

Refining

TECHNICAL

Effective Use of CO Promoter in Fluid Catalytic Cracking Operation

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Abstract

One of the most interesting catalytic technologies is the use of platinum to catalyze the conversion of carbon monoxide to carbon dioxide in an FCC regenerator. Under ideal conditions, platinum concentrations in the FCC catalyst inventory as low as 0.5 ppm are sufficient to give complete conversion of the CO to CO₂. The use of a platinum promoter not only increases FCC yields, but it significantly lowers energy requirements for an FCC unit. In addition, it is a main ingredient in cutting the cost of construction and operating environmentally acceptable FCC units by eliminating CO emissions. The use of CO promoter is also a vital part of the technology of removing SOX emissions from FCC regenerators. The availability of a proven catalytic promoter system has also permitted the construction of high temperature regenerators with resulting savings in investment. In spite of the wide-spread use of platinum catalyst in FCC units, there is surprisingly little published on the subject. The reason for this, I believe, is that the technology works so well and is so easy to test in a commercial unit that there is little incentive to seek alternate catalysts.

It is the purpose of this paper to discuss all aspects of the technology with platinum catalyst, with particular emphasis on both the short term and long term effects on unit operation and yields.

Catalyst

The catalyst universally used for CO oxidation in FCC units is platinum. Researchers¹ at Mobil R&D Corporation made the key discovery that of all of the known oxidation catalysts, platinum was the only one that could be used in low enough concentrations to catalyze CO oxidation in the FCC regenerator without catalyzing undesirable de-hydrogenation reactions in the FCC reactor. Thus, while catalysts such as nickel and copper oxide, to name a few, are excellent oxidation catalysts, they must be used at such high concentrations that they result in unacceptably high yields of hydrogen and methane in the cracking reaction.

It was once believed that the platinum needed to be impregnated directly on the surface of the entire FCC catalyst inventory. However, Upson² clearly demonstrated in commercial trials that the platinum was just as effective when added as a concentrate in the form of platinum dispersed on a solid support. This method of adding the platinum catalyst to an FCC unit is now universally accepted by the industry. The ability to control the activity of the CO promoter activity independently of the FCC catalyst activity has greatly improved the utility of this technology. Upson also noted in this publication that units in full combustion with an active alumina-base catalyst such as HFZ-20 had the unique property of lowering SOX emissions from the flue gas of the FCC regenerator. This observation formed the basis of much of the technology for lowering SOX emissions.

The "ideal" CO promoter is one with the following physical and chemical properties. The support must be a highly attrition-resistant material, have a high particle density, and have a minimum amount of particles smaller than 40 microns. These properties are, of course, necessary to minimize first cycle losses of the promoter and give high retention in the unit inventory. The support should also have a moderately high surface area and a high pore

volume to provide ready access of the reactants to the platinum catalyst. The platinum must be uniformly dispersed on the support for maximum effectiveness; this is accomplished by INTERCAT's proprietary manufacturing techniques. Chemically, the principle requirement for the support is to exclude known poisons of platinum, in particular, silica; thus, the ideal support is pure alumina. The attached specification sheet indicates that INTERCAT COP series of additives meets all of the above requirements (see Figures 1-3). The concentration of the platinum on the alumina support may vary from 100-1000 ppm, the choice is dictated more by the operating characteristics of the particular FCC unit rather than by catalytic considerations.

The concentration of platinum required in a unit inventory to accomplish complete CO oxidation is about 1-2 ppm, if the unit has uniform air distribution in the regenerator. In this case a promoter with a high platinum concentration such as COP-850 is desirable since this minimizes the cost of the support. In general, if platinum concentrations in the unit inventory above 1-2 ppm are required, it indicates mechanical problems in the unit. The most common of these is carbon monoxide bypassing the catalyst bed which results in after-burning in the plenum chamber and flue gas line. We have found that minor distribution problems can be overcome by using a lower concentration of platinum on the support such as COP-375. This results in more particles of promoter in the regenerator; however when the level of the platinum reaches 5 ppm and there is still after-burning, then a mechanical change in the regenerator must be considered.

Effect of CO Promotion on FCC Yields

When a combustion promoter is added to the circulating inventory of an FCC unit, there is an immediate impact on the yields which is largely related to the changes in

the unit heat balance. There are also longer term effects which are dependent on changes in the FCC catalyst activity and selectivity. These occur over a 30-60 day period, depending on cracking catalyst make-up rate as a percent of unit inventory. All of the above effects are highly dependent on the particular unit and the FCC catalyst being used. It is the purpose of this paper to discuss the broad principles involved in both the short-term and long-term effects of CO promotion on the FCC operation.

Turning our attention first to the unit heat balance, it is important to have a clear understanding of the broad principles involved. The first step is to consider the overall heat balance in an FCC unit. Figure 4 is a schematic representation of an FCC unit. The heat balance is described by equation 1.

