 1 depicts the process flow diagram, identifying unit operations as well as the product streams that were produced.

The process line had four separate unit operations to provide the required separations: a coarse grizzly screen, a fine trommel screen, a ferrous magnet and an air knife. The original intent was to also utilize an eddy current separator for removing aluminum cans. This unit operation was removed from the process line, due to the fact that is was undersized for the intended use. The grizzly screen, with bars having an opening of six inches, separates the non-processible material (S7) from the feed stream. The oversized material is landfilled and all remaining material (less than six inches) is conveyed to the trommel. The purpose of the trommel is to separate the soil fraction (S1) from the remaining material. The trommel has 3/4 inch openings through which the soil and degraded material pass. This material is usable as cover on the active part of the landfill, and represents a significant percentage (nearly 60 %) of what is being processed.[1] A significant amount of sampling and analytical testing was performed on this material. The majority of the tests were for comparison to Florida State compost regulations and also included bacteriological testing, fiber analysis, metals and trace chemical composition.

The oversized material (> 3/4 inch) moves from the trommel, onto a conveyor and through the final two unit operations, separating it for possible recycling. A ferrous magnet is used to separate the ferrous material (S3), and the remainder of the material enters the air knife.

The purpose of the air knife is to perform a density separation by blowing, with high speed air, the lighter, smaller material from the unit, while the denser, heavier and larger material falls to the bottom and is collected. At the entrance to the air knife all material passes over a vibrating finger screen with 3/4 inch openings, through which small, heavy material falls. These "finger screened unders" (S8) are collected for disposal. The oversized material enters the fluidizing section which was modified to produce three additional process streams. The high speed air stratifies the material to enhance the removal of smaller size, high density refuse particles. The large heavy material (S9) is bottom discharged and the lighter material that is blown through the air knife was separated into a moderately light fraction (S4/S5) containing mostly aluminum, glass, some soil and small plastic fragments, and a "super light" fraction (S2) which essentially contained plastic film.

The original process design also contained an eddy current separator between streams S3 and S4/S5. The purpose of the eddy current separator was to remove the aluminum fraction, but after a few test runs it was determined that the eddy current separator was incompatible with the capacity requirements and particle size of the feed stream. At this point in the process line, the feed stream was a soil-coated heterogenous mix of material that did not permit the equipment to operate properly. Since this unit was removed, the residue stream (S4/S5) contained a significant amount of aluminum. With proper equipment, the residue would have been separated into two separate streams: aluminum (S4) and residue (S5).

Evaluation Objectives and Methodology

The EPA MITE evaluation established a number of objectives with our overall goal being an assessment of the landfill reclamation system during the demonstration period. Among them were to:

- Determine the maximum processing rate for the tested equipment.
- Evaluate the unit operations and their ability to produce process streams of required purity.
- Determine the composition of the mined material.
- Evaluate the soil fraction in comparison with Florida State compost standards to determine its applicability as a soil amendment.
- Evaluate the marketability of the product materials such as ferrous, plastic, and aluminum.
- Determine the cost of operation.

In pursuing these objectives, a one week time period was devoted to monitoring the system/process flows and obtaining the necessary samples. The on-site data collection for the evaluation was divided into three parts: mass balance, stream sampling and waste characterization, and air monitoring at the site.

Mass Balance. The mass balance was conducted to ensure that all material was accounted for, and the waste composition study yielded accurate results. The landfill scale was used for all materials at the input and output locations. Prior to placing the material on the process line, mixed, excavated material was loaded into a roll off box and weighed. At the output of each of the unit operations, conveyors emptied each of the process streams into separate roll off boxes. These were also hauled to the scale house daily for weighing.

