United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-83-050 Aug. 1983

EPA

Project Summary

Adaptation of the Simplex Gasification Process to the Co-Conversion of Municipal Solid Waste and Sewage Sludge

J. C. Arbo, D. P. Glaser, M. A. Lipowicz, R. B. Schulz, and J. L. Spencer

The feasibility of making sturdy briquettes with dewatered sewage sludge (DSS), municipal solid waste (MSW), and coal for use in gasifiers was demonstrated. This investigation consisted of preparing briquettes with laboratory equipment and then testing them for strength, stability, and caking propensity. Parameters investigated included: coal-to-waste ratio, moisture content, type of binder, and MSW to DSS ratio.

Optimum conditions were identified that included 1:1 to 2:1 coal-to-waste ratio, 12 to 19 percent moisture content in the finished briquettes, and MSW-to-DSS ratio of 8 for the 20 percent solids sludge. It was recommended that the findings be confirmed with the use of commercial briquette production equipment and in pilot scale gasifiers.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Simplex process developed at Columbia University, New York, converts cellulosic waste to clean, medium-Btu fuel gas through cogasification with coal. The principal innovation of Simplex is the briquetting step, in which coal and cellulosic waste such as MSW or forest pulp are pressed into briquettes. When these briquettes are gasified in a moving-bed gasifier, the waste fibers act as wicks, absorbing the tars that cause swelling and agglomeration of caking coal. Because the briquettes retain their size and shape throughout the gasifier, the flow of briquettes through the gasifer zones is smooth and stable.

Simplex was originally developed for gasification of eastern bituminous caking coal and refuse-derived fuel (RDF). Municipalities, however, generate both MSW and sewage sludge, and it is natural to dispose of MSW and sludge together. Codisposal has been applied to several waste-disposal technologies such as incineration, pyrolysis, and composting. Codisposal through the Simplex method, which is called Simplex-S, has several advantages over these conventional codisposal processes. The destruction of heavy organic wastes in MSW and safe disposal of heavy metals contained in sludge are accomplished at a relatively low cost. The nongasifiable components of Simplex-S briquettes end up embedded in a glassy, nonleachable frit. Thus they can be disposed of safely or put to use as road-building aggregates.

The development of Simplex and Simplex-S processes requires several steps:

- Phase I: Laboratory Research with Emphasis on Briquette Development. Briquette formulations that produce sturdy, noncaking briquettes must be developed.
- Phase II-A: Process Optimization Studies with Emphasis on Commercial Briquette Production. The formulations developed in Phase I must

be tested and adapted to the requirements of commercial briquetting equipment.

- Phase II-B: Bench Scale Gasification Tests. The performance of the briquettes produced in II-A will be evaluated in the 4-ton-per-day prototype Simplex unit in the Fossil Energy Laboratory of Columbia University.
- Phase III: Pilot Plant Gasification Tests. Commercially produced briquettes should be evaluated in pilot plant runs in which material balances, throughput rates, and process efficiencies can be determined.

Because the Simplex development is now in its final phase (Phase III) after successful completion of previous phases, development of Simplex-S benefits greatly from the experience gained in the Simplex development.

The work reported here represents the first phase of Simplex-S development: the formulation, fabrication, and testing of briquettes (composed of coal, RDF, and DSS) that satisfy the following conditions:

- Briquettes must be of adequate strength to maintain their structural integrity as they descend through the several zones of the gasifier.
- The cellulosic waste must prevent the fusing and agglomeration that eastern coals normally exhibit.
- The briquettes must be stable in storage.
- During briquetting no moisture is to be expressed which will require additional treatment and disposal.

Materials and Procedure

The dewatered sewage sludge was obtained from the 25th Ward Water Pollution Control Plant in New York City and was approximately 20 percent solids. For experiments where higher solids content was desired, the sludge samples were concentrated to 40 percent in a vacuum oven at 60°C.

Eastern bituminous coal was screened to remove preexisting fines and then crushed and screened to 14 mesh.

RDF fuel consisting primarily of newsprint and plastic was obtained from the Baltimore County Resource Recovery Facility, Cockeysville, Maryland, which is operated by Teledyne National.