Equation 1:

$$H_c = (H_f - H_p) + H_R + H_{loss} + H_{air}$$

Where:

H_c = Heat released in the regenerator by the combustion of coke
 $(H_f - H_p)$ = Change in enthalpy in heating the feed from the raw oil temperature to the reactor outlet temperature
 H_R = Heat of reaction
 H_{loss} = Heat loss from the reactor and regenerator to the atmosphere
 H_{air} = Heat required to raise the air temperature from the blower outlet to the flue gas temperature

Stated in simple terms, the heat from the combustion of the coke in the regenerator must provide the heat to vaporize the feed and raise it to the reactor outlet temperature, provide the heat of reaction, supply the heat to raise the combustion air from the blower outlet to the flue gas temperature, and also supply the heat losses to the atmosphere. This equation can be simplified by noting that the heat of reaction and the heat losses are very nearly

constant and further, if the flue gases temperature is treated as a parameter, the equation reduces to the form: $Coke, wt\% FF = m \cdot (H_f - H_p) + Constant$.

A plot showing this relation for partial and for full CO combustion is shown in Figure 5. Thus, if one specifies the raw oil temperature and the reactor temperature, the usual independent variables on an FCC unit, it is possible to calculate the change in enthalpy of the feed. From this, the coke on fresh feed can be calculated using the relationship in Figure 5. While this approach gives the coke yield on fresh feed, it does not permit the calculation of either the regenerator temperature or the catalyst circulation rate, the dependent variables in the FCC unit heat balance. To do this, we must be able to calculate the delta coke-on-catalyst, that is:

$$C_{cat} = C_s - C_r$$

Where:

C_{cat} = Delta coke-on-catalyst
 C_s = Coke on the spent catalyst
 C_r = Coke on the regenerated catalyst

The cat-to-oil ratio is then calculated by the equation:

$$C/O = Coke_{FF} / C_{cat}$$

Where:

C/O = Weight of catalyst to weight of fresh feed
 $Coke_{FF}$ = Coke as a wt% on FF
 C_{cat} = Delta coke-on-catalyst as wt% of catalyst

With the C/O determined, a simple heat balance around the regenerator gives the regenerator temp. In Figure 6, we have made this calculation using the same assumptions as in making the overall heat balance calculation in Figure 5.

There is one additional factor that must be reckoned with. In cat cracking, the term coke-on-catalyst is loosely defined to include both the coke actually on the catalyst

surface, the catalytic coke, and the hydrocarbons entrained with the circulating catalyst, the stripper coke. When a unit is put into full burn, these two components of the coke yield tend to offset one another; the catalytic coke goes up and the stripper coke goes down. The relative magnitude of this change has a large effect on the change in the operation and yields in going from normal combustion, or unpromoted operation, to full combustion.

To put the problem into perspective, consider a hypothetical case of an FCC unit going from unpromoted to promoted operation. The sequence of events is as follows: As CO is burned to CO₂, the regenerator temperature rises and the cat circulation goes down. As a result of the higher regenerator temperature, excess O₂, and longer residence time in the regenerator, the residual carbon (CRC) goes down. This results in a more active catalyst which in turn results in a higher coke-on-catalyst. This tends to raise the regenerator temperature still more. Offsetting the effect is the action of the stripper. As the circulation rate goes down, the amount of hydrocarbon carried over to the regenerator is lowered; in addition, if the stripping steam rate (lb/hr) is not changed, then the stripping steam per 1,000 pounds of circulating catalyst will go up resulting in more efficient stripping. The unit will equilibrate at a new unit heat balance; in general the coke rate will be lower and the regenerator temperature will be higher and the carbon-on-regenerated catalysts will be lower. The conversion will be higher and the magnitude of these changes will be largely dependent on the magnitude of the shift in the coke yield from stripper coke to catalytic coke. The main variable involved as to how the unit equilibrates after CO oxidation has been initiated are the change in carbon-on-regenerated catalysts and the change in the stripping rate. Unfortunately, both of these changes are difficult to predict.

If we could neglect the effect of the stripper, then the data of Upson

shown in Figures 7 and 8 could be used in a trial and error method to estimate the changes in unit operation. If stripping is a large factor, then the approach would not be valid. The reason the stripper is such a significant factor is that a change in the stripper hydrocarbons has a large affect on the heat of the combustion of the coke. The normal coke deposited on a catalyst surface has a hydrogen content of 5.5 wt%. The hydrogen content of coke in an FCC unit with a well designed stripper would be 6.5 - 7.0 wt%; while that from a poorly designed, or simply a stripper operating well above its original design, would be 8.5 - 9.0 wt%. The hydrogen content of coke can be calculated from a simple Orsat analysis of the flue gas.

