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TECHNICAL REPORT
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Project Title: **UTILIZATION OF ILLINOIS COAL GASIFICATION
SLAGS FOR PRODUCTION OF ULTRA-LIGHTWEIGHT
AGGREGATES** DE-FC22-92PC92521

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ABSTRACT

This research is aimed at testing and developing the expansion potential of gasification solid residues (slag) to manufacture ultra-lightweight aggregates (ULWA). Conventional ULWAs are manufactured by pyroprocessing of perlite or vermiculite ores and have unit weights in the range of 5-15 lb/ft³. These materials are sold for approximately \$200/ton (or \$1.00/ft³) and have numerous applications including loose fill insulation, insulating concrete, precast products, filtration media, and agricultural applications. In a previous project, Praxis Engineers demonstrated that lightweight aggregates (LWA) with unit weights of 25-55 lb/ft³ can be produced from Illinois coal slags and used as substitutes for conventional LWAs. In this program, tests are being undertaken in a pilot-scale vertical shaft furnace to identify operating conditions for the expansion of Illinois slags such that the product can be substituted for ULWA. Upon completion of testing, a large batch of expanded slag will be produced for evaluation in various applications, both in this phase and in subsequent Phase II testing.

Bench-scale expansion tests conducted with two slags during the previous reporting period resulted in product unit weights of 12 and 18.5 lb/ft³, respectively. The potential for slag clinkering was identified, and two approaches to resolve this problem were successfully tested: blending of perlite ore with the feed slag and acid treatment of the feed slag. During the initial pilot plant runs using two Illinois slags, expanded products with unit weights of 12.5-26.5 and 20-52 lb/ft³, respectively, were produced.

Tests conducted using a long-flame gas burner successfully reduced the fusion problem such that neither blending with perlite nor acid treatment were required. These tests to study the impact of gas flow rates on Illinois No. 6 slag resulted in product unit weights of 18.4-52.0 lb/ft³, indicating that this method can be used to produce expanded products with a wide range of unit weights. Efforts are under way to generate products with lower unit weights.

"U.S. DOE Patent Clearance is NOT required prior to the publication of this document."

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EXECUTIVE SUMMARY

Regulatory trends with respect to solid waste disposal, landfill costs, and public concern make utilization of solid wastes a high-priority issue. Therefore, the manufacture of value-added products from Illinois coal gasification slags is a means of promoting the utilization of Illinois coals in an environmentally acceptable manner. Utilization of these slags may also have a positive impact on the overall gasification process economics, especially when the avoided costs of disposal are considered.

The major objective of this project is to produce ultra-lightweight aggregates (ULWAs) from solid residues or slags generated from the gasification of Illinois coals. Conventional ULWAs have unit weights between 3 and 15 lb/ft³ and are produced commercially by subjecting naturally occurring expansible perlite and vermiculite ores to thermal processing in a vertical shaft furnace (VSF). These materials wholesale for approximately \$200/ton (or \$1.00/ft³) for use in the following industrial applications:

- ▶ Loose fill insulation
- ▶ Insulating concrete
- ▶ Precast products
- ▶ Agricultural applications
- ▶ Filtration media

In Phase I of the project, a thermal expansion concept developed by Praxis in a previous project for the expansion of Utah and Texas coal gasification slags is being applied to Illinois coal slags to produce ULWAs. The research is proposed to be conducted in two phases, each of one year's duration. The focus in this phase is on the development of techniques for producing ULWA from Illinois coal slags using batch laboratory and continuous pilot-scale equipment and to produce a large batch of product using commercial-scale equipment. The VSF system process variables to be studied during this R&D work include:

- ▶ Expansion temperature vs. unit weight
- ▶ Furnace draft (combustion air flow rate)
- ▶ Benefits of slag preheating
- ▶ Impact of slag particle size on expansion
- ▶ Impact of flame profile (burner design)

Using operating conditions suitable for Illinois slag expansion determined during the pilot-scale tests, a batch of expanded slag aggregate will be produced in a commercial-sized furnace for physical characterization to assess the furnace performance. Full-scale operating conditions, heat and mass balances, and off-gas analyses will be obtained and compared to those for conventional ULWA production. Detailed

characterization of the expanded slag and demonstration of its use in various applications will be performed during Phase II of the project.

