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A DESIGN EVALUATION OF THE 20-cm (8-inch)
SECONDARY BURNER SYSTEM

by

J. S. Rode

MASTER

Prepared under
Contract EY-76-C-03-0167
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ABSTRACT

This report describes an evaluation of the design of the existing 20-cm (8-inch) engineering-scale secondary burner system in the HTGR reprocessing cold pilot plant at General Atomic Co. The purpose of this evaluation is to assess the suitability of the existing design as a prototype of the HTGR Recycle Demonstration Facility (HRDF) secondary burner system and to recommend alternatives where the existing design is thought to be unsuitable as a prototype. This evaluation has led to recommendations for the parallel development of two integrated design concepts for a prototype secondary burner system. One concept utilizes the existing burner heating and cooling subsystems in order to minimize development risk, but simplifies a number of other features associated with remote maintenance and burner operation. The other concept, which offers maximum cost reduction, utilizes internal gas cooling of the burner, retains the existing heating subsystem for design compatibility, but requires considerable development to reduce the risk to acceptable limits. These concepts, as well as other design alternatives, are described and evaluated.

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1. SUMMARY

This report describes an evaluation of the existing cold pilot plant design of the 20-cm (8-inch) engineering-scale secondary burner system. The purpose of this evaluation is to assess the suitability of the existing design as a prototype of the HTGR Recycle Demonstration Facility (HRDF) secondary burner system and to recommend alternatives where the existing design is thought to be unsuitable as a prototype. This evaluation satisfies the intent and requirements of Experimental Plan Activities 501-502, "Equipment Design Evaluation," and 501-503, "Initial Design Evaluation Report," for Subtask 215 (Crushed Particle Burning).

This evaluation has led to recommendations for the parallel development of two integrated design concepts for a prototype secondary burner system. One concept utilizes the existing burner heating and cooling subsystems but simplifies a number of other features associated with remote maintenance and burner operation; this concept involves minimum development risk to achieve design objectives. The other concept modifies the cooling subsystem but retains the existing heating subsystem for design compatibility; this other concept also eliminates or simplifies a number of other features associated with heating, cooling, remote maintenance, and burner operation. The modified cooling subsystem uses an internal gas-cooled heat exchanger. This second integrated design concept offers the potential for maximum cost reduction, simplicity of design, and ease of fabrication, but involves significantly greater risk. Therefore, it must be studied in more detail and tested in existing pilot plant equipment before implementation as part of the prototype secondary burner system.

2. INTRODUCTION

Possible modification of the existing dry head-end cold pilot plant engineering-scale equipment to reliable and maintainable equipment that

is prototypical of the HRDF design required an evaluation of the existing equipment design. This evaluation was conducted in the same manner as the recent evaluation of the 40-cm (16-inch) primary burner system.⁽¹⁾

Selection of the features of the existing design to be evaluated was based on discussions of experienced or expected problems with cognizant persons (see Acknowledgements) and consideration of the sources of the requirements for these features (Table I). The following thirteen features were selected and constituted the scope of this design evaluation, as follows:

1. Separability of upper and lower cooling shrouds.
2. Remote disconnects of burner assemblies.
3. The concept of a coolant pressure boundary (shroud) external to the vessel.
4. The method of heating the burner vessel and its contents.
5. The method of attachment of vessel thermocouples.
6. The method of fabrication of the susceptor.
7. The type of insulation used for the induction coil.
8. The design of the insulation bonnet assembly.
9. The design of the upper cap assembly.
10. The location of the solids feed entry port.
11. The product removal valve assembly.
12. The separability of the induction coil, susceptor, and insulation.
13. Control of the gap between the susceptor and burner tube.

3. EVALUATION OF THE PRESENT SYSTEM

The principal functions of the thirteen selected design features of the existing 20-cm secondary burner system were derived from FAST Diagrams

(Appendix I) and are listed in Table I. As these functions indicate, ten of these thirteen features are concerned with various aspects of process equipment design or manufacturing, and the other three features involve remote maintenance requirements.

The advantages and disadvantages of each of these features of the present system are listed in Appendix II in a generally random order. Also listed are technical specifications or other constraints imposed on the design of these features. All of the existing burner system design features are able to perform the principal functions for which they were designed. The chief problems generally involve difficult or expensive fabrication, poor maintainability, or difficult installation.

The installed costs of the evaluated features of the existing burner system are given in Appendix III. They include purchased material, manufacturing costs, and installation (technician labor). The costs are based on actual purchase orders, service requests, and internal department work requests. The features analyzed are all defined by released drawings or other traceable documents, as noted on the worksheets in Appendix III.

4. ALTERNATIVES

After evaluation of the present system had been completed, the techniques of value engineering were used to generate new ideas, designs, and methods for achieving the same functions performed by the existing design features. The generation of new ideas was carried out without the imposition of any design constraints in order to enhance freedom of thought and to maximize the number of potential alternative designs. New ideas were generated in a creative thinking session with three other engineers, two of whom had been personally involved in various aspects of the design, fabrication, installation, and operation of the 20-cm secondary burner (see Acknowledgements). An average of four new ideas were conceived for each of the thirteen design features considered. These ideas are listed in Appendix IV.

Once a number of ideas had been conceived for each design feature, then constraints and technical specifications were applied against them. In addition, ideas with similar or compatible features were combined. The aim was to reduce the number of alternatives to be evaluated further to a maximum of two or three. Then the advantages and disadvantages of each remaining alternative were compiled. The alternatives, constraints, advantages, and disadvantages for each of the thirteen design features are given in Appendix V.

Before costs could be estimated for each of the remaining alternatives, enough technical information had to be compiled about each one to serve as a basis for cost development. This information included equipment sizes, pressure and temperature ratings, amounts of construction materials used, etc. The costs, which are given in Appendix V, were based on various sources, such as GA Purchasing Dept. data, verbal quotations from suppliers, and literature data.⁽²⁾ Standard equipment escalation factors were applied to bring all estimated costs to a January, 1977 base for comparison.

5. COMPARISON OF ALTERNATIVES AND THE PRESENT SYSTEM

Value engineering techniques for evaluation of several alternative designs utilize the concepts of 'performance' and 'value.'⁽³⁾ Performance, in this case, is a composite, quantitative rating of how well a particular design satisfies all significant evaluative criteria, such as maintainability, reliability, ease of implementation, customer acceptance, etc. Value is the ratio of performance to estimated cost (value index), higher ratios being preferred over lower ratios. Normally, if the total cost of a design is known with reasonably high confidence (>85%), the value index is sufficient to determine the merits of one alternative over another. However, in this evaluation, the cost estimates are known with a confidence level of no more than 75%. Therefore, in this evaluation both performance and value have been considered in judging the relative merits of alternative designs.

The actual ratings and estimates for the thirteen design features are given in Appendix VI. A brief discussion of the results in each case follows:

Design Feature #1 - Cooling Shroud Separability

The use of a non-removable (welded) cooling shroud integral with the burner tube (ideas B and C, Fig. 1) improves the maintainability of the overall burner system in comparison to either the use of a single removable shroud (idea A, Fig. 1) or the existing burner (Fig. 2). Maintainability, in this case, includes ease of installation of the shrouds, ease of replacement of the shroud expansion devices, and accessibility of the burner tube for inspection, although the latter characteristic is not considered (by General Atomic Co. personnel) to be an important criterion for evaluation except in the area of the gas distributor plate.

The incorporation of metal bellows into an integral welded shroud (idea B) virtually eliminates leakage of cooling air and thereby results in the best effect on burner operation and performance.

Naturally, the criterion of ease of implementation in the cold pilot plant favors the existing design. However, idea B would have the least impact on current HRDF design, because it is already incorporated into the conceptual design of the Hot Engineering Test Facility (HETF) secondary burner.

Customer (ERDA) acceptance of any of the three alternative shroud designs seems favorable. Nevertheless, in the author's opinion, acceptance of alternative A is slightly enhanced by accessibility of the burner tube for inspection, which might still be a consideration during licensing of the HRDF.

The overall weighted performance of alternative B is the highest. This alternative also yields the largest cost savings, which gives it

the highest value. It should be noted that the cost savings estimated for alternative B is conservative in that associated simplification of design and reduction of cost of remote fixtures are not included.

Design Feature #2 - Remote Disconnects

In this case, only one practical alternative design is proposed: the mid-vessel remote flange is eliminated and the lower remote flange is relocated to a cooler zone below the gas distributor plate. This design is already incorporated into the HETF conceptual design (Fig. 3). In addition to eliminating a remote flange, clamp, and seal ring, this design provides a better seal at the lower flange (lower temperature), eliminates present induction heater power input limitations, and continues to permit the removal of the gas distributor plate for repair or replacement.

Consequently, the alternative design seems clearly superior to the present design (Fig. 4) with respect to all the evaluative criteria (maintainability, impact on burner operation and performance, impact of the change on current HRDF design, and ERDA acceptance) except one, the ease of implementation in the pilot plant. Even in this area, however, the alternative design is given a high rating, since it would not be difficult to implement.

Both the overall weighted performance index and the value index of the alternative design are higher than those of the present design.

Design Feature #3 - Method of Cooling the Burner and Its Contents

Two alternative designs to the existing external cooling shroud were evaluated (Fig. 5): the use of an internal heat exchanger consisting of an array of vertically-oriented tubes (A) and direct gas

cooling of the bed (B). Both alternatives utilize gaseous carbon dioxide (CO₂) as coolant.

Calculations show conclusively that alternative B is technically infeasible. In order to remove the maximum amount of heat generated during the combustion phase (117 kW or 400,000 Btu/hr)⁽⁴⁾ it would be necessary to sustain a superficial gas velocity of approximately 650 cm/sec (21 ft/sec) through the bed, even assuming the maximum allowable gas temperature rise of 960°C from the sublimation temperature of CO₂ to bed temperature! Such a gas velocity is eight times the maximum permitted to avoid exceeding in-vessel filter capacity and adversely affecting bed fluidization characteristics.

On the other hand, alternative A is quite feasible. A total flow of approximately 10 m³/min STP (350 SCFM) of gaseous CO₂ at supply conditions of 675 kPa (83 psig) and 50°C (122°F) through four U-tubes (1.6 cm o.d. x 16 BWG x 3.4 m overall length) is adequate to remove the maximum heat generated. The number and size of the cooling tubes represent only 5 percent of the burner tube inside cross-sectional area and, therefore, should not adversely affect bed fluidization characteristics. Tube-to-bed heat transfer coefficients for these calculations were estimated from experimental data obtained with the 20-cm secondary burner at appropriate flow conditions.⁽⁵⁾

Alternative A is considered to be superior to the existing burner design (external cooling shroud) with respect to process performance characteristics. Bed temperature response to changes in coolant flow is expected to be faster because of improved coolant-side heat transfer and a thinner tube wall. In addition, vertical tubes are known to dampen slugging and this may have a favorable effect on burner operation and performance.

The maintainability of alternative A, of course, is inferior to that of the existing burner design because of the difficulty of removing

the tubes for repair. Ease of implementation and impact on HRDF design also favor the existing design.

Finally, it would seem likely that ERDA acceptance of alternative A would be unfavorably influenced by the relatively poor reliability of such a design, as experienced, for example, by EXXON in their pressurized fluidized-bed coal combustors.⁽⁶⁾

The existing method of cooling has the highest performance rating. However, when installed capital costs are factored in, the much less costly alternative A shows a significantly higher value.

Design Feature #4 - Method of Heating the Burner and Its Contents

Hot gas (CO_2) heating was evaluated as an alternative to induction heating of the burner and its contents. The feasibility of this method for the primary burner heatup had been discussed before.^(1,7) The same approach to calculating bed temperature-time profiles for the secondary burner was used in this evaluation.

Three variations of this alternative heating method were evaluated. In alternative A, hot gaseous CO_2 is blown up through the bed only (Fig. 6). Even based on somewhat optimistic assumptions and thermal modeling, it can be seen that heatup time for a 60 kg batch of crushed particles is three to five times longer than the current requirement, depending on the selected ignition temperature (Fig. 7). This results from high heat losses to the surroundings and stored heat in the vessel wall and insulation. Only 24 percent of the heat given up by the gas, in this case, is usable; i.e., absorbed by the particle bed. This alternative, therefore, is unacceptable.

In alternative B, hot gaseous CO_2 is passed through the external shroud only (Fig. 8). Again, based on optimistic assumptions and thermal modeling, it can be demonstrated that this alternative is

probably infeasible. Although higher allowable mass flow rates of heating gas in the shroud result in higher bed heating rates at low temperatures, higher heat losses at high bed temperatures prevent the bed temperature from rising much above 775°C (Fig. 9). Since the ignition temperature of some particles might be as high as 800°C, this alternative is unacceptable. Heat losses are higher in this case because of the loss of the insulating air gap between the insulation and the burner tube and the introduction of substantial convective heat transfer from the heating gas to the insulation. Only 19 percent of the heat given up by the gas is usable in this case.

In alternative C, the first two alternatives are combined. Hot gaseous CO₂ is blown simultaneously up through the bed and through the external shroud. In this case the combined flows of hot gas are sufficient to overcome the heat losses, and bed heatup is rapid and sustained (maximum bed temperature >900°C). Over 30 percent of the heat given up by the gas is usable (Table II). Heatup to 800°C is achieved in approximately ten minutes, which is well under the required heatup time of one hour (Fig. 10) and well under even the 'optimized' heatup time achieved for the 20-cm (engineering-scale) secondary burner of approximately forty minutes.

Based on alternative C, the cost of a system for delivering hot gaseous CO₂ to the burner was estimated. The system (Fig. 11) consists of a 0.19 m³ (50 gallon) pressurized liquid propane storage tank, a 10 kW electrical immersion heater for vaporizing the propane, a direct-fired gas heater rated at 359 kW (1.23 x 10⁶ Btu/hr) for heating the gaseous CO₂ from ambient to 982°C (1,800°F), and all the necessary piping, valves, and controls. The direct-fired heater burns propane gas at atmospheric pressure and 16°C (60°F).

Because this equipment is very conventional commercial equipment with many years of proven performance and relatively little maintenance, the reliability and maintainability of the hot gas heating

subsystem are rated as high or higher than those of the existing induction heating subsystem. In fact, the maintainability of the hot gas subsystem is thought to be superior to that of the induction heating subsystem because all of its components that require maintenance can be located remote from the burner itself; i.e., outside the burner cell in a hot reprocessing facility. This means reduced downtime in the event that the heating subsystem requires maintenance.

The hot gas and induction heating subsystems were rated equally in terms of effect on burner performance. Hot gas appears to give faster heatup, but induction heating is better during the 'tailburn-soak' phase of the operating cycle because of superior burner control. The hot gas technique allows for some waste heat recovery in an economizer upstream of the direct-fired heater by heat exchange between hot off-gas and cold CO₂. In addition, use of the hot gas method eliminates the potential (but very unlikely) problem of a criticality caused by breach of the induction coils and the burner wall to allow ingress of water. On the other hand, the hot gas method results in more solid waste for a commercial reprocessing plant due to the larger amounts of CO₂ in the off-gas (~170 kg/batch) which are converted to solid waste in the off-gas treatment system (although this only adds approximately 1 percent to the amount of CO₂ normally treated in a 10,000 fuel element/year reprocessing plant).

The existing induction heating subsystem, of course, has a definite advantage in terms of ease of implementation in the pilot plant and impact on HRDF design. Moreover, it is felt that ERDA acceptance of the induction heating method is more likely until (and if) actual data could be collected to verify the potential advantages of hot gas heating in the areas of maintainability and cost.

