United States District Court,
D. Delaware.

W.R. GRACE & CO.-CONN,
Plaintiff.
v.
INTERCAT, INC. and Conoco, Inc,
Defendants.

Civil Action No. 93-522 LON

Sept. 8, 1997.

Patentee brought action against competitors, alleging infringement of its patents for reducing sulfur oxide emissions from hydrocarbon conversion processes, such as fluid catalytic cracking. The District Court, Longobardi, Senior District Judge, held that: (1) patents were literally and directly infringed; (2) patents were not invalid as obvious; (3) patents were not invalid for indefiniteness; (4) patents were not invalid due to inequitable conduct during application process; and (5) infringement was willful.

Judgment accordingly.

Affirmed, 155 F.3d 572, 1998 WL 372484.

4,469,589. Cited.

Robert H. Richards, III, of Richards, Layton, & Finger; Wilmington, DE, of counsel, John J. Mackiewicz, Gary H. Levin, and David R. Bailey, of Woodcock, Washburn, Kurtz, Mackiewicz & Norris, Philadelphia, PA, for Plaintiff.

Arthur G. Connolly, Jr., of Connolly Bove, Lodge & Hutz; Wilmington, DE, of counsel, Nels T. Lippert, Cecelia O'Brien Lofters, and William P. DiSalvatore, of White & Case, New York City, for Defendants.

OPINION

LONGOBARDI**, Senior District Judge.**

I. NATURE AND STAGE OF THE PROCEEDINGS

W.R. Grace & Co.-Conn. ("Grace") is the owner of five patents relating to a composition, or the use of a composition, to reduce sulfur oxide ("SOx") emissions from hydrocarbon conversion processes, such as fluid catalytic cracking ("FCC") processes. The five patents-in-suit are U.S. Patents 4,469,589 (" '589 Patent"), 4,472,267 (" '267 Patent"), 4,495,305 (" '305 Patent"), 4,495,304 (" '304 Patent"), and 4,790,982 ("

'982 Patent").

By stipulation, this case was tried on the basis of sixteen representative claims: claims 7, 21, 33, and 34 of the '589 Patent; claims 5, 23, 31 and 39 of the '267 patent; claims 3, 15, 30, and 35 of the '305 Patent; claims 6, 20, and 40 of the '304 Patent; and claim 32 of the '982 Patent. The '304 and '305 Patents cover compositions of spinel-containing SOx-reducing additives that are combined with hydrocarbon conversion catalysts, such as crystalline aluminosilicates (e.g., zeolites). The '589 and '267 Patents address the catalytic process through which the introduction of particular additives is used to reduce the level of SOx that is emitted from FCC units. The '305 and '267 Patents differ from the '304 and '589 Patents in that the '305 and '267 Patents require the SOx-reducing additive to contain a rare earth metal (e.g., cerium) in order to promote the oxidation of sulfur dioxide to sulfur trioxide as part of the SOx removal function of the additive.

The asserted claims of the '304, '305, '267, and '589 Patents arise from two related patent applications filed simultaneously on July 29, 1980. The '982 Patent came later. Claim 32, the only claim from the '982 Patent that is at issue in this case, requires that the composition contain not only spinel and a rare earth metal such as cerium, but also a fourth metal component to promote (or catalyze) the sulfate reduction step of the additive's operational cycle.

Grace alleges that Intercat, Inc. ("Intercat") has contributed to and induced the direct infringement by Conoco, Inc. ("Conoco") of the patents-in-suit. Intercat sold Conoco additives called NO-SOX and NO-SOX-PC. Conoco then introduced those additives to its FCC units, where the NO-SOX products allegedly combined with the cracking catalyst to form the claimed compositions and to perform the claimed SOx-removal process. In its defense, Intercat contends that its NO-SOx products do not infringe any of the patents-in-suit and that the patents are invalid for obviousness, for failing to distinctly claim the subject matter of the invention, and for inequitable conduct before the Patent and Trademark Office ("PTO").

At the close of Grace's case, Intercat and Conoco moved under Fed.R.Civ.P. 52(c) for judgment as a matter of law ("JMOL") on the question of infringement. At the close of Defendants' case, Grace moved under Fed.R.Civ.P. 52(c) for JMOL on each of the inequitable conduct defenses. In addition to addressing these two JMOL motions, this Court will resolve all questions relating to infringement and invalidity. This Opinion represents this Court's findings of fact and conclusions of law.

This Court has jurisdiction over the subject matter of this action under 28 U.S.C. s. 1331 and s. 1338. Venue is proper under 28 U.S.C. s. 1391 and s. 1400.