In general, one can set up certain criteria to judge how a unit will respond to CO promoter. If the CRC is above 0.15%, and/or the hydrogen content of the coke is above 7 wt%, then the use of promoter will offer significant yield advantages as well as improved operation and energy savings. For units operating below these criteria, improved operation and energy savings would be obtained along with some marginal improvements in yield.

In summary, the short-term effects of CO promotion are largely dependent on the response of the unit to the change in unit heat balance. Here, we generally encounter a number of variables that are specific to the unit and the catalyst being used. The effect of CO promotion is generally always positive with respect to yields with the largest gains for units with high CRC and poor stripping.

Long Term Effects of CO Promotion

When we consider the long-term effects of CO promoter, the most comprehensive study on the effect of CO combustion on FCC yields was published⁴ by Hartzell and Chester of Mobil Oil Corporation.

They reported the detailed results of a six month test in Mobil Oil's Torrance, California FCC unit. The results are particularly valuable in that they include data for partial combustion as well as for full combustion, and they also include complete yield data in a laboratory pilot plant for catalyst samples taken from the commercial unit during the test.

The data from these trials are shown in Table 1. The conclusions that they reached were that full combustion resulted in a gain of 2.0 vol% naphtha with a 4.4 vol% increase in conversion. The combustion air required to achieve these yields was 3,600 SCF/BBL in both cases. These data clearly demonstrate that the air required for full combustion is the same as that for conventional combustion.

Table 1
Operating Conditions & Yields
in Various Regeneration Modes*

Regeneration mode	Conventional	Partial combustion	Complete combustion
CO ₂ /CO	1.3	3.7	>100
C/O, lb/lb	12.8	8.4	6.6
CRC	0.40	0.21	0.02
Feed temp., °F	495	250	250
Dense bed, °F	1180	1260	1311
Dilute phase, °F	1185	1274	1342
Flue gas, °F	1250	1270	1386
Combustion air rate, SCF/BBL	3600	3300	3600
Excess O ₂ , %	0.2	0.2	2.5
Conversion, vol %	64.6	68.8	69.0
C ₅ + gasoline, vol %	45.2	47.9	47.2
i-C ₄ , vol %	4.5	4.8	4.7
n-C ₄ , vol %	1.5	1.3	1.3
C ₄ Olefins, vol %	8.4	6.9	7.2
C ₃ , vol %	3.6	2.7	3.0
C ₃ =, vol %	6.8	7.8	8.8
C ₂ -, FOE	6.4	5.8	6.7
LCO, vol %	30.1	25.1	24.7
Coke, wt %	7.1	6.9	6.4

*20° API feed

Table 2
Effect of Regeneration Mode on Yields*

Regeneration mode	Partial	Complete
Conversion, vol %	69.1	72.0
C ₅ + gasoline, vol %	46.4	47.0
i-C ₄ , vol %	5.1	6.7
n-C ₄ , vol %	1.6	2.1
C ₄ Olefins, vol %	6.9	7.4
C ₃ , vol %	6.8	4.6
C ₃ =, vol %	7.6	9.2
C ₂ -, FOE	5.3	6.0
LCO, vol %	26.2	23.5
Coke, wt %	7.2	6.1

*25° API feed

Table 3
Effect of Promoter on Selectivity

Days from start of test	0	25	36	79
Relative promoter content	0	20	50	130
Oxidation activity, CO ₂ /CO @ 1240°F	2.1	3.8	9.1	32.8
Metals (Ni + V), ppm	578	427	418	618
Fresh catalyst make-up, % inventory	2.0	1.8	2.0	1.4
Regeneration process	Conventional	Partial	Complete	Partial
Regenerator temp., °F	1154	1223	1287	1205
Catalyst activity	65	67	70	65
Est. yields at 70 vol % conversion				
C ₅ + gasoline, vol %	59.5	60.3	63.1	58.4
Coke, wt %	2.3	2.0	1.7	2.3
Hydrogen factor	18	20	18	20
CPFI	1.24	0.98	0.73	1.24

$$CPF = \frac{\text{Coke}/(100 - \text{Conv})}{(\text{Conv})}$$

$$CPF = \text{Coke}/(\text{Conv})/(100 - \text{Conv})$$

The most striking results are for partial combustion. With the 20 API feedstock, the maximum selectivity was obtained with a CO₂/CO ratio of 3.7. The gain in gasoline yield was 2.7 vol% higher than the base case. The SCF/BBL of air required was actually 300 SCF/BBL less than the base case. It is also important to notice that the fuel gas yield for full combustion was 10% less than for partial combustion. The authors also point out that the optimum gasoline yield for partial combustion is somewhat dependent on feedstock. This is shown in Table 2. With a lighter feedstock, there is a gain in gasoline in going from partial to full combustion.

The authors of the paper also made a very important contribution to promoter technology. They showed the long term effects of promoter operation on unit yields. Very frequently, promoter trials are run over a very short time period by loading promoter into the unit and noting the effects on unit operation and yields. As noted above, the effect on yields over the short term is largely related to changes in the unit heat balance. Hartzell and Chester showed that contrary to what one would normally expect,

the catalyst activity and selectivity actually increased as regenerator temperature was increased. These data are shown in Table 3.

