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THE GENERAL ATOMIC REPROCESSING PILOT PLANT: DESCRIPTION AND RESULTS OF INITIAL TESTING

by
PROJECT STAFF

MASTER

Prepared under
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GENERAL ATOMIC COMPANY

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ABSTRACT

In June 1976 General Atomic completed the construction of a reprocessing head-end cold pilot plant. In the year since then, each system within the head end has been used for experiments which have qualified the designs. This report describes the equipment in the plant and summarizes the results of the initial phase of reprocessing testing.

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1. INTRODUCTION

The fuel for a high-temperature gas-cooled reactor (HTGR) consists of small coated particles embedded in fuel elements made from graphite, which acts as a neutron moderator (Fig. 1). The reactor utilizes thorium by converting it to U-233. Thorium can be incorporated into the fuel in a number of ways. To optimize the thorium-uranium fuel cycle, a system of separate fuel particles has evolved (Ref. 1). The two types of particles used are characterized by the coatings applied to them (Fig. 2): BISO particles are coated with a relatively porous buffer layer of carbon and then with a dense coating of pyrolytic carbon; TRISO coatings have a silicon carbide (SiC) coating placed between two layers of pyrolytic carbon. The SiC layer provides a means of separating the TRISO particles from the BISO particles in head-end reprocessing operations, and it enhances fission product retention in the fissile particles. BISO coatings are used for particles which are initially loaded only with thorium oxide; TRISO coatings are used for particles loaded with uranium. After irradiation, the BISO fertile particles contain quantities of U-233. Separation of the fertile particles from the fissile TRISO particles and subsequent recovery of the bred U-233 for use in refabricated fuel is an indispensable part of the recycle of HTGR fuel. The development and demonstration of this recycle technology is the goal of the Department of Energy (DOE) funded National HTGR Fuel Recycle Development Program.

In June 1976 General Atomic (GA) completed the construction of a cold engineering-scale head-end pilot plant (Fig. 3). The purpose of the plant is to demonstrate the feasibility of the technology on an acceptable scale. In the coming years, it will evolve into a cold prototype. In the year since its completion, each system within the head-end pilot plant has been used for design verification experiments (or qualification testing).

Fig. 1. HTGR fuel element

Fig. 2. HTGR coated fuel particles

Fig. 3. Plant arrangement

This report describes the equipment in the pilot plant and summarizes the results of qualification testing. The information given is a compilation of results published in Refs. 2 through 12. Appendix A gives the process flow diagrams and piping and instrumentation drawings, and Appendix B, the major assembly drawings.

2. HEAD-END REPROCESSING FLOW SHEET

The purpose of the dry head end of the reprocessing flow sheet is to prepare fuel particles for dissolution and solvent extraction. It comprises fuel element size reduction, crushed fuel element burning, particle classification, particle crushing, and crushed particle burning (Ref. 1). Unit operations are connected by the solids handling system (Fig. 4).

Fuel elements are reduced to $\sim 4760 \mu\text{m}$ in a series of crushers (two overhead eccentric jaw crushers and one double-roll crusher) which are mounted in one frame; this system is designated the UNIFRAME. After screening, the crushed material is pneumatically conveyed to a product bunker and then to the feed bunker of the fluidized-bed crushed fuel element burner (or primary burner). The primary burner fluidizes crushed fuel elements with carbon dioxide and heats the initial charge with an induction heater. Oxygen is introduced to begin combustion, and cooling gas removes the heat of combustion through the burner wall. The fluidized bed temperature is maintained at around 900°C . Fine particles are entrained by the fluidized gas and recycled to the bed after separation from the gas; fresh feed is continuously added to the burner. The graphite and outer carbon coatings are burned off, and the product is conveyed to the primary burner product bunker. The burner operates on a semicontinuous basis, i.e., only a part of the bed is dumped at any one time, until the end of an operating campaign. If the product is within specification, it is transferred to the pneumatic classifier feed bunker; if it contains excess carbon or graphite, it can be recycled to the primary burner feed bunker. The burned-back fuel particles are fed into a moving air stream within a zigzag classification column.

The light TRISO fissile particles are carried out of the top of the classifier, and the dense BISO particles, which are massive ThO_2 , fall out

FUEL ELEMENT SIZE
REDUCTION SYSTEM

PRIMARY BURNER

PNEUMATIC
CLASSIFICATION

SECONDARY
BURNER

PARTICLE
CRUSHER

Fig. 4. Cold head-end layout

of the bottom, ready for dissolution and solvent extraction. In the event of unsatisfactory separation, particles from either or both classifier product bunkers can be recycled for reclassification.

The burned-back TRISO particles still contain inner carbon coatings which must be burned. They are conveyed to a particle crusher (where they are crushed), and the crushed particles are fed to the fluidized-bed crushed particle burner (or secondary burner), which combusts carbon and converts heavy metal carbides to oxides. The batch of feed is fluidized with carbon dioxide and induction heated prior to the introduction of oxygen. Product from the secondary burner is pneumatically transported to the secondary burner product bunker. The economics of fuel reprocessing require an optimal separation of fissile and fertile particles, since there are penalties associated with crossover from fissile to fertile and vice versa. The pilot plant is expected to be able to process fuel of the type used in the Fort St. Vrain (FSV) HTGR reactor. The fissile and fertile particles have TRISO coatings, so after particle classification, both fractions are separately crushed and burned.

3. FUEL ELEMENT SIZE REDUCTION

3.1. EQUIPMENT DESCRIPTION

The UNIFRAME fuel element size reduction system (Figs. 5 through 8) comprises a number of large components:

1. Primary crusher.
2. Secondary crusher.
3. Tertiary crusher.
4. Oversize monitoring system.
5. Ventilation enclosure.
6. Drive system.
7. Structural machine frame.
8. Remote fixtures.

These components are described below.

3.1.1. Primary Crusher

The primary crusher is an overhead eccentric jaw crusher which consists of two major assemblies: the pitman and the stationary jaw. The fuel elements are crushed between the wear plates to <0.15-m ring-size fragments by a motion induced by a rotating eccentric shaft and the toggle assembly (Fig. 9). The toggle assembly has vertical members to facilitate proper ventilation and assure minimal material holdup. Figure 10 shows the crushing cavity. The large adjusting screws shown in Fig. 11 are used to adjust the angle of the stationary jaw.

Fig. 5. UNIFRAME size reduction system (less drives and enclosures)

35-135-192-27

Fig. 6. UNIFRAME size reduction system (less drives and oversize monitor)

Fig. 7. UNIFRAME size reduction system with ventilation enclosure partially removed

Fig. 8. UNIFRAME size reduction system

Fig. 9. Primary crusher (enclosures open)

35-135-192-37

Fig. 10. Primary crusher (overhead view)

35-135-192-10

Fig. 11. Primary crusher showing stationary jaw adjusting screws

35-135-192-11

Fig. 12. Secondary crusher (enclosures removed)

3.1.2. Secondary Crusher

The secondary crusher is also an overhead eccentric jaw crusher (Fig. 12). The primary crusher product discharges into the secondary crushing cavity and is further reduced to $<0.05\text{-m}$ fragments by crushing between the wear plates. Side cheek plates are attached to the machine frame. The crushed product discharges under gravity to the tertiary crusher for the final size reduction stage. Figure 12 shows only the secondary pitman and the toggles, since the secondary stationary jaw is located deep within the machine frame. The secondary crusher toggle assembly is identical to that of the primary crusher, and both are secured to the machine frame by two locking bolts and nuts, such as those shown in Fig. 12.

3.1.3. Tertiary Crusher

The tertiary crusher, shown in Fig. 13, is a double-roll crusher which consists of two major assemblies: the double-roll assembly and a structural support frame. The secondary crusher product discharges into the tertiary crusher and is reduced to $\leq 4760\text{-}\mu\text{m}$ ring-size material by crushing between the rotating roll surfaces. The tertiary crusher product discharges into the oversize monitoring system. Figure 14 shows the two rolls and the crushing cavity of the tertiary crusher located beneath the stationary jaw of the secondary crusher; Fig. 15 shows the tertiary crusher from the drive side. Material is discharged from the tertiary rolls in a long, narrow band which, for maximum screener efficiency, must be redirected and concentrated into a centered position above the screener. This is accomplished by the tertiary side chutes (Fig. 16), which are stepped and louvered to permit ventilation.

3.1.4. Oversize Monitoring System

The oversize monitoring system consists of a screener and an oversize crusher. This system forms a process safeguard which prevents oversize

35-135-192-18

Fig. 13. Tertiary crusher (end cover removed)

35-135-192-21

Fig. 14. Tertiary crusher (looking into tertiary crusher cavity)

35-135-196-10

Fig. 15. Tertiary crusher (drive side)

35-135-192-23

Fig. 16. Tertiary roll discharge (view looking up into rolls)

product from leaving the UNIFRAME system. Oversize product is separated by the vibratory screener and further reduced, if necessary, to an acceptable size by the oversize crusher. The outer housing of the screener forms a part of the UNIFRAME ventilation system and is a feed hopper to the pneumatic transport system. The screen itself is a perforated plate. Figure 17 shows the assembled vibratory screener. The screener can be isolated from the rest of the UNIFRAME by a crusher shroud shutoff valve (Fig. 18) which allows the screener to be removed without spillage.

3.1.5. Ventilation Enclosure

The ventilation system ensures that all product materials are contained within the UNIFRAME system. All components are enclosed to minimize material holdup and confine airborne products. Horizontal surfaces have been minimized, and areas which could contribute to material holdup have been eliminated, reduced, or shrouded. A schematic view of the ventilation enclosure is shown in Fig. 19.