The overall weighted performance of the existing induction heating subsystem is rated higher than that of a hot gas heating subsystem. A substantial capital cost savings with the hot gas subsystem, however, gives it a higher value.

Design Feature #5 - Method of Vessel Thermocouple Attachment

The evaluation of spring-loaded thermocouples (A), tube-skin thermocouples (B), and the present method of vessel thermocouple attachment reported for the primary burner ⁽¹⁾ also applies to the secondary burner.

The overall weighted performance of the present design seems to be somewhat better than for either alternative. Substantially lower costs for the two alternatives, however, result in significantly better values for the alternatives (by a factor of 2). There appears to be a slight advantage of alternative A over alternative B, but the difference is not significant.

Design Feature #6 - Method of Fabrication of Susceptor

As indicated in the primary burner design evaluation, ⁽¹⁾ a comparison of the three alternatives - casting, forging, roll and weld non-magnetic 300-series stainless steel - and the present design (roll and weld Rolled Alloy 333, Fig. 12) is not possible at this time. The relative merits and costs of these techniques are highly dependent on the fabricator selected and on the time of fabrication. Such information must be obtained at the time of actual prototype design.

Design Feature #7 - Type of Burner Insulation

Two alternatives to the present induction coil insulation (ceramic, Fig. 13) were evaluated. One was based on the use of moldable fiber insulation like WRP-X (alternative A). The other was based on dry fiber blankets like FIBERFRAX (alternative B). The ceramic appears to have higher maintainability than either A or B because of its superior handling characteristics (structurally rigid). However, the insulation characteristics of the fiber insulations (A or B) are better than those of the ceramic because of the lower thermal

conductivity of the fibers. ERDA acceptance of alternative A or the present type of insulation would probably be the same, if it is assumed that maintainability and insulation characteristics are the most important evaluative criteria.

The overall weighted performance of the ceramic insulation appears to be better than that of either type of fiber. However, because of its low cost, the dry fiber blanket (B) appears to be the best value. Ultimately, of course, the evaluation of insulation will depend on the maintenance philosophy adopted for a commercial reprocessing plant.

Design Feature #8 - Design of the Insulation Bonnet Assembly

The 'split-dome' construction of the insulation bonnet assembly (Figs. 14 & 15) was compared to the 'unitized' insulation bonnet assembly (Fig. 16) used on the 40-cm primary burner (alternative A); to a two-piece insulation assembly (Fig. 17) consisting of a removable cylinder and a circular section attached to the top of the upper cap assembly (alternative B); and to a single large removable insulation enclosure (Fig. 17, alternative C).

It had already been determined as a result of the primary burner design evaluation that the 'unitized' design was superior to the 'split-dome' design in terms both of performance and cost.⁽¹⁾ Nevertheless, it appears that alternative B offers even better overall performance based on superior maintainability and ease of fabrication. In addition to requiring somewhat more handling than B, alternative C requires more cell space for storage during maintenance periods and probably leaks more heat to the cell heating, ventilating, and air conditioning (HVAC) system; however, it is difficult to assess the cost impact of these factors.

The overall weighted performance of alternative B is rated the highest. Since the cost of this alternative is the lowest, its

value is also higher than the other two alternatives and significantly higher than the present design.

Design Feature #9 - Design of the Upper Cap Assembly

Only one alternative to the present design (Fig. 18) of the upper cap assembly was evaluated. It is the HETF secondary burner cap design (Fig. 3) in which the filter plenum chamber is eliminated and the filter blowback piping is headered outside the upper cap assembly. A remote top flange is provided with the assembly.

This alternative design was judged to be superior to the present design in virtually all the evaluative criteria considered. In particular, the alternative design offers much greater maintainability and ease of fabrication than the present design. It was not possible to develop a realistic cost for the alternative design because of the lack of design details, but the cost should be much less than the present design as a result of simplicity of design and ease of fabrication.

Design Feature #10 - Location of Solids Feed Entry Port

Only one alternative to the present side entry solids feed port was evaluated, a top entry solids feed port. The top entry appears to have a significantly higher performance index. It simplifies the cooling shroud design, reduces the stresses on the vessel, and is compatible with the improved (HETF) design of the upper cap. The only drawback of this design appears to be the introduction of internals into the upper section of the burner (the feed should be introduced below the bottom of the filters); the internals might have an undesirable effect on bed fluidization characteristics during operation after bed addition.

Costs are not available for either the existing side entry solids feed port or the alternative top entry port. However, the top entry

cost, when coupled with the cooling shroud cost reduction, is believed to be less than the side entry cost. Therefore, the overall weighted performance index, which favors the top entry, was used to select the preferred design.

Design Feature #11 - Product Removal Valve Assembly

Two alternatives to the present product removal valve assembly design (Fig. 19) were considered: (1) a design similar to the HETF primary burner product removal valve assembly in which a retractable valve plug seats against the gas distributor (alternative A) and (2) a concept involving the elimination of the valve assembly altogether with elutriation of the product solids from the burner with a 'push-pull' type transport system (alternative B, Fig. 20).

Alternative B involves the use of a 2.5 cm (1-inch) diameter (nominal) dip-tube that enters the burner tube just below the bottom of the in-vessel filters and extends approximately 2 meters vertically down the inside of the burner tube to a point just above the gas distributor plate. Gaseous CO₂ at ambient temperature and a pressure of approximately 287 kPa (27 psig) is admitted at a flow of 7.7 m³/min. STP (271 SCFM) to the bottom of the dip-tube. A pressure of 60 kPa (12 in. Hg vacuum) is maintained at the outlet of the tube by a rotary blower. Under these conditions, the gas velocity in the tube is approximately 230 m/sec, which is 86% of the acoustic velocity and approximately 70 times the terminal settling velocity of the largest particle in the product solids. This velocity is sufficient to elutriate the entire 48 kg bed of particles out of the burner in approximately 30 minutes (Fig. 21).

Since alternative B requires no active components (other than block valves) near the burner itself, its maintainability is far superior to either alternative A or the present design. Alternative B should result in less system downtime and shorter downtime for maintenance.

Accountability, a very important criterion, is best with the present design, which provides a 'sweep tube' to effect virtually complete product removal. Of course, a similar device could also be incorporated into alternative B.

The present design also provides the best operability, since it allows for the most controllable regulation of product solids flow.

The reliability of alternative B was given the highest rating because of the absence of moving parts (except for a conventional rotary blower, which is highly reliable but could be spared if necessary to provide high reliability).

Because of the importance of accountability and flow regulation as evaluative criteria, it is felt that ERDA acceptance of the present assembly over the alternatives is likely.

The overall weighted performance of the present assembly is therefore rated considerably higher than that of either alternative. Alternative A cost is not available without detailed design, but alternative B is probably more expensive than the present system, particularly in view of the fact that use of high pressure gas makes ASME Code design of the burner mandatory in alternative B. Thus, the present system appears to be the best value.

Design Feature #12 - Separability of the Induction Coil, Susceptor and Insulation

The construction of the induction coil, susceptor, and insulation integral with the burner tube (A) is the only proposed alternative to the present system (Fig. 22). The maintainability of alternative A is superior to that of the present design because there are fewer separate components to handle. This alternative is also expected to result in somewhat less radioactive solid waste in a hot reprocessing facility, if it is assumed that maintenance downtime is infrequent, the

coil does not fail, and fiber rather than ceramic insulation can be used. Since the HETF conceptual design employs such an assembly, the impact of alternative A on current HRDF design was rated the most favorable. Impact on criticality control (ability to detect water leaks) and ERDA acceptance appear to be about the same for both designs.

The overall weighted performance and value index of alternative A were rated higher than those of the more costly present design.

Design Feature #13 - Controlled Gap Between the Susceptor and Burner Tube

The existing burner system design (Fig. 22) does not provide for control of the gap between the susceptor and the burner tube, which complicates installation. Two methods of overcoming this problem were considered: (1) Provide an integral cooling shroud, eliminate a separate susceptor, and suscepr directly on the shroud (alternative A, Fig. 1B). In this manner, the gap is fixed during fabrication of the burner tube assembly by welding of the shroud (susceptor) to the tube; (2) Provide a single removable shroud, eliminate a separate susceptor, and again, suscepr directly on the shroud (alternative B, Fig. 1A). In this case, the gap could be controlled by installing spacers between the shroud (susceptor) and the burner tube.

The overall weighted performance of alternative A is the highest, based on superior maintainability (ease of installation), ease of fabrication, and adaptability of the HETF conceptual design which incorporates this idea to an HRDF prototype design.

Alternative A also has the lowest installed cost, which gives it the highest value index.

5. DEVELOPMENT OF INTEGRATED BURNER SYSTEM DESIGN CONCEPTS

Until now, each of the thirteen design features (for the existing design and alternatives) has been evaluated independently, without consideration of interfacing with any of the other features. As with the evaluation of the 40-cm primary burner, it is prudent, however, to consider the effect of the best designs in each case on the whole system, and in so doing, to develop an integrated burner system design concept that constitutes the best 'composite' of design options.

Toward this end, Table III lists both the 'best value' option and the 'best performance' option for each of the thirteen design features from the results in Appendix VI. From this list, it can be argued that the methods of heating and cooling the burner and its contents are the design features with the largest number of interfaces and the greatest impact on the total system. Once these designs are established, most of the designs for the other features fall into place.

Two integrated burner system design concepts were developed. One represents the 'best value' composite of design features but may include inherent, relatively high development risks of failure to achieve design objectives. The other represents the 'minimum risk' composite but may result in only modest improvements in performance or cost.

Best Value Composite

Although the existing external cooling shroud is the 'best performance' option for cooling the burner when one considers its heat removal function only, at least half the difference between the performance indexes of the existing shroud and internal heat exchanger can be eliminated by successful pilot plant testing of this alternative concept. Furthermore, the potential cost savings with an internal heat exchanger is so large that removal of cost uncertainties will still result in a 'value' advantage for the internal heat

exchanger. Therefore, the internal heat exchanger concept offers great potential for an optimum method of cooling the burner and its contents. Nevertheless, this design involves considerable risk. Potential problems include mechanical support of the tubes; heat exchanger maintenance; tube failures; loss of some operating flexibility because of higher vessel wall temperatures; and effects of internal components on fluidization and in-vessel filter interference. For example, EXXON has experienced continuing problems of internal cooling coil damage from thermal stress, corrosion, and bending in their pressurized fluidized-bed coal combustors.⁽⁶⁾

Similarly, although the existing induction heating system is the 'best performance' option for heating the burner, elimination of this system would also eliminate the need for a susceptor and would make use of external fiber insulation even more defensible (features 6, 7, 12 and 13, Table III). Furthermore, most of the difference between the performance indexes of the existing system and the combined bed and shroud hot gas (CO₂) heating system can be eliminated by successful pilot plant testing of this alternative concept. Finally, the much lower cost estimated for the hot gas heating system means that the 'value' advantage of this option will probably be preserved even after the removal of cost uncertainties. Therefore, the hot gas heating concept offers great potential, in my opinion, for an optimum method of heating the burner and its contents. However, this concept also involves considerable risk. Potential problems include maintenance and control of the direct-fired heater and control of the burner during 'tailburn' and 'soak' phases of the operating cycle.

More importantly, the 'best value' cooling concept (internal cooling tubes) is incompatible with the 'best value' heating concept (hot gas heating), since the former concept involves elimination of the external shroud and the latter concept requires the use of the shroud. This is different from the primary burner, where internal bed heating was sufficient and neither heating nor cooling required

the external shroud. In the case of the secondary burner, it appears from cost estimates of the present design and the alternatives (Appendices III and V, respectively) that more money can be saved by elimination of the external cooling shroud (~\$48,000 per burner) than by elimination of the induction heating subsystem (~\$32,800 per burner). Therefore, the best value concept for both heating and cooling couples the use of internal gas-cooled tubes with the present induction heating subsystem.

Based on the foregoing concept, the following features can be eliminated altogether: cooling shroud (feature #1), separate susceptor (elimination of the shroud allows direct susceptance on the burner tube)(feature #6), insulation bonnet assembly (feature #8), and the gap between the susceptor and the burner tube (feature #13). Dry fiber blanket insulation, which is the 'best value' option for feature #7, is compatible with the induction heating subsystem.

Feature #2: The 'best value' option, elimination of the mid-vessel remote flange and relocation of the lower remote flange, etc., should be adopted as the prototype design feature. Its performance index is also superior to that of the existing design.

Feature #5: Successful pilot plant testing of the 'best value' option, the spring-loaded thermocouples, would increase its performance index at least to a par with the existing thermocouples. This option merits testing for feasibility as a prototype design.

Feature #9: Since costs were not available on the alternative design of the upper cap assembly, the preferred design is based on the performance index. On this basis, the upper cap assembly design for the HETF secondary burner is the preferred design.

Feature #10: On the basis of superior performance and probable lower cost, the top solids feed entry port is the preferred design.

Feature #11: The present design of the product removal valve assembly has both the 'best value' and 'best performance' indexes and should be retained.

Feature #12: Since the separate susceptor is eliminated from the 'best value' integrated design concept, this feature involves only the separation of the induction coil and coil insulation. Both performance and value criteria indicate that the coil and its insulation (dry fiber blanket) should be constructed integral with the burner tube.

The 'best value' integrated burner system design concept that results from these considerations is given in Table IV and illustrated in Fig. 23.

Minimum Risk Composite

In this concept, the existing induction heating subsystem and the external cooling shrouds remain as the methods of heating and cooling the burner and its contents, respectively. Thus, most of the risk associated with the 'best value' integrated burner system design concept is eliminated. Based on this decision, the following features can be modified as follows:

Features #1 and #13: The external cooling shroud design should be modified to provide for a single integral welded shroud with bellows similar to the HETF secondary burner shroud design. Maintenance procedures for removal of the burner and induction coil should be altered to be compatible with the shroud design. This design offers improvement in the maintainability, operation, and performance of the burner system.

Features #2 (remote disconnects), #5 (vessel thermocouple attachment), #7 (type of insulation), #9 (upper cap), #10 (solids feed entry

port), and #11 (product removal valve): Same as 'best value' integrated burner system design concept.

Features #6 and #12: The separate susceptor, of course, is retained as part of the induction heating subsystem in this concept since the external shroud is used. (Methods of fabrication of the susceptor should be investigated for the design of the HRDF burner.) The induction coil, susceptor, and coil insulation (dry fiber blanket) should be constructed integral with the burner tube.

Feature #8: Since the external cooling shroud is retained, the insulation bonnet assembly is retained also. Both the 'best performance' and 'best value' for the alternatives considered are provided by the same design, a two-piece insulation assembly which consists of a removable cylinder and a top section which is permanently attached to the top of the upper cap assembly.

The 'minimum risk' integrated burner system design concept that results from these considerations is given in Table V and illustrated in Fig. 24.

7. CONCLUSIONS AND RECOMMENDATIONS

1) Methods of heating and cooling the prototype primary burner and its contents should be determined before any other prototype design features are selected.