Slag Preparation. During this reporting period, a large batch of Illinois slag (15 drums) was size-classified and processed for char removal following procedures identified earlier. Removal of char prior to slag expansion allows better control during expansion, and the recovered char may be used as filler or recycled to the gasifier as feed.

Pilot Plant Setup and Testing. A 4-inch diameter x 5-ft tall vertical shaft furnace which had been designed and fabricated for an earlier project was commissioned and tested at the outset of the project. Problems experienced with slag clinkering were initially addressed by pretreating the slag feed with acid or blending it with perlite. It was also determined that modifying the burner design may reduce the problem, and the furnace was modified accordingly. The new burner configuration provides more even heat distribution with high-temperature air rather than flame contacting the slag particles. The furnace preheater can also be used as an indirect heat horizontal furnace if desired. Tests in the modified furnace resulted in excellent performance, reducing fusion and eliminating the need for acid treatment of the feed or blending with perlite.

Several gas flow rates were used to generate a wide range of temperatures in the expansion zone and produce products with various unit weights. These tests were run at temperatures between 1400 and 1675°F using three slag feed size fractions (8 x 14, 14 x 20, and 20 x 30 mesh), and the product unit weights ranged between 18.4 and 52 lb/ft³. Further testing will continue with the objective of lowering the product unit weight further.

Tests were also conducted using the preheater as an indirectly heated horizontal furnace. These tests generated products with unit weights of 18.6 lb/ft³ without any fusion problems.

Testing in a commercial-scale furnace, scheduled for the end of Phase I, will provide valuable operating data and allow assessment of the reproducibility of product quality under industrial operating conditions. While unit weight is a good measure of expanded product quality, other characterization tests will also be carried out on expanded slag products to evaluate their performance for commercial applications.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

OBJECTIVES

A primary objective of this program is to test and demonstrate the feasibility of producing ultra-lightweight aggregates (ULWA) from slags generated during the gasification of Illinois coals. An additional objective is to evaluate these products as substitutes for conventional ULWAs in a number of applications including loose fill insulation, insulating concrete, and precast lightweight products. These objectives will be met by the following activities:

- ▶ Test and develop the potential for producing ULWA from Illinois coal slags using R&D work done by Praxis Engineers in previous projects
- ▶ Characterize the expanded Illinois slags
- ▶ Evaluate expanded Illinois coal slag as a substitute for conventional ULWA using ASTM and Perlite Institute standards and procedures
- ▶ Experimentally determine the suitability of products which can utilize expanded slag as a substitute for expanded perlite, such as precast lightweight products, insulating concrete, and loose fill insulation
- ▶ Conduct an economic evaluation of expanded slag production using a vertical shaft furnace (VSF), including estimates of equipment size, production rates, and material and heat balances.

These objectives will be achieved in two phases, each lasting one year. The Phase I work is aimed at bench-, pilot-, and commercial-scale testing to optimize VSF expansion of Illinois coal slags, and characterization of the expanded products in accordance with ASTM and industry standards. The projected Phase II work, to be undertaken in the second year, will emphasize comprehensive characterization and utilization of expanded Illinois slags for selected applications, culminating in applications demonstration tests. The performance of the expanded slags in these applications will be monitored and economic analyses evaluating the marketability of these products will be conducted. It is planned to perform this work at the facilities of a major ULWA user. The project will result in a technology transfer package that will permit implementation of VSF technology for slag expansion at coal gasification demonstration projects using Illinois coals, such as the Wabash River Coal Gasification Repowering Project or the Franklin, Indiana, coal gasification project.

INTRODUCTION AND BACKGROUND

Illinois coals are excellent feedstocks for coal gasification due to their high volatiles content, high Btu content, and low cost. Their high sulfur content, which reduces their desirability for pulverized coal-fired boilers, is actually an advantage for gasification since the sulfur is recovered in its elemental form as a saleable by-product. The advantages of Illinois coals for gasification can be further enhanced by processing the gasification solid residue (slag) for commercial use rather than disposing of it as a solid waste.