3.1.6. Drive System

The primary, secondary, and tertiary crushers are motor-driven by gear reducers and rubber belts from a common motor framework which is isolated from the UNIFRAME structure. The oversize crusher drive is fixed to its separate base, and the screener drive is an integral part of the screener configuration. Each processing component has an independent drive system with separate controls (Fig. 7).

3.1.7. Structural Machine Frame

The machine frame is a structural machined weldment designed to support the UNIFRAME components, to position the components with respect to each other, and to confine the size reduction process within the frame. The four supporting columns are rigidly fixed to and mounted on an isolated concrete foundation.

35-135-196-7

Fig. 17. Vibratory screener separator

Fig. 18. Crusher shroud shutoff valve

Fig. 19. UNIFRAME ventilation enclosure

3.1.8. Remote Fixtures

A number of lift fixtures are available to demonstrate the remote features of the UNIFRAME (Figs. 20 through 25).

3.2. TEST RESULTS

3.2.1. Primary Crusher

The tests on the primary crusher led to the selection of a 0.05-m close side setting (CSS) (minimum gap at the bottom of the jaws) and a 14-deg nip angle (angle included by the two jaws). The 0.05-m CSS produced feed small enough for the secondary crusher, and the 14-deg nip angle combined a high probability for complete crushing with an acceptable crusher gape (feed opening). To permit adjustments of the primary crusher to a minimum nip angle of 13 deg, the height of the stationary jaw cheek plate assemblies had to be modified. In addition, a fuel element entry chute was fabricated and installed above the primary crusher; Fig. 26 shows the primary stationary jaw and the entry chute mounted in the maintenance fixture. To reduce the tendency of fuel element fragments to wedge or bridge between the side plates, a design change was incorporated which put chamfers on the top interior edges of the guide plates, clamp plate, and side plate (Fig. 27).

3.2.2. Secondary Crusher

In general, secondary crushing was accomplished without major problems. In some runs, however, fuel element fragments formed bridges by interlocking the fracture planes between the coolant and the fuel holes (Fig. 28). The crushing cavity was modified as shown in Fig. 29, and the problem was eliminated.

35-135-191-18

Fig. 20. Lift fixture adaptor for handling primary fixed jaw

Fig. 21. Lift fixture for primary pitman assembly

35-135-191-7

Fig. 22. Typical load test arrangement for pitman lift fixture

35-135-200-11A

Fig. 23. Lift fixture and primary fixed jaw

35-135-200-2A

Fig. 24. Lift fixture and primary pitman assembly

35-135-200-6A

Fig. 25. Lift fixture and secondary pitman assembly

Fig. 26. Primary crusher stationary jaw showing modifications and entry chute

Fig. 27. Primary pitman assembly showing chamfered side plates

Fig. 28. Formation of bridges in fuel element fragments: (top) bridged fragments in test SC-15 and (bottom) typical interlocking to form bridges

Fig. 29. Secondary crusher modification showing deeper crushing cavity and 14-deg nip angle

3.2.3. Tertiary Crusher

Tests on the tertiary crusher revealed no operating problems. In all the tests, the material was crushed at rates equal to or greater than the discharge rates of the secondary crusher. The quantity of oversize product (+4750- μ m mesh size) was well within the <5% specified in the design.

3.2.4. Oversize Monitoring System

The oversize crusher was operated with a throughput of ~ 10 wt % (i.e., 11.3 kg) of one fuel element. The process time for this quantity was well below the UNIFRAME system 15-min maximum allowable time. Material holdup was in excess of the required <0.5% in one of the tests, and design modifications are planned to reduce the holdup to an acceptable value. Screener tests revealed excessive blinding of the perforated plate by lodged graphite particles. The perforated plate was replaced with a 4750- μ m wire mesh screen, and blinding of the screen was greatly reduced; however, a gradual buildup in blinding occurred, requiring the addition of a screener self-cleaning device (Figs. 30, 31).

3.2.5. UNIFRAME System Tests

The UNIFRAME system tests revealed no significant operating problems with any of the equipment, including the modified secondary crusher. Material balances were within the specification of <0.5% material unaccounted for (MUF). Material holdup was reasonable, and with minor modifications can be further reduced. Process times were well within the 15-min allotted time period. However, the screener and oversize crusher operated for the full 15 min to reduce residual material on the screen surface. Material was preferentially discharged into the pneumatic transport system from the equipment item closest to the product collection hopper. This condition was corrected by intermittent operation of the oversize crusher, and a discharge valve was installed as a second corrective measure. Screener

Fig. 30. Screener showing 4750- μ m wire mesh screen installed

Fig. 31. Screener with self-cleaning kit installed (screen removed)

blinding continued to increase slowly throughout the tests, indicating the eventual need for a maintenance plan or alternative for correcting this undesirable condition. The UNIFRAME product met the primary burner feed size distribution specification.

4. CRUSHED FUEL ELEMENT BURNING

4.1. EQUIPMENT DESCRIPTION

The crushed fuel element burner, or primary burner, assembly (Fig. 32) comprises the burner vessel itself, heating, cooling, insulation, a gas distributor, and an assembly from which the vessel hangs. The off-gas passes through a cyclone/filter combination, and the small particulates (or fines) separated from the gas are reinjected into the burner from two pressurized fines hoppers. Feed is metered to the burner by a rotary valve, and product leaves through a vertex line into a pneumatic transport system.

4.1.1. Burner Vessel

The primary burner vessel is a 0.40-m-diameter, 5-m-high cylinder. To enhance the heat transfer between the vessel wall and the cooling air which flows through an annular space along the length of the vessel, pin fins are welded to the outside of the wall over a height of 1.8 m. The welding on the pins is shown in Figs. 33 through 35. The burner vessel is installed by lowering it into the heating section (Fig. 36).

4.1.2. Heating System

The bed is heated by an induction heater whose power source is a motor generator set (Fig. 37). Current flows through a water-cooled copper coil which "suscepts" on a thin metal tube, which is also the outer boundary of the lower section of the cooling gas annular passage. The susceptor tube radiates heat to the burner vessel wall. The induction coil, shown with some other components in Fig. 38, has two zones, allowing heating of both deep and shallow beds. The assembly of the heater section is shown in Fig. 39.

1. BURNER ASSEMBLY	4. UPPER INTAKE SHROUD ASSEMBLY
2. BURNER VESSEL ASSEMBLY	5. HEATER ASSEMBLY
3. INSULATION BONNET ASSEMBLY	6. KNIFE GATE ASSEMBLY

Fig. 32. Prototype primary burner assembly

Fig. 33. Pin welder and holding fixture for primary burner

Fig. 34. Cooling pin welding in progress for primary burner

Fig. 35. Finished pin sample for primary burner

(a)

Fig. 36. Sequence of 0.4-m primary burner installation: (a) heater section is connected to upper cooling jacket by means of heater and shroud transfer rails

35-135-189-3

(b)

(c)

Fig. 36. Sequence of 0.4-m primary burner installation: (b) 0.4-m primary burner vessel is unloaded from shipping cradle to tilt-down fixture, where vessel can be rotated for thermocouple and insulation installation, (c) finned section of 0.4-m primary burner containing 21,600 pins in a 2-m length of the vessel

35-135-189-8 (d)

35-135-189-12 (e)

Fig. 36. Sequence of 0.4-m primary burner installation: (d) 0.4-m primary burner tube on remote handling fixture, (e) erected vertical on tilt-down fixture, the 0.4-m primary burner is ready for transfer to burner platform

35-135-191-9 (f)

35-135-191-26 (g)

Fig. 36. Sequence of 0.4-m primary burner installation: (f) with upper cooling jacket doors swung open, burner vessel is being inserted through heater section, (g) completed 0.4-m primary burner vessel installation

Fig. 37. Induction heater installation for prototype burners

(a) Heater base plate

(b) Two-zone induction heating coil

(c) Susceptor

Fig. 38. Components of heater assembly

HOLDING FIXTURE
WITH CERAMIC

TRUNNION
FIXTURE

- (a) Ceramic insulation is picked up with holding fixture and transferred to trunnion fixture

- (b) Fixture is rotated so that ceramic insulation is bottom-side up

Fig. 39. Sequence for assembly of 0.4-m primary burner heater section

- (c) Susceptor is inserted into ceramic insulation with susceptor lifting force

- (d) Susceptor-ceramic assembly is rotated so that it is right-side up

Fig. 39. Sequence for assembly of 0.4-m primary burner heater section

(e) Ceramic-susceptor assembly is picked up by susceptor flange with lifting fixture

(f) Susceptor-ceramic assembly is positioned on lower intake plenum

Fig. 39. Sequence for assembly of 0.4-m primary burner heater section

(g) Induction coil is slipped over ceramic insulation

(h) Completed primary burner heater assembly

Fig. 39. Sequence for assembly of 0.4-m primary burner heater section

4.1.3. Cooling System

Cooling air compressed by a rotary blower (Fig. 40) passes into the burner assembly via two intake plenum assemblies and leaves via one central exhaust plenum. The amount of air passing through the upper and lower cooling jackets can be independently controlled. The major components of the cooling system are shown in Figs. 41 through 43.

4.1.4. Burner Top

The top assembly of the burner is held by a swing bolt clamp (Fig. 44). The top cap has penetrations for a feed inlet, gas outlet, and thermowell (Fig. 45).

4.1.5. Plenum

The burner plenum is a perforated cone with a 0.025-m vertex. The plenum is held in place by a remote clamp (Fig. 46) which has its own electric resistance heaters located as shown in Fig. 47. The clamp heaters prevent excess temperature gradients across the remote clamp. The plenum can be removed using a plenum cart (Fig. 48).

4.1.6. Fines Recycle System

Fines leaving the cyclone and the filter fall down a combined line into two pressurized hoppers (Fig. 49). While one hopper is filling, the other is either pressurizing or transporting fines back to the burner. A detailed assembly drawing of the primary burner is given in Fig. 50, and a general view of the upper part of the burner system is given in Fig. 51.