2) Cooling the burner with an internal heat exchanger (vertical array of parallel tubes) may be feasible from a process point of view but involves considerable risk at this time. Nevertheless, this concept warrants further evaluation to verify feasibility. Several aspects of this concept must be evaluated in detail before a final decision is made:

- a) Process-side ΔP . It must be acceptably low.
- b) Effects of the tubes on slugging, mixing and other dynamic characteristics of the fluidized bed.
- c) Means of supporting the tubes and the mechanical effects of the tubes, their supports, and inlet/outlet CO_2 piping on stresses, vibration, bending, erosion, etc. The effect of process gases on the corrosion of tubes and other internal components.
- d) Physical interference with and effect on performance of in-vessel filters by tubes and other internal components.

If a more detailed evaluation indicates this concept is still feasible, then it should be tested in both the 10-cm and 20-cm (engineering-scale) secondary burners. Based on 3 experiments with each burner, the cost of implementing this concept on the prototype 20-cm secondary burner is estimated to be approximately \$40,600 (includes exempt and non-exempt direct labor charges for design, engineering, installation, testing, and the cost of sub-prototype heat exchangers for the 10-cm and 20-cm [engineering-scale] burners).

3) The induction heating concept, which requires no further development on the secondary burner, should continue to be used. However, if cooling of the burner by an internal gas-cooled heat exchanger (item 2, above) proves to be infeasible and the external cooling shroud is used, then the combined bed and shroud hot gas (CO_2) heating concept should be evaluated further. In particular, the following aspects of this alternative design should be evaluated in more detail in order to reduce the risks inherent in this concept:

- a) Controllability.
- b) Heatup time. It must be compatible with the HRDF operating cycle and production (availability) requirements.
- c) Effects of the hot gas on the bed material, including attrition, elutriation, etc.

- d) Mechanical effects of the hot gas on the vessel and any internals, i.e., stress, vibration, erosion, etc.

Then this alternative heating concept should be tested on both the 10-cm and 20-cm (engineering-scale) secondary burners if further evaluation looks promising. Implementation cost of this concept on the prototype 20-cm secondary burner is estimated to be approximately \$116,000 (includes exempt and non-exempt direct labor charges for design, engineering, installation, testing, and the cost of a hot CO₂ delivery system for the 10-cm and 20-cm [engineering-scale] secondary burners).

4) If internal cooling proves to be feasible (coupled with induction heating), then design features #1 (cooling shroud), #6 (susceptor), and #8 (insulation bonnet assembly) should be eliminated from the prototype burner design. If internal cooling is not feasible, then the integrated burner system design concept presented in Table V should be developed. Implementation costs are given in Appendix V.

5) The mid-vessel remote flange (20-cm Grayloc remote clamp) should be eliminated from the prototype burner design. The lower remote flange (15-cm Grayloc remote clamp) should be relocated to a cooler zone below the distributor.

6) A spring-loaded thermocouple and a tube-skin thermocouple should be installed and tested along with the existing vessel thermocouples on the 20-cm engineering-scale burner. Particular attention should be given to their reliability and accuracy.

7) Ways of handling and installing dry fiber blanket insulation like FIBERFRAX between the induction heating coils and the burner tube should be investigated and implemented once the method of heating the prototype secondary burner is established.

8) Those other features - upper cap assembly, solids feed entry location, and the integral construction of the induction coil, insulation, susceptor (if used), and burner tube - which have already been incorporated into the HETF secondary burner system design should be incorporated into the HRDF design if HETF program testing verifies the feasibility of these designs for hot reprocessing operations.

9) The present design of the product removal valve assembly should be retained at this time for the prototype burner. However, if additional funds become available and schedules permit, both alternative designs described in earlier sections of this report should be tested on the 20-cm secondary. In particular, the accountability and operability of these concepts should be tested. Implementation costs for these alternative designs are given in Appendix V, based on a requirement of two experiments to test each alternative design.

10) Remote maintenance fixtures should be evaluated in light of the results and recommendations of this study.

8. FUTURE WORK

Future design evaluation studies of the 20-cm secondary burner should include the following areas:

- 1) Optimization of the burner operating cycle, including heatup based on HRDF availability allocations and plant economics.
- 2) Determination of the optimum specification for unburned carbon in the burner product once leacher and solvent extraction impurity limits are defined.
- 3) In-vessel filter reinforcement.

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Installation: T. D. Wright and W. S. Rickman

Operation: W. S. Rickman

Value Engineering: L. Abraham, U. S. Park
and W. S. Rickman

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- (5) GA-A14214, "Quarterly Progress Report for the Period Ending November 30, 1976," December, 1976, pp. 4-21 through 4-29.
- (6) EPA-600/7-76-011, "Studies of the Pressurized Fluidized-Bed Coal Combustion Process," EXXON Research & Engineering Co., Sept., 1976, pp. 98-105.
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TABLE I
SCOPE OF EVALUATION - DEFINITION OF DESIGN FEATURES

FUNCTION	SUBSYSTEM/ COMPONENT/ PART	FEATURE	SOURCE OF REQUIREMENT				
			PROCESS	REMOTE MAINT.	FACILITY		
					ACCP	GA	HRDF
1. Allow removal	heating assy. & upper cooling shroud	separability of cooling shroud (upper & lower sections)		x			
2. Allow removal/reassembly	remote flanges	remote disconnect of burner assemblies		x			
3. Transfer heat	cooling air shroud	pressure boundary external to vessel	x				
4. Increase (bed) temperature	heating subsystem	method of heating burner	x				
5. Sense temperature	vessel T/Cs	method of vessel T/C attachment	x				
6. Transform energy	susceptor tube	method of fabrication of susceptor					x
7. Reduce heat transfer	ceramic insulation	type of induction coil insulation (ceramic vs fiber)		x			
8. Allow removal	insulation bonnet assy.	'split-dome' vs. 'unitized' design		x			
9. Resist pressure; support weight	upper cap assy.	interface between top of burner and filter assy.	x	x			
10. Transport weight	solids feed entry	side vs top entry	x				
11. Resist pressure	product removal valve	valve design	x				
12. Transfer heat	induction coil, susceptor, insulation	separability of coil, susceptor & insulation		x			
13. Permit expansion	susceptor & vessel tube	uncontrolled gap between susceptor & tube	x				

TABLE II
HEAT BALANCE FOR HOT GAS HEATUP
 (Shroud & Bed)

Heat In:

<u>Source</u>	<u>Avg. Rate</u> (kW)	<u>Distribution</u> (%)
Shroud Gas (CO ₂)	155	96.1
Fluidizing Gas (CO ₂)	6	3.9
Total	161	100.0

Heat Out:

Stored Heat in Bed (usable heat)	49	30.5
Losses:		
Wall (stored heat)	27	16.9
Insulation (stored heat)	82	50.6
Surroundings	3	2.0
Total	161	100.0

TABLE III
BEST OPTIONS FOR DESIGN FEATURES

Design Feature	'Best Value' Option	'Best Performance' Option
1. Cooling shroud separability	Provide an integral welded shroud with bellows.	Same as 'Best Value.'
2. Remote disconnects	Eliminate middle Grayloc flange. Relocate lower Grayloc flange to cooler zone below distributor (HETF design).	Same as 'Best Value.'
3. Method of cooling burner/contents	Use internal gas-cooled tubes.	*
4. Method of heating burner/contents	Blow hot gaseous CO ₂ through bed <u>and</u> external shroud.	*
5. Method of vessel T/C attachment	Use spring-loaded thermocouples.	*
6. Method of fabrication of susceptor	No conclusion.	No conclusion.
7. Type of induction coil insulation	Use dry fiber blanket (e.g. FIBERFRAX).	*
8. Insulation bonnet assy.	Use a two-piece insulation assy.	Same as 'Best Value.'
9. Upper cap assy.	No conclusion.	Eliminate filter plenum. Provide external blowback system. Use remote top flange. (HETF design)
10. Solids feed entry.	No conclusion	Top entry.
11. Product removal assy.	*	*

* Existing pilot plant design.

TABLE III (cont)
BEST OPTIONS FOR DESIGN FEATURES

	Design Feature	'Best Value' Option	'Best Performance Option
12.	Separability of coil, susceptor and insulation	Integral construction of coil, susceptor and insulation.	Same as 'Best Value.'
13.	Uncontrolled gap between susceptor and tube	Provide an integral welded shroud with bellows.	Same as 'Best Value.'

TABLE IV
BEST VALUE INTEGRATED BURNER SYSTEM DESIGN CONCEPT

Method of cooling burner - Internal gas-cooled tubes.

- Eliminate external shroud.
- Eliminate insulation bonnet assembly.

Method of heating burner - Induction heating.

- Eliminate susceptor (suscept directly on tube).
- Use dry fiber blanket (e.g. FIBERFRAX) insulation for induction coil.
- Provide integral construction of coil and insulation.

Remote disconnects

- Eliminate middle remote flange. Relocate lower remote flange to cooler zone below distributor (HETF design).

Miscellaneous Features

- Use spring-loaded thermocouples on vessel tube.
- Eliminate filter plenum. Provide external blowback system. Use remote top flange (HETF design).
- Provide top solids feed entry.
- Retain existing product removal assembly valve.

TABLE V

MINIMUM RISK INTEGRATED BURNER SYSTEM DESIGN CONCEPT

Method of cooling burner - External shroud.

- Provide an integral welded shroud with bellows.
- Use a two-piece insulation assembly (cylinder + fixed top section).

Method of heating burner - Induction heating.

- Investigate methods of fabrication of susceptor.
- Use dry fiber blanket (e.g. FIBERFRAX) insulation for induction coil.
- Provide integral construction of coil, susceptor and insulation.

Remote disconnects

- Eliminate middle remote flange. Relocate lower remote flange to cooler zone below distributor (HETF design).

Miscellaneous features

- Use spring-loaded thermocouples on vessel tube.
- Eliminate filter plenum. Provide external blowback system. Use remote top flange (HETF design).
- Provide top solids feed entry.
- Retain existing product removal valve assembly.

Figure 1

OPTIONS FOR DESIGN FEATURE #1

A - Single Removable Shroud

B - Non-Removable Cooling
Shroud with Bellows

C - Non-Removable Shroud
with Sliding Seal

- ### NOTES
- 1 PART NO 704 DOUBLE SOLENOID CAPEND ATZ 2" BORE, 15" STROKE BOTH ENDS CUSHIONED ROD END NO 2
 - 2 PART NO 504 DOUBLE SOLENOID CAPEND ATZ 2 1/2" BORE 1" STROKE BOTH ENDS CUSHIONED ROD END NO 2
 - 3 PART NO 504 DOUBLE SOLENOID CAPEND ATZ 2 1/2" BORE 28 STROKE BOTH ENDS CUSHIONED ROD END NO 2
 - 4 SOURCE MILLER FLUID POWER 17015 YORK RD BENSenville ILL (BULLETIN NO 4906-175) 60180
 - 5 SOURCE THOMSON INDUSTRIES INC MANHASSET N.Y. 11030
 - 6 SOURCE BEAVER PRECISION PRODUCTS INC 1970 BIG BEAVER RD TROY MICH 48064
 - 7 SOURCE UNION CARBIDE CORP CARBON PRODUCTS DIV 270 PARK AVE NEW YORK N.Y. 10017
 - 8 JUM 1 IN ITEM 58 A DEN FOLLOWER KS TEMS 46 47 48 AND BEARINGS TEM 1 ONLY THAT AMOUNT WHICH IS REQ'D TO ALIGN THEM TO EACH OTHER
 - 9 SPACER PADS INDICATED ARE TO BE MACHINED TO CORRECT THICKNESS REQUIRED TO OBTAIN PROPER SEALING OF SHROUDS IN THEIR CLOSED POSITION AND PROPER ALIGNMENT OF SHROUDS SHAFTS & AIR MOTORS TO EACH OTHER
 - 10 SPACER PADS INDICATED MAY BE MACHINED OR SHIMMED IF PROPER SEALING & ALIGNMENT CAN NOT BE OBTAINED THRU ADJUSTMENT IN SLOTTED HOLES & NOTE 9
 - 11 LENGTH OF SCREWS INDICATED MAY HAVE TO BE SHORTENED OR REPLACE SCREWS WITH SIMILAR SCREWS OF A SHORTER LENGTH IF SUBSTANTIAL MACHINING OF THE SPACER PADS IS REQ'D FOR ALIGNMENT PURPOSES
 - 12 AFTER ALL ADJUSTMENTS AND FINAL ALIGNMENT IS MADE DRILL 1/25 DIA X .005 X 1/8 DEEP AND INSERT PIN TEM 62 WHERE INDICATED
 - 13 APPLY GRAFOIL TAPE ITEM 37 TO SURFACES INDICATED IN AS MANY LAYERS AS IS NECESSARY TO FILL GAPS AND PROVIDE A PROPER SEAL WHEN SHROUDS ARE IN THEIR CLOSED POSITION
 - 14 SOURCE: McMASTER CARR SUPPLY CO 9601 JOHN ST SANTA FE SPRING CA 90670
 - 15 DRILL OUT PHOSPHOR (BRN) HOLE IN STEM IS PRIOR TO INSTALLATION

- ### ASSY PROCEDURE
- 1 BURNER ASSY 5247004 IS TO BE CRADLED IN FRAME ITEM 2 AND ADJUSTED SO THAT IT HANGS PARALLEL TO FRAME IN BOTH DIRECTIONS BEFORE ANY ADJUSTMENTS CAN BE MADE
 - 2 ADJUST SHROUDS ITEM 5 & 6 SO THAT THEY MAKE A PROPER SEAL TO BURNER ASSY AS SHOWN ON SHEET 3 NEXT ADJUST FIXED SHROUD TEM 7 IN PLACES SO THAT IT WILL MATE PROPERLY WITH SHROUDS TEM 5 & 6 IN THEIR CLOSED POSITION
 - 3 ADJUST BONNETS TEM 3 & 4 SO THEY MAKE A PROPER SEAL TO BURNER ASSY AS SHOWN ON SHEET 5
 - 4 ADJUST HEATER ASSY TEM 10 THAT MAKES A PROPER SEAL TO SHROUDS ITEM 5 & 6 AND ANGLES CONCENTRIC TO BURNER ASSY AS SHOWN ON SHEET 4
 - 5 ADJUST SHROUDS ITEM 9 & 10 SO THAT THEY MAKE A PROPER SEAL TO HEATER ASSY TEM 12 AS SHOWN ON SHEET 2. EXT ADJUST FIXED SHROUD TEM 11 THAT IT MATES PROPERLY WITH SHROUDS ITEM 9 & 10 IN THEIR CLOSED POSITION
 - 6 ADJUST AIR MOTORS ITEM 38 & 40 SO THEY RUN PARALLEL TO SHAFTS ITEM 52 & 54 AND SO THAT THE DISTON RODS ARE FULLY EXTENDED TEM 38, 39 OR FULLY RETRACTED (ITEM 40) WHEN SHROUDS ARE IN THEIR CLOSED POSITION
 - 7 ADJUST STOP BRACKETS ITEM 41 SO THAT THEY ACT AS A STOP FOR HEATER ASSY TEM 12 AND RE-TRACTED SEAL IN SHROUDS WHEN HEATER ASSY IS RE-TRACTED AND SLIDE BACK INTO PLACE AS SHOWN ON SHEET 3