During previous work funded by EPRI, Praxis established that slags have inherent properties of expansion upon thermal treatment which, depending on the process conditions, reduces their unit weight to between 15 and 60 lb/ft³. This characteristic is similar to that of naturally occurring expansible shales, clays, and perlite which are used to manufacture lightweight aggregates (LWA). The production of LWAs from slag at a 50 lb/hour pilot scale was demonstrated using a rotary kiln, a method commonly used for the production of lightweight aggregates from shales and clays. The expanded slags thus produced had unit weights ranging between 25 and 55 lb/ft³. Upon evaluation in accordance with ASTM Standards C-330 and C-331, they were found to be suitable for the production of lightweight structural concrete (ASTM C 330) and lightweight blocks (ASTM C 331). For example, the 28-day compressive strength of concrete test specimens made with expanded slag exceeded the ASTM strength requirement of 2500 psi for structural concrete and the 2000 psi requirement for load-bearing lightweight concrete blocks at the specified concrete unit weight. Also, pilot kiln test results confirmed that products with considerably lower unit weights can be produced from slag and substituted for ultra-lightweight aggregates (ULWA) made from expanded perlites. Conventional ULWAs have unit weights between 5 and 15 lb/ft³ and are produced commercially by subjecting naturally occurring expansible perlite and vermiculite ores to thermal processing in a vertical shaft furnace (VSF). These materials wholesale for approximately \$200/ton (or \$1.00/ft³) for use in the following industrial applications:

- ▶ Loose fill insulation
- ▶ Insulating concrete
- ▶ Precast products
- ▶ Agricultural applications
- ▶ Filtration media

Basic work to develop techniques for producing ULWA from slag has been done with very satisfactory initial results.

In this phase of the project, Praxis will test the expansion potential of Illinois coal slags and produce a large batch of expanded slag to evaluate its potential for use as a substitute for conventional ULWAs.

EXPERIMENTAL PROCEDURES

In order to obtain reproducible results, the experimental procedures used for bench- and pilot-scale tests were standardized. A data sheet was developed to record all relevant test conditions and a standard perlite ore was used periodically to calibrate the furnace.

Pilot testing in the vertical shaft furnace (VSF) was conducted using operating conditions such as induced draft rates and operating temperatures identified during bench-scale tests. The pilot plant, shown in Figure 1, consists of a 4-in. diameter x 5-ft tall VSF with a 1½-inch burner nozzle located at the bottom. The feed is drawn from a bin via a vibratory feeder with a nominal capacity of 10 lb/h for material sized at 0.3-0.5 mm. The pilot plant has the capability of preheating the feed up to 1500°F in a rotary drum preheater prior to its introduction into the furnace. Three feed entry points are located at top, middle, and bottom of the furnace to provide various residence times. The furnace is connected to a 12-inch collection chamber under induced draft conditions. The pressure drop in the collection chamber and the temperature in the furnace are controlled by valve settings.

The furnace is operated for 15 minutes at set conditions to verify operating conditions prior to starting the feed. Each test is run for a minimum of 15 minutes after which the operation is shut down to collect the product and examine the furnace for signs of slag fusion. The product, along with any dropout or clinker in the furnace, is then weighed and compared to the total feed to check for losses. The unit weight of the product is then measured. The following process operating parameters were monitored:

- ▶ Furnace temperature at four locations (three feed ports and in cyclone)
- ▶ Furnace draft
- ▶ Slag preheat temperature and retention time
- ▶ Slag particle size and feed rate
- ▶ Product unit weight

Initial exploratory pilot tests were conducted to identify the test conditions and procedures that will be used as a starting point for commercial VSF expansion of slag.

Figure 1. Pilot Plant Setup

TECHNICAL WORK COMPLETED

The technical work completed during the third quarter of Phase I is described below by task.

Task 1: Procurement and Preparation of Illinois Slag Samples

A large (approximately 2000 lb) slag sample generated from Illinois basin coal using the Texaco gasification process was procured and processed during this quarter. The sample is currently being characterized. A sample of this size should be sufficient to complete the remaining Phase I and projected Phase II experimental work. This approach is cost-effective and ensures the uniformity of samples over the two project phases. This sample is from the same source as one of the small samples currently being used for laboratory- and pilot-scale test work.

Praxis' previous work with slag utilization indicated that preparation of the slag, i.e., size control and removal of the char or magnetic phases, results in a more homogenous feed and is important from the viewpoint of expanded slag product quality control. This preparation work is being done at a commercial laboratory, and the data generated will provide equipment sizing information for slag sample preparation unit operations. While the preparation steps for slag are different from those utilized to prepare perlite, the latter must also be prepared prior to pyroprocessing.