After 36 days of promoter operation, the activity of the catalyst measured on their laboratory test increased from 65% to 70% conversion. There was also a dramatic increase in gasoline selectivity and a significant reduction in the carbon-producing-factor for the catalyst. These data clearly show the long term improvements possible with complete CO combustion. The key factor here is that in complete combustion, the temperature in the regenerator is more uniform and combustion is completed in the dense bed. One theory of catalyst deactivation holds that fresh catalyst particles are subjected to severe thermal deactivation when they are burned in the dilute phase of the regenerator. The more active fresh catalyst particles have a high carbon-on-spent catalyst and therefore, on combustion, the actual particle temperature can easily exceed the average temperature of the dilute phase by several hundred degrees. However, when the combustion occurs in the dense phase, heat transfer is so rapid that

particle temperatures are much closer to the average.

Other commercial results that show the lower deactivation rates for catalyst with CO promoter are the data published by Demmel & Lim⁵. They demonstrated a unique application of CO promoter that has found wide application in FCC units. They showed that replacing a REY type of catalyst without promoter, with an octane catalyst with promoter, a significant gain in octane without sacrificing gasoline yield could be obtained. The test results are summarized in Table 4. Frequently, when octane type catalysts are used, the regenerator temperature falls because of the lower coke making characteristics of the catalyst. This results in higher carbon-on-regenerated catalyst which in turn lowers the selectivity and the octane potential of the catalyst. Recognizing this, Demmel & Lim included a combustion promoter with the octane catalyst so that as the REY catalyst was displaced from the inventory, the unit went into full combustion and the carbon-on-regenerated catalyst fell to 0.06 wt% from 0.12 wt%. In addition, the full combustion aided in maintaining a suitable equilibrium activity since early octane catalysts were considerably less stable than REY catalysts.

Logistics of Handling CO Promoter

When CO promoters were first introduced as separate catalysts the additives were shipped in drums and added to the FCC regenerator using some form of a "shot pot". Promoter was added as required to control after burn in the unit. This approach was time-consuming and very frequently too much promoter was used. An improvement to this method is to ship the promoter in predetermined dosages in mylar bags. This approach is satisfactory for small units but not for units that require additive addition rates above 10 pounds per day. For these operations INTERCAT® has pioneered the development of an

Table 4

Catalyst	REY-type	Octaine Catalyst & Co-Promoter
Operating Conditions		
Raw Oil, B/D	21,700	24,000
Reactor Temp., °F	965	965
Regenerator Dense, °F	1,250	1,280
Regenerator Dilute, °F	1,270	1,270
Raw Oil, Temp., °F	630	640
Carbon-on-Regent. Cat., %/ont	0.12	0.06
CO ₂ /CO Ratio	0.75	11.4
Yields		
Conversion, % vol	75.7	74.0
C ₅ + gasoline, % vol	60.1	63.1
Total C ₄ 's, % vol	14.9	12.5
Total C ₃ 's, % vol	10.2	7.8
C ₂ & Ltr., % vol	2.3	2.7
Coke, % wt	4.7	3.6
Ron Clear	88.9	91.9
Mon Clear	79.1	80.6

automatic addition system that adds a fixed dosage of additive to the unit on a predetermined time interval. These units are available in sizes that range from 25 cubic feet to 1,100 cubic feet. The photograph in Figure 9 gives a general idea of the appearances of the smaller units. We have found that use of the automatic addition systems gives significant savings in promoter costs and in operator time. The savings are the result of adding the promoter in small doses rather than in one large daily dose or as required to control after burn. In addition the systems have weigh cells that provide exact data permitting closer monitoring of promoter usage.

Another aspect of handling the promoters and solid additives that INTERCAT® has developed⁶ has been the use of Bulk Bins (see Figure 10). Our normal method of shipping additive was in drums holding 300 pounds. The additive was vacuumed from the drums into the addition system using a vacuum system that is an integral part of the unit. With the Bulk Bins, 2000 pounds of additive can be loaded into the addition system. There are no

empty drums to dispose of and the operation is relatively dust free.

Conclusion

In conclusion, the use of CO promoter when properly applied, will result in an immediate improvement in the yields and operation of an FCC unit. Longer term there is the possibility of making significant gains in activity and selectivity of the FCC catalyst. This can lead to improved yields and reductions in catalyst costs. The complete evaluation of CO promoter in an FCC unit requires a well thought out and organized program. INTERCAT stands ready to assist refinery personnel on the planning and execution of such a program.