ITEM	DESCRIPTION	QTY	UNIT
16 80	HEX LOCK WAT 3/8-16	8	ASSEMBLY
12 79	HEX HD SCR 3/8-16 LG	8	ASSEMBLY
78			
32 77	HEX HD SCR 3/8-16 LG		
16 76	HEX HD SCR 3/8-16 LG		
24 75	HEX HD SCR 3/8-16 LG		
12 74	HEX HD SCR 3/8-16 LG		
16 73	HEX HD SCR 3/8-16 LG		
16 72	SOCH HD CAP SCR 3/8-16 LG		
8 71	SOCH HD CAP SCR 3/8-16 LG		
12 70	SOCH HD CAP SCR 3/8-16 LG		
32 69	SOCH HD CAP SCR 3/8-16 LG		
8 68	SOCH HD CAP SCR 3/8-16 LG		
16 67	SOCH HD CAP SCR 3/8-16 LG		
32 66	SOCH HD CAP SCR 3/8-16 LG		
8 65	SOCH HD CAP SCR 3/8-16 LG		
16 64	SOCH HD CAP SCR 3/8-16 LG		
8 63	SOCH HD CAP SCR 3/8-16 LG		
16 62	SOCH HD CAP SCR 3/8-16 LG		
12 61	LOTTER PIN 3/8 DIA LG	8	ASSEMBLY
16 60	FLAT WASH 3/8 DIA LG	8	ASSEMBLY
16 59	FLAT WASH 3/8 DIA LG	8	ASSEMBLY
16 58	SHIM STOCK 3/8 DIA LG	8	ASSEMBLY
4 57	HEX HD SCR 3/8-16 LG	8	ASSEMBLY
12 56	100 NO 100 LINEAR BEARING		
2 55	25A CUBIC INCH SHAFT (4-90-99) 440000		
4 54	25A CUBIC INCH SHAFT (4-90-99) 440000		
4 53	25A CUBIC INCH SHAFT (4-90-99) 440000		
4 52	25A CUBIC INCH SHAFT (4-90-99) 440000		
6 51	504 JUM 1 ROD JUM 1		
1 50	5247060 GUIDE & STOP ASSY		
8 49	5247062 ROD JOINT ASSY		
8 48	5247058 SLIDING BLOCK ASSY		
8 47	5247058 SLIDING BLOCK ASSY		
8 46	5247058 SLIDING BLOCK ASSY		
6 45	2 1/2" PIN		
4 44	2 1/2" CLEVIS BRACKET		
2 43	2 1/2" EYE BRACKET		
2 42	2 1/2" ROD CLEVIS		
4 41	2 1/2" ROD EYE		
2 40	AIR MOTOR		
2 39	AIR MOTOR		
2 38	AIR MOTOR		
1 37	66300 GRAFOIL TAPE (1/2" WIDE)		
4 36	5247061 ROD JOINT ASSY		
2 35	5247059 2 ROD GUIDE		
1 34	5247060 2 GUIDE & STOP ASSY		
2 33	524710 1 STOP BRACKET		
6 32	5247098 4 SPACER PAD		
4 31	5247097 2 BLOCK MTG		
2 30	5247097 1 BLOCK MTG		
4 29	5247097 3 BLOCK MTG		
2 28	5247098 3 SPACER PAD		
4 27	5247099 1 ANGLE BRKT		
2 26	5247098 2 SPACER PAD		
2 25	5247098 5 SPACER PAD		
2 24	5247099 2 ANGLE BRKT		
2 23	5247100 1 BEARING MTG ANGLE		
6 22	5247098 8 SPACER PAD		
4 21	5247098 9 SPACER PAD		
20			
9			
6 18	5247098 1 SPACER PAD		
2 17	5247099 3 ANGLE BRKT		
4 16	5247098 6 SPACER PAD		
8 15	5247097 6 BLOCK MTG		
4			
12 12	5247025 1 HEATER ASSY		
11 11	5247010 1 FIXED SHROUD ASSY		
1 10	5247011 1 RIGHT SHROUD ASSY		
1 9	5247012 1 LEFT SHROUD ASSY		
4 8	5247013 1 HEATER ASSY		
4 7	5247014 1 HEATER ASSY		
1 6	5247015 1 HEATER ASSY		
1 5	5247016 1 HEATER ASSY		
1 4	5247017 1 HEATER ASSY		
1 3	5247018 1 HEATER ASSY		
1 2	5247019 1 HEATER ASSY		
1 1	5247020 1 HEATER ASSY		

FIGURE 2

SUPPORT FRAME & SHROUD ASSY

FLUID BED, 8 IN SECONDARY BURNER

5247095

GENERAL ATOMIC COMPANY

AT-100

AT-100

AT-100

NOTES:

- ITEM TO BE SUPPLIED BY GRAY TOOL CO.
- DENOTES .375 REF. FLANGE THICKNESS ON ITEMS 6, 7, & 8 SEAL RINGS.

1 VESSEL ASSEMBLY

REQD/ASSEMBLY	ITEM	PART NO	DESCRIPTION	MATL
1	11	48506	CLAMP, NO. 6	304SS
1	10	49135	CLAMP, NO. 8	304SS
1	9	70438	CLAMP, NO. 12M	304SS
1	8	51279	SEAL RING, NO. 62	304SS
1	7	6137	SEAL RING, NO. 170	304SS
1	6	6133	SEAL RING, NO. 122	304SS
1	5	5-7075-1	SPOOL HUB ASSEM.	304SS
1	4	5-7077-1	LOWER VESSEL	
1	3	5-7077-2	UPPER VESSEL	
1	2	5-47013-1	UPPER CAP	
1	1	5-7333-1	VESSEL ATTACHMENT	

REQD/ASSEMBLY		PART NO		LIST OF MATERIAL	
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES DECIMALS .XXXXX FRACTIONS 1/32 ANGLES .2° ALL MACHINED SURFACES		PROPRIETARY INFORMATION THIS DOCUMENT IS THE PROPERTY OF GENERAL ATOMIC CO. AND WILL BE RETURNED UPON REQUEST OR WHEN NO LONGER NEEDED BY THE REQUESTING ORGANIZATION. CON- TAINED HEREIN MAY NOT BE DIS- SEMINATED TO OTHERS NOR MAY THE DOCUMENT BE COPIED, IN WHOLE OR IN PART, WITHOUT THE EXPRESS CONSENT OF GENERAL ATOMIC CO.		FIGURE 4 VESSEL ASSEMBLY FLUID BED - 8 IN. SECONDARY BURNER	
NEXT AS'Y GWS 5247005		SCALE 1/8		GENERAL ATOMIC COMPANY SAN DIEGO, CALIFORNIA	
				DRAWING NUMBER 352 5247006	

352 5247006 B

Figure 5

METHODS OF COOLING BURNER

A - Internal Heat Exchanger

B - Direct Gas Cooling

Figure 6

THERMAL MODEL FOR INTERNAL GAS HEATING

Figure 7

BED TEMPERATURE RESPONSE TO INTERNAL GAS HEATING

Figure 8

THERMAL MODEL FOR SHROUD HEATING OF BED

Figure 9

BED TEMPERATURE RESPONSE TO SHROUD HEATING

Figure 10

BED TEMPERATURE RESPONSE TO COMBINED GAS HEATING

Figure 11

METHODS OF HEATING BURNER

Present Design (Induction Heating)

Alternative: Hot Gas Heating

NOTES

1. REMOVE ALL BURRS & SHARP EDGES
2. DIMENSIONS AND TOLERANCES PER ANSI Y14.5.
3. WELDS TO BE BY MANUAL ARC, GMA OR GTA PROCESS.
4. LIQUID PENETRANT INSPECT WELDS PER ASTM-E-165 WITH ACCEPTANCE STD'S PER APPENDIX VIII OF ASME B+PV CODE, SECT VIII, DIV I
5. WELD FILLER METAL TO BE A333. SOURCE
6. BUTT WELD JOINTS SHALL HAVE COMPLETE JOINT PENETRATION & FUSION FOR THE FULL WELD LENGTH & JOINT SURFACES SHALL BE SMOOTH AND FREE FROM UNDERCUTS, OVERLAPS, ABRUPT RIDGES OR VALLEYS.
7. SOURCE: ROLLED ALLOYS INC.
3311 CONCORD AVE.
DETROIT, MICH. 48211

① SUSCEPTOR TUBE

ITEM	PART NO.	DESCRIPTION	MATL	QTY
1	5247028-4	RING 1/4 THK PLATE	ROLLED ALLOY 333	AMS-5593
3	5247028-3	FLANGE 1/4 THK PLATE	333 ALLOY	
2	5247028-2	TUBE .12 SHEET	ROLLED ALLOY 333	
1	5247028-1	SUSCEPTOR TUBE ASSY		

REQD/ASSEMBLY	LIST OF MATERIAL
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES: DECIMALS .XXX ± .05 XXX.05 FRACTIONS 1/32 ANGLES ± 2° ALL MACHINED SURFACES	FIGURE 12 SUSCEPTOR TUBE ASSY - FLUID BED, 8" SECONDARY BURNER
APPROVED FOR CONSTRUCTION DATE	GENERAL ATOMIC COMPANY SAN DIEGO, CALIFORNIA DRAWING NUMBER 5247025

NOTES

1. REMOVE ALL BURRS & SHARP EDGES.
2. DIMENSIONING & TOLERANCING PER ANSI Y14.5
3. MATERIAL: FUSED SILICA CAST FOAM 50
4. SOURCE: GLASROCK PRODUCTS, INC.
2210 MARIETTA BLVD NW
ATLANTA, GA 30318

① CERAMIC INSULATION

1		5247027-1	CERAMIC INSULATION	3	4
ITEM		PART NO.	DESCRIPTION	MATERIAL	
REQD/ASSEMBLY		LIST OF MATERIAL			
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: DECIMALS .XXX ± .015 FRACTIONS 1/2 ± 1/32 ANGLES ± 2° ALL MACHINED SURFACES		PROPERTY INFORMATION: THIS DOCUMENT IS THE PROPERTY OF GENERAL ATOMIC CO. AND WILL BE RETURNED UPON REQUEST OR WHEN NO LONGER NEEDED BY THE RECIPIENT. INFORMATION CON- TAINED HEREIN MAY NOT BE COM- MUNICATED TO OTHERS NOR MAY THE DOCUMENT BE COPIED IN WHOLE OR IN PART WITHOUT THE EXPRESS CONSENT OF GENERAL ATOMIC CO.			
NEXT ASSY 5247025		FIGURE 13 CERAMIC INSULATION- FLUID BED, 8 IN SECONDARY BURNER			
LTR DATE		ISSUE DESCRIPTION		DRAWING NUMBER	
A		APPROVED FOR CONSTRUCTION		852 5247027	
DR		CHK.		ISSUE	
DES.		APPRO.		A	
APPRO.		APPRO.		SCALE 1/2

① LEFT HALF BONNET ASS'Y

NOTES

1. DIMENSIONS & TOLERANCES PER ANSI-Y14.5
2. REMOVE ALL BURRS & SHARP EDGES
3. WELD BY MANUAL ARC GMA OR GTA PROCESS
4. WELD FILLER METAL TO BE AWS-A5.9 TYPE ER 308
5. SURFACE CONTOURS OF ALL WELDS TO BE SMOOTH & FREE FROM UNDERCUTS, OVERLAPS, ABRUPT RIDGES OR VALLEYS
6. LIQUID PENETRANT INSPECT WELDS PER ASTM-E-165 WITH ACCEPTANCE STD PER APPENDIX VIII, SECT. VIII OF ASME BOILER & PRESSURE VESSEL CODE

SOURCE: Bimba Mfg. Co.
 MONROE, ILLINOIS 60449
 ALL STAINLESS INC.
 75 RESEARCH RD.
 HINGHAM, MA. 02043

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DATE	ISSUE DESCRIPTION	DR	CHK	DES	APPD	APPD
10-1-75	APP'D FOR CONSTRUCTION	DLJ	10-1-75	10-1-75	10-1-75	10-1-75
10-1-75	APP'D FOR CONSTRUCTION	DLJ	10-1-75	10-1-75	10-1-75	10-1-75

FIGURE 14

LEFT HALF
 BONNET ASS'Y-8" IN
 SECONDARY BURNER

GENERAL ATOMIC COMPANY
 SAN DIEGO, CALIFORNIA
 DRAWING NUMBER
 852 5247040

EST. WT. -

SHEET 1 OF 2

NOTES

1. DIMENSIONS & TOLERANCES PER ANSI-Y14.5
2. REMOVE ALL BURRS & SHARP EDGES
3. WELD BY MANUAL ARC GMA OR GTA PROCESS
4. WELD FILLER METAL TO BE AWS-A5.9 TYPE ER308
5. SURFACE CONTOURS OF ALL WELDS TO BE SMOOTH & FREE FROM UNDERCUTS, OVERLAPS, ABRUPT RIDGES OR VALLEYS
6. LIQUID PENETRANT INSPECT WELDS PER ASTM-E-165 WITH ACCEPTANCE STDs PER APPENDIX VIII, SECTION III, DIV 1 OF THE ASME BOILER & PRESSURE VESSEL CODE.

① RIGHT HALF BONNET ASS'Y

AR	6	5247041	-6	STIFFENER 1/2" x 1/2" ANGLE	304 SS	ASTM-A-276
	1	5247047	-1	RIGHT LOWER SUPPORT BRACKET		
	1	5247046	-1	RIGHT UPPER SUPPORT BRACKET		
	1	5247045	-1	INSULATION BONNET, RIGHT HALF		
	2	5247041	-2	CLAMP PAD 1/2" x 1/2" ANGLE	304 SS	ASTM-A-276
	1	5247041	-1	RIGHT HALF BONNET ASSY		
-/		ITEM	PART NO.	DESCRIPTION	MATL	