4.1.7. Instrumentation

The control room instrumentation is shown in Fig. 52. Burner operation draws extensively on the capabilities of a process control computer,

INTAKE
FILTER

POWER SUPPLY
AND CONTROL
PANEL

Fig. 40. Cooling air blower installation in blower vault for prototype burners

Fig. 41. Upper cooling jacket assembly

Fig. 42. Exhaust plenum assembly, insulation bonnet assembly, and lower shroud assembly

Fig. 43. Lower intake plenum

35-135-191-24

Fig. 44. Swing bolt clamp installation

35-135-196-12

Fig. 45. 0.4-m burner top cap assembly and cross connection elbow

76G1531

Fig. 46. Primary burner plenum and remote clamp

Fig. 47. Remote clamp heater location

Fig. 48. Plenum carts for 0.4-m primary burner

35-135-194-15

Fig. 49. Primary burner fines recycle system

ALL DIMENSIONS IN INCHES

Fig. 50. Primary burner assembly

Fig. 51. Primary burner system for the HTGR reprocessing cold pilot plant

Fig. 52. Burner control room instrumentation

DIOGENES[®] (Fig. 53). The DIOGENES[®] system is a hard-wired real-time dedicated process controller. Each control loop accepts a 4-20 milliamp dc analog signal from the process and provides a continuous 4-20 milliamp dc analog output signal back to the process. The analog (A) input signals are converted to digital (D) form for interfacing with the computer-based central controller, and the digital feedback instructions from the central controller are reconverted to analog output signals. The A/D and D/A conversion is performed by process interface modules (PIMs); one PIM is required for each DIOGENES[®] channel which has an analog input and/or an analog output.

The configuration of the control loops is set up by the operator beforehand with pins and wire links on a functionally diagrammed diode pinboard called the channel function matrix (CFM). All loops may be digitally controlled by the central controller using an automatic one-second scan arrangement. This is the normal mode of operation, or the "central" control mode. A variation of this mode is the "central manual" mode, which allows a loop to be manually controlled through the operator's console. In addition, there is a completely separate and independent analog "backup" control mode, which is effective even if the central controller breaks down. The major control functions are given in Table 1.

4.1.8. Operating Cycle

The steps in the operating cycle are shown in Table 2, and variations in key parameters during an operating cycle are shown in Fig. 54.

4.2. TEST RESULTS

4.2.1. Heat-Up Tests

Removal of the outer induction shroud corrected a problem of excessive magnetic susception and heat loss, and the 0.4-m primary burner was then successfully operated in six heat-up tests. The shroud can be replaced,

Fig. 53. DIOGENES[®] digital process controller for the HTGR reprocessing cold pilot plant

TABLE 1
PRIMARY BURNER MAJOR CONTROL FUNCTIONS

Function	Method of Control	Type of Sensor	Control Criterion
Fluidized-bed heating	Induction heater cascaded to bed/vessel/susceptor temperature	Type K (Chromel-P/Alumel) thermocouples	Fresh feed or particle beds must be heated to ignition temperatures (700°C) in ≤ 2 hr The clamp to hub ΔT must be $< 112^\circ\text{C}$ for vessel flanges
Postignition bed temperature control	Adjustment of oxygen flow	Type K thermocouples	Control temperatures must be controlled within $\pm 10^\circ\text{C}$ of set points ($\sim \pm 1\%$)
Oxygen flow	Equal percentage control valve	Precision gas flowmeter (SWIRLMETER [®])	Flow must be within $\pm 3\%$ of set point
Fluidizing gas (CO ₂) flow	Equal percentage control valve: adjustment of CO ₂ flow set point based on bed temperature to maintain a constant total gas flow velocity	Precision gas flowmeter (SWIRLMETER [®])	Flow must be within $\pm 3\%$ of set point
Vessel cooling	Adjustment of cooling air flow and maintenance of proper cooling air blower discharge pressure	Type K thermocouples; flow averaging (ANNUBAR [®]) Pitot tubes	Full bed must be maintained at 900°C while burning at 800 g carbon per min Air flow must be within $\pm 3\%$ of set point Temperatures must be maintained within $\pm 10\%$ of set point ($\sim \pm 1\%$)

TABLE 2
PRIMARY BURNER OPERATION

First Campaign Start-Up

1. Turn on power
2. Establish CO₂ flows
3. Load burner with initial bed
4. Open O₂ isolation valves
5. Turn on induction heater

First and Intercampaign

1. Initiate O₂ flow to plenum
2. Reduce CO₂ flow to plenum
3. Turn off induction heater
4. Start flow of cooling air
5. Initiate O₂ flow to vertex
6. Reduce CO₂ flow to vertex
7. Start fines recycle (as appropriate)
8. Adjust cooling air flow
9. Start fresh feed on demand
10. Stop fresh feed on demand
11. Stop fines recycle at high above-bed temperature
12. Reduce cooling air flow
13. Reduce O₂ flow at high off-gas concentration
14. Increase CO₂ flows
15. Dump bed to low level
16. Re-establish bed with fresh feed^(a)

Final Tail Burn

1. Stop fresh feed by load cell system
2. Reduce O₂ flows
3. Increase CO₂ flows
4. Increase cooling air flow
5. Shut off O₂ at high off-gas concentration
6. Increase CO₂ flows to shutdown level
7. Dump entire bed

^(a) When step 16 is finished, begin again with step 1.

Fig. 54. 0.4-m primary burner operating cycle with feed to the top of the first coil

if required, for remote maintenance or decontamination if a copper shroud is used as a magnetic shield inside the stainless shroud.

In three of the heat-up tests, heating to the 700°C autoignition temperature was studied, with the single lower induction coil being used to heat beds of crushed graphite, TRISO coated fertile fuel particles, and mixed graphite (83%) and fuel particles (17%) simulating fresh feed. Two additional heat-up tests involved the use of the lower and upper coils to heat beds of particles and simulated fresh feed to 700°C. In the sixth heat-up test, the upper and lower coils were used to heat a fuel particle bed to three temperatures: 200°, 400°, and 700°C. Portions of the bed were removed at each temperature to study the effects of the discharge material temperature on product removal and transport. These runs completed the first series of tests on the 0.4-m primary burner.

The 2-hr maximum heat-up time required by the acceptance criterion for induction heating of the 0.4-m vessel can easily be met if no interruptions occur. The average time required in the three uninterrupted bed heat-ups was 1 hr, 23 min. Similar heat-up times resulted from the use of either the single lower coil or both the upper and lower coils. However, the larger bed required for the use of both coils brought about (1) carry-over of excessive amounts of fuel particles during fuel particle bed heat-up and (2) nonisothermal bed temperatures during the initial portion of the fresh feed bed heat-up, indicating that use of the single lower coil is preferable for heat-up.

4.2.2. Initial Combustion Test

During the initial combustion tests, the overall 0.4-m burner system response to low carbon combustion with pressurized vertex fines recycle was studied. A low carbon bed consisting of 85 wt % carbon coated FSV TRISO fertile particles and 15 wt % graphite ($\leq 4760 \mu\text{m}$) was the start-up bed; additional coated particles were fed during combustion to maintain sufficient bed height for induction-heated tail burning. The dual, parallel, pressurized hopper system was successfully used to recycle fines to the

vertex during the combustion and tail burning phases of operation. The fines system operated without problems, and the 0.4-m burner lower bed temperature was stable in response to the intermittent vertex fines flow. The fines recycle subsystem instrumentation and bed temperature response indicated uninterrupted material flow. The bed temperature fluctuated $\pm 10^{\circ}\text{C}$.

The burner mechanical system required modification in two areas: (1) the horizontal deflection of the burner was unacceptable, and stiffer alignment devices were installed; (2) "breathing" of the unstiffened surface of the filter chamber caused surface deformations, so stiffening strips were welded onto the sides of the filter chamber.

4.2.3. Initial Normal Operation With Vertex Fines Recycle

The purpose of this run was to verify the ability of the fines system to cope with the net fines accumulation (i.e., fines generated minus fines burned) during the initial, high bed carbon content phase of the operating cycle. A midreactor oxygen system was installed prior to the run. The burner was started up and fed with typical ratios of BISO/TRISO fuel particles and crushed graphite (similar to the loadings of HTGR fuel elements). Feeding continued until the equivalent of eight fuel elements had been added. This yielded a bed with about 26 wt % carbon, at which point the inventory of fines should have reached a maximum. The bed was burned out without induction heating, since it was too small to remove heat from the entire zone heated by the lower induction coil. Level sensors installed in the fines recycle system showed that the fines inventory was within the capacity of the system at all times. The system operated steadily, with the maximum burn rate being reached, and even exceeded, for substantial portions of the run.

5. PARTICLE CLASSIFICATION, CRUSHING, AND CRUSHED PARTICLE BURNING

5.1. PARTICLE CLASSIFICATION

5.1.1. Equipment Description

The differences in density and/or size of fissile and fertile fuel particles were utilized to separate them in a moving gas stream. A zigzag classifier column (Fig. 55) provided an opportunity for gas and particles to mix. The fissile particles were carried over and separated from the classifying gas in a cyclone (Fig. 56), and the classifying gas went to a classifier filter bunker where any fine particulates were separated by sintered metal filters (Fig. 57). The classifier blower had a variable-speed motor controlled by the DIOGENES[®] process control computer (Section 4.1), and the input to the computer came from a rotameter (Fig. 58) which measured the flow rate of air entering the classifier column. Figure 58 also shows the pipe through which the fertile particles fell. The classified particles were collected in two bunkers from which the fissile or fertile streams could go on to the next stage or be recycled to the classifier feed bunker if classification were not satisfactory.

