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FORMAL REPORT

POLYETHYLENE ENCAPSULATION FULL-SCALE TECHNOLOGY DEMONSTRATION

Polymer Solidification National Effort
TTP No. CH321202

FINAL REPORT

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ABSTRACT

A full-scale integrated technology demonstration of a polyethylene encapsulation process, sponsored by the U.S. Department of Energy (DOE) Office of Technology Development (OTD), was conducted at the Environmental & Waste Technology Center at Brookhaven National Laboratory (BNL) in September 1994. As part of the Polymer Solidification National Effort, polyethylene encapsulation has been developed and tested at BNL as an alternative solidification technology for improved, cost-effective treatment of low-level radioactive (LLW), hazardous and mixed wastes. A fully equipped production-scale system, capable of processing 900 kg/hr (2000 lb/hr), has been installed at BNL. The demonstration covered all facets of the integrated processing system including pre-treatment of aqueous wastes, precise feed metering, extrusion processing, on-line quality control monitoring, and process control.

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EXECUTIVE SUMMARY

A Full-Scale Polyethylene Encapsulation Technology Demonstration using a non-radioactive surrogate waste was conducted at the Brookhaven National Laboratory (BNL) Environmental & Waste Technology Center (EWTC) on September 13 and 15, 1994. The objective of this program, sponsored by the U.S. Department of Energy (DOE) Office of Technology Development, is the demonstration and transfer of new, innovative polymer process technologies for the solidification of DOE's radioactive, hazardous and mixed wastes.

Many facilities throughout the DOE complex are experiencing or anticipating performance and environmental compliance difficulties with current cement solidification systems. This is the impetus behind the growing interest in pursuing alternatives to cement processes, such as polymer solidification. Through years of laboratory-scale development and ultimately with a full-scale technology demonstration, BNL has shown polyethylene encapsulation to be an improved, cost-effective solidification technology applicable to a broad range of low-level radioactive, hazardous and mixed wastes.

The Technology Demonstration held at BNL was attended by over 80 people representing DOE and the private sector. They observed a fully integrated polymer encapsulation system including waste pretreatment, material transfer, material/feed metering, extrusion processing, on-line monitoring, and process control. The demonstration activities were divided into morning and afternoon sessions. The morning sessions were held in an auditorium and included presentations on technology applicability from BNL Administration, the DOE Area Office, DOE Headquarters, and BNL Technology Transfer. Technical overviews were provided on the real-time monitoring system developed by Ames Laboratory, the pretreatment process supplied by VECTRA Technologies and the Integrated BNL Polyethylene Encapsulation Process. The afternoon sessions were held at the EWTC Full-Scale Test Facility and included tours of bench-scale R&D laboratories and full-scale processing equipment, followed by the process demonstration and a question and answer session.

Pretreatment of a nitrate salt waste surrogate, based on a recipe from Rocky Flats Plant was conducted using a stirred vacuum dryer to make the aqueous concentrate amenable to extrusion. The surrogate waste was dried from a moisture content of 65% to less than 1% moisture and the resulting dry powder was ground to attain a uniform particle size distribution. During the process demonstration, the pretreated surrogate nitrate salt waste was processed at a nominal waste loading of 60 wt%. On the first demonstration day, September 13, 1994, the extruder was operated at a screw speed of 50 rpm (maximum extruder screw speed is 100 rpm) corresponding to an output rate of 3.5 kg/min (7.7 lb/min) or 5040 kg/day (11,100 lb/day). At 50 rpm, the actual time to produce a final waste form in a 208 liter (55 gal.) drum was one hour and twenty minutes. On September 15, 1994, an extruder screw speed of 80 rpm was used. This corresponded to a processing rate of 5.4 kg/min (11.9 lb/min) or 7780 kg/day (17,100 lb/day) and produced a 208 liter (55gal.) waste form in 50 minutes.

Several problems were encountered and remedied prior to, during, and following the demonstration activity. However, the demonstration was a success and provided confirmation of process viability. BNL is planning a "hot" production-scale demonstration of a transportable polyethylene encapsulation system in collaboration with an industrial partner and an EM-30 site. In this way, an effective, orderly transfer of technology to the commercial sector and DOE "customers", i.e., site personnel responsible for waste management and environmental restoration activities, will be ensured.

ACKNOWLEDGEMENTS

The authors greatfully acknowledge L. Ayres with assistance from G. Brown, A. Lopez and J. Lund for helping to plan, coordinate and complete the numerous logistical details required for the successful completion of the demonstration. We also extend our thanks to those who contributed to the overview sessions held each day during the demonstration. Specifically, we thank M. Butler (DOE), R. Duffey (BNL DAT), A. Johnson (DOE), M. Klimus (DOE), D. Langiulli (BNL OTT), J. Mayberry (SAIC), J. Mulligan (BNL DAT), and C. Polanish (DOE).

Special thanks to P. Colombo who recently retired as Head of the Environmental and Waste Technology Center. Pete believed in this technology from the start, and throughout its development at BNL, he provided the vision and leadership needed to ensure its steady progress. We wish you the best of luck and smooth sailing!

DEDICATION

This report is dedicated to the memory of J.D. (Don) Cassidy, who died on December 6, 1994. Don was an integral member of our team and his invaluable contributions helped make this demonstration project successful. More importantly, Don was a warm and caring person who will be dearly missed.

1.0 INTRODUCTION

The objective of this program, sponsored by the DOE Office of Technology Development, is the technology demonstration and transfer of new and innovative polymer processes for the solidification of radioactive, hazardous and mixed wastes. Through laboratory-scale development these processes have shown potential for improved, cost-effective performance compared with conventional technologies. Sodium nitrate salts are a high volume mixed waste generated at many facilities throughout the DOE complex including Rocky Flats Plant (RFP), Westinghouse Hanford Co. (WHC), Los Alamos National Lab (LANL), Oak Ridge National Lab (ORNL), Westinghouse Savannah River Co (WSRC), and West Valley. A polyethylene encapsulation system for sodium nitrate salts and other radioactive, hazardous, and mixed waste streams has been developed at Brookhaven National Laboratory (BNL) from process conception through parameter optimization, waste form testing, and scale-up feasibility. BNL has been working with RFP and other DOE sites to implement this technology as a replacement for conventional cement solidification processes. Use of polyethylene encapsulation of nitrate salt at RFP will provide improved waste form performance and increased encapsulation efficiency resulting in production of 70% fewer drums for storage, transport and disposal. Resultant cost savings of up to $1.5 to 2.7 million/year at RFP have been estimated [1].

The development of any new process requires scale-up demonstration, testing, and evaluation prior to implementation. Rocky Flats Plant has supported the need to conduct such a demonstration as soon as possible. In this regard, BNL recently completed a full-scale technology demonstration of the polyethylene encapsulation process using a non-radioactive surrogate waste that closely resembles actual RFP nitrate salt waste (an evaporator concentrate) in chemical and physical form. A production-scale plastics extruder was procured and installed at BNL for this purpose. A suitable pre-treatment process, i.e., vacuum drying, was identified based on vendor tests using production-scale equipment. The dryer system was leased to BNL and integrated into the polyethylene encapsulation system. A Transient Infrared Spectrometer (TIRS) monitoring system developed and operated by Ames Laboratory was used to provide on-line monitoring of actual waste loadings for improved quality assurance/quality control. BNL installed and integrated all necessary feed and metering equipment and provided computerized overall system control and data logging. Following completion of the technology demonstration for RFP surrogate nitrate salts, the BNL facility is available to conduct additional scale-up and full-scale feasibility testing for other surrogate mixed waste streams applicable to polyethylene encapsulation.

Demonstration activities were held at BNL on September 13 and 15, 1994. Representatives from DOE facilities, EPA, NRC, and commercial vendors who have expressed interest in this process were invited to attend and/or participate in the Polyethylene Encapsulation Technology Demonstration. Over 80 people, representing DOE and the private sector, attended (attendee list included as Appendix I). The morning sessions were held in an auditorium and included presentations on technology applicability from the BNL administration, the DOE Area Office, DOE Headquarters, and the BNL Technology Transfer Office. Technical overviews were provided on the real-time monitoring system developed by Ames Laboratory, the pretreatment process supplied by VECTRA Technologies and the integrated BNL Polyethylene Encapsulation Process (a copy of the agenda is included as Appendix II). The afternoon sessions were held at the Environmental & Waste Technology Center Full-Scale Test Facility and included tours of bench-scale R&D laboratories and full-scale processing equipment, followed by the process demonstration and a questions and answer session. Photographs taken during the demonstration are included in Figures 1.1 through 1.6.

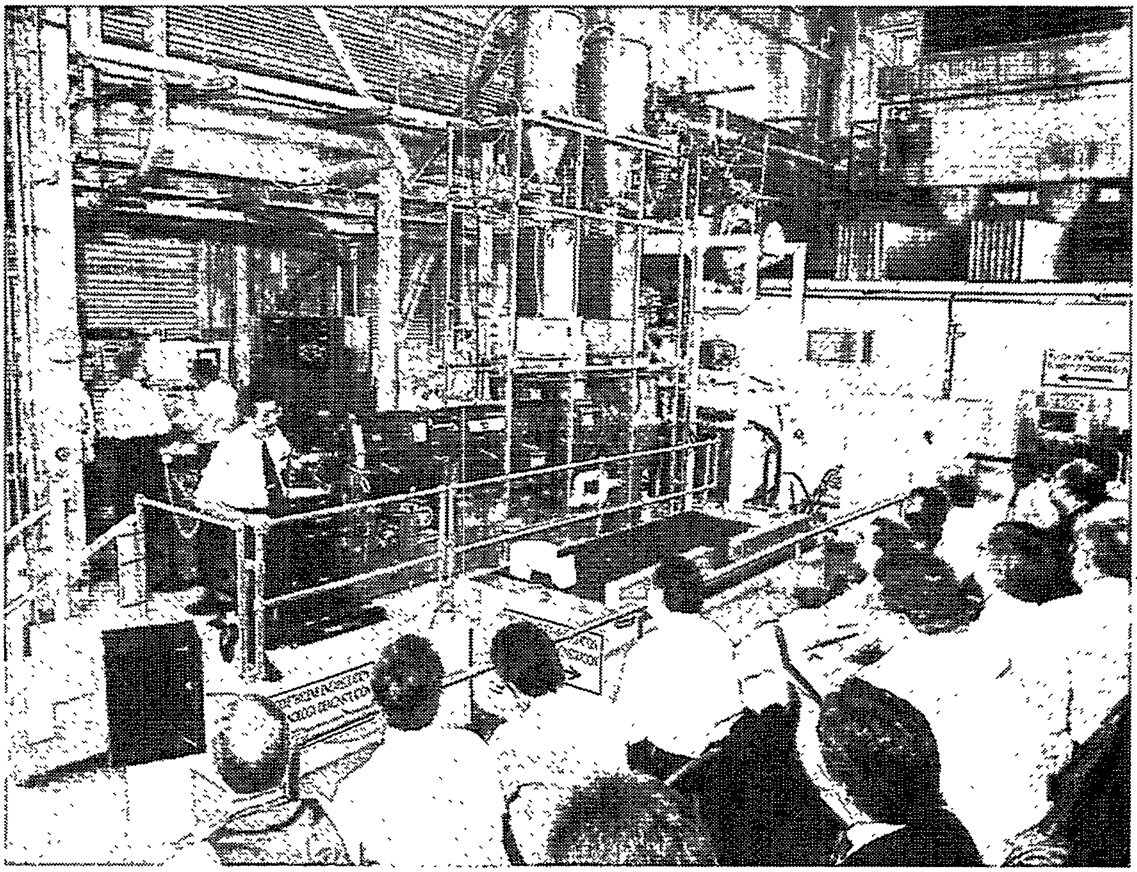

Figure 1.1 Introduction to afternoon session of the Polyethylene Encapsulation Technology Demonstration.