Stream Sampling and Waste Characterization. Each product stream (soil (S1), plastic (S2), ferrous (S3), and aluminum/residue (S4/S5)) was sampled for characterization, with subsamples being taken for analysis. To obtain product samples, 1 - 1.5 yd^3 samples were collected from the roll off containers and delivered to the sampling area. The material was spread evenly over a grid and a random number chart was used to select the grid square for subsampling. These subsamples were weighed and shipped to the analytical laboratory for chemical analysis. The remaining material was placed on a sorting table for characterization, using the thirteen categories as listed below:

- Paper and paperboard
- Glass
- Ferrous metal
- Non-ferrous metal
- Textiles
- Plastic
- Rubber/leather
- Non-processible
- Inert (soil)
- Yard waste
- Food waste
- Aluminum
- Unidentifiable

Air Monitoring. An air quality survey was also performed and conducted concurrently with the product sampling and characterization. Twelve individual air sampling episodes, three ambient measurements, four at the grizzly screen and five at the trommel, were conducted over five days. Both upstream and downstream measurements were taken. Air samples were evaluated for total and respirable particulate matter (dust) and microbial agents, including total bacteria and total fungi, a range of metals and fibers.

RESULTS AND DISCUSSION

Mass Balance

The actual equipment used in this demonstration was provided by vendors for the purposes of this demonstration. This limited the process train and the ability to match the throughput capacities of the equipment. Under ideal circumstances and unlimited resources, the vendors would be included in the planning process and it is likely that processing capacity and availability could be increased. Availability averaged 53 % , assuming 24 possible hours for the first week of the field test, and reached a peak of 89 %. During hours of operating 292 tons of mined material were processed. The average processing rate during the evaluation was 13.3 tons per hour (TPH), with a minimum of 10.9 TPH and a maximum of 18.1 TPH obtained.[4] Operation was stopped during the periodic rain showers, common for Florida, and one instance of equipment failure, which was quickly repaired.

The mass balance data were collected during 24 hours of evaluation. A summary of the mass balance appears in Table 1, as weight percentages of each stream as a fraction of the total amount of material processed (292 tons). The criteria for closure of the mass balance was that the sum of the output streams had to equal or exceed 90% of the input stream over the entire length of the evaluation. The average output/input was 90.2 % and the criteria was met, indicating closure of the mass balance.[5] The product streams can be accurately expressed as a fraction of the total amount of material processed.

Waste Characterization

Twenty nine samples of the four product streams (S1, S2, S3, S4/S5) were collected and characterized by the project team (Some streams were sampled and characterized more frequently, due to the amount of product being produced). Of the 29 samples collected and sorted, the average sample weight was approximately 54 lb.[6] After each sample was separated into the 14 categories, each of the 14 subsamples was weighed, so that the composition of each product stream could be computed. Table 2 lists the composition of each of the four product streams, according to these fourteen categories. As shown in this Table, each product stream was not 100% pure, and contained material other than the material targeted for separation. The soil product stream (S1) was the purest, containing 94.2 % by weight of soil and inert material. The aluminum/residue stream (S4/S5) was the least pure, with respect to any recoverable component, since it was a mixture of material not isolated by any of the previous unit operations.

Table 3 presents the same information, coupled with the mass balance data. This Table can be used to measure the success of each of the unit operations in recovering the maximum amount of the respective product. Note that the purpose of the trommel, (shown in Figure 1 as producing stream S1) was to recover all soil material. Table 3 shows that the trommel recovered 94.7 % of the total amount of soil excavated with the remaining 5.3 % appearing in other product streams, S2-S9. The plastic was not as easily recovered by the air knife, with only 42.1 % of the total amount found in this stream (S2). This is a reasonable value, since the majority of the plastic was film, and it was easily entrained and adhered to other materials, being removed before entering the air knife, the last unit operation in the process line.

Soil Fraction Analysis

The soil fraction underwent chemical analysis for 16 metals. None of the metals tested that would be regulated under RCRA would exceed regulatory limits. Table 4 shows the results of several of the analyses and the Florida State Heavy Metal Criteria for Compost, Concentration Code 1. Concentration Code 1 is the most stringent regulatory limit for metals of the four Heavy Metal Criteria Codes for compost. The soil fraction does not exceed any of these regulatory limits. For unrestricted use in Florida (Florida Compost Classification Type A), the material must also contain less than or equal to 2% foreign matter.[7] The soil fraction contained synthetic fibers in the range of 1% to 2% and fibrous glass in the range of 2% to 5%. There was also the visible presence of broken glass. Even though the soil fraction meets the most stringent Heavy Metal Criteria for compost, it would only be Classified as a Type C compost or lower. The allowable use would be restricted, but still would be suitable for some institutional operations and at a landfill, as cover soil.