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2. Upson, L. L.; FCC Operations "Catalytically Promoted Combustion Improves FCC Operations", Paper No. Am-79-39 presented at the March 1979 NPRA Annual Meeting, San Antonio, Texas.
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Figure 1
COP®-850 Combustion Promoter
for CO Oxidation

DESCRIPTION

In the early 1970's, Mobil Research and Development Corporation patented the use of platinum group metals on a solid substrate, for the oxidation of CO to CO₂ in the fluid catalytic cracking process. All catalyst manufacturers that produce and sell CO oxidation promoters license the right to practice the technology covered by these patents. Most catalyst manufacturers produce an additive containing a platinum group metal supported on a FCC catalyst or catalyst matrix. Unfortunately this approach to formulating the additive has not produced a product that optimizes the CO oxidation potential of the original technology.

INTERCAT has developed a production method that uniformly deposits the active metal throughout specifically engineered substrate. The substrate has been developed jointly by INTERCAT and a major producer of specialty alumina chemicals. This has resulted in a product that, based on active metal content, is the most efficient CO oxidation catalyst promoter available. INTERCAT'S COP-850 has the attrition resistance, bulk density, and particle size distribution of the circulation catalyst inventory which enhances retention of the additive in the FCC unit.

Tests by major refiners have demonstrated that INTERCAT'S COP-850 is the most efficient and cost effective CO oxidation promoter available.

TYPICAL PROPERTIES

Particle Size Distribution	Weight %
0-20 Microns	0
0-40 Microns	2
0-80 Microns	70
0-120 Microns	98
Average Particle Size (Microns)	72

ATTRITION RESISTANCE

wig-L-bug Method 1.1 weight percent loss

SURFACE AREA 100 m²/g

Apparent Bulk Density (ABD) 1.0 g/cc

PACKAGING

Plastic pails containing 20 kg. each, 2 lb. and 5 lb. moisture proof bags. Other types of packaging available upon request.

Figure 2
COP®-550 Combustion Promoter
for CO Oxidation

DESCRIPTION

In the early 1970's, Mobil Research and Development Corporation patented the use of platinum group metals on a solid substrate, for the oxidation of CO to CO₂ in the fluid catalytic cracking process. All catalyst manufacturers that produce and sell CO oxidation promoters license the right to practice the technology covered by these patents. Most catalyst manufacturers produce an additive containing a platinum group metal supported on a FCC catalyst or catalyst matrix. Unfortunately this approach to formulating the additive has not produced a product that optimizes the CO oxidation potential of the original technology.

INTERCAT has developed a production method that uniformly deposits the active metal throughout a specifically engineered substrate. The substrate has been developed jointly by INTERCAT and a major producer of specialty alumina chemicals. This has resulted in a product that, based on active metal content, is the most efficient CO oxidation catalyst promoter available. INTERCAT'S COP-550 has the attrition resistance, bulk density, and particle size distribution of the circulation catalyst inventory which enhances retention of the additive in the FCC unit.

INTERCAT'S COP-550 contains less platinum group metal than our COP-850. It has been developed to allow the refiner to economically optimize the number of catalytically active sites in the FCC unit regenerator. Keeping total promoter costs constant, changing from COP-850 to COP-550 will result in a 35% increase in catalytically active sites in the regenerator. This is particularly useful in units that have mild regeneration conditions, poor air distribution, or high stack losses.

TYPICAL PROPERTIES

Particle Size Distribution:	Weight %
0-20 Microns	0
0-40 Microns	2
0-80 Microns	70
0-120 Microns	98
Average Particle Size (Microns)	72

ATTRITION RESISTANCE

wig-L-bug Method 1.1 weight percent loss

SURFACE AREA 100 m²/g

Apparent Bulk Density (ABD) 1.0 g/cc

PACKAGING

Plastic pails containing 20 kg. each, 2 lb. and 5 lb. moisture proof bags. Other types of packaging available upon request.

Figure 3
COP®-375 Combustion Promoter for
CO Oxidation

DESCRIPTION

In the early 1970's, Mobil Research and Development Corporation patented the use of platinum group metals on a solid substrate, for the oxidation of CO to CO₂ in the fluid catalytic cracking process. All catalyst manufacturers that produce and sell CO oxidation promoters license the right to practice the technology covered by these patents. Most catalyst manufacturers produce an additive containing a platinum group metal supported on a FCC catalyst or catalyst matrix. Unfortunately this approach to formulating the additive has not produced a product that optimizes the CO oxidation potential of the original technology.

INTERCAT has developed a production method that uniformly deposits the active metal throughout a specifically engineered substrate. The substrate has been developed jointly by INTERCAT and a major producer of specialty alumina chemicals. This has resulted in a product that, based on active metal content, is the most efficient CO oxidation catalyst promoter available. INTERCAT'S COP-375 has the attrition resistance, bulk density, and particle size distribution of the circulation catalyst inventory which enhances retention of the additive in the FCC unit.

INTERCAT'S COP-375 contains less platinum group metal than our COP-850 or COP-550. It has been developed to allow the refiner to economically optimize the number of catalytically active sites in the FCC unit regenerator.