Many other facilities throughout the DOE complex are experiencing or anticipating performance and environmental compliance difficulties with current cement solidification systems. Interest in pursuing innovative alternatives to cement processes, such as polymer solidification, is growing. Beginning in mid-FY-92, BNL was asked by EM-50 to assist in coordinating efforts to develop a national program for implementing polymer solidification processes throughout the DOE complex. Key operations and site personnel were contacted to confirm current and anticipated solidification needs, discuss applicability of polymer solidification systems, and coordinate polymer technology development efforts in an effective manner. A letter report summarizing these efforts was issued [2]. As interest in polymer solidification continues to build, BNL will provide on-going support in this area. Future objectives include assisting in "hot" technology demonstrations at appropriate DOE sites using actual waste and the eventual implementation of these processes to provide improved final waste forms. BNL has received inquiries from several companies interested in commercializing the polyethylene encapsulation process. To this end, BNL will identify a suitable industrial partner(s) and negotiate agreements for continued cooperation. Several DOE sites have expressed interest in participating in a "hot" demonstration of the polyethylene encapsulation process to be conducted using a mobile processing unit. This effort will combine the resources of EM-50, EM-30 and industry to demonstrate system viability under actual field conditions and expedite commercialization of a much needed, improved final waste form process.

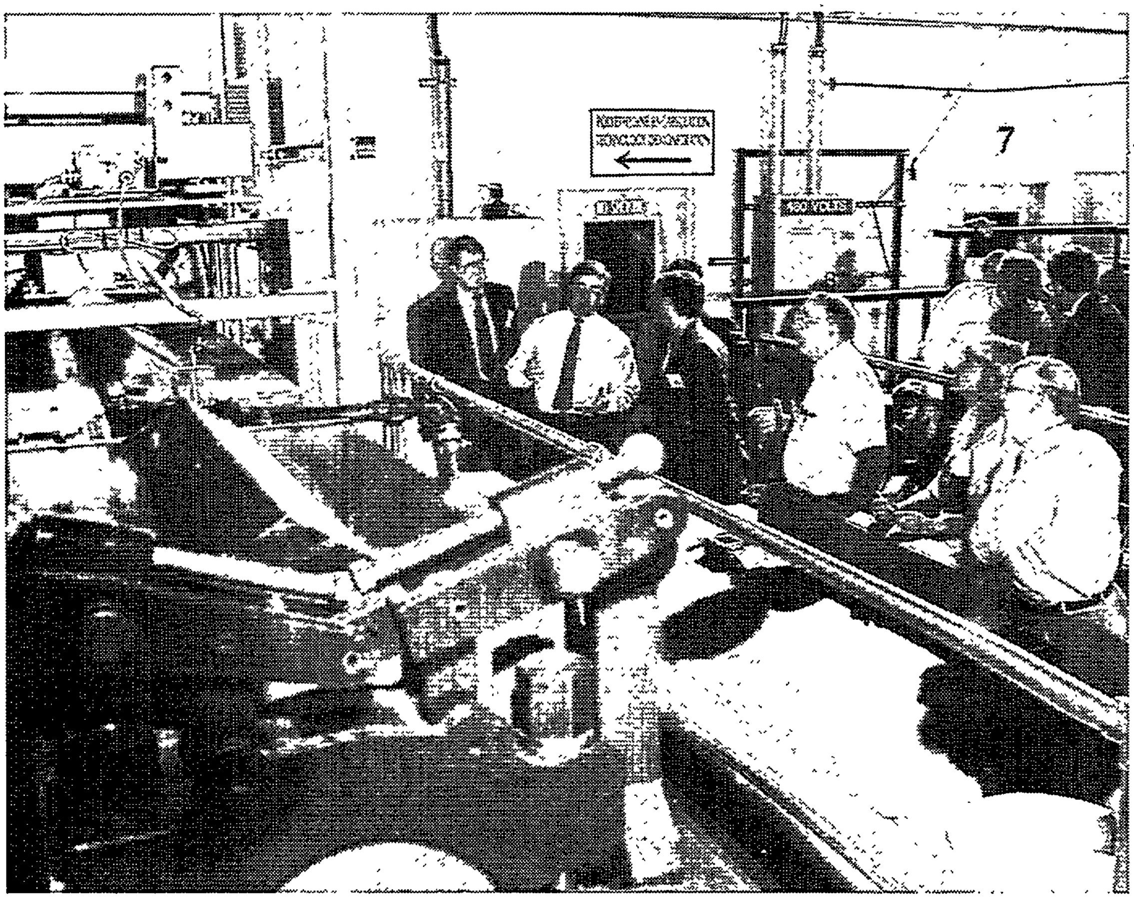

Figure 1.2 Technology Demonstration attendees receive explanation of the VECTRA vacuum dryer pre-treatment system.

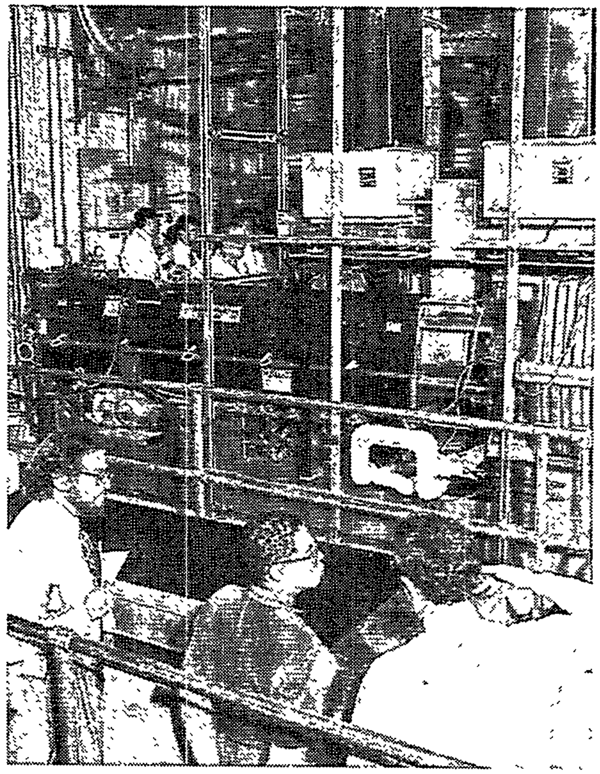

Figure 1.3 Attendees get a close-up view of the feed/metering system.

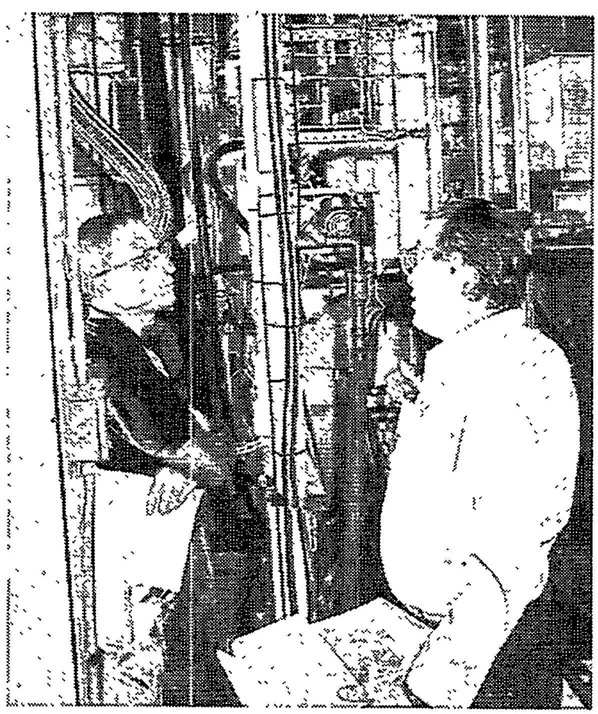

Figure 1.4 Discussion of extrusion system during equipment inspection.

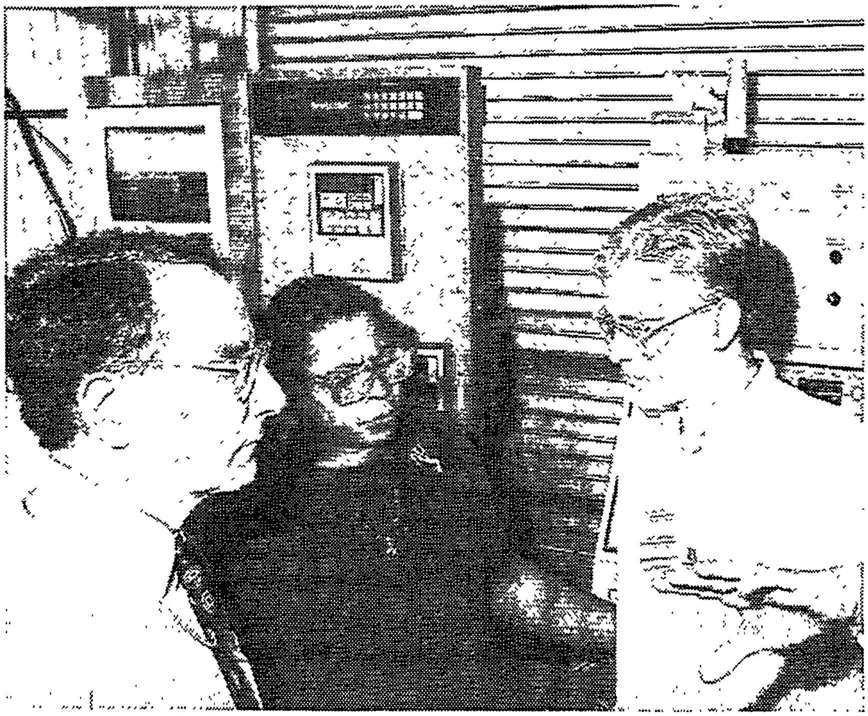

Figure 1.5 Describing operation of process control system.

Figure 1.6 Examining a section of the final waste form product for homogeneous mixing.

2.0 BACKGROUND

Polyethylene is a thermoplastic polymer with a melting point of approximately 120°C. Once heated above its melting point, it can be combined with dry waste to form a homogeneous mixture. Cooling of the melt results in the formation of a solid monolithic waste form. Solidification is guaranteed and is independent of the chemical nature of the waste material. This expands waste stream compatibility since constituents in the waste will not affect the solidification chemistry and variations in waste composition over time will not require any process modifications, thereby simplifying process operations.

Polyethylene was first considered as a solidification agent for LLW over two decades ago by researchers at Oak Ridge National Laboratory [3], but processing difficulties were encountered and development was not pursued. Ten years later as part of the Waste Form Development / Test Program, sponsored by the U.S. Department of Energy's Low-Level Waste Management Program, BNL conducted a survey of potential binder agents which identified polyethylene as a leading solidification candidate [4,5]. Selection criteria were based on considerations such as compatibility with waste, material properties, solidification efficiency, ease of processability and economic feasibility. Over the last twelve years, BNL has developed a single-screw polyethylene encapsulation extrusion process, and has expanded the process applicability to include hazardous and mixed waste as well as LLW.

A broad range of waste types are applicable to polyethylene encapsulation since solidification is independent of the chemical nature of the waste material. For example, the process has been successfully applied to treat aqueous evaporator concentrates (nitrates, chlorides, sulfates, borates), sludges, blowdown solutions, molten salt oxidation spent salts, soils and soil washing residues, incinerator fly ash and bottom ash, and ion exchange resins. In each case, higher waste loadings resulting in increased volume reduction compared with conventional technologies have been achieved. Performance of polyethylene final waste forms has been thoroughly investigated [6,7,8] and, in general, is well above minimum requirements specified by the Nuclear Regulatory Commission (NRC) [9,10] and the Environmental Protection Agency (EPA) [11]. Polyethylene waste forms were judged to be extremely durable under anticipated storage and disposal conditions by evaluating potential failure mechanisms, e.g., exposure to high radiation doses, microbial degradation, harsh chemical environments, and extremes in temperature.