REQD/ASSEMBLY									
UNLESS OTHERWISE SPECIFIED									
DIMENSIONS ARE IN INCHES.									
TOLERANCES									
DECIMALS .XXXX 0.1500 & 0.2500									
FRACTIONS 1/32 1/16 3/32 1/8 1/4 3/8 1/2 5/8 3/4 7/8 1 1 1/4 1 1/2 1 3/4 2 2 1/4 2 1/2 3 3 1/4 3 1/2 4 4 1/4 4 1/2 5 5 1/4 5 1/2 6 6 1/4 6 1/2 7 7 1/4 7 1/2 8 8 1/4 8 1/2 9 9 1/4 9 1/2 10 10 1/4 10 1/2 11 11 1/4 11 1/2 12 12 1/4 12 1/2 13 13 1/4 13 1/2 14 14 1/4 14 1/2 15 15 1/4 15 1/2 16 16 1/4 16 1/2 17 17 1/4 17 1/2 18 18 1/4 18 1/2 19 19 1/4 19 1/2 20 20 1/4 20 1/2 21 21 1/4 21 1/2 22 22 1/4 22 1/2 23 23 1/4 23 1/2 24 24 1/4 24 1/2 25 25 1/4 25 1/2 26 26 1/4 26 1/2 27 27 1/4 27 1/2 28 28 1/4 28 1/2 29 29 1/4 29 1/2 30 30 1/4 30 1/2 31 31 1/4 31 1/2 32 32 1/4 32 1/2 33 33 1/4 33 1/2 34 34 1/4 34 1/2 35 35 1/4 35 1/2 36 36 1/4 36 1/2 37 37 1/4 37 1/2 38 38 1/4 38 1/2 39 39 1/4 39 1/2 40 40 1/4 40 1/2 41 41 1/4 41 1/2 42 42 1/4 42 1/2 43 43 1/4 43 1/2 44 44 1/4 44 1/2 45 45 1/4 45 1/2 46 46 1/4 46 1/2 47 47 1/4 47 1/2 48 48 1/4 48 1/2 49 49 1/4 49 1/2 50 50 1/4 50 1/2 51 51 1/4 51 1/2 52 52 1/4 52 1/2 53 53 1/4 53 1/2 54 54 1/4 54 1/2 55 55 1/4 55 1/2 56 56 1/4 56 1/2 57 57 1/4 57 1/2 58 58 1/4 58 1/2 59 59 1/4 59 1/2 60 60 1/4 60 1/2 61 61 1/4 61 1/2 62 62 1/4 62 1/2 63 63 1/4 63 1/2 64 64 1/4 64 1/2 65 65 1/4 65 1/2 66 66 1/4 66 1/2 67 67 1/4 67 1/2 68 68 1/4 68 1/2 69 69 1/4 69 1/2 70 70 1/4 70 1/2 71 71 1/4 71 1/2 72 72 1/4 72 1/2 73 73 1/4 73 1/2 74 74 1/4 74 1/2 75 75 1/4 75 1/2 76 76 1/4 76 1/2 77 77 1/4 77 1/2 78 78 1/4 78 1/2 79 79 1/4 79 1/2 80 80 1/4 80 1/2 81 81 1/4 81 1/2 82 82 1/4 82 1/2 83 83 1/4 83 1/2 84 84 1/4 84 1/2 85 85 1/4 85 1/2 86 86 1/4 86 1/2 87 87 1/4 87 1/2 88 88 1/4 88 1/2 89 89 1/4 89 1/2 90 90 1/4 90 1/2 91 91 1/4 91 1/2 92 92 1/4 92 1/2 93 93 1/4 93 1/2 94 94 1/4 94 1/2 95 95 1/4 95 1/2 96 96 1/4 96 1/2 97 97 1/4 97 1/2 98 98 1/4 98 1/2 99 99 1/4 99 1/2 100 100 1/4 100 1/2 101 101 1/4 101 1/2 102 102 1/4 102 1/2 103 103 1/4 103 1/2 104 104 1/4 104 1/2 105 105 1/4 105 1/2 106 106 1/4 106 1/2 107 107 1/4 107 1/2 108 108 1/4 108 1/2 109 109 1/4 109 1/2 110 110 1/4 110 1/2 111 111 1/4 111 1/2 112 112 1/4 112 1/2 113 113 1/4 113 1/2 114 114 1/4 114 1/2 115 115 1/4 115 1/2 116 116 1/4 116 1/2 117 117 1/4 117 1/2 118 118 1/4 118 1/2 119 119 1/4 119 1/2 120 120 1/4 120 1/2 121 121 1/4 121 1/2 122 122 1/4 122 1/2 123 123 1/4 123 1/2 124 124 1/4 124 1/2 125 125 1/4 125 1/2 126 126 1/4 126 1/2 127 127 1/4 127 1/2 128 128 1/4 128 1/2 129 129 1/4 129 1/2 130 130 1/4 130 1/2 131 131 1/4 131 1/2 132 132 1/4 132 1/2 133 133 1/4 133 1/2 134 134 1/4 134 1/2 135 135 1/4 135 1/2 136 136 1/4 136 1/2 137 137 1/4 137 1/2 138 138 1/4 138 1/2 139 139 1/4 139 1/2 140 140 1/4 140 1/2 141 141 1/4 141 1/2 142 142 1/4 142 1/2 143 143 1/4 143 1/2 144 144 1/4 144 1/2 145 145 1/4 145 1/2 146 146 1/4 146 1/2 147 147 1/4 147 1/2 148 148 1/4 148 1/2 149 149 1/4 149 1/2 150 150 1/4 150 1/2 151 151 1/4 151 1/2 152 152 1/4 152 1/2 153 153 1/4 153 1/2 154 154 1/4 154 1/2 155 155 1/4 155 1/2 156 156 1/4 156 1/2 157 157 1/4 157 1/2 158 158 1/4 158 1/2 159 159 1/4 159 1/2 160 160 1/4 160 1/2 161 161 1/4 161 1/2 162 162 1/4 162 1/2 163 163 1/4 163 1/2 164 164 1/4 164 1/2 165 165 1/4 165 1/2 166 166 1/4 166 1/2 167 167 1/4 167 1/2 168 168 1/4 168 1/2 169 169 1/4 169 1/2 170 170 1/4 170 1/2 171 171 1/4 171 1/2 172 172 1/4 172 1/2 173 173 1/4 173 1/2 174 174 1/4 174 1/2 175 175 1/4 175 1/2 176 176 1/4 176 1/2 177 177 1/4 177 1/2 178 178 1/4 178 1/2 179 179 1/4 179 1/2 180 180 1/4 180 1/2 181 181 1/4 181 1/2 182 182 1/4 182 1/2 183 183 1/4 183 1/2 184 184 1/4 184 1/2 185 185 1/4 185 1/2 186 186 1/4 186 1/2 187 187 1/4 187 1/2 188 188 1/4 188 1/2 189 189 1/4 189 1/2 190 190 1/4 190 1/2 191 191 1/4 191 1/2 192 192 1/4 192 1/2 193 193 1/4 193 1/2 194 194 1/4 194 1/2 195 195 1/4 195 1/2 196 196 1/4 196 1/2 197 197 1/4 197 1/2 198 198 1/4 198 1/2 199 199 1/4 199 1/2 200 200 1/4 200 1/2 201 201 1/4 201 1/2 202 202 1/4 202 1/2 203 203 1/4 203 1/2 204 204 1/4 204 1/2 205 205 1/4 205 1/2 206 206 1/4 206 1/2 207 207 1/4 207 1/2 208 208 1/4 208 1/2 209 209 1/4 209 1/2 210 210 1/4 210 1/2 211 211 1/4 21									

FIGURE 15

RIGHT HALF BOXJET
ASS'Y - 8th SECONDARY
BURNER

SAN DIEGO, CALIFORNIA

	DRAWING NUMBER	ISS
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852	5247041	P
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EST. WT -

NOTES:

1. DIMENSIONING & TOLERANCING PER ANSI Y14.5
2. REMOVE ALL BURRS & SHARP EDGES.
3. WELD BY MANUAL ARC MIG OR TIG PROCESS.
4. BUTT WELDS TO BE 100% FULL PENETRATION.
5. WELDS TO BE LIQUID PENETRANT INSPECTED PER ASTM-E165 IN ACCORDANCE WITH GAC RQ-1-2 ACCEPTANCE STD
6. WELD FILLER MATERIAL SHALL BE ANS-A5.9 TYPE ER308
7. SURFACE CONTOURS ON ALL WELDED JOINTS TO BE SMOOTH & FREE FROM UNDERCUTS, OVERLAPS, ABRUPT RIDGES OR VALLEYS

9. SOURCE: REFRACTORY PRODUCTS CO., 500 N. CENTRAL MT. PROSPECT, ILLINOIS 60056. (SUPPLIED BY GENERAL ATOMIC CO.)

① INSULATION BONNET ASSEMBLY

SECTION A-A

APPROVALS		DATE
STRUCTURAL	NUT	4-8-75
MATERIAL		
WELDING		

LTR	DATE	ISSUE DESCRIPTION	DR	CHK	DES	APPD	APPD
A	7/24/75	APPROV. FOR CONSTRUCTION	HJR	3-31-75	4-1-75	4-1-75	4-1-75

REQD/ASSEMBLY	ITEM	PART NO.	DESCRIPTION	MATL	SPEC
AR 3	WRP-X-AQ	INSULATION			
1 2	5244063-2	BONNET .098 SHEET	304 SS	ASTM-A-240	
1	5244063-1	INSULATION BONNET ASSY.			

UNLESS OTHERWISE SPECIFIED	PROPRIETARY INFORMATION
DIMENSIONS ARE IN INCHES.	THIS DOCUMENT IS THE PROPERTY OF GENERAL ATOMIC CO. AND WILL BE RETURNED UPON REQUEST OR WHEN NO LONGER NEEDED BY THE RECIPIENT. INFORMATION CONTAINED HEREIN IS NOT TO BE COMMUNICATED TO OTHERS NOR MAY THE DOCUMENT BE COPIED IN WHOLE OR IN PART WITHOUT THE EXPRESS CONSENT OF GENERAL ATOMIC CO.
TOLERANCES:	
DECIMALS .XXXX .05 .XXS .03	
FRACTIONS 1/2 1/4 3/8 1/8	
ANGLES 1/2 1/4	
ALL MACHINED SURFACES	

NEXT ASSY.	5244005
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FIGURE 16	INSULATION BONNET ASSY.- FLUID BED, 16 IN. PRIMARY BURNER
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GENERAL ATOMIC COMPANY	SAN DIEGO, CALIFORNIA
DRAWING NUMBER	852 5244063 A
ISSUE	

852 5244063 A

Figure 17

Insulation Bonnet Assembly Alternatives

B: 2-Piece Assembly

C: 1-Piece Removable Enclosure

NOTES

- ▷ SOURCE FALL TRINITY MICRO CORP
CORTLAND, N.Y. 13045
(SUPPLIED BY GENERAL ATOMIC CO.)
- ▷ SOURCE JOHNS MANVILLE RO BOX 66, NORTH
BRUNSWICK, N.J. 08902

① UPPER CAP ASSY

ITEM	QTY	RECD/ASSEMBLY	PART NO	DESCRIPTION	MATL	REF
12	1		HEX HD BOLT, 1/2-13UNC-24x1 1/2	304 S STL	ASTM A-193 GRADE B8.2	
11	20		HEX NUT, 1/2-13UNC-2B	304 S STL	ASTM A-193 GRADE B8.2	
10	24		LOCK WASH., 1/2 I.D.	302 S STL	ASTM A-193 GRADE B8.2	
9	20		HEX HD BOLT, 1/2-13UNC-24x2 1/4 LG.	304 S STL	ASTM A-193 GRADE B8.2	
8	6		113-36-H FILTER	NASTELLOY		
7						
6	1		SGC 1264-2 FILTER PLENUM GASKET			
5	2		SGC 1264-1 FILTER PLENUM GASKET			
4	1		5247022-1 UPPER CAP			
3	1		524705-1 FILTER PLENUM ASSY			
2	1		524707-1 FILTER PLENUM CAP ASSY			
1	1		524708-1 UPPER CAP ASSY			

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES DECIMALS XX2 FRACTIONS 2 ANGLES 2 SURF MACHINED SURFACES		PROPERTY INFORMATION THIS DOCUMENT IS THE PROPERTY OF GENERAL ATOMIC CO AND WILL BE RETURNED UPON REQUEST OR WHEN NO LONGER NEEDED BY THE RECIPIENT INFORMATION CONTAINED HEREIN MAY NOT BE COMMUNICATED TO OTHERS NOR MAY THE DOCUMENT BE COPIED OR IN PART WITHOUT THE EXPRESS CONSENT OF GENERAL ATOMIC CO. SCALE 1/2		FIGURE 1B UPPER CAP ASSY- FLUID BED, 8 IN. SECONDARY BURNER		GENERAL ATOMIC COMPANY 601 DEER CREEK DRAUGHTSMAN 5247013 59	
RDG RELEASED B 7/76 A 11/76 LTR DATE ISSUE DESCRIPTION DR CHK DES APPD SEE ECN 50177 FOR APP'D FOR CONSTRUCTION 5247006 NEXT ASSY 5247006							

NOT 9-10-76

208.23

59

SHEET 1 OF 1

Figure 20

"PUSH-PULL" PRODUCT REMOVAL SYSTEM

Figure 21: PRODUCT REMOVAL CHARACTERISTICS IN A PUSH-PULL ELUTRIATION SYSTEM

NOTES

1. ASSEMBLE ITEM 1 IN AN INVERTED POSITION WITH THE ITEM 7 INLETS & OUTLETS AT THE TOP
2. SOURCE: STANDARD PRESSED STEEL CO.
3733 Mc GRAW
SAN DIEGO, CA. 92117

① HEATER ASSEMBLY

VIEW 13 SCALE 1/4

- 4 16 119FW-820 NUT-SELF-LOCKING (1/2-20) 1786 CRES, AWS-5725
- 4 15 WASHER-FLAT, 3/16 ID, 1/4 OD 18-B SS, ASA B27.2
- 8 14 DOWEL PIN 3/16 DIA x 1/2 LG 18-B SS ASA B9.20
- 1 13 5247034-1 INSULATOR CAP
- 1 12 5247033-1 BOTTOM SUPPORT PLATE
- 1 11 028-1 SUSCEPTOR TUBE
- 1 10 029-2 SPACER, BOTTOM
- 1 9 027-1 CERAMIC INSULATION
- 4 8 032-1 TUBE, SUPPORT ROD
- 1 7 5247036-1 INDUCTION COIL
- 6
- 1 5 020-1 SHROUD, OUTER
- 1 4 021-1 SPACER, TOP
- 1 3 030-1 INNER SHROUD
- 1 2 031-1 TOP SUPPORT PLATE

REQD/ASSEMBLY		LIST OF MATERIAL	
ITEM	PART NO	DESCRIPTION	MATL
1	1	HEATER ASSEMBLY	
FIGURE 22			
HEATER ASSEMBLY-FLUID BED, 8 IN.			
SECONDARY BURNER			
DRAWING NUMBER		SCALE 1/4 & NOTED	
852		5247025	

SECTION A-A
SCALE: 1/2

Figure 23

BEST VALUE INTEGRATED BURNER SYSTEM DESIGN CONCEPT

Figure 24

MINIMUM RISK INTEGRATED BURNER SYSTEM DESIGN CONCEPT

APPENDIX I

FAST Diagrams

FAST Diagram

Secondary Burner System

How?

Why?

Limit Concentration
Meet Codes
Limit Temperature
Prevent Criticality
Minimize Volume

Support Weight
Allow Movement
Prevent Corrosion
Resist Pressure
Allow Removal

Scope

Heating Subsystem

FAST Diagram

Feed Addition Equipment

FAST Diagram

Burner Tube Assembly (on-line)

FAST Diagram

Product Removal Equipment

FAST Diagram

Remote Flanges

FAST Diagram

Upper Cap Assembly

FAST Diagram

Insulation Bonnet Assembly

FAST Diagram

Cooling Subsystem

FAST Diagram

Insulation Subsystem

APPENDIX II

Evaluation of Present System

FORM A

EVALUATION OF PRESENT SYSTEM

Feature # 1

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Separability of cooling shroud (upper and lower sections)	<ol style="list-style-type: none"> 1. Permits local inspection of vessel. 2. Facilitates removal of shroud with overhead crane. 3. Permits maintenance access to burner vessel and induction heating system. 4. Facilitates removal of vessel. 5. Warpage or vessel distortion less of a problem than with a single shroud. 	<ol style="list-style-type: none"> 1. Additional seals required to prevent leakage of cooling air (compared to single shroud). 2. A good seal is difficult to achieve. 3. Initial installation is more difficult, i.e., requires more handling, time. 4. Expensive construction. 	<ol style="list-style-type: none"> 1. Minimize heat leak to surroundings. Cell temp. limit 120°F. Waste heat rejection rate limited also by allowable heat load on cell ventilation (HVAC) system. 2. Reduce cooling air leakage (blower size).