TYPICAL PROPERTIES

Particle Size Distribution:	Weight %
0-20 Microns	0
0-40 Microns	2
0-80 Microns	70
0-120 Microns	98
Average Particle Size (Microns)	72

ATTRITION RESISTANCE

wig-L-bug Method 1.1 weight percent loss

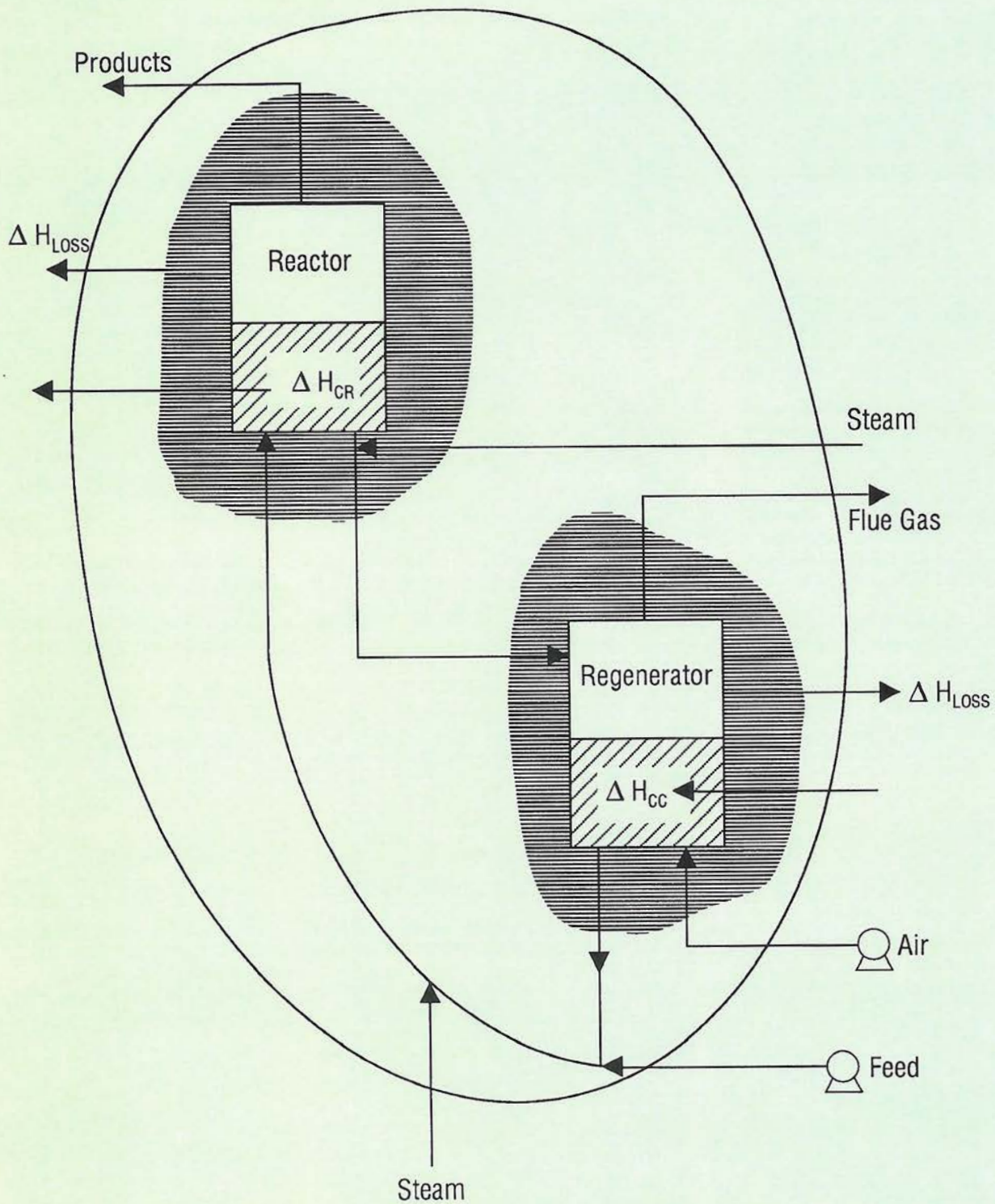
SURFACE AREA 100 m²/g

Apparent Bulk Density (ABD) 1.0 g/cc

PACKAGING

Plastic pails containing 20 kg. each, 2 lb. and 5 lb. moisture proof bags. Other types of packaging available upon request.