In preparing briquettes, all materials (except the RDF) including a binder such as lime are first mixed together by hand and RDF is then added and mixed in. This procedure prevents the RDF from wicking up moisture prematurely, which results in poor mixing and lower briquette quality. The briquettes weigh about 40 g each and are pillow shaped with dimensions of 6 cm by 6 cm by 3 cm.

To manufacture the briquettes, a predetermined amount of material is weighed out and charged into the die. The plunger is then inserted and pressed down by hand. The die assembly is placed in a manually-pumped hydraulic press. The press is pumped rapidly to the desired pressure (35-42 MPa) which is maintained for about 10 seconds. The pressure is then released, and the briquette is ejected. The ejected briquette is weighed to determine moisture loss, sealed in a plastic bag, and labeled for testing.

The strength of the briquettes was determined by the Radial Compression Test, which measures the resistance of a briquette to compressive forces applied to its edges. This test, which provides a measure of the briquettes' resistance to crushing or attrition in the gasifier, was performed on briquettes in two states representative of various stages in processing:

- "green" briquettes that have been freshly pressed with no other treatment, and
- pyrolyzed briquettes that have been exposed to a nitrogen atmosphere at 870°C for at least 20 minutes.

Based on previous experience with Simplex briquettes, the minimum radial compression load of 9 kg was considered satisfactory.

The tendency of the briquettes to agglomerate and fuse was evaluated by pyrolyzing a sample of briquettes in an inert atmosphere. Stacks of three briquettes of the same composition are placed in an electric furnace. After the furnace is sealed and is purged with nitrogen, the furnace is turned on. Heating is maintained until temperatures have exceeded 870°C for at least 20 minutes. The furnace is then turned off and is allowed to cool overnight while the nitrogen purge is maintained. After cooling, the pyrolyzed briquettes are removed and caking propensity is determined by assigning an Adhesion Index to the briquette samples according to the type of adhesion they exhibit and the amount of finger pressure required to separate them. The Adhesion Index is a scale from 1 to 8, where 1 represents no adhesion after pyrolysis and 8 represents complete fusion. Maximum acceptable Adhesion Index is 5, which represents a line contact between briquettes that requires moderate finger pressure to separate.

Experimental Results

The main purpose of the experiments was to determine the maximum amount of sludge that could be incorporated into briquettes to satisfy certain conditions deemed desirable based on Simplex experience. For this purpose the following variables were investigated: coal-to-waste (RDF + DSS) ratio (1:1 and 2:1), RDF-to-DSS weight ratio (1:1 to 15:1), and percentage of sewage sludge solids (20% to 40%). Ratios are reported on a dry weight basis.

The major parameters measured were:

1. moisture level of briquettes because it is a good indication of the stability and strength of briquettes and it also serves as a unifying parameter for the major variables investigated;
2. radial fracture load because it is the principal criterion for evaluating strength;
3. percent moisture expressed during briquetting because moisture loss would create an undesirable effluent stream; and
4. Adhesion Index, the main measure of caking propensity.

Typical experimental results are presented in Tables 1-3.

Discussion

Based on the requirement that the briquettes should withstand at least a 9 kg radial fracture load, the test results indicate that a minimum RDF:DSS ratio for briquettes with 20 percent solids DSS and a 1:1 coal-to-waste ratio is about 8:1, whereas the mimimum ratio is about 2.5:1 for briquettes with 40 percent solids DSS. When the coal-to-waste ratio is increased, although RDF-to-DSS ratio decreases, the percentage of sludge incorporated in the briquettes does not seem to change significantly.

If we establish the requirement that little or no water is expressed during briquetting, similar conclusions are reached -- the maximum percentage of DSS in briquettes is about 5 percent for sludge with 20 percent solids and 8:1 RDF-to-DSS ratio. Because most of the moisture in the briquettes was introduced with the DSS, one can conclude that more sludge solids can be incorporated in the briquettes when the solids are introduced as high-solids DSS. This is demonstrated in Table 2 which shows that for 1:1 coal to waste ratio briquettes of acceptable quality are obtained with about 14 percent sludge, when a 2.5:1 RDF-to-DSS ratio and 40 percent solids sludge is used.