5.1.2. Test Results

5.1.2.1. Component Testing. Component testing comprised loading the sintered metal filters in the filter bunker, calibrating the rotameter together with testing the response of the automatic control, calibrating the load cells of the product bunkers, and demonstrating the pneumatic transport recycle from either or both product bunkers to the classifier feed bunker [the classifier feeder is in the solids handling system (Section 6)].

OVERHEAD LINE
(FISSILE STREAM
PLUS CLASSIFYING
GAS)

ZIGZAG
CLASSIFIER
COLUMN

CLASSIFIER
FEED
BUNKER

CLASSIFIER
FEEDER

35-135-207-11

Fig. 55. Top part of particle classifier assembly

35-135-207-10

Fig. 56. Classifier cyclone

35-135-207-9

Fig. 57. Classifier filter bunker (for removing fine particulates from classifying gas)

Fig. 58. Lower part of particle classifier assembly

5.1.2.2. BISO/TRISO Fuel Particle Classification. Mixtures of BISO/TRISO fuel particles were classified as follows: (1) composition (6.2 to 63 wt % TRISO), (2) total feed rate (0.85 to 1.90 kg/min), and (3) gas velocity (3.4 to 7.6 m/s). At 6.0 m/s, the crossover (i.e., wt % TRISO in the BISO stream or vice versa) was less than 1% in either direction over the entire range of solids feed rates and compositions.

5.1.2.3. TRISO/TRISO Fuel Particle Classification. FSV TRISO/TRISO fuel particle mixtures were classified at feed rates of 0.09 to 0.42 kg/min with gas velocities between 4.3 and 5.3 m/s. Five batches of particles containing 93% enriched uranium were used, and all had a nominal composition of approximately 55 wt % fertile particles, 45 wt % fissile particles. The minimum fissile stream contamination was 3.2%, and the minimum fertile stream contamination was 14%. These tests indicated that secondary classification, i.e., reclassifying each stream, would be required to achieve satisfactory particle separation. Therefore, future development testing is planned.

5.2. PARTICLE CRUSHING

5.2.1. Equipment Description

The fuel particle crusher, developed to break the SiC coating of the TRISO fuel particles, is shown mounted on top of the secondary burner feed hopper in Fig. 59. The 560-W (3/4-hp) variable-speed dc electric motor with a 40:1 reducer which powers the crusher through open drive gears is located behind the particle crusher.

There are two types of particle crushers: one for FSV fertile particles and large HTGR (LHTGR) fissile particles and one for FSV fissile particles. In both cases, the crushing rolls are nominally 0.10 m in diameter and 0.10 m long. The gap between the rolls is fixed by the geometry of the side plates, which contain penetrations for the roller bearings supporting the rolls. The difference between the two crushers is

10 cm

Fig. 59. Fuel particle crusher and drive motor (mounted on secondary burner feed hopper)

in the nominal crushing gap, namely, 480 μm for FSV fertile and LHTGR fissile particles and 280 μm for FSV fissile particles. The crusher rolls are either flame hardened or carburized and hardened; the side plates are hardened tool steel. The rolls and side plates have the same hardness, i.e., R_c 60.

5.2.2. Test Results

The size of the product from the particle crusher must be acceptable for the crushed particle (or secondary) burner, and the number of unbroken particles must be minimized while the product is kept as coarse as possible in the interests of good fluidization. Acceptable burner feed was produced from all three types of fuel particles during initial testing at an acceptable rate (60 kg/hr).

The fertile crusher was used to crush FSV fertile particles during testing of the secondary burner. After the crusher had processed ~ 150 kg of material, the amount of unbroken fuel particles rose from $<1\%$ to $>2\%$. Wear was noted in the crusher body side plates adjacent to the actual crushing area in a local area (about 10 to 20 mm long) between the rolls. This area essentially consisted of a groove. Silicon carbide fuel particle coatings were evidently abrading the hardened steel surface, thus causing the groove (Fig. 60). Installation of boron carbide inserts at the relevant spot substantially alleviated the problem.

The fertile crusher rolls were decontaminated and examined for evidence of wear after they had crushed ~ 500 kg of material. Roll diameters were measured in 20 places and compared with previous measurements. No positive, definable trends in the wear of the roll crushing faces were noted.

5.3. CRUSHED PARTICLE BURNING

5.3.1. Equipment Description

The crushed particle burner, or secondary burner, burns away inner carbon coatings from crushed TRISO fuel particles and oxidizes any

Fig. 60. Particle crusher side plate showing wear groove after 150 kg of throughput

carbides in the fuel particle kernels to oxides. The burner is operated batchwise, accepting ~60 kg of crushed TRISO particles in each batch. The secondary burner assembly is shown in Fig. 61; the assembled burner is shown in Figs. 62 through 64.

5.3.1.1. Burner Vessel. The burner vessel consists of two Hastelloy-X pipe sections. The upper vessel houses the off-gas filter assembly (Fig. 65), and the lower section has an internal diameter of 0.20 m and is connected to the upper section by a remote flange (Fig. 66).

5.3.1.2. Heating System. A lower shroud around the 0.20-m burner section contains an induction heater coil coupled to a metal susceptor cylinder which forms a cooling air annular passage. Induction heating of the susceptor causes it to increase in temperature and radiate heat to the burner wall such that the fluid bed is heated to ignition temperature. The induction coil assembly is shown in Fig. 67, and the capacitor bank in Fig. 68. The generator set is common to the primary and secondary burners (Fig. 37).

5.3.1.3. Cooling System. Cooling air enters the shroud at the top and bottom of the burner assembly and leaves via a common exhaust plenum, as in the primary burner. Figures 69 through 74 show the burner system in various stages of assembly.

5.3.1.4. Burner Top. The burner top cap installation is shown in Fig. 75, and the insulation bonnets are shown in Fig. 76.

5.3.1.5. Plenum. Figure 77 presents the plenum and burner outlet valve. The valve itself was taken from a Volkswagen automobile engine. The lower assembly is shown in place in Fig. 78.

5.3.1.6. Instrumentation. The DIOGENES[®] process control computer, described in Section 4, was used.

Fig. 61. Secondary burner assembly

Fig. 62. Overall secondary burner system installation

76G1535

Fig. 63. Upper portion of 0.2-m secondary burner

76G1530

Fig. 64. Lower portion of 0.2-m secondary burner

Fig. 65. Burner upper vessel with part of integrated cooling jacket and skirted support plate and feed pipe

Fig. 66. Upper and lower burner vessels connected with semiremote Grayloc flanges

35-135-195-19

Fig. 67. Induction heating coil assembly

Fig. 68. Induction heater capacitor bank and coil connections

Fig. 69. Secondary burner upper intake and exhaust plenum shrouds ready to install

Fig. 70. Lower intake plenum shroud and spool shroud assembly for secondary burner

Fig. 71. Induction heater in place. Thermocouples from susceptor tube are seen on top; lower intake plenum is also shown.

Fig. 72. Upper intake and exhaust plenum (left, right, and fixed section)

35-135-195-16

Fig. 73. Burner vessel and induction heater unit in place

Fig. 74. Upper bonnets are installed; upper intake and exhaust plenum shrouds are put together with burner vessel and induction heater in place

35-135-195-11

Fig. 75. Burner top cap installation

Fig. 76. Upper insulation bonnets for secondary burner ready to mount on frame

Fig. 77. High-temperature bed removal system for secondary burner

35-135-194-1

Fig. 78. Lower spool hub assembly connected to lower burner vessel via Grayloc semiremote flanges

5.3.1.7. Operating Cycle. The induction heater system is actuated to heat the feed to combustion temperature (700°C) while keeping a 0.5-m/s upflow of CO₂; this takes less than 1-1/2 hr. The off-gas filters are blown back every 30 s with a backflow burst of CO₂. This dislodges any accumulation of fine material from the filter surface.

When the bed temperature reaches 700°C, oxygen is added on a ramp basis to the carbon dioxide fluidization gas stream. After about 10 min, the inlet gas stream is pure oxygen flowing at about 0.9 m/s. Cooling air is brought through the annular shrouds and modulated to keep the fluidized bed temperature at 900° ± 10°C. After about 1-1/2 hr, only a small percentage of the initial bed carbon remains. Induction heating is actuated on demand of low bed temperature. When bed carbon is below 2%, the burning cycle is stopped using pure carbon dioxide for fluidization. The bed is cooled, followed by opening of the product valve port so that the material can flow into a vacuum pneumatic transport line which carries it to a product bunker.

5.3.2. Test Results

5.3.2.1. Heat-Up Tests. During checkout of the induction heater, problems were encountered with excessive magnetic susception and heating of the outer metal shroud. The outer shroud was removed, but could be replaced if a copper liner was used to cut the magnetic field. The distributor plate hole design allowed "weeping" and "jetting" of the bed. A new design with smaller holes was installed, and heat transfer coefficients were measured using crushed feed and burner product. The tests simulated the use of several burner wall temperature limitations, since heat-up and tail-burn of the secondary burner are limited by wall temperature. Fluidizing gas flow was varied only at the 900°C wall temperature. The heat transfer characteristics of the feed and product material indicate the very high heat transfer capabilities of this material. Initial automation of the burner cycle was accomplished, and the groundwork was laid for more extensive automated control.

5.3.2.2. Parametric Study. Seven burner runs were made on the 0.20-m secondary burner to complete a parametric study of process variables. The last three runs were made in quick succession over a 17-hr period. Each test used 60 kg of crushed FSV TRISO fertile fuel particles as feed. The acceptance criteria were fully met in each burner run, and the operation of the overall system was excellent.

Analysis of the parametric study led to the recommendation of the following values for process variables:

1. Fluid bed superficial velocity should be 0.80 m/s during the main burn period.
2. Ignition temperature should be 600°C.
3. Fluid bed temperature should be 850°C during the main burn period.
4. Filter blowback frequency should be 1 cycle/min.
5. Fluid bed superficial velocity should be 0.45 m/s by the end of the tail burning period.