3.0 WASTE DESCRIPTION

3.1 Surrogate Composition

A surrogate nitrate salt solution, an evaporator concentrate containing 35 wt% dissolved solids, was prepared and used as the waste material during the Full-Scale Technology Demonstration. The mixed waste surrogate composition was based on characterization data from Rock Flats Plant and is shown in Figure 3.1. Nitrate salt wastes are currently generated and stored at several nuclear and DOE facilities. These wastes are produced from the neutralization of nitric acids used in spent fuel reprocessing, uranium purification/enrichment, ion exchange resin regeneration, and high-level waste treatment.

3.2 Surrogate Preparation

The surrogate was prepared within plastic-lined 208 liter (55 gal.) drums in 113 liter (30 gal.) batches. The quantities of the salts and water added to create a surrogate batch are shown in Table 3.1. The ingredients, ordered as Technical Grade chemicals from Brand-Nu Laboratories, CT, were added and mixed thoroughly to ensure a homogeneous solution. A total of 13 batches were prepared with a dissolved solids concentration of 35 wt%. The dryer was successful in drying these batches to an acceptable moisture content, i.e., <1wt%. However, due to the limited time schedule and difficulties encountered during shake-down testing of the pre-treatment dryer, to be discussed in Section 4.1.1 , an additional 14 batches were prepared with a dissolved solids concentration of 70 wt%. This reduced the length of time required to drive off the water and residual moisture. These batches were made with the same recipe as shown in Table 3.1 with the exception that half the quantity of water was used. The high solubility of the salts made it possible to prepare well-mixed homogeneous solutions even at 70 wt% solids.

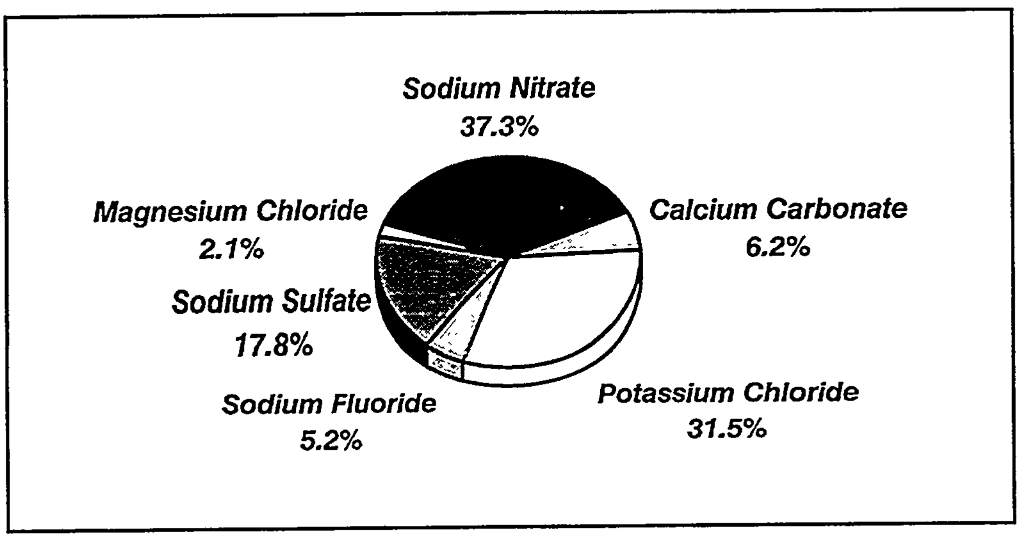

Figure 3.1 Mixed waste salt surrogate based on RFP characterization data. Dissolved solids concentration: 35 wt%.

Table 3.1 **Quantities of ingredients added to prepare 113 liter surrogate batch containing 35 wt% solids.**

Compound	**Formula**	**Quantity in 113 liter batch (kg)**
Water	H_2O	113.5
Sodium nitrate	$NaNO_3$	22.9
Sodium sulfate	Na_2SO_4	10.9
Sodium fluoride	NaF	3.2
Potassium chloride	KCl	19.3
Magnesium chloride	$MgCl_2$	1.3
Calcium carbonate	$CaCO_3$	3.8

4.0 INTEGRATED PROCESS DESCRIPTION

The BNL polyethylene encapsulation process centers on the use of a versatile, industry tested, single-screw plastics extruder. Dry or pre-treated waste and polyethylene binder are continuously fed to the extruder by individual dynamic feeders. Distributive mixing within the extruder produces a homogeneous molten mixture that is extruded directly from the die into a waste container. The molten mixture is allowed to cool forming a solid monolithic waste form.

The Full-Scale Demonstration Facility at BNL features a fully integrated encapsulation process including waste pre-treatment, material conveying, precise metering of feed materials, extrusion processing, on-line QA monitoring and process control. This facility was developed following bench-scale formulation and testing of the polyethylene encapsulation process. The BNL full-scale encapsulation system is a scale-up of the bench-scale encapsulation process and was designed to match production capacity at a typical DOE treatment facility. Figure 4.1 is a schematic of the polyethylene encapsulation process showing the primary system components. The waste pre-treatment system includes a vacuum dryer which discharges directly (gravity feeds) through a grinder into a storage drum. The pre-treated waste and low-density polyethylene (LDPE) binder are then conveyed (via material transfer system) to the feeder storage hoppers. The waste and binder materials are accurately metered to the extruder feed throat where they are extruded directly into a waste receptacle. The on-line monitor provides a real-time analysis of the waste loading in the extrudate as it exits the extruder die. A low-profile floor scale under the waste receptacle is used in conjunction with a computer for the process control loop. A photograph showing an overview of the Full-Scale Demonstration Facility is shown in Figure 4.2.

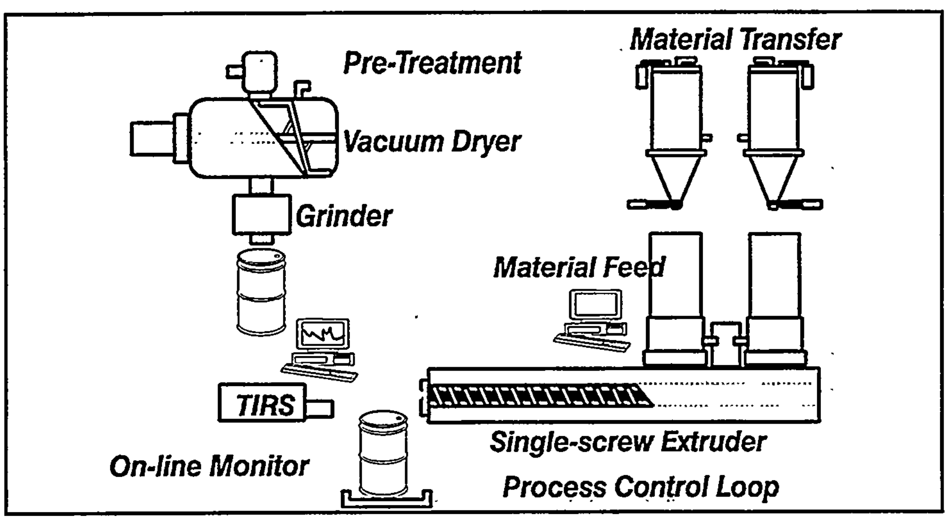

Figure 4.1 Schematic diagram of Integrated Polyethylene Encapsulation Process.

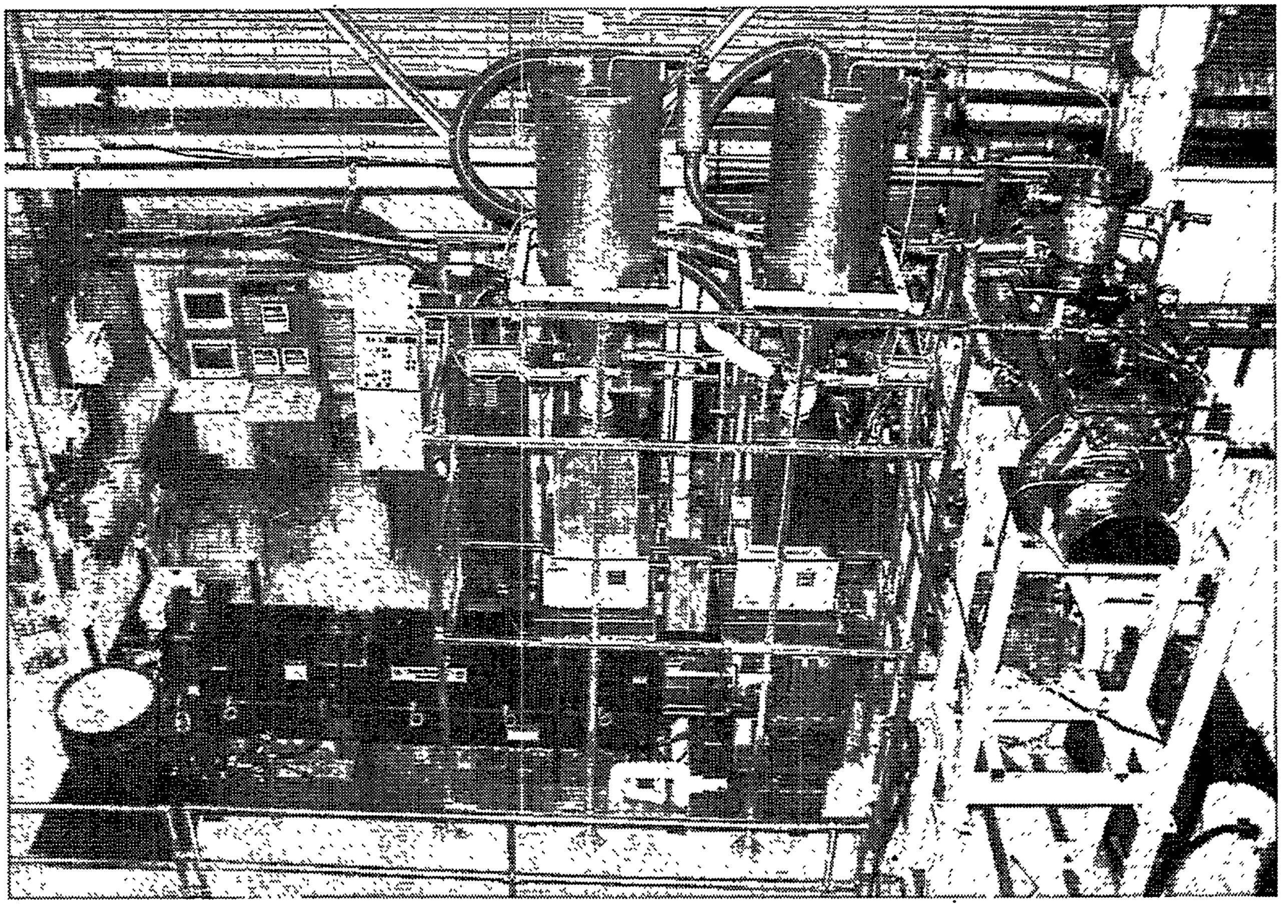

Figure 4.2 Full-Scale Polyethylene Encapsulation Demonstration Facility at BNL.

4.1 Waste Pre-Treatment

Pre-treatment of aqueous wastes is required in order to make them amenable to extrusion with polyethylene. The polyethylene encapsulation process operates between 120 - 150 °C, above the volatilization temperature of water. For effective encapsulation processing, all residual moisture must be removed from the waste prior to encapsulation. In addition, the waste must be a granular or powdered solid within a pre-determined particle size range for successful feed/metering and mixing within the extruder.