The most significant pyrolysis test results with 20 percent solid sludge, presented in Table 3 were:

a) Pyrolyzed briquettes with a 1:1 coal to waste ratio were weaker in radial

Table 1. *Moisture Level and Radial Fracture Load of Briquettes*

		20% Solids Sludge (low solids DSS)		40% Solids Sludge (high solids DSS)	
Coal:Waste	*RDF:DSS*	*Moisture Level (%)*	*Radial Fracture Load (kgf)*	*Moisture Level (%)*	*Radial Fracture Load (kgf)*
1:1	15:1	15	13	13	17
"	10:1	19	12	13	15
"	5:1	27	8	18	14
"	3:1	35	8	23	14
"	2:1	41	6	27	8
"	1:1	N.A	N.A	34	6
2:1	15:1	12	17	14	16
"	10:1	15	11	13	15
"	5:1	21	12	14	15
"	3:1	28	9	18	15
"	2:1	33	6	21	17
"	1:1	N.A	N.A	25	10

Table 2. *Moisture Loss During Compaction*

		20% Solids Sludge (low-solids DSS)		40% Solids Sludge (high-solids DSS)	
Coal:Waste	*RDF:DSS*	*Moisture Level (%)*	*Moisture Expressed (%)**	*Moisture Level (%)*	*Moisture Expressed (%)**
1:1	15:1	15	0	13	0
"	10:1	19	0	13	0
"	5:1	27	6	18	1
"	3:1	35	10	23	1
"	2:1	41	17	27	1
"	1:1	N.A	N.A	34	2
2:1	15:1	12	0	14	0
"	10:1	15	0	13	0
"	5:1	21	4	14	1
"	3:1	28	7	18	1
"	2:1	33	9	21	1
"	1:1	N.A	N.A	25	2

**Accuracy only about ± 2 percent.*

Table 3. *Pyrolysis Results for Simplex-S Briquettes*

Sludge Type	*Coal:Waste (20% solids)*	*RDF:DSS*	*Radial Fracture Load (kgf)*	*Adhesion Index (8 = highest)*
Raw	1:1	15:1	8	2
	"	10:1	9	2.5
	"	5:1	4	2.5
	2:1	15:1	21	5
	"	10:1	13	5
	"	5:1	6	4.5
Digested	1:1	15:1	9	2.5
	"	10:1	11	2
	"	5:1	6	3
	2:1	15:1	35	3
	"	10:1	17	3.5
	"	5:1	17	3

fracture load test than briquettes with 2:1 coal-to-waste ratio.

b) Adhesion was higher for briquettes with 2:1 coal-to-waste ratio.

Thus, the level of coal had the most effect. High coal levels gave higher strength but higher adhesion, indicating that levels too high or low will give inadequate performance. However, none of the briquettes surpassed the maximum acceptable Adhesion Index of 5 and more than half of the formulas had strengths over 9 kg.

Tests with high solids content sludge also gave similar results.

In addition to the major findings presented above, several other aspects of briquetting were also investigated, with the full details presented in the main report. In summary, it was found that unslaked lime was superior to slaked lime as an additive. Briquette strength generally increased as the lime level increased from 0 to 5 percent. More importantly, lime levels above 3 percent completely prevented fungal growth in humid environments for at least 4 weeks.

The loss in stength with storage was also investigated. In general, briquettes with a 5:1 RDF-to-DSS ratio showed less than 5 percent loss during 8 weeks of storage whereas briquettes with a 15:1 RDF-to-DSS ratio lost 20 to 40 percent of their initial strength. This was attributed to the high content of spongy paper in the briquettes.

The briquettes were also subjected to alternating freezing and thawing conditions. Although there was some decline in strength, it was not as severe as one might expect from a material with a relatively high water content such as these briquettes.

Conclusions

The experimental work showed that briquettes made with dewatered sewage sludge can be formulated and fabricated to met the feed requirements of a slagging gasifier. The criteria for satisfactory briquettes were:

- 9 kg mimimum radial compression strength
- little or no adhesion during pyrolysis
- no expression of moisture during briquetting
- stability in storage

These laboratory-scale results can be extended to the pilot scale with high confidence because past scale-up experience in the Simplex project showed that commercial briquetting equipment performed better than laboratory equipment.