6. DRY SOLIDS HANDLING

6.1. EQUIPMENT DESCRIPTION

The solids handling system is divided into six subsystems (Fig. 79):

1. Crusher product removal system.
2. Primary burner feed system.
3. Primary burner product removal system.
4. Particle classifier feed system.
5. Particle crusher feed system.
6. Secondary burner product removal system.

Each subsystem is required to receive material from the preceding operation, transport it, store it, weigh it, recover it from storage, and feed it to the next step. Pneumatic conveying is used to transport materials.

At the beginning of each conveying line, there is an inlet filter (Fig. 80) which prevents particulates from entering or leaving the line. The conveying lines (with internal diameters of 0.048 or 0.035 m) have gradual bends. Just before the end of each conveying line there is a bunker inlet valve which isolates the bunker, a bellows for weigh cell accuracy, and an expansion in the line diameter. This expansion is intended to begin slowing down the conveyed particles. The tangential entry to the bunker prevents perpendicular impingement of particulates on metal walls or filter surfaces (Fig. 81).

The bunkers are designed to discharge their contents. Three bunkers (the crusher product, the primary burner feed, and the secondary burner product bunkers) are equipped with aerated bottoms (Fig. 82). Gas flows via a flowmeter through a woven steel mesh cone so that the bunker contents

Fig. 79. Solids handling subsystems

Fig. 80. Conveying line inlet filter (line diameter = 0.05 m)

Fig. 81. End of a pneumatic conveying line (0.05-m conveying line expanding to 0.1 m; 0.63-m-diameter bunker)

Fig. 82. Aerated cone and bunker outlet (0.5-m diameter)

are loosened and can flow easily. Inside the bunkers are porous stainless steel filter pipes (Fig. 83) to separate the gas and solids received from the pneumatic conveying lines. The filters are cleaned by a reverse flow of high-pressure CO₂ which is distributed through a manifold and solenoid valves (Fig. 84). The manifold and solenoid valves are controlled by a cam timer. The CO₂ supply line and filter exhaust line have bellows connections, and a differential pressure gauge is installed on each bunker. The pressure gauge also serves as an inlet for argon from the argon dump system installed to prevent hazards arising from the pyrophoric nature of some of the fuel particle kernels (Fig. 85).

The rotary blowers are mounted in frames (Fig. 86) together with an electric motor, an inlet filter, an outlet filter, and an underpressure relief valve set at 40 kPa (12 in. Hg). Except for the variable-speed classifier blower, the blowers are fixed-speed units. The gas, after compression, goes to a central vent system. Level sensors are used to prevent overfilling of the bunkers. The principle involved is interruption of an ultrasonic beam propagated between two sensors. These sensors are placed just below the level at which the conveying line enters (Fig. 87).

Feeders, which control the flow rate out of a bunker, are used throughout the system. Rotary valves predominate; 0.05-m rotary valves are used below the primary burner feed bunker and the classifier feed bunkers (Fig. 88), and 0.10-m rotary valves are used below the crusher product and primary burner product bunkers. The classifier is fed by a vibrating feeder (Fig. 55), and the flow rate out of the primary burner into the primary burner product removal system is controlled by a variable-width knife gate (Fig. 89).

The bunkers rest on load cells (Fig. 90) which continuously record material weight. Several special provisions have been made to ensure that accurate readings are obtained. The bunker assemblies themselves are supported on three load cells mounted on a cage (Fig. 91). All connecting lines either contain metal bellows or, if they are narrow, are

Fig. 83. Porous stainless steel in-bunker filter pipes (0.25-m-diameter pipes in groups of six)

CO₂ SUPPLY
LINE BELLOWS

CO₂ MANIFOLD

SOLENOID
VALVE

FILTER
EXHAUST
PLENUM

FILTER EXHAUST
LINE BELLOWS

Fig. 84. In-bunker filter blowback assembly (0.91-m-diameter bunker)

Fig. 85. In-bunker filter pressure drop measurement arrangement and argon inlet line

Fig. 86. Rotary blower used to provide moving air for pneumatic conveying

Fig. 87. Ultrasonic level sensor (0.05-m diameter) used for indicating a maximum safe level in a storage bunker

35-135-207-21

Fig. 88. 0.05-m rotary feeder valve

35-135-207-23

Fig. 89. Variable-width knife gate at inlet to primary burner product removal system

Fig. 90. Bunker load cell used for monitoring weight of material within

Fig. 91. Bunker and support cage (0.63-m-diameter bunker)

unsupported over at least 0.6 horizontal meters. To prevent rotation of the bunkers, tie bars are attached to the bunker and the support cage (Fig. 92).

6.2. TEST RESULTS

Qualification testing was divided into two phases: component testing followed by subsystem testing. Component testing was concerned with confirming the suitability of the equipment selected for the pilot plant, and subsystem testing was process oriented and concerned with conveying system capacities.

6.2.1. Component Testing

The inlet filters had an acceptable pressure drop across them during conveying, and they have proved to be effective in preventing fine material from leaving a conveying line. The bunkers provided sufficient effective storage volumes; design basis materials could be discharged without bridging problems. The in-bunker filters were preloaded with fine particles, and wipes taken from the filter exhaust lines before and after filter loading revealed no evidence of any particles passing through the filters. The pressure drops across the filters were satisfactory. Generally, the level sensors worked well. However, during discharge of fuel particles at 700°C from the primary burner, the high-level alarm in the primary burner product bunker was activated. Subsequent examination showed that the faces of the sensors were coated with a layer of very fine particles. When the faces were cleaned, the alarm was deactivated. Alternative level sensors will be investigated.

The rotary valves and classifier vibratory feeder were calibrated at different speeds with the relevant materials. The feeders can be set to give appropriate flow rates. The load cells were calibrated and accuracies within 0.5% of the design load were obtained. To obtain this accuracy, any blowback systems, blowers, and burner systems related to a bunker must be

Fig. 92. Bunker tie bar used to prevent rotation of bunker on its load cells

turned off prior to taking weight readings, and people must be cleared from the vicinity of the bunker platform and nearby elevated walkways. Upgrading of support structures is being actively pursued.

6.2.2. Systems Testing

The goal of system qualification is to ensure that each subsystem can convey material at a rate compatible with upstream and downstream operations so that particle breakage is minimal. This involves establishing the conveying characteristics of each system by measuring pressure drops at different solids flow rates over a range of gas velocities. Determination of the saltation point, i.e., the point where suspension collapses and particles fill up the line, is also required. The ability to restart after plugging of the line using only the blower should be investigated.

A variable-speed blower was used for system qualification. Once the optimal conditions for a given system have been determined, a fixed-speed blower, suitably set, can be used. The final part of system qualification, i.e., measurement of fuel particle breakage during sequential operation, can be performed only during pilot plant operation with loaded fuel elements.

Pressure drops, solids flow rates, gas velocities, and line geometries were correlated for use in future design efforts. The observed pressure drops have been compared with values predicted by a modified version of a formula in Ref. 13. An example of the generally good correlation obtained is shown in Fig. 93, which gives results from the primary burner product removal system at ambient temperatures. The line geometry is shown in Fig. 94.

The secondary burner product removal system was unable to convey the large initial quantities of material leaving the burner, and so the burner outlet valve (Fig. 77) was intermittently operated. The system has been redesigned so that its capacity is substantially larger.

Fig. 93. Predicted versus observed pressure drops for pneumatic conveying of cold material in the primary burner product removal system

Fig. 94. Primary burner product removal system

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APPENDIX A
PROCESS FLOW DIAGRAMS AND
PIPING AND INSTRUMENTATION DRAWINGS

Fig. A-1. Process flow diagram: fuel particle crushing

Fig. A-2. Process flow diagram: solids handling (sheet 1 of 4)

Fig. A-2. Process flow diagram: solids handling (sheet 4 of 4)

Fig. A-4. Process flow diagram: fuel particle classification

Fig. A-5. Process flow diagram: 40-cm fluidized-bed crushed fuel element burner (sheet 1 of 2)

Fig. A-5. Process flow diagram: 40-cm fluidized-bed crushed fuel element burner (sheet 2 of 2)

Fig. A-6. Process flow diagram: 20-cm fluidized-bed crushed particle burner

Fig. A-7. Piping and instrumentation diagram: fuel particle crushing

Fig. A-8. Piping and instrumentation diagram: solids handling (sheet 3 of 4)

Fig. A-9. Piping and instrumentation diagram: fuel element size reduction

© A. LEVEL III

Fig. A-11. Piping and instrumentation diagram: 40-cm fluidized-bed crushed fuel element burner (sheet 1 of 5)

524411
COOLING AIR BLOWER
CAPACITY: 2100 SCFM
HEAD: 12.0 PSF
MOTOR HP: 150 (MAX)

524412
EXHAUST AIR COOLER
DUTY: 11500 K TO 8 BUTANE
AREA: 512 SQ FT
DESIGN P.T.
SWELL: PSIG @ °C
TRUCK: PSIG @ °C

NOTES

1. SYMBOLS & TERMINOLOGY PER ISA GUIDE STANDARDS 5-3.1-2-1
2. PROVIDE FLANGES FOR POSSIBLE BLINDING & COOLING JACKETS' LEAK.
3. INITIATE COOLING AIR FLOW WHEN MAX BED TEMP REACHES 900°C. FLOW IS INCREASED RAPIDLY TO LIMIT 'A'.
4. WHEN VERTEX OXYGEN FLOW IS INITIATED, AIR FLOW INCREASES RAPIDLY TO LIMIT 'B'.
5. WHEN FINES RECYCLE FLOW IS INITIATED THE FLOW CHANGES RAPIDLY (UP/DOWN) TO LIMIT 'C'.
6. IF BED TEMP DROPS BELOW 900°C, COOLING AIR IS SHUTOFF.
7. DELTID
8. TACHOMETER FOR RPM READOUT
9. FILTER - SILENCER
10. A INDIATOR FLOW-AVERAGING PITOT TUBE LOCATE IN LINE WITH MINIMUM OF 7 UPSTREAM DIAMETERS AND 3 DOWNSTREAM DIAMETERS OF STRAIGHT PIPE
11. DIODES PROCESS CONTROLLER (TYPICAL)
12. DAMPENED BLOCKS
13. SCR POWER CONTROL 0-10 KW