Figure 4
Overall Heat Balance FCC Unit



ΔH_{CR} = Heat of Cracking
 ΔH_{CC} = Heat of Coke Combustion

Figure 5
FCC Unit Heat Balance
Coke-on-Fresh Feed vs. Enthalpy Change of the Feed

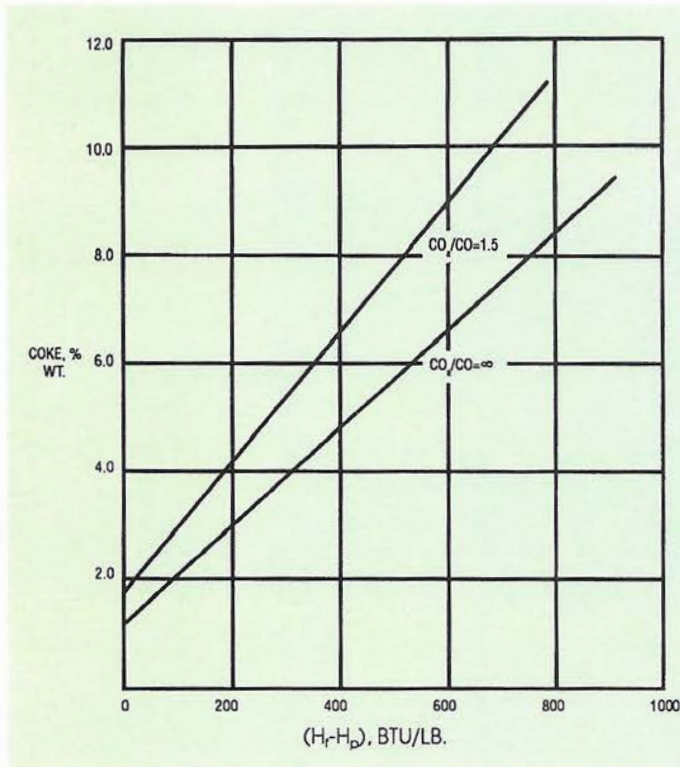


Figure 6
Regenerator Heat Balance
DELTA Coke-on-Catalyst vs.
(Regenerator Temp.-Reactor Temp.)