The soil fraction underwent testing at the Federal Seed Laboratory in Beltsville, Maryland. The soil fraction did not exhibit any phytotoxicity and in the eight samples tested, the germination percentage was comparable to the control of standard potting soil.

In addition to these analyses, the soil fraction underwent analyses for 34 additional parameters. Among those were: bacteriological agents, moisture content, pH, ammonia, TKN and nitrate nitrogen, phosphorus, potassium, total and volatile solids, BOD and COD, asbestos fibers and a range of heavy metals. Table 5 shows the results of these additional analyses.

Air Monitoring
Table 6 shows a summary of the results of the air quality survey. Measurements were taken during the week of the evaluation (over the course of five working days). The values are means of the upstream and downstream measurements at the trommel and the grizzly screen. Five upstream and five downstream locations were sampled at the trommel and four upstream and downstream measurements were taken at the grizzly screen. The permissible exposure limits (expressed as a time weighted average (TWA)) for air quality are established by three agencies: Occupational, Safety and Health Administration (OSHA), National Institute of Occupational Safety and Health (NIOSH), and the American Conference of Governmental Hygienists (ACGIH). These values are included in Table 6 only as potential target levels in evaluating the actual sample data results. The most stringent level has been listed. There were numerous analyses done, but if no detectable level of the contaminant was found, the contaminant is not listed in Table 6. The results presented in Table 6 are mean values of all upstream or downstream locations at that particular unit operation. If a < sign is listed in front of a value, this indicates that at least one sample had a value below the detection limit of the analytical equipment.

Material Marketability
One of the objectives of this evaluation was to determine if other materials were suitable for recycling. One to three pound quantities of mined recyclables were sent to several possible buyers from the representative markets. The general reaction to the ferrous, aluminum, and plastic samples was the same for each evaluator: the mined materials would require extensive cleaning and pre-prossing before they could be competitive with their source-separated counterparts. Without such preprocessing, the materials would only be suitable for lower-quality markets than those for source-separated materials where such markets exist.[*] Further processing and cleaning would also further increase the costs of reclaiming this material -- a prime consideration when evaluating the feasibility of recycling as a reclamation objective.

CONCLUSIONS

This results of this evaluation show that landfill mining is technically and environmentally feasible for the recovery of the soil fraction of landfilled material. Collier County has also demonstrated that the soil fraction represents a significant portion of the reclaimed material and can be used on the active part of the landfill in replace of purchasing cover soil. The development of an integrated process line, with optimal equipment may show greater efficiencies in material recovery and product stream purity.

From the air monitoring results, dust and metals were all observed to be present in very minor concentration well below the listed TWA permissible exposure levels. Fibers were minimal with only one gypsum fiber detected in any of the air samples taken (no asbestos was found). As expected in dealing with landfills, the airborne microbial agents measured were prevalent throughout the sampling program. Operators who may be more susceptible might wear disposable dust masks which would minimize exposure (even minor) to microbiological contaminants and metals."

While a risk assessment was not performed, the operation did not appear to pose any hazards that would not normally be present at solid waste landfilling or strip mining operations. This judgement is based on the analyses of air emissions (both chemical compounds and microorganisms) from the operations, analyses of the chemical constituents of the process streams and observation of the operations.[10] This landfill received only residential waste, and this limited the potential for exposure to hazardous materials.

When a municipality or landfill owner is examining the feasibility of landfill reclamation, particular attention must be paid to project objectives. As discussed previously, landfill reclamation can meet a number of fairly divergent objectives, and the advantages of meeting these objectives should be factored into any feasibility study. There is an economic and environmental value associated with avoided closure costs, recovery of landfill space, and energy recovery of landfilled waste. Based on the results of this MITE evaluation, recovery of soil is a feasible goal, and there is only minimal potential for the recycling of reclaimed ferrous, plastic and aluminum.

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Single copies of the final project report "Evaluation of the Collier County, Florida Landfill Mining Demonstration" (EPA/600/R93/163), on which this paper was based, can be obtained from the Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, Ohio 45268. (513) 569-7562.