4.1.1 Rotary Vacuum Dryer

A Liquid Volume Reduction System (RVR-200) was supplied under contract by Vectra Technologies, Inc., Columbia, SC. The dryer is a skid mounted system with separate modules for the blender/dryer, steam generator, condensate recovery and chiller. Dryer capacity is rated at 757 liters/day (200 gal/day) equating to 408 kg (900 lbs.) dry salt/day for the nitrate salt surrogate containing 35 wt.% solids. The dryer was specially fabricated for the BNL Full-Scale Test Facility and incorporates design features to allow flexibility in testing various wastes. The Vectra RVR-200 system uses a 425 liter (15 ft^3) blender/dryer vessel constructed of type 304 stainless steel. The mixing blades are also constructed of type 304 S/S and are arranged in a double helix with opposing pitch design. The ribbon blades are bolted to the main shaft to allow modification of the mixing blade design, e.g., replacement of the ribbon blades with plow blades. The shaft is driven by a 25 hp motor through a parallel gear reducer that drives the agitator/scraper assembly at a rate of 20 rpm. The blender/dryer vessel is equipped with four, 5 cm (2 in.) flanged ports to allow for the addition of optional high speed choppers. For certain wastes, high speed choppers may be useful in preventing clumping of the material during the "dough" phase of the drying cycle. Heat is provided by two electric steam generators that pressurize the blender/dryer steam jacket to approximately 10-15 psig. The liquid waste is heated and steam vapor is drawn from the dryer through a demister/filter assembly to a condensate system cooled by a 15 ton chiller unit. The blender/dryer discharges through a bottom 15.2 cm (6 in.) diameter, pneumatically operated ball valve, into a variable speed grinder to reduce particle size, if required. The final product is emptied to a storage drum maintained under negative pressure to prevent powder dispersion. Photographs of the RVR-200 unit installed at BNL are shown in Figures 4.3 - 4.6 including the blender/dryer skid (Fig. 4.3 and Fig. 4.4), the condensate skid (Fig. 4.5) and the chiller skid (Fig. 4.6).

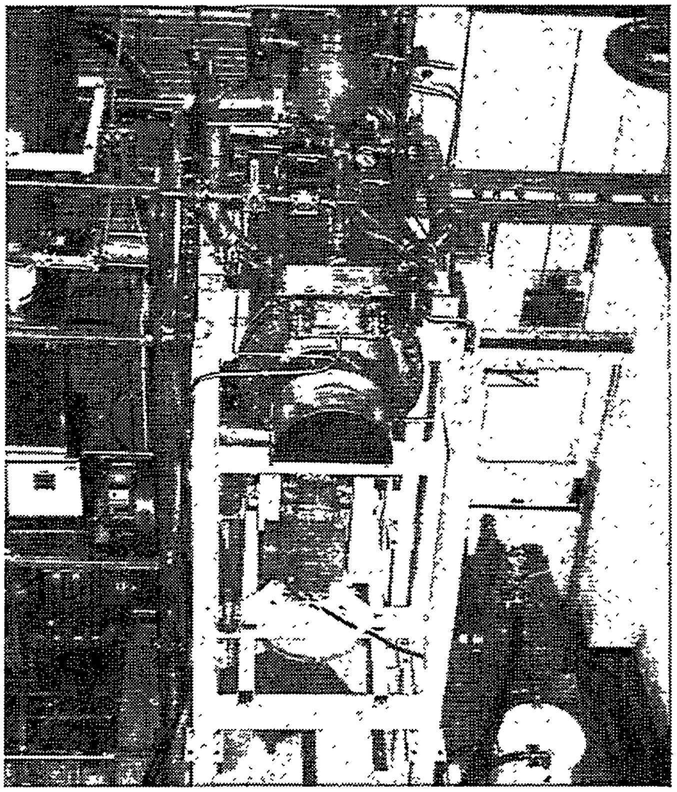

Figure 4.3 Blender/dryer skid from VECTRA RVR-200 vacuum dryer which heats, mixes and removes moisture from the waste.

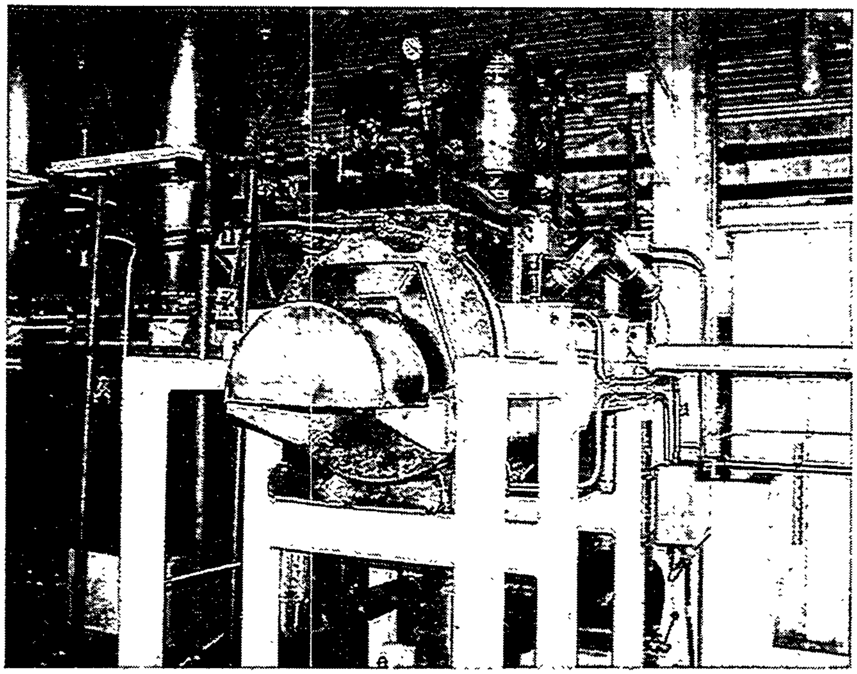

Figure 4.4 Close-up of the blender/dryer skid from the VECTRA RVR-200 vacuum dryer.

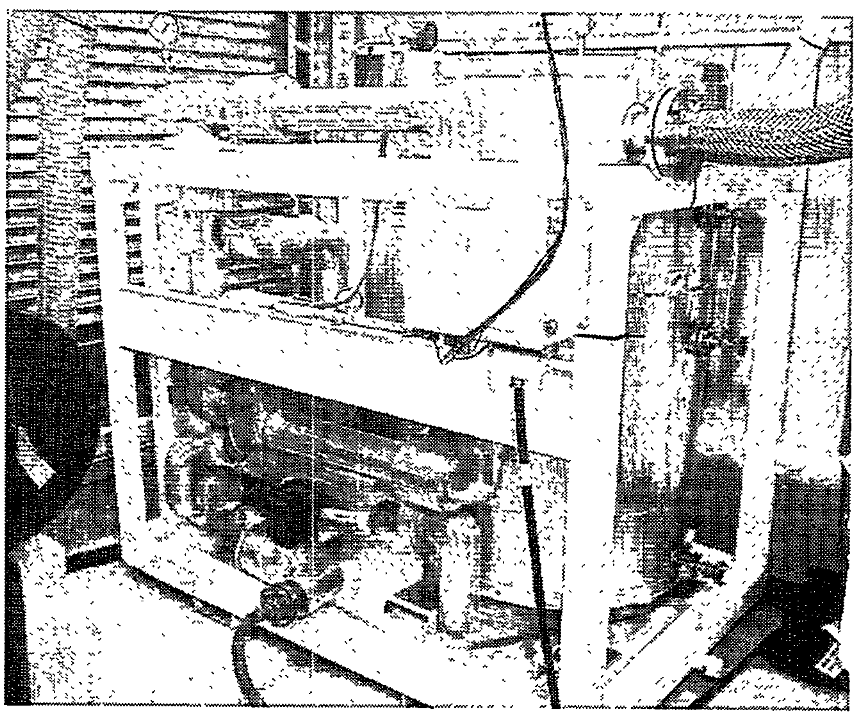

Figure 4.5 Condensate skid from VECTRA RVR-200 vacuum dryer where heat transfer coils condense clean vapors back to water.

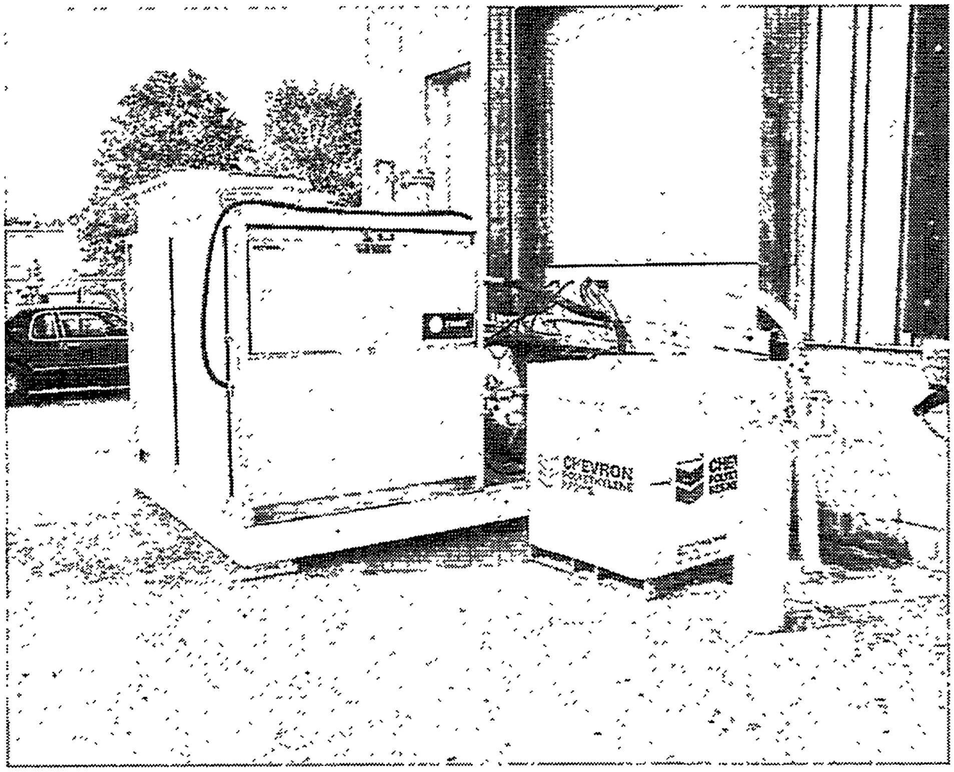

Figure 4.6 **Chiller skid from VECTRA RVR-200 vacuum dryer which provides cooling water to condensate skid.**

4.1.2 Size Reduction

Comminution was used for size reduction and was integrated into the waste pre-treatment system. Dried salt is gravity fed from the blender/dryer discharge valve directly through the grinder to the waste collection drum. A comminutor consists of multiple, reversible, rotating knife blades which impact the material until the particle size has been sufficiently reduced to fall through a semi-circular sieve screen. Figure 4.7 is a photograph showing the comminutor multiple knife blades. Particle size is adjusted by replacing the sieve screen. A 3.2 mm (1/8 in.) sieve screen was used to process the RFP surrogate. Comminution was successful in producing a particle size distribution that was amenable to extrusion.

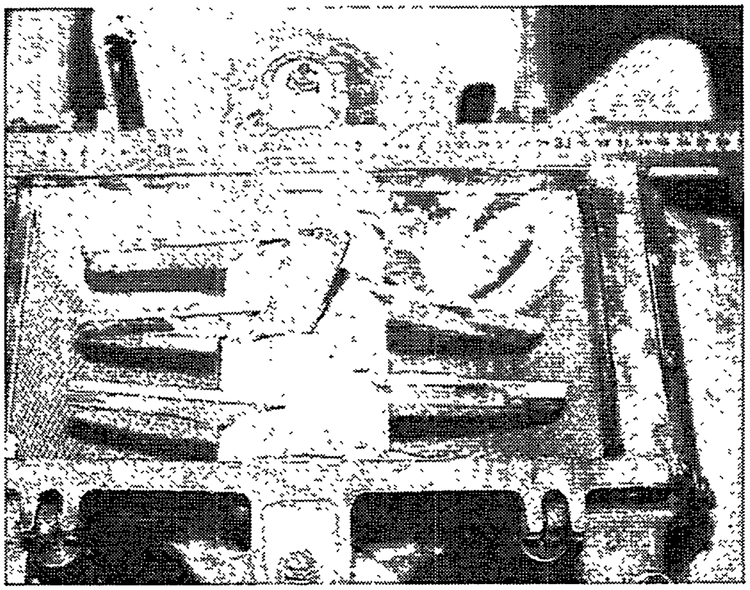

Figure 4.7 Comminutor, disassembled to view multiple rotating knife blades.