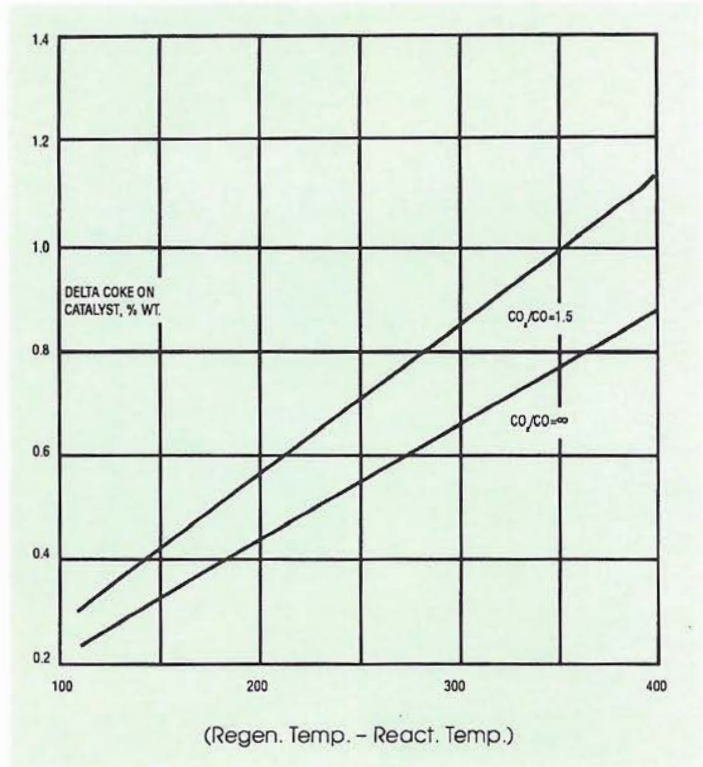


Figure 7
Effect of CRC
Upon Equilibrium Catalyst Activity

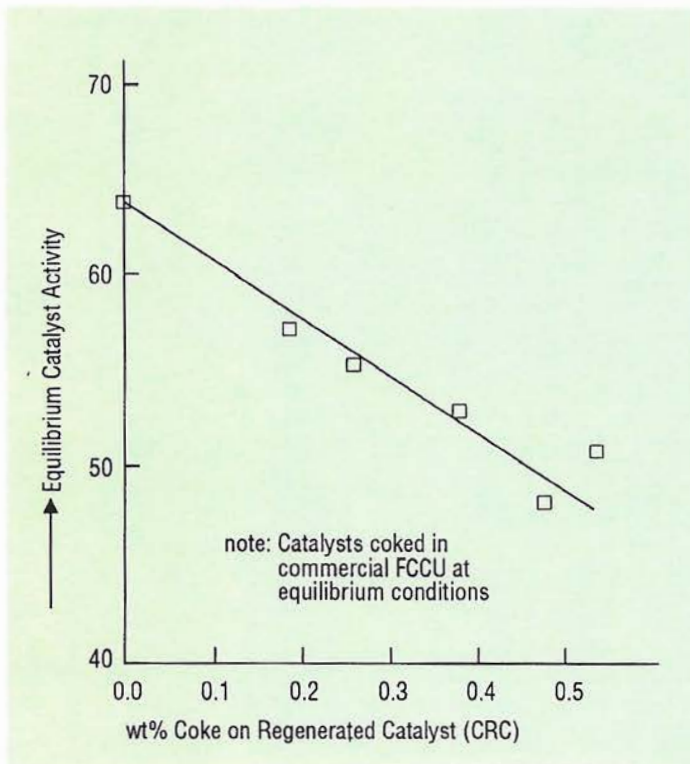


Figure 8
Coke on Regenerated Catalyst
Versus Regenerator Temperature

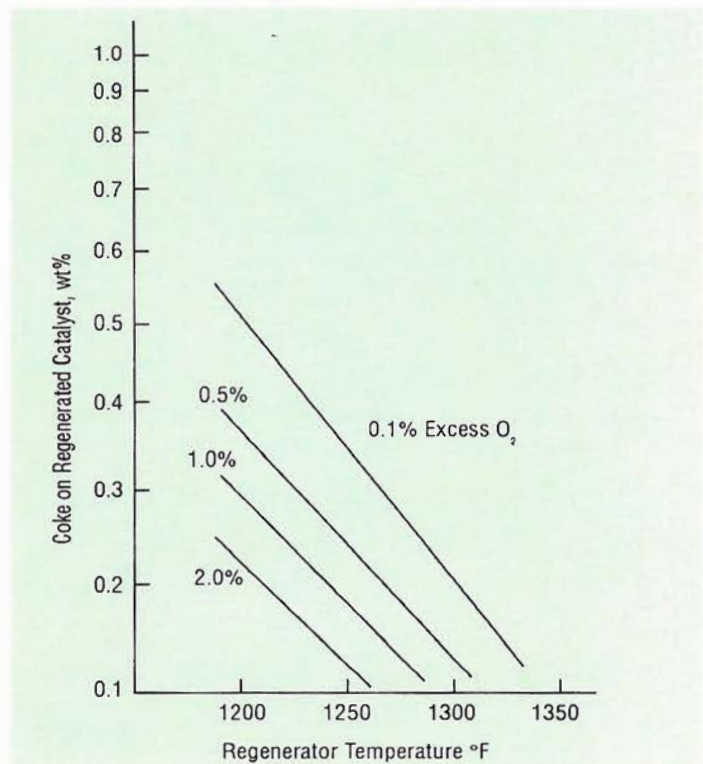
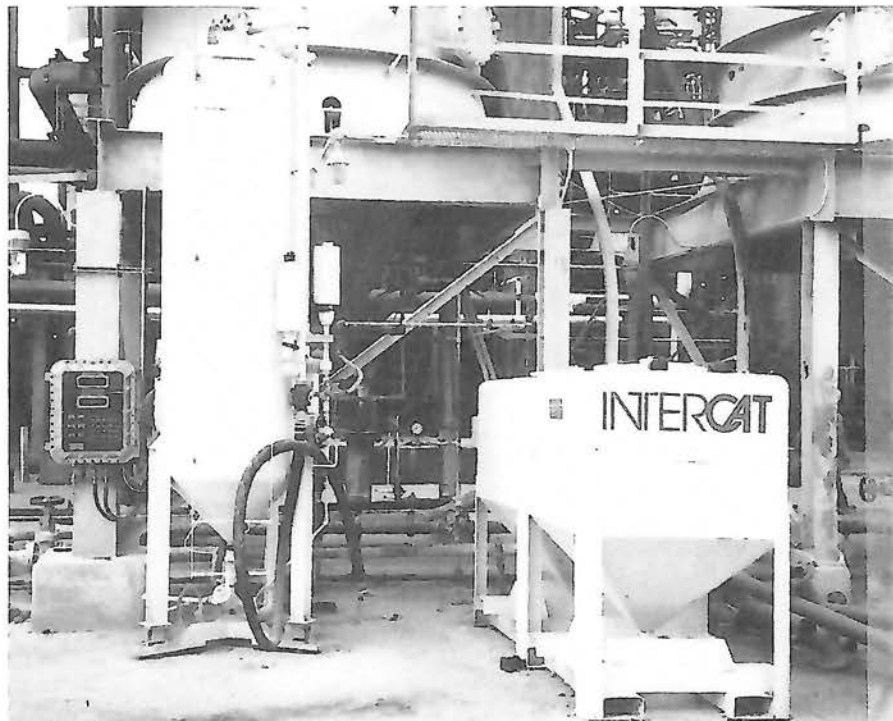


Figure 9



Figure 10



INTERCAT®

Manufacturer of specialty
FCC additives for
the Petroleum Refining Industry

For more information on INTERCAT'S
complete line of additives, contact:

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