EVALUATION OF PRESENT SYSTEM

Feature # 2

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Remote disconnects on main burner vessel.	<ol style="list-style-type: none"> 1. Allows remote dis-assembly/assembly. 2. Lower remote flange allows replacement of distributor plate and removal of clinkers and agglomerates. 3. Upper remote flange allows removal of filters. 4. Grayloc flanges give good seal. 	<ol style="list-style-type: none"> 1. Difficult to operate. 2. Imposes operating limitations on burner, i.e., full induction heater power cannot be applied due to limit on clamp-to-hub (lower) temperature gradient. 3. Expensive. 4. Unproven reliability. 	<ol style="list-style-type: none"> 1. No current requirement for middle flange (used for development purposes only). 2. Advantage #2 is important because burner disposal ('throwaway' burner concept) is expensive (hot burner processes transuranic elements; decontamination is expensive).

FORM A

EVALUATION OF PRESENT SYSTEM

Feature # 3

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Coolant shroud (pressure boundary) external to vessel.	<ol style="list-style-type: none"> 1. No negative effect on bed fluidization characteristics. 2. Secondary containment (of sorts) of contamination. 3. Reduces burner size required at same capacity, as opposed to internal cooling tubes. 4. May allow higher bed temperatures before vessel temperature limit is reached. 5. Lower temperature materials are required for shroud as compared to internal coils. 6. Upper cap assembly geometry interference favors external cooling (filter precludes other internals). 	<ol style="list-style-type: none"> 1. Difficult to fabricate. 2. Introduces sealing/expansion design problems. 	<ol style="list-style-type: none"> 1. Minimize bed temp. response time to changes in coolant flow. 2. Limit metal temp. to (TBD)°F (depends on material).

EVALUATION OF PRESENT SYSTEM

Feature # 4

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
<p>Method of heating burner (induction vs hot gas heating).</p> <p>Ref.: Induction heating</p>	<ol style="list-style-type: none"> 1. Faster heatup time with less gas circulation at same burner L/D due to low heat capacity of gas. This is very important to 2° burner operation due to shorter cycle time. 2. Off-gas O₂ control and monitoring during tailburning are easier without large additional flow of CO₂. 3. Less solid waste results due to lower off-gas CO₂ flow. Note: $\text{CaO} + \text{CO}_2(\text{g}) \rightarrow \text{CaCO}_3(\text{s})$. 4. Tailburn-soak at >800°C is easier to sustain than with hot gas. 	<ol style="list-style-type: none"> 1. High cost of heating system, including coil, capacitors, M-G set, re-circ. cooling water equipment. 2. Waste heat recovery (exchange with burner off-gas) is not possible (with induction heating). 3. Remote maintenance is complicated because much of heating system must be close to burner (inside hot cell). 4. Increases complexity of shrouding. 5. Criticality must be considered for hypothetical rupture of cooling coil. 	<ol style="list-style-type: none"> 1. DC 524701, para. 3.1.11.

FORM A

EVALUATION OF PRESENT SYSTEM

Feature # 5

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Method of T/C attachment to vessel.	<ol style="list-style-type: none"> 1. Simplicity of design. 2. Low first-time cost. 3. Minimum effect on vessel stresses (as opposed to imbedded T/Cs). 4. Good accuracy. 	<ol style="list-style-type: none"> 1. Mechanically weak. 2. Reliability is a function of the installation. 3. Cannot replace T/Cs. 	<ol style="list-style-type: none"> 1. <u>Control</u> T/Cs must be highly redundant or remotely replaceable. 2. Induction heating <u>requires</u> vessel T/Cs.

EVALUATION OF PRESENT SYSTEM

Feature # 7

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
<p>Type of burner insulation (ceramic vs fiber).</p> <p>Ref.: Ceramic</p>	<ol style="list-style-type: none"> 1. Ceramic is reusable in cold pilot plant. 2. Lower water absorption than fiber due to lower porosity. (Water can cause a criticality if the right amount is present.) 	<ol style="list-style-type: none"> 1. Ceramic is brittle. 2. Higher thermal conductivity than fiber, i.e., poorer insulating properties. 3. Higher material cost. 4. Greater weight (density) of ceramic increases handling problems. 	<ol style="list-style-type: none"> 1. Maximum operating temperature of insulated surface is 2,000°F.

FORM A

EVALUATION OF PRESENT SYSTEM

Feature # 8

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
<p>Insulation bonnet assembly design.</p> <p>Ref.: 'Split-dome' design (secondary burner)</p>	<p>1. 'Split-dome' design requires less time for maintenance than 'unitized' design (primary burner).</p>	<p>1. More expensive to fabricate.</p> <p>2. More expensive fixtures required to effect removal.</p>	<p>None</p>

EVALUATION OF PRESENT SYSTEM

Feature # 9

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Upper cap assembly.	<ol style="list-style-type: none"> 1. Allows cleanup of filter plenum. 2. Allows easy thermo-well removal. 3. Modular construction allows removal of filters also. 	<ol style="list-style-type: none"> 1. Complex fabrication problems. 2. Alignment of blowback tubes with filter inlet venturis is difficult. 3. Additional penetrations are difficult to install, if required. 	<ol style="list-style-type: none"> 1. Minimize volatile fission product deposition, i.e., cold surfaces. 2. Minimize leakage. 3. Maximize accountability, i.e., reduce crevices, stagnation zones, etc.

FORM A

EVALUATION OF PRESENT SYSTEM

Feature # 10

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
<p>Solids feed entry location.</p> <p>Ref.: Side entry</p>	<ol style="list-style-type: none"> 1. Side entry is compatible with head height limitations of pilot plant. 2. Prior experience shows side entry to be operable. 3. Side entry is compatible with the present upper cap design. 4. Side entry minimizes internals. 	<ol style="list-style-type: none"> 1. Side entry complicates shroud design. 2. Side entry increases stresses (cold zone on vessel). 3. Side entry is more expensive than top entry. 	<ol style="list-style-type: none"> 1. Entry must be at least 1-1/2" (nom.) diameter. 2. The included angle between the burner (vertical axis) and the longitudinal axis of the entry pipe must be no greater than 45°.

EVALUATION OF PRESENT SYSTEM

Feature # 11

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Product removal valve (inc. sweep)	<ol style="list-style-type: none"> 1. Present design does not adversely affect process, control or operability. 2. Present valve provides simple seal. 3. Present design involves proven technology. 4. Complete cleanout of particles is possible. 5. Product removal flow is 'meterable' by monitoring valve actuator position. 6. Present design can withstand severe upsets, e.g., major temperature increase. 	<ol style="list-style-type: none"> 1. Valve maintenance, i.e., removal, more difficult. 2. Complexity of present design results in high cost, especially Q.A. 3. Present design requires a sweep tube to perform all required functions. 4. Requires special tooling for maintenance. 	<ol style="list-style-type: none"> 1. DC 524701, para. 3.1.7. 2. Maximize accountability. 3. Maximize solids discharge rate compatible with solids transport system. 4. Provide regulatable flow. 5. Valve must interface with distributor plate.

FORM A

EVALUATION OF PRESENT SYSTEM

Feature # 12

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Separability of coil, susceptor and insulation.	1. If susceptor requires frequent maintenance, then radioactive waste (after decontamination) is minimized, compared to integral design.	1. If susceptor requires very little maintenance, radioactive waste is increased due to heavy, thick ceramic insulation. 2. More expensive fabrication. Tolerances are more important. 3. Assembly is more difficult. 4. Remote fixtures are more costly.	None

EVALUATION OF PRESENT SYSTEM

Feature # 13

FEATURE	ADVANTAGES	DISADVANTAGES	DESIGN SPECIFICATIONS/REMARKS
Uncontrolled gap between susceptor and tube.	None	Uncontrolled gap complicates installation.	Gap shall be $5/8" \pm 1/8"$ over entire length and circumference of burner.

APPENDIX III

Cost Analysis of Present System

General Atomic Company

GA 546 (Rev. 8/73)

Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS

MAJOR EQUIP/SYSTEM: Design Alternative: Existing
20-cm Secondary Burner

Date 4/12/77 By: J. Rode

SUBSYSTEM:

Ref: 5247025, 5247048, 5247049,
5247050, 5247070, 5247071

COMPONENT: Separability of Cooling Shroud
(upper & lower sections)

Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
<u>I. Engineering</u>					
A. Design					
B. Computer					
<u>II. Purchased Material</u>					
<u>III. Manufacturing</u>					
A. Planning					
B. Fabrication (1)	101	38.70	3,909	400	4,309
1. Machining					
2. Welding					
3. Sheet Metal					
4. Tool Design					
5. Heat Treat					
6. Inspection & Test					
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. _____					
11. _____					
<u>IV. Installation</u>					
A. Mech./Structural	Δ = 260	30	7,800		7,800
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
<u>V. Totals</u>	361		11,709	400	12,109
	96				

Notations in this column indicate where changes have been made

Notations in this column indicate where changes have been made

GA 546 (Rev. 8/73)

Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS					
MAJOR EQUIP/SYSTEM: Design Alternative: Existing 20-cm Secondary Burner		Date 4/12/77	By: J. Rode		
SUBSYSTEM: Ref: 5247025, 5247048, 5247049, 5247050, 5247070, 5247071					
COMPONENT: Cooling Shrouds					
Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
<u>I. Engineering</u>					
A. Design					
B. Computer					
<u>II. Purchased Material</u>					
<u>III. Manufacturing</u> (compiled by J. Budd, CMD)					
A. Planning					
B. Fabrication	1189.9	38.70	46,049	4,698	50,747
1. Machining					
2. Welding					
3. Sheet Metal					
4. Tool Design					
5. Heat Treat					
6. Inspection & Test					
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. _____					
11. _____					
<u>IV. Installation</u>					
A. Mech./Structural	420	30	12,600		12,600
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
<u>V. Totals</u>					
	1609.9		58,649	4,698	63,347
	98				

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MAJOR EQUIP/SYSTEM:	Design Alternative: Existing 20-cm Secondary Burner	Date 4/12/77	By: J. Rode
SUBSYSTEM:	Heating Subsystem, including heater assy, M-G set, induction coil, induction heating work station, recirc. c.w. system, ceramic & outer insulation	Ref: 5247025, PO 528471, PO 541686, PO 541680, PO 570105	

Notations in this column indicate where changes have been made

GA 546 (Rev. 8/73)

Notations in this column indicate where changes have been made

Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS					
MAJOR EQUIP/SYSTEM: Design Alternative: Existing		Date 4/12/77	By: J. Ro		
20-cm Secondary Burner					
SUBSYSTEM:		Ref: 5247028			
COMPONENT: Susceptor					
Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
<u>I. Engineering</u>					
A. Design					
B. Computer					
<u>II. Purchased Material</u>				726	726
<u>III. Manufacturing</u> (compiled by J. Budd CMD)					
A. Planning					
B. Fabrication				353*	353
1. Machining	8.0	38.70	310		310
2. Welding	23.5	38.70	909		909
3. Sheet Metal & Assy.	12.0	38.70	464		464
4. Tool Design					
5. Heat Treat					
6. Inspection & Test	5.0	38.70	194		194
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. _____					
11. _____					
<u>IV. Installation</u>					
A. Mech./Structural					
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
<u>V. Totals</u>	48.5		1,877	1,079	2,956
*Bottom flange					
	100				

General Atomic Company

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Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS

MAJOR EQUIP/SYSTEM: Design Alternative: Existing
20-cm Secondary Burner

Date 4/13/77

By: J. Rode

SUBSYSTEM:

Ref: PO 577496, PO 541680
5247027

COMPONENT: Ceramic Insulation

Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
I. Engineering					
A. Design					
B. Computer					
II. Purchased Material				2,805	2,805
III. Manufacturing					
A. Planning					
B. Fabrication					
1. Machining					
2. Welding					
3. Sheet Metal					
4. Tool Design					
5. Heat Treat					
6. Inspection & Test					
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. Repair					896
11. _____					
IV. Installation					
A. Mech./Structural	60	30	1,800		1,800
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
V. Totals	60		1,800	2,805	5,501
			<div style="text-align: center;"> } + 896 (repair) </div>		
	101				

Notations in this column indicate where changes have been made

GA 546 (Rev. 8/73)

MAJOR EQUIP/SYSTEM: Design Alternative: Existing
20-cm Secondary Burner

By: J. Ro

Ref: 5247013

Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
I. <u>Engineering</u>					
A. Design					
B. Computer					
II. <u>Purchased Material</u>				11,028	11,028
III. <u>Manufacturing</u> (compiled by J. Budd, CMD)					
A. Planning					
B. Fabrication				994	994
1. Machining	103.5	38.70	4,005		4,005
2. Welding	64.0	38.70	2,477		2,477
3. Sheet Metal & Assy.	15.0	38.70	581		581
4. Tool Design					
5. Heat Treat					
6. Inspection & Test	22.0	38.70	851		851
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. _____					
11. _____					
IV. <u>Installation</u>					
A. Mech./Structural	32	30	960		960
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
V. <u>Totals</u>	236.5		8,874	12,022	20,896
	102				

Notations in this column indicate where changes have been made

Notations in this column indicate where changes have been made

1

Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS

MAJOR EQUIP/SYSTEM: Design Alternative: Existing
20-cm Secondary Burner

Date 4/13/77

By: J. Rode

SUBSYSTEM:

COMPONENT: Insulation Bonnet Assy.

Ref: PO 572879, #3 & 4;
5247040, 5247041

Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
I. <u>Engineering</u>					
A. Design					
B. Computer					
II. <u>Purchased Material</u>				37	37
III. <u>Manufacturing</u> (compiled by J. Budd CMD)					
A. Planning					
B. Fabrication	326	38.70	12,616	550	13,166
1. Machining					
2. Welding					
3. Sheet Metal					
4. Tool Design					
5. Heat Treat					
6. Inspection & Test					
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. _____					
11. _____					
IV. <u>Installation</u>					
A. Mech./Structural	16	30	480		480
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
V. <u>Totals</u>	342		13,096	587	13,683
	103				

General Atomic Company

GA 546 (Rev. 8/73)

Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS

MAJOR EQUIP/SYSTEM: Design Alternative: Existing
20-cm Secondary Burner

Date 4/12/77

By: J. Ro

SUBSYSTEM:

COMPONENT: Vessel T/C Attachment

Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
<u>I. Engineering</u>					
A. Design					
B. Computer					
<u>II. Purchased Material</u>					
<u>III. Manufacturing</u>					
A. Planning					
B. Fabrication					
1. Machining					
2. Welding			100?		100?
3. Sheet Metal					
4. Tool Design					
5. Heat Treat					
6. Inspection & Test					
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. _____					
11. _____					
<u>IV. Installation</u>					
A. Mech./Structural	40*	30	1,200		1,200
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
<u>V. Totals</u>	40		1,300		1,300
*Based on 14 T/Cs.					
	104				

Notations in this column indicate where changes have been made

General Atomic Company

GA 546 (Rev. 8/73)

Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS

MAJOR EQUIP/SYSTEM: Design Alternative: Existing
20-cm Secondary Burner

Date 4/13/77

By: J. Rode

SUBSYSTEM:

Ref: 5247078, 5247079-1, -2, -3

COMPONENT: Product Removal Valve

5247082, 5247091

Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
<u>I. Engineering</u>					
A. Design					
B. Computer					
<u>II. Purchased Material</u>					
<u>III. Manufacturing</u> (compiled by J. Budd CMD)					
A. Planning					
B. Fabrication				73	73
1. Machining	91.5	38.70	3,541		3,541
2. Welding	43.5	38.70	1,683		1,683
3. Sheet Metal & Assy.	6.0	38.70	232		232
4. Tool Design					
5. Heat Treat					
6. Inspection for Test	16.7	38.70	646		646
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. <u>OV (outside vendor)</u>					228
11. _____					
<u>IV. Installation</u>					
A. Mech./Structural	28	30	840		840
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
<u>V. Totals</u>	185.7		6,942	73	7,243
			<div style="border-top: 1px solid black; width: 100px; margin: 0 auto;"></div> <div style="text-align: right; margin-top: 5px;">+ 228 (OV)</div>		
	105				