4.2 Material Conveying

Pneumatic vacuum conveyors, manufactured by Vac-U-Max, Belleville, NJ, were used to transfer the pre-treated powdered salts and the LDPE pellets to extension hoppers on the material feeders. Each feeder was fitted with a 142 liter (5 ft^3) hopper extension that increased the feeder storage capacity to 167 liters (5.9 ft^3). Figure 4.8 shows a schematic of the vacuum conveying systems. The main components of the vacuum conveying systems are control panels, suction wands, receiving tanks, low-pressure valves, and rotary positive displacement vacuum pumps. The waste material transfer system uses 64 mm (2.5 in.) suction lines in conjunction with a 7.5 hp vacuum pump. The LDPE pellet transfer system uses 76 mm (3 in.) suction lines with a 10 hp vacuum pump.

The control panel contains a series of binary timing switches that control the discharge and transfer cycles of the overall material transfer process. The control panel receives a signal (contact closure switch) from the feeder computer controller when a preset "heel" or empty point is reached in the feeder storage hopper. The Vac-U-Max control panel then engages the vacuum pumps, moves the low-pressure valve to draw atmospheric air, opens a bottom slide/discharge valve and then waits for the discharge timer to elapse. This first discharge step ensures that no material is in the receiving tank before switching to the transfer cycle. Following the discharge cycle, a brief pulse of compressed air cleans the pre-filter in the receiving tank, the slide-valve closes, and the low-pressure valve switches positions to pull a vacuum on the receiving tank and the suction wand. The system cycles in this manner until a "full" signal (full hopper) is received from the feeder computer controller, based on a weight signal from the loss-in-weight feeder scale.

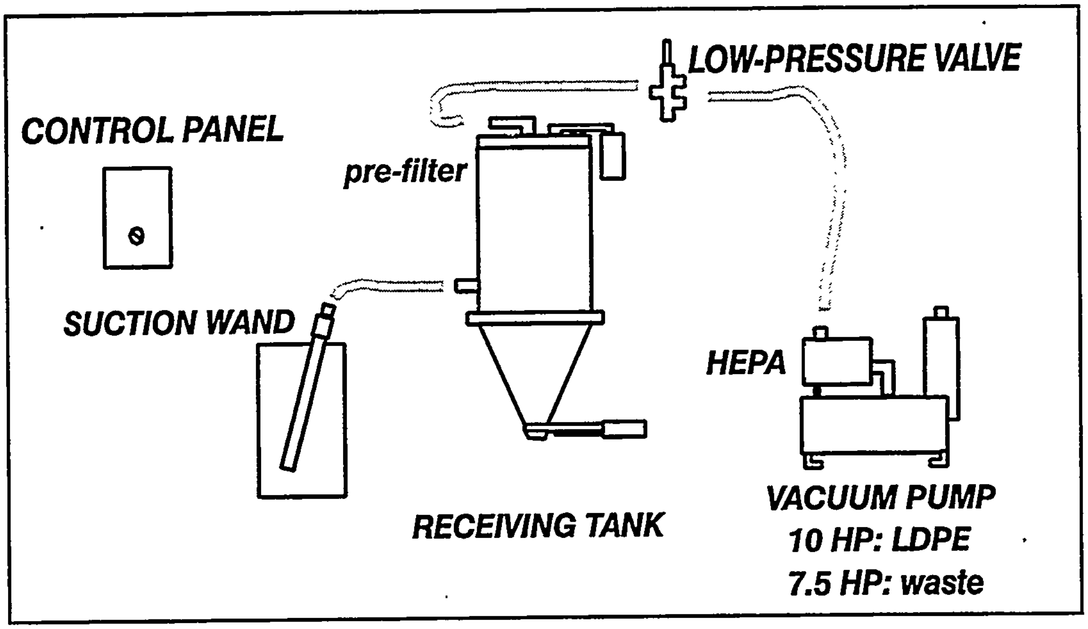

Figure 4.8 Schematic of pneumatic vacuum conveyor system.

4.3 Material Feed Metering

Material feed was accomplished with two dry material feeders, AccuRate Model 610, Whitewater, WI, converted to a loss-in-weight (LIW) system, Merrick Model 510, Lynn Haven, FL. This system provided accurate pre-determined mix ratios of waste and binder to the extruder. The LIW control system consists of three computer controllers arranged in a feedback loop: a master controller and an individual ("slave") controller for each feeder. The master controller performs a number of functions including (1) accepting a manual process setting or variable signal from the process control computer as the total feed rate, (2) setting the waste/binder ratio according to an entered recipe, and (3) controlling the individual feeder modules to maintain the feed rate and the waste/binder ratio. A "pacing" feature maintains the waste/binder ratio by decreasing the total feed rate if an underfed condition is sensed by either individual feeder module. The individual feeder control modules function to (1) accept a manual feed rate or the master total feed rate based on the waste/binder ratio from the master controller, (2) adjust the speed of the feeder to maintain ± 1% of desired delivery, and (3) signal the material transfer system when a "heel" or "full" point is reached in the hopper level.

4.4 Extrusion Processing

For the Technology Demonstration, a 11.4 cm (4.5 in.) single-screw extruder, Davis-Standard, Pawcatuck, CT, with an output capacity of 900 kg/hr (2,000 lb/hr) was selected. The capacity of this extruder when fitted with a 6.4 cm (2.5 in.) diameter die, as during the demonstration, was measured to be approximately 450 kg polyethylene/hr (1000 lb/hr). The extruder is equipped with five barrel zones and two die zones with thermocouple controllers which provide gradual heating of the waste/binder melt. The barrel heaters are cast aluminum electric "clamshell" type heaters. A cooling loop consists of distilled water circulation, a flow-through water-cooled heat exchanger, and individual zone flow indicators. A solid-state dual probe anticipatory temperature control system holds the barrel temperatures to ± 1°F. The screw is driven with a 150 hp drive. The extruder is also equipped with a two-stage vented screw with feed transition and metering sections in the first stage, and vent and metering sections in the second stage. The vent is used to pull off residual volatiles (e.g. small amounts of moisture in the waste) by a closed loop, oil-cooled vacuum pump. The production-scale extruder is shown in Figure 4.9.

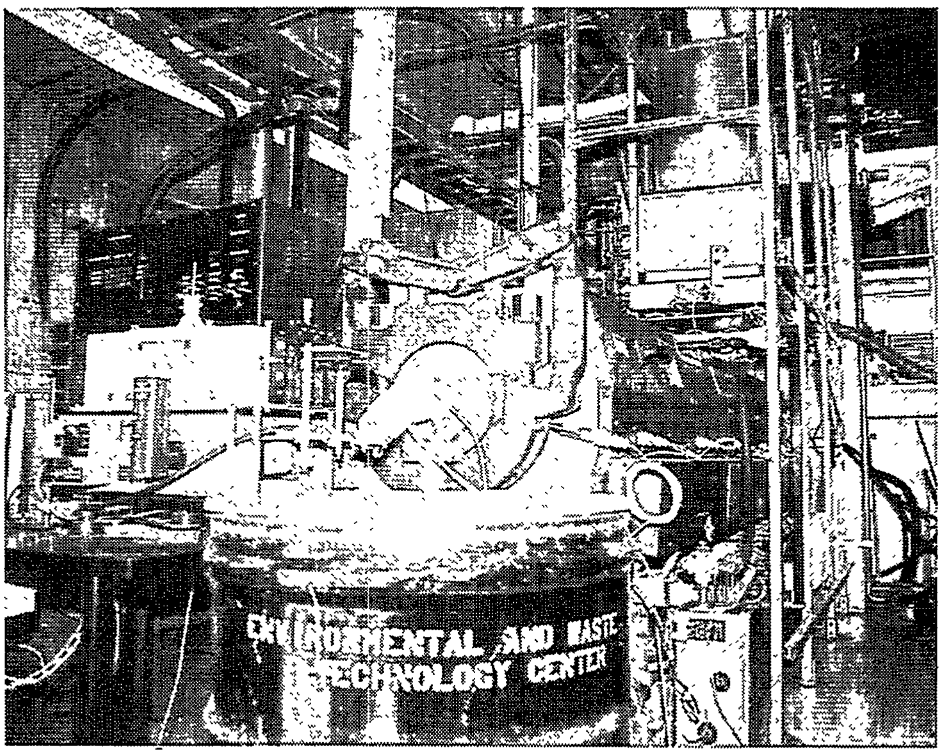

Figure 4.9 Production-scale single-screw thermoplastics extruder.

4.5 On-Line Infrared Monitoring

An on-line monitor developed at Ames Laboratory was used to provide real-time waste composition data for the waste/binder mixture as it was extruded [12]. The monitor is based on a technique known as transient infrared spectroscopy (TIRS). The monitor is installed at the end of the extruder and is operated by inducing a small temperature differential on the surface of the extruded melt, reading the infrared spectra, then providing computerized analysis to convert the spectra to a waste composition. The instrument provides real-time data on the actual waste loading of encapsulated waste exiting the extruder by calibrating the monitor with spectra for known waste loadings. The TIRS system enables the operator to continuously monitor the current product waste loading and to check for any variations in the waste/binder ratio for quality assurance and quality control purposes. A photograph of the TIRS monitor in position at the extruder die is shown in Figure 4.10.

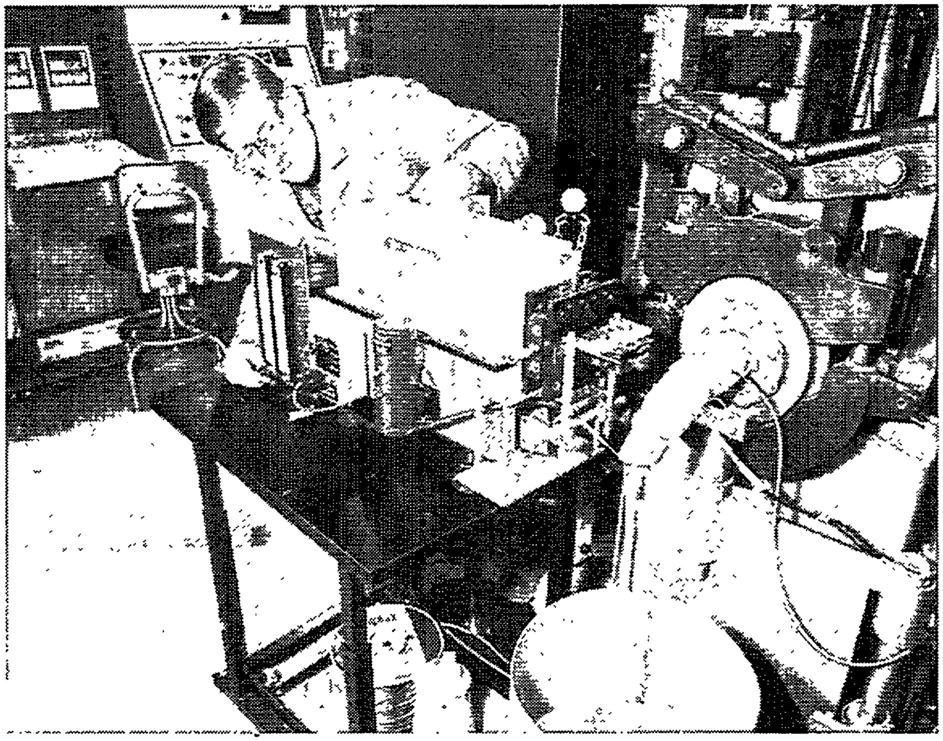

Figure 4.10 TIRS monitor located at extruder output die.