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Table 1 Mass Balance Summary

Stream No	Material	% by Weight
S1	Soil Fraction (Trommel Unders)	59.39
S2	Plastics	2.42
S3	Ferrous	1.73
S4/S5	Aluminum/Residue	7.69
S6	Additional Ferrous (a)	0.08
S7	Non-Processible	17.94
S8	Finger Screenings	3.31
S9	Heavies	7.43
	TOTAL	100

Table 2. Product Stream Purity, as Indicated by Stream Characterization

Component	Soil (S1) (59.39%)[a]	Ferrous (S3) (1.73%)	Plastic (S2) (2.42%)	Aluminum /Residue (S4/S5) (7.69%)
Paper & Paperboard	0.6	1.2	14.3	15.2
Plastics	0.3	9.0	74.5	24.3
Yard Waste	1.1	0.2	1.5	9.7
Ferrous Metals	0.0	81.5	0.1	0.4
Rubber/Leather	0.0	0.0	0.0	4.9
Textiles	0.0	1.2	4.4	8.3
Wood	0.0	2.0	0.2	15.2
Food Waste	0.0	0.0	0.0	0.1
Aluminum	0.0	0.5	0.7	5.5[b]
Glass	1.9	0.2	0.1	3.3
Inerts (Soil)	94.2	1.6	0.9	8.0
Non-Ferrous Metals	0.0	0.1	0.0	0.7
Unidentifiable	2.0	2.3	3.4	4.3
TOTAL	100.0	100.0	100.0	100.0

[a] These numbers represent the average weight percent of each stream as a fraction of the total amount of mined material.
[b] Separation of aluminum was not possible with the existing equipment. This represents the majority of the aluminum.

Table 3. Distribution of Target Material among the Product Streams.

Target Material	Soil (S1)	Plastics (S2)	Ferrous (S3)	Additional Ferrous[a] (S6)	Aluminum/ Residue[b] (S4/S5)	Finger Screen Unders (S8)	Air Knife Heavies (S9)	TOTAL
Plastic	4.0%	42.1%	3.7%	0.2%	43.7%	2.6%	3.7%	100%
Ferrous	0.0%	0.0%	74.2%	3.2%	1.6%	0.5%	20.5%	100%
Aluminum	0.0%	4.3%	2.2%	0.0%	91.3%	0.0%	2.2%	100%
Inert	94.7%	0.0%	0.1%	0.0%	1.0%	0.5%	3.7%	100%

[a] The "Additional Ferrous" stream was produced by an additional ferrous magnet on the Aluminum/Residue (S4/S5) conveyor

[b] This stream contained the majority of the aluminum, since it could not be isolated by the eddy current separator.

Table 4. Comparison of Heavy Metal Limitations with Recovered Soil.

Metals (mg/kg dry wt)	Florida[a]	Recovered Soil Fraction (S1)[b]
Cadmium	< 15	1.7
Lead	< 500	56.0
Mercury	N/A	0.2
Zinc	< 900	197.5
Chromium	N/A	13.8
Nickel	< 50	3.9
Copper	< 450	32.0

[a] Florida's Heavy Metal Criteria for Compost; Code 1. Source: FAC Chapter 17-709.550(1)(e).
[b] Average of 4 samples collected daily for each of three consecutive days.

Table 5. Trace/Toxic Chemical Composition of the Recovered Soil [a]

Moisture	25.95 %
pH	7.22 %
Ammonia Nitrogen	128.0 mg/kg
--Total Organic Nitrogen	1,325 mg/kg
--TKN	1,453 mg/kg
Nitrate-N	46.8 mg/kg
Phosphorus, Total	421 mg/kg
Phosphate, Ortho (as P)	0.76 < x < 0.80 mg/kg
Potassium, Total	205 mg/kg
Total Solids	74.1 %
Total Volatile	6.63 %
BOD_5	1,253 mg/kg
COD	74,500 mg/kg

[a] All values are numerical averages. All mg/kg are dry weight units.
Greater or less than ranges (e.g., a < x < b) are based on detection limits reported by the laboratory.
Overall ranges (e.g., a-b are the lowest and highest values, respectively, reported by the laboratory.