Notations in this column indicate where changes have been made

General Atomic Company

GA 546 (Rev. 8/73)

Design Evaluation FORM B - MANUFACTURING PROCESS/TIME/COST ANALYSIS

MAJOR EQUIP/SYSTEM: Design Alternative: Existing
20-cm Secondary Burner

Date 4/14/77

By: J. Rod

SUBSYSTEM:

Ref: PO 541686, 5247028,
5247027

COMPONENT: Separability of coil, susceptor
& insulation

Item	Man Hours	Rate \$/hr	Labor \$	Mat'l \$	Total \$
<u>I. Engineering</u>					
A. Design					
B. Computer					
<u>II. Purchased Material</u>				7,427	7,427
<u>III. Manufacturing</u>					
A. Planning					
B. Fabrication (of susceptor)					353
1. Machining					310
2. Welding					909
3. Sheet Metal & Assy.					464
4. Tool Design					
5. Heat Treat					
6. Inspection & Test					194
7. Surface Finish					
8. Material Handling					
9. Assembly & Checkout					
10. _____					
11. _____					
<u>IV. Installation</u>					
A. Mech./Structural					
B. Electrical					
C. Instrumentation					
D. Plg/HVAC					
E. Inspection/Test					
F. _____					
<u>V. Totals</u>					9,657
	106				

Notations in this column indicate where changes have been made

APPENDIX IV

New Ideas for 13 Design Features

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 1

ASSEMBLY OR PART	Cooling Shroud	
	Name	number
FUNCTION	Allow	Removal (tube)
	verb	noun

QUANTITY IS WANTED

CRITICISM IS RULED OUT	HITCH HIKE
THE WILDER THE BETTER	
1. Single Shroud	21. _____
2. Integral welded shroud with bellows (forms susceptor)	22. _____
3. Radially separable (hinged) shroud	23. _____
4. Eliminate shroud	24. _____
5. Integral shroud with sliding seals	25. _____
6. Bolted-on shroud	26. _____
7. _____	27. _____
8. _____	28. _____
9. _____	29. _____
10. _____	30. _____
11. _____	31. _____
Just getting started!	Keep going!
12. _____	32. _____
13. _____	33. _____
14. _____	34. _____
15. _____	35. _____
16. _____	36. _____
17. _____	37. _____
18. _____	38. _____
19. _____	39. _____
20. _____	40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 2

ASSEMBLY OR PART	Remote Disconnects	
	Name	number
FUNCTION	Allow	Removal: filters, distributor,
	verb	noun tube

QUANTITY IS WANTED

CRITICISM IS RULED OUT

THE WILDER THE BETTER

HITCH HIKE

1. Delete middle Grayloc
2. Relocate lower Grayloc to cooler zone
3. 'Submarine hatch' on top of
4. burner (quick-opening)
5. Revise lower flange for bottom
6. removal of distributor.
7. Use external filter assy., eliminate
8. upper flange.
9. Add cleanout conn. (blind hub) at bot-
10. tom; eliminate upper Grayloc.
11. _____

21. _____
22. _____
23. _____
24. _____
25. _____
26. _____
27. _____
28. _____
29. _____
30. _____
31. _____

Just getting started!

Keep going!

12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____

32. _____
33. _____
34. _____
35. _____
36. _____
37. _____
38. _____
39. _____
40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 3

ASSEMBLY OR PART	Cooling Subsystem	
	Name	number
FUNCTION	Transfer	Heat
	verb	noun

QUANTITY IS WANTED _____

CRITICISM IS RULED OUT

THE WILDER THE BETTER

HITCH HIKE

<div style="margin-left: 40px;">Use internal cooling coil (gas-cooled)</div> <div style="margin-left: 40px;">Use external cooling tubes (water-cooled)</div> <div style="margin-left: 40px;">Use internal cooling coil (liquid-cooled)</div> <div style="margin-left: 40px;">Coolant channels in vessel wall (gas-cooled)</div> <div style="margin-left: 40px;">Use subcooled gas (sensible heat) a) refrigerated; b) expand high pressure gas.</div>	<div style="margin-left: 40px;">21. _____</div> <div style="margin-left: 40px;">22. _____</div> <div style="margin-left: 40px;">23. _____</div> <div style="margin-left: 40px;">24. _____</div> <div style="margin-left: 40px;">25. _____</div> <div style="margin-left: 40px;">26. _____</div> <div style="margin-left: 40px;">27. _____</div> <div style="margin-left: 40px;">28. _____</div> <div style="margin-left: 40px;">29. _____</div> <div style="margin-left: 40px;">30. _____</div> <div style="margin-left: 40px;">31. _____</div>
Just getting started!	Keep going!
12. _____	32. _____
13. _____	33. _____
14. _____	34. _____
15. _____	35. _____
16. _____	36. _____
17. _____	37. _____
18. _____	38. _____
19. _____	39. _____
20. _____	40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 4

ASSEMBLY OR PART	Heating Subsystem	
	Name	number
FUNCTION	Increase	(Bed) Temperature
	verb	noun

QUANTITY IS WANTED

CRITICISM IS RULED OUT

THE WILDER THE BETTER

HITCH HIKE

Blow hot gas internally & externally
through shroud.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____

21. _____
22. _____
23. _____
24. _____
25. _____
26. _____
27. _____
28. _____
29. _____
30. _____
31. _____

Just getting started!

Keep going!

12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____

32. _____
33. _____
34. _____
35. _____
36. _____
37. _____
38. _____
39. _____
40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 5

ASSEMBLY OR PART	Vessel Thermocouples	
	Name	number
FUNCTION	Sense	Temperature
	verb	noun

QUANTITY IS WANTED

CRITICISM IS RULED OUT

THE WILDER THE BETTER

HITCH HIKE

1. <u>Spring-loaded T/Cs</u> 2. <u>Weld on T/Cs to vessel</u> 3. <u>Weld on pads for T/Cs</u> 4. <u>Drill holes in vessel; insert T/Cs</u> 5. <u>Use internal wall T/Cs</u> 6. <u>Use electrical properties of tube mat'l.</u> 7. <u>Use quartz gauges</u> 8. <u>Use thermistors</u> 9. _____ 10. _____ 11. _____ Just getting started! 12. _____ 13. _____ 14. _____ 15. _____ 16. _____ 17. _____ 18. _____ 19. _____ 20. _____	21. _____ 22. _____ 23. _____ 24. _____ 25. _____ 26. _____ 27. _____ 28. _____ 29. _____ 30. _____ 31. _____ Keep going! 32. _____ 33. _____ 34. _____ 35. _____ 36. _____ 37. _____ 38. _____ 39. _____ 40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 7

ASSEMBLY OR PART	Burner Insulation	
	Name	number
FUNCTION	Reduce	Heat Transfer
	verb	noun

QUANTITY IS WANTED

CRITICISM IS RULED OUT

THE WILDER THE BETTER

HITCH HIKE

1. Moldable fiber (e.g. WRP-X)
2. Dry fiber sheet (e.g. FIBERFRAX)
3. Ceramic
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____

Just getting started!

12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____

21. _____
22. _____
23. _____
24. _____
25. _____
26. _____
27. _____
28. _____
29. _____
30. _____
31. _____

Keep going!

32. _____
33. _____
34. _____
35. _____
36. _____
37. _____
38. _____
39. _____
40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 8

ASSEMBLY OR PART	Insulation Bonnet Assembly	
	Name	number
FUNCTION	Allow	Removal (filters)
	verb	noun

QUANTITY IS WANTED

CRITICISM IS RULED OUT

THE WILDER THE BETTER

HITCH HIKE

1. Use gears (rather than air cylinders) to open 2. 'Submarine hatch' 3. 'Unitized' design 4. Replace bonnet with 2-piece insulation assembly 5. Large insulated enclosure 6. _____ 7. _____ 8. _____ 9. _____ 10. _____ 11. _____ Just getting started! 12. _____ 13. _____ 14. _____ 15. _____ 16. _____ 17. _____ 18. _____ 19. _____ 20. _____	21. _____ 22. _____ 23. _____ 24. _____ 25. _____ 26. _____ 27. _____ 28. _____ 29. _____ 30. _____ 31. _____ Keep going! 32. _____ 33. _____ 34. _____ 35. _____ 36. _____ 37. _____ 38. _____ 39. _____ 40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 9

ASSEMBLY OR PART	Upper Cap Assembly	
	Name	number
FUNCTION	Allow/Transport	Removal/Gas: thermowell filters
	verb	noun

QUANTITY IS WANTED

CRITICISM IS RULED OUT

THE WILDER THE BETTER

HITCH HIKE

HET design: eliminate filter chamber;
provide external blowback system; use
Grayloc or conventional top flange.

1. _____

21. _____

2. Use external filter assembly

22. _____

3. Eliminate filters

23. _____

4. Eliminate thermowell; replace with
side penetrations

24. _____

5. _____

25. _____

6. _____

26. _____

7. _____

27. _____

8. _____

28. _____

9. _____

29. _____

10. _____

30. _____

11. _____

31. _____

Just getting started!

Keep going!

12. _____

32. _____

13. _____

33. _____

14. _____

34. _____

15. _____

35. _____

16. _____

36. _____

17. _____

37. _____

18. _____

38. _____

19. _____

39. _____

20. _____

40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 11

ASSEMBLY OR PART	Product Removal Valve Assembly	
	Name	number
FUNCTION	Remove/Resist	Product/Pressure
	verb	noun

QUANTITY IS WANTED _____

CRITICISM IS RULED OUT	HITCH HIKE
THE WILDER THE BETTER	
1. HET primary burner valve with cone distributor	21. _____
2. Eliminate valve; use vacuum to remove product	22. _____
3. Eliminate valve; pressurize out product (like feed)	23. _____
4. Use gate valve and auger with same distributor	24. _____
5. Butterfly distributor (open to dump product)	25. _____
6. Redesign distributor to elutriate solids out top	26. _____
7. _____	27. _____
8. _____	28. _____
9. _____	29. _____
10. _____	30. _____
11. _____	31. _____
Just getting started!	Keep going!
12. _____	32. _____
13. _____	33. _____
14. _____	34. _____
15. _____	35. _____
16. _____	36. _____
17. _____	37. _____
18. _____	38. _____
19. _____	39. _____
20. _____	40. _____

FORM B

CREATIVE PHASE

C R E A T I V E T H I N K I N G

FEATURE # 13

ASSEMBLY OR PART	Gap Between Susceptor & Tube	
	Name	number
FUNCTION	Allow	Flow
	verb	noun

QUANTITY IS WANTED

CRITICISM IS RULED OUT	HITCH HIKE
THE WILDER THE BETTER	
1. Integral shroud	21.
2. Single removable shroud with fixed 'spiders' or spacers	22.
3. Single removable shroud with insertable spacers	23.
4. Single removable shroud with guide pins from top	24.
5.	25.
6.	26.
7.	27.
8.	28.
9.	29.
10.	30.
11.	31.
Just getting started!	Keep going!
12.	32.
13.	33.
14.	34.
15.	35.
16.	36.
17.	37.
18.	38.
19.	39.
20.	40.

APPENDIX V

Evaluation of Alternatives

EVALUATION PHASE - IDEA EVALUATION

Feature #1

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Single removable shroud with sliding seals.	1) At least 40" clearance req'd. to remove coil. 2) Minimize heat leak to surroundings	57,540	14,800	1) In event of burner failure, shroud is reusable. 2) Easier fabrication. 3) Easier initial installation.	1) More head room req'd 2) Warpage may affect sealing more. 3) Inspection of vessel requires removal of entire shroud (external only).	
B) Integral welded shroud with bellows.	1) Bellows availability must be greater than that of burner. 2) Shroud design must allow for removal of distributor.	51,500	14,800	1) No leakage. 2) Easier fabrication. 3) Easier installation. 4) Less head room req'd.	1) Must dispose of both shroud & burner if burner fails (increases waste). 2) External vessel inspection not possible.	
C) Single shroud welded at ends with sliding seal for thermal expansion.	1) Shroud design must allow for removal of distributor. 2) Minimize heat leak to surroundings.	54,900	14,800	1) Low leakage (between [A] and [B]). 2) Easier fabrication. 3) Easier installation.	Same as 1) and 2) for B) above.	

EVALUATION PHASE - IDEA EVALUATION

Feature #2

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Eliminate middle Grayloc flange. Relocate lower Grayloc to cooler zone (below distributor). (HETF secondary burner design)	Relocation of lower flange must permit removal of distributor.	39,300	4,400	1) Better seal at lower temp. 2) Eliminates heater power input limitations. 3) Eliminates 1 flange, clamp, seal, ring, etc.	1) An extra 'seal' is req'd. at distributor. 2) New bellows seal of distributor is unproven. Bypassing might be a problem.	

EVALUATION PHASE - IDEA EVALUATION

Feature #3

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Use internal cooling tubes, gas-cooled.	Must not adversely affect bed fluidization characteristics. Max. axial bed temp. gradient $\pm 50^{\circ}\text{C}$.	15,000	40,600	1) Possible quicker response time than external cooling. 2) Possible lower cost of cooling subsystem 3) Vertical tubes dampen slugging. 4) High pressure coolant can be used.	1) May adversely affect fluidization characteristics. 2) Burner capacity may be reduced at same diameter, or larger I.D. burner may be reqd. 3) Upper cap assy. interference. 4) Bed temp. increases limit operation due to higher wall temps.	
B) Direct gas cooling.	Any increase in particle carryover shall not exceed capacity of filters.	*		1) Quicker response. 2) Lower subsystem cost	1) Control difficult, especially during tailburning. 2) Elutriation is more of a problem. 3) Higher wall temps. limit operation. 4) Distributor redesign reqd. 5) Low heat capacity of gas probably makes direct cooling infeasible.	

* Technically infeasible; cost not estimated.

EVALUATION PHASE - IDEA EVALUATION

Feature #4

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Blow hot CO ₂ thru burner (bed)	1) Max. heatup time (to 800°C) ~1 hr. 2) Any increase in particle carry-over shall not exceed capacity of filters.	**		1) Eliminates costly induction heating equipment. 2) Some waste heat recovery possible. 3) Simplifies remote maintenance. 4) Eliminates shroud.	1) Probably slower heat up time for small (<24") burner. 2) Possible increase in burner pressure to hold constant dia.* 3) Poorer off-gas O ₂ control during tailburn. 4) Tailburn-soak at 800 °C harder to sustain. 5) More solid waste from off-gas CO ₂ .	
B) Blow hot CO ₂ thru external cooling shroud.	Max. heatup time ~1 hr.	**		1), 2) and 3) as above. 4) No effect on fluidization or particle carryover.	1) - 4) Same as in A above. 2) Greater thermal cycling of shroud.	
C) Blow hot CO ₂ both internally and thru external shroud.	Same as A) above.	46,000	116,300	1), 2) and 3) as in A) above.	1)-5) as in A) above. 6) As in B) 2) above.	

* Criticality may dictate burner diameter.