4.6 Process Control

An open-loop, integrated process control and data acquisition system coordinated material feeding and extrusion processing. Process control is accomplished using a customized computer program written with Windows-based software (LabVIEW for Windows, National Instruments, Austin, TX) installed on a standard IBM compatible PC. LabVIEW operates through graphical programming as opposed to code-based programming languages, such as FORTRAN and C. In LabVIEW, graphical icons are "wired" together to mimic subroutines and operations loops. A multifunction input/output data acquisition (DAQ) board was installed inside the computer capable of analog input (A/D conversion), buffered data acquisition (high-speed A/D conversion), analog output (D/A conversion), digital input/output, and counter/timer operations. Connected to the PC was an external SCXI (Signal Conditioning eXtension for Instrumentation) chassis used to condition input and output signals. During data acquisition, signal conditioning is often required. For example, conditioning for thermocouple signals includes amplification, linearization, and cold-junction compensation.

For the polyethylene process, the process control computer monitors the extruder output rate by weighing the quantity of material being extruded. A low-profile weigh scale located under the drum being filled sends a signal to the process computer via an RS-232 serial port. Within LabVIEW this signal is integrated to an output rate that, in turn, is sent through the SCXI chassis as a variable analog signal (0-10 V) to the Loss-in-Weight Master Controller as the updated total feed rate. This method allows the feed rate to match the extruder output rate. The process control computer also monitors the extent of drum filling, signaling the operator when the drum is full.

5.0 SYSTEM TESTING RESULTS and TECHNOLOGY DEMONSTRATION

5.1 Waste Pre-Treatment

5.1.1 RVR-200

The stirred vacuum dryer was operated in a batch mode, by charging the unit with two pre-mixed 30 gallon batches of the nitrate salt surrogate. Two salt concentrations were processed; a baseline recipe containing 35 wt% salts, in accordance with RFP characterization data, and a highly concentrated recipe containing 70 wt% salts. The surrogate was drawn into the blender/dryer unit through a vacuum waste inlet line connected to the top of the vessel. Drying time to achieve less than one percent moisture was normally 12 hours for the baseline recipe containing 35 wt% solids. For batches containing 70 wt% solids, the drying time was approximately 7 hours. A summary of the moisture contents taken, using a Sartorius Moisture Analyzer, from each dried surrogate batch is shown in Table 5.1. The first batch, which looked dry on the CCTV located on the top of the blender/dryer unit, was discharged with a moisture content of 3.3 %. When discharged through the grinder, the salts clumped together and clogged a 1.6 mm (1/16 in.) sieve screen inside the comminutor. This necessitated disassembly of the grinder to access the sieve screen for cleaning. The operating procedure was modified to include taking a grab sample of the dried salt prior to discharge to confirm moisture content.

The normal operation of the stirred vacuum dryer produced a caked layer of product coating the interior surface of the vessel near the completion of the drying cycle. The thickness of the caked layer was equal to the spacing between the ribbon blades and the wall. For the RVR-200 the spacing was 3/16 of an inch. During repetitive operation, the caked product was simply redissolved when the next batch was charged to the unit. All subsequent batches after the initial drying run started with a slightly greater solids concentration until a steady-state operation was reached.

The caking action of the salt on the vessel walls resulted in a cyclical vibration of the blender/dryer unit due to the scraping or shearing occurring between the ribbon blades and the caked layer. The cyclical nature of the vibrations, as opposed to continuous vibrations, were most likely due to a tighter tolerance in the blade to wall clearance on one side of the blade assembly. In this case, the blades with the tighter clearance would be responsible for all the shearing. Previous vendor tests of stirred vacuum dryers did produce similar vibrations with no apparent deleterious effects. However, following installation of the RVR-200 at BNL and several initial drying runs with the RFP nitrate salt surrogate, damage to the main shaft was observed during a post-processing system check. The high shear caused a fracture failure in the welds of two of the support arms from the main shaft for the ribbon blades. Jaygo, Inc., Mahwah, NJ, who manufactures the blender/dryer unit for Vectra Technologies, came to BNL, disassembled the unit and returned the main shaft to their NJ headquarters for repair. All welds were reinforced and additional bracing was added to the ribbon blade support arms. After the blender/dryer was reassembled, no other problems occurred with the dryer. Figure 5.1 is a photograph showing the main shaft and the ribbon blade configuration inside the blender/dryer unit. Close inspection of this photograph reveals the two support arm weld fractures on the top of the main shaft. Figure 5.2 is a photograph of the shaft following repairs showing the additional bracing and support welds that were added.

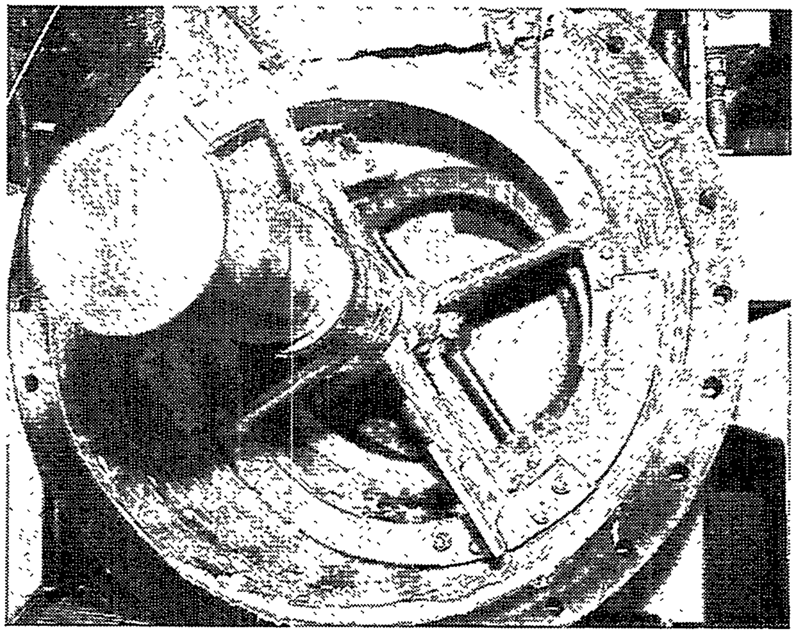

Figure 5.1 Internal view of disassembled blender/dryer showing main shaft and ribbon blades with fractured support arms.

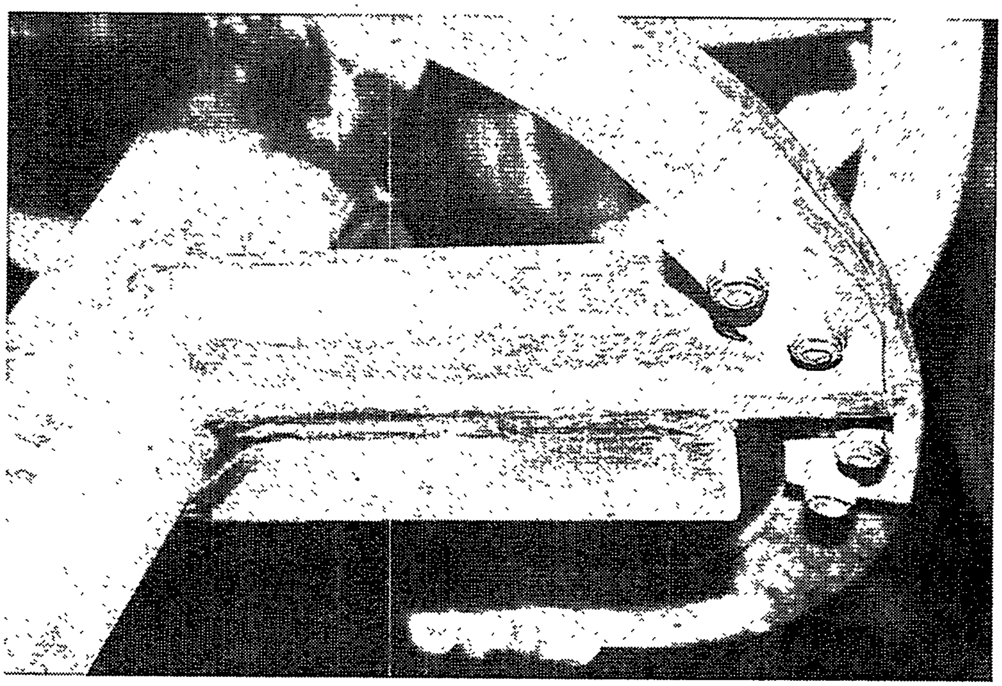

Figure 5.2 Main shaft and ribbon blades following repairs showing the additional bracing and support welds.

Table 5.1 Moisture analyses of pretreated salt surrogate.

Batch	Date discharged	Moisture content (%)
1	August 31, 1994	3.30
2	September 1, 1994	0.95
3	September 2, 1994	0.11
4	September 4, 1994	0.14
5	September 4, 1994	0.32
6	September 9, 1994	0.82
7	September 9, 1994	0.55
8	September 10, 1994	0.65
9	September 10, 1994	0.72
10	September 11, 1994	0.27
11	September 11, 1994	0.92
12	September 11, 1994	0.35
13	September 12, 1994	0.53
14	September 12, 1994	0.54

5.1.2 Comminution

Bench-scale testing at BNL determined that following vacuum dryer pretreatment, size reduction was required of waste materials for successful polyethylene extrusion and encapsulation. Size reduction provides a uniform particle size distribution that is within extrusion processing parameters. Larger particles can be effectively processed but they may adversely affect TCLP testing results if the large particles are not completely encapsulated or remain partially exposed on the surface when making 9 mm pellets. The lower boundary is limited by mixing abilities of the waste particles with the highly viscous polyethylene melt.

Figure 5.3 is a particle size distribution of the dried nitrate salt surrogate following comminution pre-treatment. The particle sizes are seen to fall between 250 and 2380 microns with the majority of particles centered at 300 microns and 1000 microns. To accomplish this, the comminutor was fitted with a 3.2 mm (1/8 in.) sieve screen and operated with the knife blades rotating in reverse in order to impact the discharged salt with the blunt portion of the blade edge. From previous experience at BNL, this particle size distribution is within acceptable processing limits for extrusion.

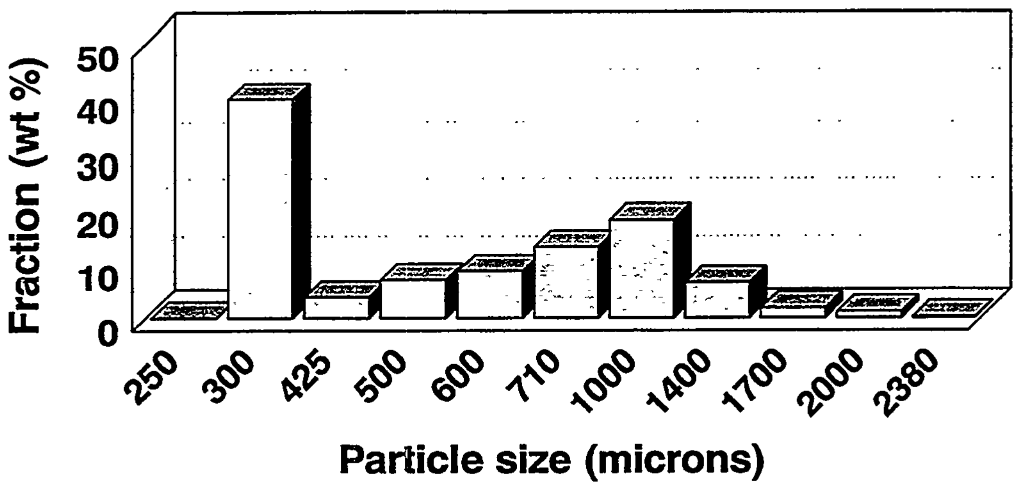

Figure 5.3 Particle size distribution of nitrate salt surrogate following pre-treatment.