Table 6 Air Quality Monitoring Results [a]

Parameter	Units	Most Stringent [b] Standard		Downstream	Upstream
<u>Grizzly</u>					
Nuisance Dust					
Total	mg/m^3	10	A	<0.19	<0.19
Respirable	mg/m^3	5	O/A	<0.21	<0.17
Microbial Agents					
Bacteria	CFU/m^3	1,000	O	44	0
Fungi	CFU/m^3	1,000	O	4917	5687
Metals (a)					
Calcium	ug/m^3	2,000	A	<10.2	<10.2
Lead	ug/m^3	50	O	<0.96	<0.71
Fibers					
Other	fibers/cc	N/A		<0.0095	<0.0101
<u>Trommel</u>					
Sample Number					
Nuisance Dust					
Total	mg/m^3	10	A	<0.25	<0.19
Respirable	mg/m^3	5	A/O	<0.27	<0.19
Microbial Agents					
Bacteria	CFU/m^3	1,000	O	881	0
Fungi	CFU/m^3	1,000	O	5577	5687
Metals					
Calcium	ug/m^3	2,000	A	20	<10.2
Copper	ug/m^3	1,000	O/A	<10	<7.1
Lead	ug/m^3	50	O	<1.2	<0.7

[a] Values that are presented are averages of all locations sampled

[b] Standards are for comparison only, and are not regulatory limits. Standards listed are as follows:
O = OSHA, N = NIOSH, A = ACGIH

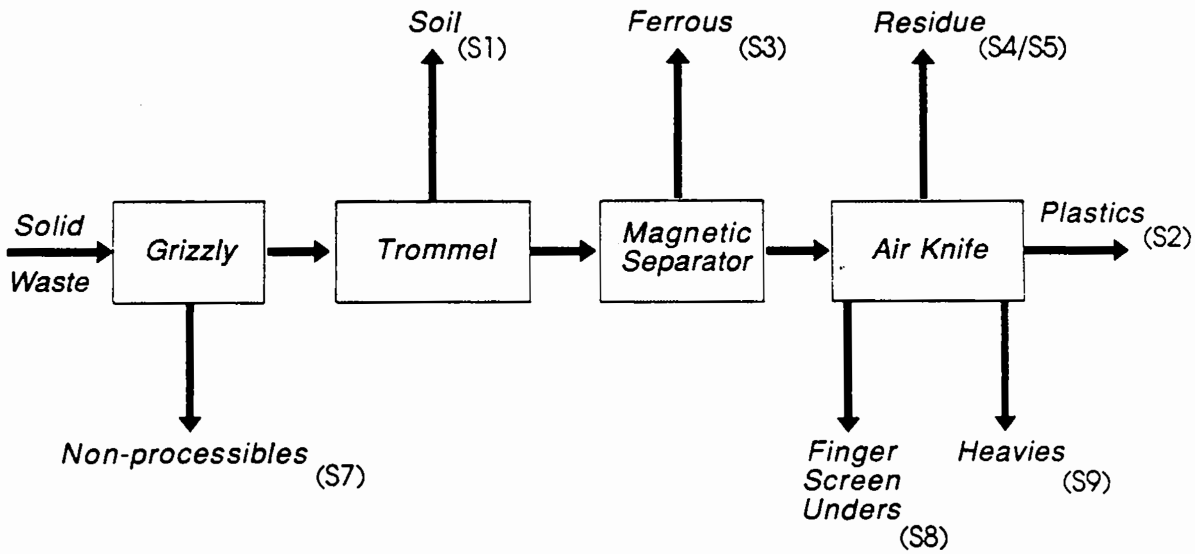

Figure 1. Process Flow Diagram for the Landfill Reclamation Demonstration.

TECHNICAL REPORT DATA

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16. ABSTRACT

In October 1993, the US Environmental Protection Agency (EPA) issued the report "Evaluation of the Collier County Solid Waste Department and was evaluated as a part of EPA's Municipal Solid Waste Innovative Technology Evaluation (MITE) Program. The purpose of the MITE program is to objectively evaluate innovative solid waste management technologies and transfer resulting information to municipalities and solid waste managers.

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17. KEY WORDS AND DOCUMENT ANALYSIS

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