II. BACKGROUND FACTS

A. *FCC UNITS*

Fluid catalytic cracking is a refinery process that converts heavy molecular weight compounds in crude oil into lighter weight compounds such as gasoline, diesel fuel, and jet fuel. (Tr. 55). In the FCC process, the catalyst circulates through the regenerator where it comes into contact with the gas-oil feed, which is the feedstock to an FCC Unit. (UF-8; Tr. 743). This gas oil commonly contains sulfur, usually between .5% and 3% by weight and in all events between .1% and 5% by weight. (Tr. 748). The gas oil comes into contact and mixes with the FCC cracking catalyst that is circulating within the FCC unit. (UF-9). That contact occurs at a high temperature, in the range of 1,250 to 1,350 degrees Fahrenheit. (Tr. 743).

In the United States, the active component of the cracking catalyst is crystalline aluminosilicate, also *known as* zeolite. (Tr. 744). The cracking catalyst looks like talcum powder and has a particle size of 20 to 120 microns in diameter. (Tr. 82). Although the catalyst is a solid, FCC units are referred to as "fluidized" because the catalysts behave like liquids when gases are passed through them. The FCC unit constantly recirculates the catalyst between the regenerator and the riser reactor sections of the FCC unit.

Unwanted byproducts of this FCC process include sulfur oxides, which are considered so harmful to the environment that they are restricted by our nation's environmental laws. (Tr. 56). There are three primary methods used to reduce the SOx emissions coming from an FCC unit. In the first, called "hydroprocessing" or "hydrotreating," the sulfur is removed from the gas-oil feed itself. Although efficient, this method of removal is extremely expensive, requiring a capital investment of $50 million or more. A second method of SOx removal is "flue gas scrubbing" in which SOx is removed from the flue gas before it enters the atmosphere. Flue gas scrubbing also requires significant capital investment. The third method is the use of a sulfur reduction additive. (Tr. 56-57).

In this third method, the SOx-reducing additive admixes with the cracking catalyst in the regenerator section of the FCC unit, is fluidized, and circulates through the FCC unit along with the catalyst. The entire process is completed in three steps. First, the SOx-reducing additive oxidizes the sulfur dioxide to sulfur trioxide. Once the sulfur trioxide is formed, the additive then captures it as a metal sulfate within the regenerator. The metal sulfate formed on the additive is stable under the conditions of the regenerator and circulates along with the cracking catalyst to the riser reactor. In the final step, the metal sulfate is reduced within the riser reactor, and the sulfur is released from the FCC unit in the form of hydrogen sulfide. (Tr. 83-85) Then the process begins anew.

Although the use of a SOx-reducing additive is not, in the long run, a cheap alternative to hydroprocessing or flue gas scrubbing, the use of an additive does not require any significant capital investment. Moreover, it offers a refiner a certain flexibility in that the refiner can adjust the amount of additive based on the sulfur content of the gas-oil feedstock. (Tr. 58-59).

B. *DEVELOPMENT OF THE SOx-REDUCING ADDITIVE INDUSTRY*

In the late-1970's, Atlantic Richfield Company ("ARCO") was operating an FCC unit near Los Angeles, California. This FCC facility was known as the Watson unit. The Watson FCC unit was subject to the regulations imposed by the South Coast Air Quality Management District ("SCAQMD"). Under those regulations, ARCO was compelled to reduce the SOx emissions of the Watson unit to a specified level by 1981 and to a much lower level by 1985. (Tr. 105-06). ARCO considered the options of a hydrotreater or a flue gas scrubber, but in order to avoid the large capital investments involved in both of those options (and in order to avoid a solid waste problem that would have resulted from the use of a flue gas scrubber), ARCO sought to develop a SOx-reducing additive as a viable way to achieve the emission standards without making a huge capital investment.

In 1979, ARCO tested a SOx-reducing additive known as SOXCAT in its Watson unit and at an Amoco refinery. SOXCAT, which was jointly developed by ARCO and Engelhard Corporation (Tr. 88), was a gamma alumina material impregnated with ceria. (UF-21). It consisted of 5% by weight cerium on alumina. The cerium in SOXCAT functioned to promote the oxidation of sulfur dioxide to sulfur trioxide, the first step in an additive's removal of SOx. (Tr. 88). The alumina was used to capture the sulfur trioxide to make the metal sulfate compound-the second step in the SOx removal process. (Tr. 89). SOXCAT had good initial activity, i.e., it functioned to reduce SOx emissions from the FCC unit flue gas, but it rapidly deactivated. (UF-22). As a result, it was determined "that SOXCAT was not an economically viable SOx additive." (Tr. 91).

After the failure of the initial trial of SOXCAT, a reorganization occurred in ARCO's development efforts. Mr. Joseph W. Powell, who testified at trial, became a supervisor in the "process development group" which was led by Dr. Louis Magnabosco. (Tr. 94). Also formed at that time was the "process research group" headed by Dr. J. Mooi. Working for Dr. Mooi was a research chemist named Dr. John Jaecker. (Tr. 94). Eventually, Engelhard Corporation decided not to continue participating in the joint development effort with ARCO. (Tr. 105).