Task 2: Characterization

Basic characterization testing of the slag sample used for bench- and pilot- scale testing was undertaken by a commercial laboratory and consists of the following:

- ▶ Particle size distribution
- ▶ Unit weight
- ▶ Hardgrove grindability index
- ▶ Loss on ignition (char content)

The same analysis is now being done on the prepared large (2000-lb) slag sample.

Task 3: Bench-Scale Testing

No bench-scale testing was conducted during this reporting period.

Task 4: Pilot-Scale Expansion Tests

A pilot vertical shaft furnace (VSF) was set up and commissioned for testing after installing a new burner configuration which provides better heat distribution in the furnace.

Pilot testing was done using three size fractions of an Illinois No. 6 coal slag. Tests were also run using the preheater as an indirectly heated horizontal furnace. The results of these tests are provided in the next section.

RESULTS AND DISCUSSION

Characterization

The compositional analyses of expanded shale/clay, expanded perlite, and expanded slag, were compiled and are presented in Table 1. Samples of acid-treated slag were also analyzed to identify the mechanism that assists in reducing slag fusion.

It was hypothesized that acid treatment induces a reaction with alkalis on the surface of the slag particles that increases the slag fusion temperature, thus reducing fusion of the slag. Samples of untreated feed, acid-treated feed, the expanded product, and the leachate were analyzed, and the results are presented in Table 2. The oxides are similar for the untreated feed, acid-treated feed, and expanded product. The leachate, however, has a lower alkali content and higher sulfite content, indicative of acid-alkali reactions.

Table 1. Chemical Analysis of Expanded Slag vs. Conventional Expanded Shale and Perlite

	Expanded Shale/Clay	Expanded Slag		Expanded Perlite
		Illinois No. 6	Utah Coal	
SiO ₂	55-65	49.1	55.8	73.8
Al ₂ O ₃	15-20	19.7	18.7	13.9
Fe ₂ O ₃	5-10	20.2	10.8	0.9
CaO	1-3	6.4	11.6	0.9
MgO	Trace	0.87	0.9	0.1
Na ₂ O	-	0.45	0.70	4.7
K ₂ O	-	2.26	1.2	4.3
TiO ₂	Trace	0.96	0.9	0.1

Ash fusion temperatures for both untreated and acid-washed feed slags were determined using ASTM procedures in a reducing atmosphere. These results, also presented in Table 2, show that the ash fusion temperatures of the acid-washed slag feed were at least 50°F higher than those for untreated slags. These results agree with the decrease in slag fusion observed for acid-washed feed samples during expansion testing.

Table 2: Analysis of Feed and Acid-Treated Samples of Slag

Element	Dow 14 x 30 Mesh Slag Feed			
	Untreated Feed	20% AW Feed	20% AW Feed Product	20% AW Feed Leachate
SiO ₂	34.69	33.71	33.08	28.61
Al ₂ O ₃	18.55	16.75	16.34	23.31
Fe ₂ O ₃	7.07	5.80	5.48	9.73
TiO ₂	1.50	1.41	1.38	1.49
P ₂ O ₅	1.51	1.40	1.32	1.63
CaO	27.62	27.94	27.90	11.51
MgO	6.28	5.61	5.48	7.49
Na ₂ O	1.82	1.58	1.53	1.84
K ₂ O	0.30	0.29	0.28	0.53
SO ₃	0.32	5.42	7.12	14.06
MnO ₂	0.04	0.03	0.03	0.06
Total	99.7	97.94	99.94	100.26
LOI (800°C)	-0.29	5.41	0.38	87.27
Ash fusion, °F				
- IDT	2110	2160		
- ST	2120	2180		
- HT	2140	2190		
- FT	2160	2200		

AW: Acid-washed

IDT: Initial deformation temperature

ST: Softening temperature

HT: Hemi temperature

FT: Fluid temperature

Bench-Scale Expansion Tests

During the previous reporting period, bench-scale tests were conducted using a muffle furnace to identify methods of eliminating the problem of slag fusion. Two alternative approaches were identified, the first involving blending small quantities of a nonfusible material such as perlite with the slag, and the second involving treatment of the slag with an acid to remove fluxing agents such as alkalis from the particle surfaces. The results of this test work are summarized in Table 3 for reference purposes. While both of

these techniques worked effectively, it was felt that modification of the burner configuration to reduce the fusion problem in the temperature range of slag expansion would be a preferable method of addressing the problem, as discussed below.