5.2 Material Conveying

Vacuum conveying proved to be an effective mechanism for waste and binder handling. The transfer systems for both the powdered nitrate salt and the LDPE pellets operated successfully. The set-up of these systems required the cycle timers in the control panel to be programmed and optimized. This was accomplished by repetitive trials with the conveying material at different cycle times in order to estimate the quantity of material that is conveyed or discharged during each cycle. The timers can not be preset from the factory since conveying and discharge rates are dependent on the material physical properties and vary greatly between different materials. The standard conveying practice with vacuum conveyors is to immerse a fluidizing suction wand in the material to be transferred. This worked very well with the LDPE pellets. However, the nitrate salts tended to bridge in the storage container which caused the suction wand to create a "rat hole" through the salts if the wand was kept in a stationary position. The nitrate salts did not collapse to fill the hole created by the suction wand. This was remedied by agitating the storage container and/or moving the wand. Improved solutions to the bridging effect of the salt have already been pursued with the pneumatic transfer system manufacturer, Vac-U-Max.

5.3 Material Feed Metering

As mentioned in section 4.3, material feed was accomplished with two dry material feeders converted to a loss-in-weight system. The designed rate capacities of the feeders were 6.9 kg/min and 5.2 kg/min, for the waste and LDPE feeders, respectively. The LIW master controller was sent a total feed rate based on the extruder output calculated by the process control software. During the beginning of the Technology Demonstration on September 13, 1994, the extruder screw speed was set at 50 rpm while running pure polyethylene. Following a tour of the equipment by the visitors, the recipe in the master controller was altered to 40% LDPE / 60% nitrate salt. The individual control module for the salt feeder was observed to highly overshoot the desired feed rate requested by the master controller before equilibrating. This had a drastic effect on the extrusion processing, causing the extruder output to slow and eventually stop due to the "plug" of waste mixture later estimated to exceed 85 wt% waste. The recipe was changed back to 100% LDPE until the extruder started processing again. It took approximately 30 minutes to clear the extruder and prepare for further processing. In order to prevent further feeding problems, the waste loading was slowly increased, starting with a 60% LDPE / 40% nitrate salt recipe to 50% LDPE / 50% nitrate salt and finally to the desired 40% LDPE / 60% nitrate salt. This required an additional 10 minutes before processing resumed at 60 wt% nitrate salt. This adjustment to the operating procedure resulted in less "overshooting" of the desired waste loading and maintaining of the waste/binder ratio within acceptable process limits. Additional procedural modifications such as adjustment of the proportional band parameter in the PID controller, setting metering limits and programming operator alarms to indicate "out of spec." conditions would help minimize the potential for exceeding process limits. No further feed metering problems were encountered during the demonstration activities.

5.4 Extrusion Processing and Parameters

A standard single-screw vented extruder is the fundamental system component in the BNL polyethylene encapsulation process. Previous experience with bench-scale processing and system testing of the full-scale process established optimum extrusion parameters for waste streams. As discussed in section 4.4, the extruder is equipped with multiple barrel and die zones with separate temperature controllers. For the demonstration with nitrate salt waste, the extruder zone temperatures were set to create a temperature ramp beginning at the extruder feed throat and ending at the extruder exit die. A temperature ramp permits mixing of the waste and binder prior to the gradual heating/melting of the binder material. The temperatures for barrel zones 1-5 were set at 280, 285, 295, 325, and 350°F, respectively. The vacuum pump located at the vented portion of the screw was maintained at a constant pressure of 15 mm Hg.

The operating plan for the Technology Demonstration on September 13, 1994 was to process the nitrate salt waste at a 60 wt% loadings (40% LDPE / 60% salt) at a moderate screw speed of 50 rpm. The extruder was initially operated at a screw speed of 50 rpm with a feeder master controller recipe of 100% LDPE / 0% salt. When the recipe was changed to 40% LDPE / 60% salt, the PID controller "overshot" the desired waste loading and resulted in an excessive waste loading that exceeded maximum processing limits. The initial indication of this condition was the waste feeder control module. Several minutes later, the extruder output slowed and eventually stopped flowing. The pressure within the extruder caused the material to back up the vacuum port since there was no longer a pressure drop through the clogged extruder die. The problem was corrected by stopping the extruder and clearing the vacuum port, then restarting while feeding 100 % LDPE to the extruder. The extruder was then gradually brought back up to a screw speed of 50 rpm and the waste loading was gradually increased from 40 wt% to the desired 60 wt%. Processing then resumed without any other difficulties. The total "down time" from the start of the problem to the time it was corrected and the extruder was properly processing again was approximately 40 minutes. The TIRS monitor detected a waste loading of 85 wt% nitrate salt just prior to when the extruder stopped processing. Previous experience at BNL with nitrate salts has indicated a processing limitation of approximately 70 wt% salt. Above this maximum waste loading there is insufficient molten polyethylene to convey the solid waste material.

The operating plan for the Technology Demonstration on September 15, 1994 was modified due to the difficulty encountered on September 13. The extrusion parameters were maintained with the exception that the screw speed and waste loading were gradually increased from the start, and a final screw speed of 80 rpm was used. For this demonstration, processing ran smoothly. The approximate extruder output, with the extruder operating at a screw speed of 50 rpm, was 3.5 kg/min. At this rate, the extruder was able to produce a final waste form in a 208 liter (55 gal.) drum in 1 hour 20 minutes. At a screw speed of 80 rpm, the extruder output was approximately 5.4 kg/min and would fill a 208 liter (55 gal.) drum in 50 minutes. A 208 liter (55 gal.) final waste form containing 60 wt.% nitrate salts weighs 276 kg (608 lbs) and contains approximately 166 kg (365 lbs) of dried nitrate salt, assuming a 95% drum filling efficiency.

5.5 On-Line Infrared Monitoring

The TIRS on-line monitor operated effectively during both demonstrations while processing within the calibration range of the monitor. The spectra obtained by the monitor is dependent upon a number of operating parameters and variables such as the physical position or distance of the IR beam from the extrudate, the linear speed of the extrudate as it passes the IR beam (determined by the extruder screw speed), and the waste loading in the extrudate. The current TIRS monitor program requires that two of these parameters remain constant but is being developed to accept two or possibly all of these parameters as variables. For the demonstration, the monitor was calibrated in a fixed position at a constant screw speed of 50 rpm, and at waste loadings of 30,40,50 and 60 weight percent RFP Surrogate. The calibration curve which plots predicted waste loading versus actual waste loading, shown in Figure 5.4, is generated using a partial least squares (PLS) algorithm. The data for this plot is shown in Table 5.2. The mathematical method of a PLS algorithm is called a full cross-validation study. The predicted waste loading value for any one sample point is calculated based on the actual waste loading values of the 18 other data points. Accuracy of the prediction is reflected in the relatively high r-squared value of 0.994.

During the demonstration, the TIRS monitor provided real-time analysis of the product waste loading as it exited the extruder. These data were periodically checked by the operators and reported to those observing the demonstration. The waste loading values determined by the monitor closely matched the actual waste loading programmed in the feeder controllers while extruding at 50 rpm. Under normal operating conditions, the difference between the programmed waste loading and the values observed by the TIRS monitor did not exceed 2%. One notable exception occurred on September 13 when a waste feed overshoot condition caused a temporary shut down. As discussed in Section 5.4, the TIRS monitor recorded a waste loading of approximately 85 wt%, well above extrusion processing limitations.

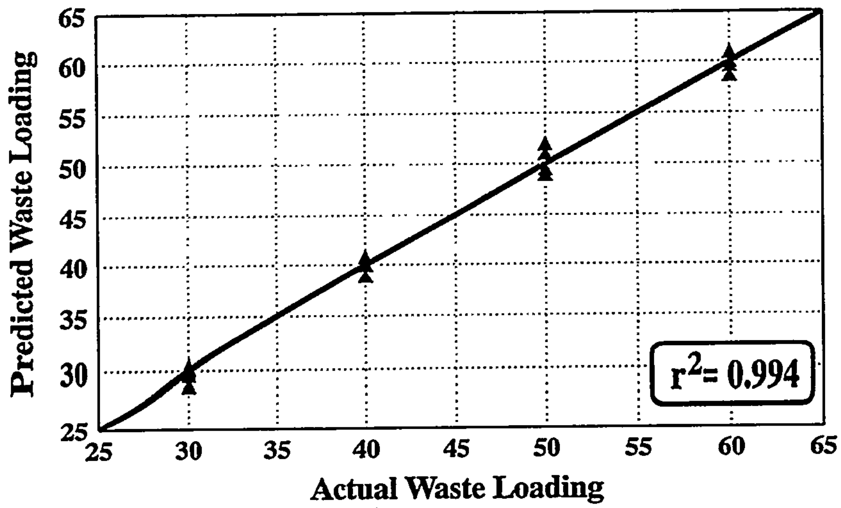

Figure 5.4 TIRS monitor calibration curve generated using PLS algorithm.

Table 5.2 Data generated by PLS algorithm for TIRS monitor calibration curve.

Sample	Actual waste loading	Predicted waste loading	Error (%)
1	50	52.026	-4.052
2	50	51.051	-2.102
3	50	49.498	1.004
4	50	49.031	1.939
5	50	48.978	2.045
6	60	58.676	2.206
7	60	60.017	-0.029
8	60	59.613	0.644
9	60	60.919	-1.531
10	40	38.910	2.724
11	40	40.760	-1.901
12	40	40.764	-1.910
13	40	40.089	-0.224
14	40	39.994	0.014
15	30	29.818	0.606
16	30	30.084	-0.279
17	30	30.392	-1.308
18	30	30.263	-0.876
19	30	28.985	3.383

6.0 WASTE FORM CHARACTERIZATION

6.1 Performance Testing

A 208 liter (55 gal.) waste form generated during the second technology demonstration and smaller approximately 19-57 liter (5-15 gal.) waste forms generated while performing process shake-down testing and calibrating the TIRS monitor were sectioned and samples removed for density/homogeneity analyses and compression testing. Compression testing was conducted according to ASTM D-695, " Standard Method of Test for Compressive Properties of Rigid Plastics [13]." Densities were determined using a Quantachrome Multipycnometer. The 208 liter waste form was halved with one side cut into seven layers. A 5.1cm x 5.1cm x 10.2 cm (2 in. x 2 in. x 4 in.) rectangular sample was cut from each layer for compression testing, and an irregularly shaped piece was removed for density measurements. The mean values for compressive strength and density for this waste form are shown in Table 6.1, and represent the values obtained for a waste form containing slightly less than 60 wt% RFP Surrogate. This waste form contains slightly less than 60wt% surrogate because, while processing on the second demonstration day, the waste loading was gradually increased from 40 wt% to 60 wt% in order to avoid feeding an excess of waste salt to the extruder. The purpose for following this operating procedure was explained in Section 5.4, Extrusion Processing and Parameters.

The smaller waste forms were produced at waste loadings of 30, 40 and 50 wt% surrogate. Similar samples were removed from these waste forms for compression and density testing. These results are also presented in Table 6.1. The densities increased from 1.10 g/cm^3 for 30 wt% surrogate to 1.30 g/cm^3 for the waste form containing approximately 60 wt% surrogate. These values are consistent with previous testing at BNL which determined a density of 1.36 for a 60 wt% surrogate waste form. The small errors in mean density for each waste loading indicate the high homogeneity of the final waste forms.

The mean compressive strengths for waste forms containing 30, 40, 50 and 60 wt% surrogate are plotted in Figure 6.1. The compressive strengths far exceed the 60 psi minimum waste form strength recommended by the NRC [10].

Table 6.1 Summary of full-scale waste form properties.

Waste loading (wt%)	Density (g/cm^3)	2σ Error	Compressive strength (psi)	2σ Error
30†	1.10	0.01	2300	80
40†	1.24	0.03	2420	140
50†	1.25	0.04	2380	120
60*	1.30	0.08	2150	50

† Values based on 3 replicates. * Values based on 7 replicates.