COMPONENT NUMBERS NOT USED ON THIS SHEET	
EQUIPMENT	524411 THRU 524416
P. RING	524417
VALVES	524418 THRU 524421
INSTRUMENTS	524422 THRU 524425

Fig. A-11. Piping and instrumentation diagram: 40-cm fluidized-bed crushed fuel element burner (sheet 3 of 5)

Fig. A-11. Piping and instrumentation diagram: 40-cm fluidized-bed crushed fuel element burner (sheet 4 of 5)

APPENDIX B
MAJOR ASSEMBLY DRAWINGS

Fig. B-4. Pitman installation: UNIFRAME

- NOTES:
1. REMOVE BURRS & SHARP EDGES
 2. DIMENSIONS & TOLERANCES PER. ANSI Y 14.5
 3. ITEM 2 (2 PLS) TO BE WELDED IN PLACE AFTER ITEM 4 IS WELDED
 4. PLUG WELD 4 VENT HOLES & GRIND SMOOTH
 5. CHECK PLATE ASSY'S ⑧ MUST BE INTERCHANGEABLE FROM ONE FACE OF JAW ASSY ⑥ TO THE OTHER.

Fig. B-5. Stationary jaw assembly: primary crusher, UNIFRAME

NOTES

1. DIMENSIONS & TOLERANCES PER ANSI Y14.5
2. REMOVE ALL BURRS & SHARP EDGES.
3. ALL WELDS PER AWS D1.1
4. STRESS RELIEVE BEFORE MACHINING
5. BEFORE MACHINING AUSTENITIZE @ 1380° F, ISOTHERMAL ANNEAL @ 1200 F FOR 12 HRS APPROX BHN 197.
6. HARDENED STEEL BALLS (SUPPLIED BY G.A.C.) TO BE PRESSED THRU EACH I.D FOR SIZING. USE A LUBRICANT THAT AVOIDS GALLING AND WILL NOT CONTAMINATE, SUCH AS WHITE LEAD OR MoS₂.
7. 'A' DIM'S & TO & MUST BE HELD FOR INTER-CHANGEABILITY.
8. STAMP OR MARK ITEMS ON & TO IDENTIFY MAT'L.
9. VENDOR TO SUPPLY DOCUMENTATION OF MEASUREMENT OF PARALLELISM OF BUSHINGS AFTER COMPLETION OF 6.

TABLE I				
ASSY N°.	ITEM	'A'	MAT'L	HEAT TREAT
5210013-1	5	16.000	AISI-4340	5
5210013-2	6	17.000	AISI-4340	5
5210013-3	7	18.000	AISI-4340	5
	4		AISI-4340	5
5210013-8	12	16.000	410	4
5210013-9	13	17.000	410	4
5210013-10	14	18.000	410	4
	11		410	4

2	2	2	2	2	2	15	5210014-1	BUSHING		
2						14	5210013-14	TOGGLE R 1" PLATE	SEE	TABLE I
	2					13	5210013-13	TOGGLE R 1" PLATE	SEE	TABLE I
		2				12	5210013-12	TOGGLE R 1" PLATE	SEE	TABLE I
2	2	2				11	5210013-11	SLEEVE	SEE	TABLE I
						10		10 TOGGLE ASSY		
						9		9 TOGGLE ASSY		
						8		8 TOGGLE ASSY		
		2				7		7 TOGGLE R 1" PLATE	SEE	TABLE I
			2			6		6 TOGGLE R 1" PLATE		
				2	5	5		5 TOGGLE R 1" PLATE		
			2	2	2	4		4 SLFIVE	SEE	TABLE I
					3	3		3 TOGGLE ASSY.		
					2	2		2 TOGGLE ASSY.		
					1	1	5210013-1	TOGGLE ASSY

5 6 7 TOGGLE
12 13 14 TOGGLE

FOR -1 ONLY 5 2 PLACES
FOR -2 ONLY 6 2 PLACES
FOR -3 ONLY 7 2 PLACES

2 PLACES 12 FOR -8 ONLY
2 PLACES 13 FOR -9 ONLY
2 PLACES 14 FOR -10 ONLY

1 TOGGLE ASSY.
2 TOGGLE ASSY.
3 TOGGLE ASSY.
8 TOGGLE ASSY.
9 TOGGLE ASSY.
10 TOGGLE ASSY.

4 FOR -1, -2 & -3 ONLY
11 FOR -8, -9 & -10 ONLY

4 SLEEVE
11 SLEEVE

Fig. B-7. Toggle assemblies: primary and secondary crushers, UNIFRAME

Fig. B-9. Pushing block assembly: primary and secondary jaw crushers, UNIFRAME

NOTES
 1. DIMENSIONS & TOLERANCES PER ANSI Y14.5.
 2. MANUFACTURED & ASSEMBLED BY OTHERS.

1	5210026-1	PITMAN/TOGGLE ASSY	STL.	COM1
2	5210014-2	SHAFT	STL.	COM1
3	5210013-3	TOGGLE ASSY (450)	STL.	COM1
4	5210013-10	TOGGLE ASSY (410)	STL.	COM1
5	5210023-1	PUSHING BLOCK ASSY	STL.	COM1
6	5210026-7	CAP	STL.	COM1
7	5210026-8	SCREW 1/2-13 X 1 1/2 LG	STL.	COM1
8	5210026-9	WASHER	STL.	COM1

Fig. B-10. Pitman/toggle assembly: primary crusher, UNIFRAME

Fig. B-11. Tertiary crusher assembly: UNIFRAME

NOTES:

SOURCE:

GENERAL ELECTRIC CO.
SAN DIEGO
N° 197400, WATER COOLED

SOURCE:

FISHER-KLOSTERMAN INC.
8901 MARGRAVE ST
LOUISVILLE KY 40201

1	17	SE4000-1	ASSY	
1	16	SE4000-1	PIPE ASSY	
1	15	SE4000-1	PIPE	
6	14	SE4000-1	CAPACITOR	
1	13	SE4000-1	COVER PLATE	
1	12	SE4000-1	PIPE	
1	11	SE4000-1	FLANGE GASKET ASSY	
1	10	SE4000-1	BURNER ASSY	
1	9	NO	NO(S) CYCLONE COLLECTOR	
1	8	SE4000-1	LOCATION ASSY	
1	7	SE4000-1	PIPE BURNER ASSY	
1	6	SE4000-1	PIPE BURNER ASSY	
1	5	SE4000-1	FILTER ASSY	
1	4	SE4000-1	BURNER ASSY	
1	3	SE4000-1	BURNER ASSY	
1	2	SE4000-1	COOLING WATER GAS PIPING	
1	1	SE4000-1	EQUIPMENT ASSY	

Fig. B-12. Burner arrangement: 16-in. fluidized-bed primary burner (sheet 1 of 3)

NOTES:

1 ALL CLAMPS & SEAL RINGS TO BE PROVIDED BY GRAY TOOL COMPANY, 7135 ARDMORE STREET, HOUSTON, TEXAS 77001.

1	9	I-4839	SIZE 140 GRAYLOC SEAL RING	HASTELLOY-X	1
1	8	I-4839	GR 140 GRAYLOC CLAMP	SA-350-CF8M	1
1	7		1 1/2" GRAYLOC CLAMP	SA-350-CF8M	1
1	6		SIZE 14 GRAYLOC SEAL RING	HASTELLOY-X	1
1	5	I-4538	14" GRAYLOC SWING BOLT CLAMP	PER I-4538 REV A	1
1	4	I-4538	SIZE 140 GRAYLOC SEAL RING	HASTELLOY-X	1
1	3	5244012-1	LOWER CAP ASSEMBLY		
1	2	5244011-1	HUB & CONE ASSEMBLY		
1	1	5244010-1	SPOOL ASSEMBLY		

APPROVALS	DATE
BY: NUT	4/10/75
MATERIAL	
WELDING	

Fig. B-13. Spool assembly: 16-in. fluidized-bed primary burner

(1) HEATER & SHROUD ASSY

APPROVALS	DATE
1. NWJ	1/4/75
2. [Signature]	1/4/75
3. [Signature]	1/4/75

NOTES:

SOURCE: CRAWFORD FITTING COMPANY
29900 SOLOH RD
SOLOH, OHIO 44139

NOTES CONTINUED ON SHEET 2.