Table 3. Results of Bench-Scale Tests Conducted in a Muffle Furnace

slag	Size, mesh	Slag Prep	Firing Temp., °F	Product Unit Weight, lb/ft ³
Illinois No. 5	30 x 70	None	1700	26.7
Illinois No. 5	30 x 70	AW	1700	18.5
Illinois No. 6	14 x 30	PB	1700	12.0
Illinois No. 6	30 x 50	PB	1700	20.0

AW: Slag surface treated with dilute acid.

PB: Slag blended with 20% perlite before expanding.

Pilot-Scale Expansion Tests

Initial pilot tests conducted during the previous reporting period using a 14 x 30-mesh Texas lignite slag feed blended with perlite resulted in no fusion problems in the furnace. These results are shown in Table 4. During these tests, at a temperature of 1520°F, the slag expanded to a unit weight of 21.6 lb/ft³ while the perlite expanded to 15.3 lb/ft³. In the next batch of pilot tests, two Illinois slags surface-treated with acid were utilized. The results of these tests, also given in Table 4, confirm that these slags may be expanded in a vertical shaft furnace. For the Illinois No. 6 slag, products with unit weights of 20-60 lb/ft³ were produced by varying the process conditions. The Illinois No. 5 slag resulted in expanded products with unit weights in the 12.5-26.5 lb/ft³ range.

As an alternative to adjusting the feed, it was determined that certain modifications in the furnace configuration to make it more suitable for a slag feed could address the fusion problem. The major modification implemented was use of a burner that provides a longer flame--and hence more even heat distribution--in the furnace.

Table 4. Results of Exploratory Pilot-Scale Tests

Test No.	Size, mesh	Treat-ment	Preheat Temp, °F	Res. Time min	Furnace Settings			Product, lb/ft ³	Expansion
					Port	Gas	Draft, " WG		
Perlite									
	100 x 0	-	-	-	L	F	-0.8	8	Good
Texas Lignite Slag									
803-8	16 x 30	PB	-	-	L	3/8	-0.37	Slag: 21.6 perlite: 15.3	Good
Illinois No. 6 Slag									
616-2	16 x 30	None	1000	1.5	U	3/4	-0.8	60	Partial
616-3	8 x 16	AW	1000	1.5	-	3/4	-1.0	56	Partial
618-6	16 x 30	AW	-	-	L	F	-0.85	20	Good
Illinois No. 5 Slag									
618-5	16 x 30	AW	-	-	M	F	0.8	26.5	Partial
618-7	30 x 70	AW	1300	-	L	F	-0.62	12.5	Good

AW: Slag surface treated with dilute acid.

PB: Slag blended with 20% perlite before expanding.

The modified pilot furnace has the following operational controls:

- ▶ The natural gas flow rate (SCFM) controls the heat input to the furnace.
- ▶ The cyclone draft (inches water gauge) controls particle fluidization.
- ▶ Burner differential pressure (δP) is the pressure drop between the air into the burner mixing chamber and the pressure after the mixer. This is a measure of the air flow into the burner and helps distribute heat into the upper section of the furnace.
- ▶ One of the three feed ports to the furnace (upper, middle and lower) is used at a time. Using the lower feed port introduces the feed particles directly into the flame while they get fluidized; using the upper feed port allows the feed particles to be heated gradually but may reduce the retention time.
- ▶ The furnace temperature is measured at four locations in the furnace, i.e., in the cyclone (T1) and at the upper (T2), middle (T3), and lower (T4) feed ports. However, only the temperature at the upper feed port is reported.
- ▶ The feed size is controlled by screening the slag into various size fractions prior to feeding to obtain a better understanding of fluidization requirements.
- ▶ The feed rate can be varied but is typically set at 10 grams/minute for all tests reported.