** Technically infeasible; cost not estimated.

EVALUATION PHASE - IDEA EVALUATION

Feature #5

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Use spring-loaded thermo-couples (T/Cs).	Must sense outer surface temp. within $\pm 10^{\circ}\text{C}$.	600	60**	1) T/Cs can be easily replaced. 2) No welding on vessel reqd. 3) More uniform contact with vessel possible.	1) Spring may not be enough to ensure good contact., i.e. accuracy of measurements.	
B) Weld pad to outside of vessel. Weld metal T/C sheath to pad for $>1"$.	Must sense metal temp. within $\pm 10^{\circ}\text{C}$.	600	75**	1) Good accuracy of measurement possible 2) Contact is mechanically strong.	1) Requires extensive welding on vessel. 2) Relocation of T/Cs is expensive and takes more time than spring-loaded T/Cs.	

* For vessel T/Cs.

** Install and test one T/C.

EVALUATION PHASE - IDEA EVALUATION

Feature #6

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Centrifugal casting	I.D. $\pm 0.03''$ O.D. $\pm 0.03''$	*	*	Cost???	1) Requires more machining. 2) Metal waste? 3) Tolerances a problem? 4) Casting may not be possible with Hastelloy X.	2
B) Forging	Same as above.	*	*	Cost???	1), 2) and 3) as above	3
C) Use non-magnetic 300 series stainless steel. Roll and weld as done now.	Same as above.	*	*	Cost lower than RA-333 susceptor, since 300 SS tube easier to fabricate.	1) Lower strength than Hastelloy X. May warp unless properly supported. 2) Lower corrosion resistance than Hastelloy X. 3) Higher creep rate than Hastelloy X.	1

* Highly variable, depending on supplier. Must be estimated at time of actual prototype design.

EVALUATION PHASE - IDEA EVALUATION

Feature #7

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Moldable fiber, e.g., WRP-X.	1) Max. burner wall temp. 900 °C (1650°F) un- der all normal operating modes 2) Max. insulation temp. 2000°F.	616	1,160	1) Not brittle. 2) Lower thermal con- ductivity than cera- mic. 3) Lower specific wt. 4) Lower mat'l. cost. 5) Reusable in cold pi- lot plant.	1) Higher water absorp- tion.	
B) Dry fiber sheet (e.g. FIBERFRAX)	1) and 2) as above	300	1,160	1)-4) as above.	1) as above. 2) Not reusable in cold pilot plant.	

EVALUATION PHASE - IDEA EVALUATION

Feature #8

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Unitized design (present 40-cm primary burner).		1,100	1,400	1) Cheaper to fabri- cate. 2) Cheaper fixtures required to remove.	1) Requires more time to remove filters.	
B) Replace bonnet with 2-piece in- sulation assy. (cylinder + top attached to top of burner).		750	3,000	1) and 2) as above.	1) Heat leak may be ex- cessive during oper- ation.	
C) Use single large insulated enclo- sure.		1,100	3,000	1) and 2) as above. 3) Good accessibility to top of burner. 4) Initial fabrication simplified by ab- sence of attached insulation to burner	1) More space may be reqd. for lifting operation (of insu- lation enclosure) and subsequent tem- porary storage.	

Ref.: 'Split-dome' design, 5247040 and 5247041.

EVALUATION PHASE - IDEA EVALUATION

Feature #9

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) HET design: eliminate filter chamber; provide external blow- back system; use remote top flange.	1) Minimize cold surfaces for F.P. deposition 2) Minimize leak- age. 3) Reduce crevices, stagnation zones, etc.	*	**	1) Fabrication easier and cheaper. 2) Alignment of blow- back tubes with fil- ter assy. is easier during installation. 3) Eliminates filter plenum, a source of cleanup problems. 4) Allows a simplified thermowell and feed pipe penetration.	None	

* Cost not available.

** None, since this design will be implemented in the HETF.

EVALUATION PHASE - IDEA EVALUATION

Feature #10

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Top entry* (HETF)	1) Entry must be $\geq 1\frac{1}{2}$ " dia. 2) Included angle between vertical axis of burner and long. axis of entry pipe $\leq 45^\circ$.	**	***	1) Simplifies shroud design. 2) Reduces stresses on vessel.	1) Interferes with present design of upper cap assy. 2) Introduces some internals.	

* Ref.: side entry.

** Cost not available.

*** None, since this design will be implemented in the HETF.

EVALUATION PHASE - IDEA EVALUATION

Feature #11

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) HETF primary burner valve design.	1) DC 524701, para. 3.1.7.	*	7,900+**	1) Possibly eliminates sweep tube.	1) Requires redesign of distributor plate.	
	2) Maximize accountability.			2) Cheaper construction?	2) Technology unproven w.r.t. operation.	
	3) Maximize solids discharge rate compatible with transport.			3) Provides regulatable flow.		
	4) Provide regulatable flow.			4) Takes valve out of burner body - more maintainable.		
B) Eliminate product removal valve. Elutriate product out top with a 'push pull' system.	1) thru 4) as above	8,000	17,400	1) Low capital cost. 2) Better reliability? 3) Better maintainability?	1) Control of solids flow may be difficult. 2) Technology unproven 3) Accountability may be a problem. 4) Large gas flows and/or low vacuum may be required.	

* Cost not available.

** Add material cost of an 'HETF valve design' for the secondary burner.

EVALUATION PHASE - IDEA EVALUATION

Feature #12

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Integral construction of coil, susceptor and insulation.		7,160	*	1) If susceptor needs little maintenance and coil doesn't fail, amount of rad-waste is reduced from use of fiber insulation. 2) Cheaper construction. 3) Assy. and installation easier. 4) Remote fixtures are cheaper.	1) If susceptor needs frequent maintenance or coil fails, amount of rad-waste is increased. 2) If coil leaks a small flow of water, detection will be difficult due to absorption of water by fiber insulation	

* None, since this design will be implemented in the HETF.

EVALUATION PHASE - IDEA EVALUATION

Feature #13

Ideas - Arrange & Combine	Modify & Add Constraints	Cost \$		Advantages	Disadvantages	Rating
		Unit	Impl.			
A) Provide integral shroud	Gap shall be 5/8" + 1/8" over entire length and circumference of burner.	51,500	14,800	1) Eliminates separate susceptor. 2) Gap automatically controlled because shroud welded to burner. 3) Fabrication easier. 4) Installation easier.	None	
B) Provide single removable shroud with spacers.	Same as above.	58,500	14,800	1), 3) and 4) as above. 2) Spacers control gap.	None	

APPENDIX VI

Comparison of Alternative Designs

EVALUATION PHASE IDEA SELECTION WORKSHEET

Design Feature # 1

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E W E I G H T O F	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability	9	6 54	8 72	8 72	6 54
Effect on Burner Operation & Performance	9	7 63	10 90	8.5 77	5 45
Ease of Implementation in Pilot Plant	6	5 30	3 18	3 18	10 60
Impact of Change on HRDF Design	5	2 10	10 50	8 40	3 15
ERDA Acceptance	10	9 90	8 80	8 80	7 70
* Upper & lower cooling shrouds.					
TOTAL-WEIGHTED FACTORS	X	247	310	287	244
COST (ESTIMATED) \$,per burner	X	57,540	51,500	54,900	63,350*
WT. FACTOR COST RATIO $\times 10^3$	X	4.3	6.0	5.2	3.9

EVALUATION PHASE

IDEA SELECTION WORKSHEET

Design Feature # 2

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability	9	9 81			7 63
Impact on Burner Operation & Performance	9	9 81			6 54
Ease of Implementation in Pilot Plant	6	9 54			10 60
Impact of Change on HRDF Design	5	10 50			7 35
ERDA Acceptance	10	10 100			8 80
TOTAL-WEIGHTED FACTORS	X	366			292
COST (ESTIMATED) \$ per burner	X	39,300			64,720
WT. FACTOR COST RATIO $\times 10^3$	X	9.3			4.5

EVALUATION PHASE IDEA SELECTION WORKSHEET

Design Feature # 3

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E W E I G H T O F	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Process (Cooling) Performance Characteristics (including fluidization)	10	8 80	0 0		6 60
Maintainability	9	3 27	10 90		8 72
Ease of Implementation in Pilot Plant	6	4 24	4 24		10 60
Impact of Change on HRDF Design	5	6 30	6 30		10 50
ERDA Acceptance	10	6 60	4 40		10 100
* Upper & lower cooling shrouds.					
** Technically infeasible; costs not estimated.					
TOTAL-WEIGHTED FACTORS	×	221	184		342
COST (ESTIMATED) \$ per burner	×	15,000	**		63,350*
WT. FACTOR COST RATIO $\times 10^3$	×	15	-		5.4

EVALUATION PHASE IDEA SELECTION WORKSHEET

Design Feature # 4

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E W E I G H T O F	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability	9	9 81	9 81	9 81	6 54
Reliability	9	9 81	9 81	9 81	9 81
Effect on Burner Performance	9	0 0	1 9	10 90	10 90
Ease of Implementation in Pilot Plant	6	6 36	6 36	6 36	10 60
Impact of Change on HRDF Design	5	6 30	5 25	5 25	10 50
ERDA Acceptance	10	0 0	1 10	9 90	10 100
* Technically infeasible; cost not estimated.					
TOTAL-WEIGHTED FACTORS	X	228	242	403	435
COST (ESTIMATED) \$ per burner	X	*	*	46,000	78,787
WT. FACTOR COST RATIO $\times 10^3$	X	-	-	8.8	5.5

EVALUATION PHASE IDEA SELECTION WORKSHEET

Design Feature # 5

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E W E I G H T O F	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Ease of Installation	9	10 90	6 54		7 63
Reliability	9	7 63	10 90		9 81
Ease of Implementation in Pilot Plant	6	9 54	6 36		10 60
Impact of Change on HRDF Design	5	10 50	10 50		10 50
ERDA Acceptance	10	7 70	10 100		9 40
TOTAL-WEIGHTED FACTORS	X	365	362		384
COST (ESTIMATED) \$ per burner	X	600	600		1,300
WT. FACTOR COST RATIO x 10	X	6.1	6.0		3.0

EVALUATION PHASE

IDEA SELECTION WORKSHEET

Design Feature # 7

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E W E I G H T O F	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Burner System Maintainability	9	8 72	6 54		10 90
Insulation Characteristics	9	10 90	10 90		8 72
Ease of Implementation in Pilot Plant	6	7 42	8 48		10 60
Impact of Change on HRDF Design	5	9 45	9 45		10 50
ERDA Acceptance	10	10 100	8 80		10 100
TOTAL-WEIGHTED FACTORS	×	349	317		372
COST (ESTIMATED) \$ per burner	×	616	300		5,501
WT. FACTOR COST RATIO $\times 10^2$	×	57	106		6.8

EVALUATION PHASE

IDEA SELECTION WORKSHEET

Design Feature # 8

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	WEIGHT OF IMPORTANCE	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability	9	7 63	10 90	8 72	9 81
Ease of Fabrication	9	9 81	10 90	10 90	4 36
Ease of Implementation in Pilot Plant	6	6 36	8 48	9 54	10 60
Impact of Change on HRDF Design	5	9 45	8 40	3 15	10 50
ERDA Acceptance	10	10 100	9 90	7 70	8 80
TOTAL-WEIGHTED FACTORS	X	325	358	301	307
COST (ESTIMATED) \$ per burner	X	1,100	750	1,100	13,683
WT. FACTOR COST	X	30	48	27	2.2
RATIO $\times 10^2$					

EVALUATION PHASE

IDEA SELECTION WORKSHEET

Design Feature # 9

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	IMPORTANCE WEIGHT OF	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability	9	10 90			6 54
Ease of Fabrication	7	10 70			4 28
Process Effects (Plateout, Leakage, Stagnation)	8	10 80			7 56
Ease of Implementation in Pilot Plant	6	6 36			10 60
Impact of Change on HRDF Design	5	10 50			10 50
ERDA Acceptance	10	10 100			6 60
* Cost not available.					
TOTAL-WEIGHTED FACTORS	X	426			308
COST (ESTIMATED) \$ per burner	X	*			20,896
WT. FACTOR COST RATIO $\times 10^2$	X	*			1.5

EVALUATION PHASE IDEA SELECTION WORKSHEET

Design Feature # 10

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E W E I G H T O F	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Effect on Fluid-Bed Operation	10	7 70			10 100
Impact on Vessel Stress	10	10 100			6 60
Effect on Shroud Design	10	10 100			6 60
Compatibility with Upper Cap Design	5	10* 50			10** 50
Ease of Implementation in Pilot Plant	6	6 36			10 60
Impact of Change on HRDF Design	5	10 50			10 50
ERDA Acceptance	10	10 100			8 80
* HETF design of upper cap. ** Pilot Plant (eng.-scale) design of upper cap.					
*** Cost not available.					
TOTAL-WEIGHTED FACTORS	X	506			460
COST (ESTIMATED) \$ per burner	X	***			***
WT. FACTOR COST RATIO	X	-			-

EVALUATION PHASE

IDEA SELECTION WORKSHEET

Design Feature # 11

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	WEIGHT OF IMPORTANCE	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability	9	6 54	10 90		4 36
Accountability	10	7 70	8 80		10 100
Operability (Control & Flow Regulation)	10	7 70	4 40		10 100
Reliability	9	6 54	10 90		6 54
Ease of Implementation in Pilot Plant	6	6 36	3 18		10 60
Impact of Change on HRDF Design	5	3 15	5 25		10 50
ERDA Acceptance	10	7 70	4 40		10 100
* Cost not available.					
TOTAL-WEIGHTED FACTORS	X	369	383		500
COST (ESTIMATED) \$ per burner	X	*	>8,000		7,243
WT. FACTOR COST RATIO $\times 10^2$	X	-	< 4.8		6.9

EVALUATION PHASE IDEA SELECTION WORKSHEET

Design Feature # 12

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	I M P O R T A N C E W E I G H T O F	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability	9	10 90			5 45
Impact on Rad-Waste Treatment*	9	9 81			8 72
Impact on Criticality Control (Water Leak Detection)	4	6 24			6 24
Ease of Implementation in Pilot Plant	6	6 36			10 60
Impact of Change on HRDF Design	5	10 50			5 25
ERDA Acceptance	10	10 100			10 100
* Assumes infrequent maintenance of coil & susceptor.					
TOTAL-WEIGHTED FACTORS	X	381			326
COST (ESTIMATED) \$ per burner	X	7,160			9,660
WT. FACTOR COST RATIO $\times 10^2$	X	5.3			3.4

EVALUATION PHASE

IDEA SELECTION WORKSHEET

Design Feature # 13

RATE FROM 10 (EXCELLENT) TO 0 (POOR)

EVALUATIVE CRITERIA	WEIGHT OF IMPORTANCE	BEST ALTERNATIVES FROM 'T' CHART WORKSHEETS			
		IDEA A	IDEA B	IDEA C	PRESENT
Maintainability, Including Ease of Installation	9	8 72	6 54		6 54
Ease of Fabrication	8	9 72	9 72		6 48
Ease of Implementation in Pilot Plant	6	3 18	5 30		10 60
Impact of Change on HRDF Design	5	10 50	2 10		3 15
ERDA Acceptance	10	8 80	9 90		7 70
* Upper & lower cooling shrouds & susceptor (separate).					
TOTAL-WEIGHTED FACTORS	X	292	256		247
COST (ESTIMATED) \$ per burner	X	51,500	58,500		66,300*
WT. FACTOR COST RATIO $\times 10^3$	X	5.7	4.4		3.7