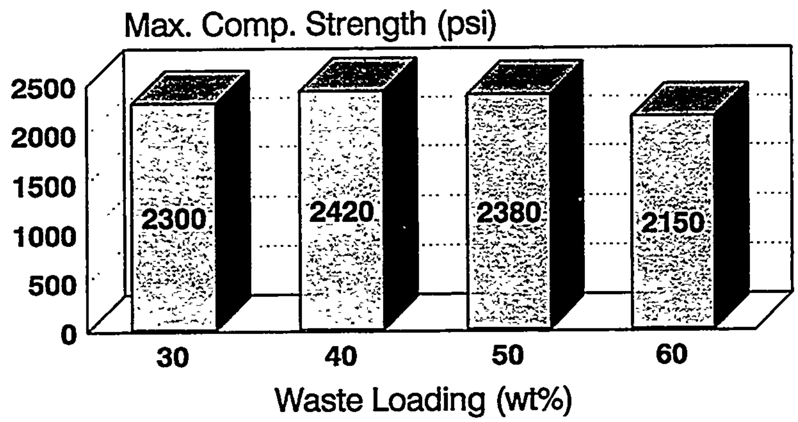

Figure 6.1 Compressive strength of samples from full-scale waste forms.

6.2 Final Waste Form Sectioning

Sectioning the large-scale waste forms revealed voids and/or cracks at the center of each waste form that varied depending on the overall size of the waste form. Both 208 liter waste forms, generated on the two demonstration days, contained an irregular shaped void approximately 5-8 cm (2-3 in.) in diameter and a large crack which propagated 20-31 cm (8-12 in.) in both directions from the void but did not reach the outer surface. The 208 liter waste forms also contained a larger, cylindrically-shaped, void directly below the upper surface of the waste form. These large voids were approximately 2.0 cm (0.75 in.) below the upper surface, 10.0 cm (4 in.) in height and 46.0 cm (18 in.) in diameter.

The smaller 19-57 liter (5-15 gal.) waste forms sometimes contained smaller center voids, compared to the 208 liter waste forms, and a number of small cracks which emanated from the voids in various directions. The cracks varied in size and length depending on the waste loading in the waste form. However, there was no discernable relationship between the number of cracks, their size and the waste loading. The smaller waste forms did not contain the large void under the upper surface.

Formation of voids and cracks are believed to be dependent on the heat transfer and cooling rates of the large waste forms. As the waste form cools, solidification first occurs on the top exposed (uncovered) surface followed by the sides and then gradually the interior of the waste form. A substantial period of time is required for the entire waste form to cool to ambient temperature due to the large thermal mass of full-scale waste forms. Heat conduction through the outer layers which have already solidified is slow and retards the cooling of the waste form interior. The outer dimensions of the final waste form are specified once an outer layer has solidified. However, the interior of the waste form which is still molten continues to shrink as it gradually cools (density increases). The large void beneath the upper surface is formed when the top of the waste form solidifies rapidly but the interior, which takes substantially longer to solidify, contracts away from the top solidified surface. The time lag between solidification of the top surface and the interior of the waste form results in the formation of a gap or void. Small voids or cracks that sometimes occur in the center of the waste forms are likely caused in a similar manner. The process of solidifying from the outside to the center can create tensile stresses in the waste form which manifest themselves as cracks.

Voids and cracks were not observed on bench-scale waste forms and are, therefore, related to process scale-up issues. Voids do not reflect flaws with fundamental thermoplastic encapsulation. Since the waste has been micro-encapsulated, interior voids and cracks do not pose a direct threat to the stability of a final waste form. However, cracks which have propagated to the outer surface increase the total surface area of the waste form and can create pathways for contaminant migration. The direct cause for void and crack formation has not been proven but an engineering solution may be developed to reduce or eliminate these difficulties. One possible solution is to fill a large waste form container to a limiting depth, e.g., 15 cm (6 in.), and allow the waste form to solidify before adding another layer. Smaller waste forms that were less than approximately 10-20 cm (4 - 8 in.) in height were observed to be void and crack free. A series of waste form containers can be rotated in this manner until they are filled. Another solution is to alter the final waste form geometry to facilitate rapid and more uniform cooling. Preliminary experiments at BNL with altered waste form geometries have been successful.

6.3 Waste Form Cooling

An experiment to model the cooling curve of a 208 liter (55 gal.) waste form was conducted following the second technology demonstration on September 15, 1994. Prior to the demonstration, a 208 liter (55 gal.) drum was modified by fixing three thermocouples within the drum to enable the temperatures to be recorded as the waste form cooled to ambient temperature. The thermocouples were placed down the centerline of the drum at different heights; one in the center, one located 2.5 cm (1 in.) above the bottom and one located 2.5 cm (1 in.) below the top fill line. This experiment was conducted in conjunction with a request from The Westinghouse Hanford Company (WHC) Waste Receiving and Processing (Wrap 2A) Facility. WHC was interested in comparing actual cooling data for a polyethylene waste form with computer generated theoretical cooling curves for a 4 foot cubic polyethylene waste form.

Thermocouple data were recorded using LabTech Notebook installed on a standard PC. Data acquisition was initiated immediately after the drum was filled. The resulting cooling curve that was generated is shown in Figure 6.2. It can be seen that a total of nearly 140 hours were required for the entire waste form to reach ambient temperature. The data from zero to .65 hours was accidentally overwritten by the data acquisition program while writing the data to a floppy disk drive. The fault was detected and all data following the 65 hour mark was successfully retrieved.

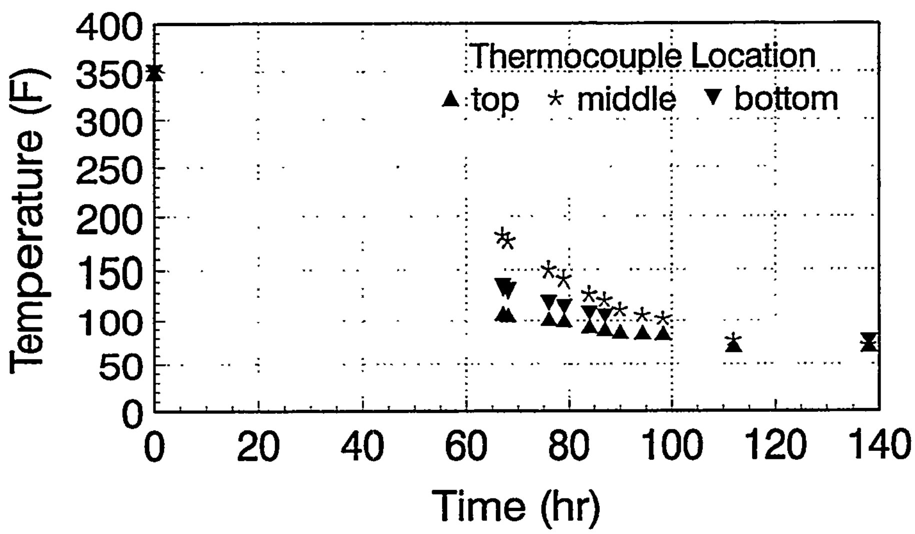

Figure 6.2 **Cooling curve for 208 liter waste form containing 60wt.% RFP surrogate / 40wt.% LDPE.**

7.0 SUMMARY & CONCLUSIONS

The BNL polyethylene encapsulation process has developed from proof-of-principle through bench-scale testing to production scale technology demonstration. The full-scale system at BNL's Environmental & Waste Technology Center complements a fully-equipped process development and testing facility for investigating encapsulation technologies for various waste steams. The Polyethylene Encapsulation Full-Scale Technology Demonstration was conducted using a simulated nitrate salt waste that closely resembled actual waste from a DOE facility in both chemical and physical composition. Successful integration of waste pre-treatment, material handling, feed metering, extrusion processing, on-line monitoring, and process control during the production-scale demonstration provided confirmation of process viability.

Several problems were encountered and remedied prior to, during, and following the demonstration activity. These difficulties and steps taken to solve them are summarized below:

- During pre-treatment, two ribbon blade support shafts fractured due to high shear of the dried salt. Additional bracing was added which provided sufficient support of the ribbon blade. All additional drying runs were completed without incident. Follow-up inspection of the shaft conducted by the manufacturer revealed no further damage.

- During the initial drying run, salt was discharged prematurely, prior to achieving complete dryness. This resulted in plugging of the comminution screen with wet salt, requiring disassembly and cleaning of the comminutor. This was remedied by replacing the original 1.6 mm (1/16 in.) comminution screen that became clogged with a 3.2 mm (1/8 in.) screen. The shaft rotation was reversed to provide a more blunt cutting action of the blades. A salt sample was also removed from the dryer on all following drying runs, and a moisture analysis was conducted to determine the moisture content. This ensured that the salt was completely dry before discharging to the comminutor. No further difficulties were experienced after these modifications.

- During the extrusion run on September 13, a waste feeder overshoot condition was experienced when the operators switched from processing 0 wt% waste to 60 wt% waste at an operating speed of 50 rpm. In attempting to reach the desired set point the PID controlled loss-in-weight feeders supplied an excess quantity of dried salt which then formed a solid plug that was difficult to extrude. Switching back to 100 wt% polyethylene allowed the operators to void the plug and resume normal processing. No equipment disassembly was required and the system was cleared and operating again within 40 minutes. Modification of the operating procedure to gradually raise the waste feeder set point alleviated any further feeder problems.

- Voids were observed in several large-scale waste forms produced during the demonstration. These difficulties were all related to process scale-up issues and do not reflect fundamental flaws with thermoplastic encapsulation. Further testing is required to elucidate the mechanism involved with void formation. Additional testing should primarily focus on the areas of temperature and heat transfer of the final waste form, however, physical changes may also be investigated. These may include: (1) attempting to control the rate of cooling of the waste form, (2) altering the extrusion parameters, e.g., die temperature, (3) changing the extruder die configuration, and (4) changing the geometry of the final waste form. Preliminary engineering solutions to this problem have been successful.

Future work on the polyethylene encapsulation process will include treatability studies to examine applicability to new waste streams. BNL is also working with industrial partners and DOE waste generators to field test the process using actual waste and ensure technology transfer to industry and DOE customers.

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APPENDIX 1: Attendee list to BNL Polyethylene Encapsulation Full-Scale Technology Demonstration.

Attendees for Tuesday, September 13 and Thursday, September 15, 1994
"" denotes attendance both Tuesday and Thursday*

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APPENDIX 2: Agenda for BNL Polyethylene Encapsulation Full-Scale Technology Demonstration.

POLYETHYLENE ENCAPSULATION FULL-SCALE TECHNOLOGY DEMONSTRATION

Environmental & Waste Technology Center
Department of Advanced Technology
Brookhaven National Laboratory

September 13, 15, 1994

AGENDA

Hamilton Seminar Room, Chemistry Building:

9:00 a.m.	Coffee and Registration	
9:30 a.m.	Introduction	P. Kalb (BNL Environmental & Waste Technology Center)
9:35 a.m.	Waste Management & Environmental Restoration Activities at BNL	M. Butler (DOE Area Office)
9:45 a.m.	Department of Advanced Technology (DAT) Overview	R. Duffey (BNL DAT)
9:55 a.m.	BNL Overview and Technology Transfer Programs	D. Langiulli (BNL Office of Technology Transfer)
10:05 a.m.	DOE Office of Technology Development Programs	A. Johnson (DOE EM-542)
10:15 a.m.	Technology Application to Federal Facilities Compliance Act	C. Polanish (DOE Area Office)
10:25 a.m.	15 minute break	
10:40 a.m.	Overview of the Polyethylene Encapsulation Technology Demonstration	P. Kalb (BNL Environmental & Waste Technology Center)
11:30 a.m.	Vectra RVR Pre-treatment System	M. Hill (VECTRA Technologies)

Full-Scale Technology Demonstration Facility, *Environmental & Waste Technology Center:*

11:45 a.m.	TIRS On-Line Monitor for Quality Assurance/Quality Control	S. Wright (Ames Laboratory)
12:00 p.m.	Lunch	
1:15 p.m.	Assemble in front of Cafeteria (Berkner Hall) for bus ride to the Environmental & Waste Technology Center (E&WTC)	
1:30 p.m.	Tour of E&WTC	P. Kalb (BNL E&WTC)
1:35 p.m.	Equipment Inspection	
2:00 p.m.	Process Demonstration	
3:00-4:30 p.m.	Bus departure to parking lot of Berkner Hall	