Upon commissioning the furnace with the modified burner, tests were conducted to study the effect of the pressure drop across the burner on the VSF temperature profile measured in the cyclone and in the furnace at the feed ports, as indicated below:

- T1: Cyclone, 68" from VSF bottom
- T2: Upper port, 54" from VSF bottom
- T3: Middle port, 34" from VSF bottom
- T4: Bottom port, 14" from VSF bottom

The temperature readings were plotted as a function of the furnace height, as shown in Figure 2. For a given value of

Figure 2. Effect of changing pressure differential δP (inches WG) across burner on VSF temperature profile at two gas levels at cyclone pressure drop of $-0.5''$ WG.

natural gas (say 70 SCFM), the temperature profile in the furnace could be dropped by increasing the value of δP from $0.3''$ to $0.5''$ water gauge. A similar temperature profile curve was developed for a natural gas level of 80 SCFM, as shown in Figure 2. The temperature at the bottom, being over 2000°F , could not be measured. The temperature monitored for expansion (T_2) at the upper feed port typically dropped by $200\text{--}250^{\circ}\text{F}$ for an increase in δP from $0.3''$ to $0.5''$ water gauge. The figure presents the effect of a pressure drop on the temperature profile in the furnace. Following furnace testing, the feed was introduced into the furnace, and the results are discussed below.

Tests 408/1 through 408/13 were run using three size fractions of Illinois No. 6 slag at 10 g/min feed to study the effect of the feed entry port, as shown in Table 5.

Tests 308/1 through 408/4 were run using a 14 x 20-mesh feed introduced at the upper feed port, and products with unit weights between 31 and 50 lb/ft^3 were obtained. However, tests 412/1 through 412/2, using identical conditions but with the feed introduced through the middle feed port, had fusion or clinker problems. The pressure drop in the cyclone was increased to increase fluidization in test 412/3, but with little improvement. Tests 412/4 and 412/5 were successful but

at a lower gas flow (or lower temperature), resulting in product unit weights in the 43-52 lb/ft³ range. It appears from these tests that the upper feed port may be better suited for the 14 x 20-mesh slag feed.

Test 408/5 using a 20 x 30-mesh feed introduced via the upper feed port resulted in slag expansion but had clinker problems. In test 408/6, the same size feed introduced via the middle port achieved steady expansion. Efforts were made to reduce the unit weight for this feed in tests 408/7-408/9 by reducing the gas flow rate and air pressure drop to 0.2" WG, resulting in product unit weights of 43-45 lb/ft³. Test 408/10, at 85 SCFM and 0.3 δP , yielded similar results.

Test 408/11 was run using a coarser 4 x 8-mesh feed introduced via the middle feed port, resulting in the slag particles dropping out to the bottom. Therefore, a slightly finer (8 x 14 mesh) feed was used in tests 408/12 and 408/13 using the middle and upper ports, respectively. In spite of making adjustments to increase the draft, these results were not satisfactory due to the coarse feed size.

Based on these tests, it was concluded that an 8 x 14-mesh size feed may be too coarse for the pilot furnace. The feed port may be varied as appropriate for different feed size intervals since the best results were obtained for the 14 x 20-mesh fraction fed to the upper feed port and for the 20 x 30-mesh fraction fed to the middle feed port. Additional tests are being conducted to include finer particle sizes (30 x 50 mesh) and using a broader size range such as 14 x 50 mesh.

The unit weight of the expanded products from successful tests was in the range of 31-55 lb/ft³. Pilot testing is continuing in order to achieve a further reduction in the unit weight of the product without the use of acid washing of the slag surface prior to firing.

The manufacturer's experience indicates that operation of a pilot-scale furnace is considerably more difficult than that of a commercial-size furnace due to the limited height, wall effects, and turbulence caused by air leakage from the three feed ports which need to be kept open to take temperature measurements. Operation of a large commercial furnace is easier since it has permanently installed temperature probes and a fixed feed point, thus reducing turbulence due to leakage. However, testing in a pilot furnace is less expensive and provides a better opportunity to understand the effect of operating variables.

Table 5. Illinois No. 6 Test Results Using Modified Furnace (no pretreatment, preheater off)