41	5244025-41	4.5" X 1.20 X 1.00	18-8SS	COML
1	40	5244094-1	SHIELD RING	
1	39	5244095-1	INSULATION RING	
8	38		LEX BOL, 1/4-20 X 5/8	18-8SS COML
6	37		WASHER 250TD 62503 X .063	18-8SS COML
2	36	5244015-1	SUPPORT BRACKET ASSY	
6	35		HEX BOL, 1/4-20 X 1 3/4"	18-8SS COML
6	34		HEX NUT, 1/4-20	18-8SS COML
2	33		HEX NUT, 1/2-13	18-8SS COML
2	32		WASHER, .500 ID X .63 X 1.250	BRASS COML
6	31	5244025-31	SPACER, 2.04 X 1.6	BRASS ASTM-B-135
4	30	5244025-30	SPACER, 2.04 X 1.6	BRASS ASTM-B-135
2	29	5244025-29	TOP BUSHING	BRASS ASTM-B-135
1	28	5244016-2	RIGHT REAR SHROUD ASSY	
1	27	5244016-1	LEFT REAR SHROUD ASSY	
1	26	5244017-2	RIGHT FRONT SHROUD ASSY	
1	25	5244017-1	LEFT FRONT SHROUD ASSY	
1	24	5244025-24	SHROUD ASSY	
1	23	5244042-1	RING SEAL	
1	22	5244043-1	RING ASSY	
1	21	5244044-1	SEAL RING ASSY	
1	20	5244040-1	LOWER PLENUM ASSY	
6	19	19	HEX NUT, 1/4-20 X 1.00 LG	18-8SS COML
6	18	5244025-18	WASHER, 1/2 ID X 3/4 OD X .38	18-8SS
17				
16				
6	15	5244025-15	SPACER, 2.04 X 1.6 X 1.15 LG	304SS ASTM-A-261
6	14	1610-6-316	SWAGelok 1" UNION	
12	13	119FW-820	NUT, FLOCKING, DOUBLE HERRING	AMS 7280
12				
6	11	5244039-1	COUPLING ROD	
1	10	5244032-1	EXHAUST PLENUM ASSY	
6	9	5244036-1	ROD SHROUD	
1	8	5244029-2	SPACER RING	
1	7	5244030-1	HEATER SHROUD	
1	6	5244037-1	HEATER COIL ASSY	
1	5	5244027-1	CERAMIC INSULATOR	
1	4	5244028-1	SUSCEPTOR TUBE	
1	3	5244029-1	SPACER RING	
1	2	5244026-1	HEATER BASE	
1	1	5244025-1	HEATER & SHROUD ASSY	

Fig. B-14. Heater and shroud assembly: 16-in. fluidized-bed primary burner

NOTES:

1. DIMENSIONS & TOLERANCES PER ANSI Y14.5
2. LEAVE END RADII APPROX. AS SHOWN.
3. STUDS TO BE ATTACHED TO ITEM 8 & ITEM 9 TRANSVERSELY SPACED AT A MAXIMUM INTERVAL OF EVERY FOURTH COIL.
4. TYPE & SPECIFICATION OF MATERIALS TO BE DETERMINED BY FABRICATOR
5. ITEM 1, INDUCTION COIL ASSY TO MEET PERFORMANCE REQUIREMENTS PER GENERAL SPECIFICATION NO 118768-02.

① INDUCTION COIL ASSY

SPECIFICATION CONTROL DWG.

QTY	ITEM	DESCRIPTION	REMARKS	APPROVAL
1	6	9244031-6	SHIM	
1	5	9244031-5	LOWER SHOOTING COIL, 1" OD. X .063 WALL	
1	4	9244031-4	UPPER SHOOTING COIL, 1" OD. X .063 WALL	
1	3	9244031-3	HEATING COIL, 1" OD. X .063 WALL	
1	2	9244031-2	HEATING COIL, 1" OD. X .063 WALL	
1	1	9244031-1	INDUCTION COIL ASSY	

APPROVALS		DATE
STRUCTURAL	NLS	4-8-75
MATERIAL		
WELDING		

Fig. B-15. Induction and coil assembly: 16-in. fluidized-bed primary burner

SECTION A - A TYP (3 PLACES)

NOTES

1. DIMENSIONS & TOLERANCES PER ANSI-Y14.5
2. REMOVE BURRS & BREAK SHARP EDGES
3. WELD BY MANUAL ARC, MIG OR TIG PROCESS
4. BUTT WELDS TO BE 100% FULL PENETRATION EXCEPT WHERE INDICATED OTHERWISE.
5. TACK WELD AS REQ'D.
6. WELD FILLER METAL SHALL BE AWS TYPE ER-308L
7. LIQUID PENETRANT INSPECT WELD PER ASTM E165 WITH ACCEPTANCE CRITERIA PER ASME BOILER & PRESSURE VESSEL CODE SECT VIII APPX VIII

1	7	5244056-3	LIFTING LUG	1/2 PLATE	304 L SS	ASTM A 240
2	6	5244056-2	LIFTING LUG	1/2 PLATE	304 L SS	ASTM A 240
2	5	5244056-1				
2	4	52				
1	3	52				
1	2	52				
1	1	52				

APPROVALS

STRUCTURAL: NWJ DATE: 10/1/78

MATERIAL: _____

WELDING: _____

RELEASED

Fig. B-18. Shroud and saddle assembly: 16-in. fluidized-bed primary burner

3927744056

SECTION A-A

① CAP INSULATOR ASSY.

NOTES.

- 1 DIMENSIONS & TOLERANCES PER ANSI Y14.5.
- 2 REMOVE ALL RAPS & SHARP EDGES.
- 3 BUTT WELDS TO BE 100% FULL PENETRATION.
- 4 WELD PLATE INTERNAL TO BE AWS TYPE ER 308.
- 5 WELD BY MANUAL ARC MIG OR TIG PROCESS.
- 6
- 7 SURFACE CONTOURS ON ALL WELDED JOINTS TO BE SMOOTH AND FREE FROM UNDERCUTS, OVERLAPS, RAPID RIDGES & VALLEYS.
- 8 ALL WELDS TO BE LIQUID PENL XRAY INSPECTED PER ASTM E 165 IN ACCORDANCE WITH MIL-R-12 ACCEPTANCE STD.
- 9 SOURCE: GRAY TOOL CO. 7135 ARDMORE ST. HOUSTON, TEX. 77001
- 10 SOURCE: WEP REFRACTORY PRODUCTS CO. 500 W. CENTRAL RD. MT PROSPECT, ILLINOIS 60056 SUPPLIED BY GENERAL ATOMIC CO.
- 11 DO NOT WELD ATTACH ITEMS 3, 4, 5 & 6 TO ITEM 2.

NO	7	WPPX-AQ	INSULATION		10
1	6	5244062-4	TYP PLATE (RIGHT)		
1	5	5244062-3	TYP PLATE (LEFT)		
1	4	5244062-2	11" HHT 1 SEC 7T (RIGHT)		
1	3	5244062-1	INSULATOR SECTION (LEFT)		
1	2	5244062-1	INNER CAP ASSY		
1	1	5244062-1	1" HHT 1 SEC 7T (LEFT)		9

APPROVALS		DATE
STRUCTURE	NUT	4 8 75
MATERIAL		
WELDER		

Fig. B-19. Cap insulator assembly: 16-in. fluidized-bed primary burner

Fig. B-23. Burner and frame installation: 8-in. fluidized-bed secondary burner

352 E-47004-A

(-1)
LOWER VESSEL ASSY

(-2)
UPPER VESSEL ASSY

9	547008-2	FLANGED HUB	1/4 PLATE	AMS 5530
8	547007	FLANGE		
7	547006	FLANGED HUB		
6	547005	FLANGED HUB		
5	547004	FLANGE	1/4 PLATE	AMS 5530
4	547003	FLANGED HUB		
2	547002	UPPER VESSEL ASSY		
1	547001	LOWER VESSEL ASSY		

NOTES

1. REMOVE ALL BURRS AND SHARP EDGES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5.
3. WELDS TO BE 100% FULL PENETRATION.
4. WELD FILLER METAL TO BE HASTELLOY 'X'.
5. WELD BY MANUAL AEC, MIG OR TIG PROCESSES.
6. SURF. FINISH ON ALL WELD JOINTS TO BE SMOOTH & FREE OF UNDESIRABLE CUTS, OVERLAPS, ASBESTH RIDGES OR VALLEYS.
7. SOURCE: CABOT CORP. (STELLITE DIV.) - PROD. SPEC. NO. 1137, ROMANO, IND.
- 8.
9. FABRICATOR SHALL QUALIFY EACH WELDING PROCEDURE & WELDING PERFORMANCE IN ACCORDANCE WITH SECTION IX OF THE ASME BOILER & PRESSURE VESSEL CODE.
10. RADIOGRAPH INSPECT WELDS PER ASTM-E 94 WITH ACCEPTANCE STANDARDS PER PAR. UW-51, SECT. VIII, DIV. 1 OF ASME BOILER & PRESSURE VESSEL CODE.

RELEASE

Fig. B-24. Vessel assemblies: 8-in. fluidized-bed secondary burner

Fig. B-25. Vessel mounting support assembly: 8-in. fluidized-bed secondary burner

Fig. B-27. Heater assembly: 8-in. fluidized-bed secondary burner

NOTES

1. DIMENSIONS & TOLERANCES PER ANSI Y14.5
2. ITEMS SHOWN IN PHANTOM TO BE INSTALLED BY GENERAL ATOMIC CO
3. ATTACHMENT STUDS ON ITEM 2 COIL TO BE LONGITUDINALLY SPACED AT A MAXIMUM INTERVAL OF EVERY SIXTH COIL
4. TO BE FABRICATED BY TOLCO DIV. OF PARK-OHIO INDUSTRIES INC. 4620 EAST 71ST ST. CLEVELAND, OHIO 44109
5. TYPE & SPECIFICATION OF MATERIAL TO BE DETERMINED BY FABRICATOR
6. ITEM 1 INDUCTION COIL ASSEMBLY TO MEET PERFORMANCE REQUIREMENTS PER GENERAL ATOMIC SPEC NO 25 524701, ISSUE A

SPECIFICATION CONTROL DRAWING

4	4	5247031	4	SUPPORT	TRANSITE	1
2	3		3	SHIELDING COIL, 3/8" O.D. X .06" WALL COPPER TUBE		1
1	2		2	INDUCTION COIL, 3/8" O.D. X .06" WALL COPPER TUBE		1
1	1	5247031	1	INDUCTION COIL ASS'Y		4

(1) INDUCTION COIL ASS'Y

NOT RELEASED

Fig. B-28. Induction coil: 8-in. fluidized-bed secondary burner

8525247031

NOT RELEASED

Fig. B-29. Fixed section: upper intake and exhaust plenum, 8-in. secondary burner