Several formulation variables had strong effects on the properties of briquettes; sludge moisture content, level of sludge solids in briquettes, and level of lime were the most important factors determining the quality of freshly pressed briquettes. The level of coal (or coal-to-waste ratio) had less effect on the properties of freshly pressed briquettes but had strong effects on the strength and adhesion levels of pyrolyzed briquettes.

Sludge Moisture Content

The amount of DSS that can be successfully incorporated in briquettes is limited by the amount of water added with the sludge. The experiments showed that the practical limit for briquette moisture content is 18 to 20 percent by weight. Thus, the maximum level of DSS that can be included in 2:1 coal-to-waste briquettes is determined by the percent solids in the DSS: approximately 3.4 percent sludge solids for DSS with 20 percent sludge solids; approximately 8.8 percent sludge solids for DSS with 40 percent sludge solids.

If the moisture level is above the 20 percent limit, then briquettes may fail to meet one or more criteria: moisture may be expressed during the high-pressure briquetting step or briquettes may not be strong enough to withstand handling. Because the 20 percent limit is based on testing with laboratory equipment, briquettes made with commercial equipment may have higher moisture tolerance: commercial equipment presses briquettes faster, which may prevent moisture loss and commercially-pressed briquettes are generally stronger than laboratory-pressed briquettes. A higher tolerance for moisture would allow larger amounts of DSS to be incorporated into briquettes.

Binders

Unslaked lime was shown to be an essential briquette component and the most effective of the binders tested. At 3 percent by weight and above, unslaked lime enhanced briquette strength and prevented fungal growth. Below 3 percent, the briquettes may be weak and susceptible to fungal growth. The ideal level appears to be 5 percent because levels above 5 percent do not improve strength.

Coal-to-Waste Ratio

The ratio of coal to DSS and RDF had little effect on freshly prepared briquette strength or storage characteristics--the only effects are attributed to the effects of moisture. But the coal-to-waste ratio did affect the pyrolyzed strength and the caking tendency of briquettes: pyrolyzed briquettes with a 1:1 coal-to-waste ratio were marginal in strength but showed little caking tendency; pyrolyzed briquettes with a 2:1 coal-to-waste ratio had good strength but marginally acceptable caking tendency. Because strength is more important, the 2:1 ratio is the better of the two ratios tested; however, an intermediate ratio--e.g., 3:2--is probably better than either.

Recommendations for Future Work

The tests and evaluations performed in this program demonstrated the technical feasibility of incorporating DSS in Simplex briquettes. Laboratory scale tests also indicate that these briquettes have suitable properties as a feed for a moving-burden slagging gasifier.

However, before the Simplex-S process is applied in full-scale gasification, testing in commercial-scale mixing and briquetting equipment would be desirable. Because the commercial press produces thicker briquettes at a faster rate with more pressure, some of the formulas that were marginal in this experimental program may prove satisfactory in a commercial briquetting operation. Among the results that should be examined are:

- Moisture expression: determine maximum briquette moisture levels, examine methods of handling expressed moisture from high-moisture briquettes, and test effects of production rate and compaction pressure.
- High moisture RDF: fabricate briquettes using RDF with moisture representative of RDF freshly prepared from urban waste.
- Briquette strength: determine maximum briquette moisture levels, and test the effects of mixing, compaction pressure, and precompaction on briquette strength.

In addition to verifying the results of this experimental program, future work should address the mixing and feeding operations that are necessary in commercial-scale briquetting.

The full report was submitted in fulfillment of Cooperative Agreement No. CR 806998010 by the New York State Energy Research and Development Authority under the partial sponsorship of the U.S. Environmental Protection Agency.

J. C. Arbo, D. P. Glaser, M. A. Lipowicz, R. B. Schulz, and J. L. Spencer are with Dynocology Incorporated, Harrison, NY 10528.
***Atal E. Eralp** is the EPA Project Officer (see below).*
The complete report, entitled "Adaptation of the Simplex Gasification Process to the Co-Conversion of Municipal Solid Waste and Sewage Sludge," (Order No. PB 82-112 418; Cost: $10.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆U S GOVERNMENT PRINTING OFFICE· 1983—659-017/7163

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300

RETURN POSTAGE GUARANTEED