Test No.	Size, mesh	Furnace Settings					Product, lb/ft ³	Expansion
		Port	Gas SCFM	Air Pressure Drop, δp	Cyclone Draft "WG	Temp, °F		
408/1	14 x 20	U	85	0.50	0	1640	50.0	
408/2	14 x 20	U	85	0.45	0	1675	31.0	
408/3	14 x 20	U	85	0.45	0	1685	35.6	
408/4	14 x 20	U	75	0.45	0	1645	40.0	
408/5	20 x 30	U	75	0.45	0	1600	45.8	Partial clinker
408/6	20 x 30	M	75	0.45	0	1600	52.0	
408/7	20 x 30	M	70	0.2	0	1620	45.7	
408/8	20 x 30	M	65	0.2	0	1600	43.0	
408/9	20 x 30	M	55	0.2	0	1580	45.0	
408/10	20 x 30	L	85	0.3	0	1600	47.9	
408/11	4 x 8	M	80	0.5	-0.2	1480	38.4	drop out
408/12	8 x 14	U	80	0.5	-0.2	1480	10.4	drop out & clinker
408/13	8 x 14	M	85	0.5	-0.2	1400	NA	
412/1	14 x 20	M	95	0.45	0	1560	38.3	clinker
412/2	14 x 20	M	83	0.50	0	1470	31.1	clinker
412/3	14 x 20	M	95	0.40	-0.20	1510	51.0	clinker
412/4	14 x 20	M	76	0.45	-0.05	1390	52.0	
412/5	14 x 20	M	75	0.5	0	1390	43.0	
412/6	14 x 20	M	85	0.5	0	1450	40.0	

The next batch of tests was carried out using the preheater in the indirect-fired horizontal furnace mode. The results are given in Table 6. The expansion of the slag was achieved without any problems, and the product unit weights ranged from 18 to 34 lb/ft³. The test giving the lowest unit weight product was repeated successfully for one hour. However, no attempt was made to further lower the unit weight by utilizing a higher temperature due to the design limitations of the preheater. Modifications are currently under way to allow use of the preheater at higher temperatures. These modifications will also allow testing of a larger preheater in a horizontal furnace mode, which is also used for the expansion of perlite ores.

Table 6: Tests Conducted Using the Indirect-Fired Shaft Furnace

Test No.	Size, mesh	rpm	Horizontal Furnace				Product, lb/ft ³
			Port	Gas SCFM	Inlet Temp, °F	Exit Temp, °F	
412/7	14 x 30	3	-	110	1400	450	20.0
412/8	14 x 30	3	-	105	1460	450	20.0
412/9	20 x 30	3	-	95	1460	450	25.7
412/10	20 x 30	3	-	85	1450	450	18.0
412/11	20 x 30	3	-	80	1440	425	22.0
412/12	40 x 50	3	-	95	1460	450	34.0

CONCLUSIONS AND RECOMMENDATIONS

Based on work completed under Phase I of the project to date it can be concluded that:

- ▶ When blended with 20% perlite to overcome problems of slag fusion, a Texas lignite slag expanded to a unit weight of 21.6 lb/ft³ and the perlite expanded to 15 lb/ft³. This technique can also be applied to Illinois slags.
- ▶ Acid treatment of an Illinois No. 5 slag feed to overcome slag fusion problems resulted in a product with a unit weight of 12.5 lb/ft³, and a product unit weight of 20 lb/ft³ was achieved

using an acid-treated Illinois No. 6 slag feed. These tests indicate that Illinois slags can be expanded with minimal fusion problems to produce products with unit weights of approximately 12 lb/ft³.

- ▶ The problem of slag fusion can also be alleviated using the modified burner configuration that was tested successfully during this reporting period. This approach resulted in products with unit weights of 31-55 lb/ft³ from an Illinois coal slag and 21 lb/ft³ using another slag. Work is currently under way to reduce these unit weights further.
- ▶ Use of an indirectly heated horizontal furnace consistently provided products with a unit weight of 18 lb/ft³ using an Illinois No. 6 slag. This technique will be studied further as a means of generating products with even lower unit weights.

The following work is planned for the next quarter:

- ▶ Conduct additional testing with both the VSF and the indirectly heated horizontal furnace to produce lower-unit-weight products.
- ▶ Select the appropriate method to generate a large batch of expanded product for testing and evaluation during Phase II of the project.
- ▶ Evaluate the expanded products to identify their potential commercial applications.

While producing a 12 lb/ft³ or lower unit weight product from slag is important, products in the 20-30 and 30-60 lb/ft³ ranges also have numerous applications. The project goal is to generate a wide range of products which have a variety of applications and cover a very diverse market. As such, the primary emphasis during Phase I of this project has been to produce low-unit-weight products from Illinois slags. During Phase II, the emphasis will shift to testing expanded slags of various unit weights to determine their potential in the various applications identified earlier.

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