Aug 9, 2015

APPROVAL LEVEL No. 1

SHEET 1 OF 3

NOTES
 1. DIMENSIONING & TOLERANCING PER ANSI Y14.5
 2. SOURCE: HAYWARD, UPG CO
 300 FAIRMOUNT AVE, BUTTE, N.J.
 3. SOURCE: LADSON TRICLOVER
 1805 60th ST, MONROE, LA 70140
 4. SOURCE: BABCO ENTERPRISES
 301 E. 27th ST., LONG BEACH, CAL., 90806
 5. SOURCE: OWENS INSTRUMENT, INC.
 P.O. BOX 975, UICHTMAN CITY, WICD, 46368
 6. UPGRADES FROM ENG. SHEET 4

1	31	5201100-31	REAR FL 2557		
1	30	6025	PRESSURE INDICATOR		
1	29	4040X-1	GASKET		
16	28	5201100-28	WASHER - FLAT 1/4 NOM.	SS	
4	27		NUT-HEX 1/4-20	SS	
4	26		SCR-HEX NO CAP 1/4-20X1 1/2	SS	
6	25		SCR-HEX NO CAP 1/4-20X1	SS	
1	24		GASKET 1/6 SHEET	NEOPRENE	
1	23	5201100-23	GASKET 1/6 SHEET	NEOPRENE	
1	22	124444-4	CLAMP		
1	21	625 922	SOLIDS FLOW RATE SENSOR		
1	20	5201100-20	HOUSING ASSY - SOLIDS FLOW RATE SENSOR		
1	19	5201100-19	HOUSING ASSY - SCREENERS TO FLOW RATE SENSOR		
16	18	5201100-18	PLAT WASHER NOM 1/6	SS	
6	17		HEX NUT 3/8-11 NC	SS	
16	16		HEX NO BOLT 1/4-18X1 1/4	SS	
1	15		GASKET 1/6	NEOPRENE	
1	14		GASKET 1/6	NEOPRENE	
16	13		PLAT WASHER NOM 1/6		
6	12		HEX NO BOLT 1/4-18X1 1/4		
2	11	5201100-11	PLT, 2" S.W. BO 1/2" S.W.		
2	10	144444-2	FERRULE		
5	9	124444-2	CLAMP		
5	8	4040X-1	GASKET		
1	7	62440-2	ELBOW		
1	6	7440-2	TEE		
1	5	5201100-5	BALL VALVE, 2" PG		
1	4	5201100-4	INLET FILTER		
1	3	5201100-3	TRANSITION PIECE		
1	2	5201100-2	SPRNG. PIECE		
1	1	5201100-1	ASSEMBLY		

Fig. B-31. Crusher product removal subsystem No. 1 (sheet 1 of 2)

Fig. B-31. Crusher product removal subsystem No. 1 (sheet 2 of 2)

① INLET FILTER ASSY
②

NOTES

- 1 DIMENSIONS & TOLERANCES PER ANSI Y14.5.
- 2 REMOVE ALL BURRS & SHARP EDGES.
- 3 WELDS TO BE MANUAL ARC, GMA OR GTA PROCESS.
- 4.
- 5.
- 6 FILTER ELEMENT TO BE 250 CFM, 2.0W6, 99.97 EFF.
- 7 ALTERNATE: MAYBE ROLL FORMED AND SEAM WELDED.
- 8 SOURCE:
LADISH TRICLOVER
2809 60th ST.
KNOXSHAW NY 53140
- 9 UPGRADED FROM DWS 8222079A

1	1	9	5201103-9	FILTER ELEMENT		
1	1	8	11.250 DIA (.062 WALL) TUBING	304 SS		
1	1	7	2 IPS (.065 WALL) SCH. 5	304 SS		
1	1	6	1 1/2 IPS (.065 WALL) SCH. 5	304 SS		
1	1	5	1/4 IN. 10-32	FERRULE - WELD IN TYPE	304 SS	
1	1	4	1/4 IN. 10-32	FERRULE - WELD IN TYPE	304 SS	
1	1	3	5201103-3	COVER - 10 GA (.062)	304 SS	
1	1	2	5201103-2	ASSEMBLY		
1	1	1	5201103-1	ASSEMBLY		

DDO | RELEASE

Fig. B-32. Inlet filter assembly

QUAL LEVEL 3 APPROVAL LEVEL 1 SHIP 1001

Fig. B-33. Blowback assembly

NOTES

1. REMOVE BURRS & SHARP EDGES.
2. DIMENSIONS & TOLERANCES PER ANSI Y14.5
3. ALL BUTT WELDS SHALL BE FULL PENETRATION.
4. WELD BY MANUAL ARC GTA OR GMA PROCESS
5. TO BE SUPPLIED BY GENERAL ATOMIC CO.

6. SOURCE:

LADISH TRIGLOVAP
2809 60th st.
KENOSHA WI. 53140

7. UPGRADED FROM DWG 02024A

① MANIFOLD ASSY

1	4	141111-1	FERRULE		
1/4	3	520111-3	TUBE 3/4 DIA X .065 WALL	304L SS	
1/4	2	520111-2	TUBE 1 DIA X .065 WALL	304L SS	
1	1	520111-1	MANIFOLD ASSY		

Fig. B-35. Manifold assembly blowback

Fig. B-36. Bunker

- NOTES:
1. DIMENSIONS & TOLERANCES PER ANSI Y14.5
 2. REMOVE ALL BURRS AND SHARP EDGES
 3. WELD BY MANUAL ARC, GMA OR GTA PROCESS
 4. WELD LOCATIONS / JOINT CONFIGURATION OPTIONAL
 5. UPDATED FROM DWG 07006 A

QTY	PART NO.	DESCRIPTION	MATERIAL	FINISH	REMARKS
12	6101115-6	APPROX 1000 3/8" DIA 1/2" THK	STEEL	AS SUPPLIED	QTY 1000
5	5	-5 BRACE 1" x 2" x 1/4" THK	STEEL	AS SUPPLIED	QTY 5
5	4	-4 BASE 1/8" THK	STEEL	AS SUPPLIED	QTY 5
6	3	-3 LUG 1/8" THK	STEEL	AS SUPPLIED	QTY 6
1	2	-2 FRAME 1" x 2" x 1/4" THK	STEEL	AS SUPPLIED	QTY 2
1	1	ASSEMBLY			

Fig. B-37. Support cage

ASSY No.	A	B	C	D	E
-1	24.00	9.00	(24 3/4)	21 1/8	2.38
-14	22.00	8.00	(22 3/4)	19 1/8	2.38
-15	15.00	4.500	(15 3/4)	12 1/8	2.38
-16	25.12	9.00	(25 1/8)	23.01	2.94

- ① ASSY
- ④ ASSY
- ⑤ ASSY
- ⑥ ASSY

16	520116-16	ASSEMBLY			
15	520116-15	ASSEMBLY			
14	520116-14	ASSEMBLY			
4	4	4	13	-13	NUT, HEX JAM 3/8-24 SST 304
2	2	2	12	-12	WASHER, FLAT NOM 3/8
2	2	2	11	-11	SPECIAL ROD END N° 6
2	2	2	10	-10	LOCKWASHER NOM 5/16
2	2	2	9	-9	WASHER, FLAT NOM 5/16
2	2	2	8	-8	NUT, HEX 5/16-18
2	2	2	7	-7	SCR, SOC SHOULDER 3/8 DIA x 1"
3	3	3	6	-6	LOCKWASHER NOM 3/8
3	3	3	5	-5	NUT, HEX 3/8-16
3	3	3	4	-4	BOLT, HEX HD 3/8-16 x 1 1/2
2	2	2	3	-3	SPACER
2	2	2	2	-2	BAR
1	520116-1	ASSEMBLY			

0521520116 D

Fig. B-38. Stay rod

Fig. B-40. Zigzag chamber, pneumatic classification

NOTES:

1. DIMENSIONS & TOLERANCES PER ANSI Y14.5
2. WELD BY MANUAL ARC, GMA OR GTA PROCESS
3. LIQUID PENETRANT INSPECT WELDS PER ASTM E-165
4. REMOVE ALL BURRS & SHARP EDGES
5. FINISH: SAND AND BEAD BLAST

1	1	21	5221009-14	CYCLONE EXTENSION ASSY		
8	8	20		NUT, HEX 1/4-20	SS	CONL
8	8	19		LOCKWASHER 1/4		
8	8	18		BOLT, HEX HD 1/4-20 X 1		
4	4	17		NUT, HEX 3/8-16		
4	4	16		LOCKWASHER 3/8		
4	4	15		BOLT, HEX HD 3/8-16 X 1/2		
8	8	14		NUT, HEX 1/2-13		
8	8	13		LOCKWASHER 1/2		
8	8	12		BOLT, HEX HD 1/2-13 X 1 1/4	SS	
2	2	11		GASKET .040 SHEET	NEOPRENE	
1	1	10		GASKET .040 SHEET	NEOPRENE	
1	1	9		GASKET .040 SHEET	NEOPRENE	CONL
1	1	8	5221009-1	CYCLONE SEPARATOR		
1	1	7	5221009-1	INLET FEED DUST		
1	1	6	5221009-1	FINES TAKE-OFF		
1	1	5	5221009-1	LARGE PARTICLE CONE		
1	1	4	5221009-1	210-PAG WINDER		
1	1	3	5221009-1	210-PAG CHAMFER		
1	1	2	5221009-1	210-PAG ASSEMBLY		
1	1	1	5221009-1	210-PAG ASSEMBLY		

1-2 CLASSIFIER ASSEMBLY

Fig. B-41. Prototype pneumatic classifier assembly

Fig. B-42. Particle crusher equipment assembly