In the process research group, Dr. Jaecker, among others, searched for a viable additive. He recorded his progress in a laboratory notebook (DTX-13). Although Dr. Jaecker's writing is difficult to read, the relevant substance can be extracted. On page 38563, entered on November 19, 1979, Dr. Jaecker indicated that he and a co-worker, Marvin Johnson, discussed what they could do to keep SOXCAT from deactivating. They "agreed that placing an ion into the alumina to prevent the possible movement of Ce into the lattice and thereby lose the activity might work." Other possibilities were also discussed.

On November 26, 1979, Dr. Jaecker had a discussion with Dr. Mooi about SOXCAT. (DTX-13 at 38565). Dr. Mooi suggested microspheres of silica as a substrate. Dr. Jaecker also noted that Dr. Mooi "liked the spinel idea" especially with magnesium aluminate "which was used before." Dr. Jaecker wrote that Dr. Mooi "said it (magnesium aluminate spinel) prevented Co from penetrating alumina." (DTX-13 at 38565).

In a meeting held on December 3, 1979, Dr. Jaecker suggested cerium on magnesium aluminate spinel as a potential additive. Notes from that meeting indicate that Dr. Jaecker believed that the "spinel structure may prevent Ce from becoming buried" in the alumina. Other possibilities were also suggested. (PTX-204).

Subsequent to the December 3, 1993, meeting, the process research group sent Mr. Powell a sample of cerium impregnated magnesium aluminate spinel for pilot plant testing. (Tr. 108). A pilot plant is a miniature catalytic cracking unit. (Tr. 98). ARCO had developed tests to measure both the initial activity of various compositions of SOx-reducing additives and their rate of deactivation. (Tr. 102-03). Mr. Powell explained the results of the testing:

> The cerium spinel test results were really amazing in the results that came back. We had been used to testing the SOXCAT material and whereas the baseline emission level for our little pilot plant was, maybe, 500 ppm, 5 percent concentration of SOXCAT, we would maybe take that emission level down to 250.
>
> When we first did the initial activity test of the spinel material, the engineer came back and told me that they got almost no SOx coming out of the flue gas of the little pilot plant unit. It was like eight, nine, ten ppm, almost within the scatter of the data that we had for our analysis.

(Tr. 108-09). Mr. Powell was so astounded by the results that he thought there must be something wrong with the equipment. Mr. Powell instructed his employees to recalibrate the pilot plant unit. When they did, the same results were indicated, verifying that the equipment was not faulty. (Tr. 109-10).

Mr. Powell testified that he was "so amazed" he personally went to the pilot plant, which was several blocks from his office, just to look at the material. Mr. Powell recounted the real surprise of the experiment:

And the shock was that we-a lot of this work was aimed at improving the stability of SOXCAT, but the surprise was that this was the initial activity test, not the stability test. We were yet to do a stability test. And so that was a complete surprise. We weren't expecting initial activities that were much higher than SOXCAT. And that's what I remember. That was quite an exciting time.

(Tr. 110). The subsequent deactivation tests showed that not only was the cerium-impregnatedmagnesium aluminate spinel material more active initially in the reduction of SOx emissions, but it was also much more stable than SOXCAT. (Tr. 111). The cerium-impregnated magnesium aluminate spinel material was given the designation HRD-265. FN1

FN1. HRD stands for Harvey Research and Development. At the time of these experiments, Mr. Powell was working at the ARCO Harvey Technical Center in Harvey, Illinois. (Tr. 74, 111).

In a report dated March 17, 1980, Dr. Jaecker and some of his colleagues discussed their experiments:

The major source of deactivation appears to be the transfer of cerium to the interior of the alumina lattice, probably in a reduced state, where it is unavailable for catalysis.

This conclusion led to the recent preparation and Testing of $MgAl_2O_4$ spinel as a support for cerium, on the theory that the Mg// ions would occupy holes in the alumina lattice, forming a barrier to cerium diffusion. We are currently exploring other means of providing these barriers, which involve impregnating alumina with magnesium, other alkaline earths and lithium. This route should be less expensive than the spinel manufacture.

(DTX-1 at 1). The researchers noted that the use of magnesium aluminate spinel reduced deactivation "markedly." (DTX-1 at 15).

ARCO contracted with a company called KATALCO to manufacture the spinel additive. (Tr. 119). The results of the first commercial trial of that material at the Watson FCC unit were disappointing. (Tr. 120). A second commercial trial was performed at Amoco's Whiting refinery in Whiting, Indiana. (Tr. 121). This trial also failed due primarily to mechanical problems in the unit. (Tr. 122). Having experienced apparent setbacks with their own material, ARCO tested Grace's Additive R, which was then the only additive available commercially. (Tr. 123-24). The results of those tests showed Additive R to be no more effective than SOXCAT. (Tr. 124). KATALCO decided not to manufacture any more additive, so ARCO approached alternative suppliers. Grace's chemical division produced a test quantity of HRD-276, a ceria-impregnated magnesium aluminate spinel, in 1983. (Tr. 125). Commercial tests of HRD-276 were "a brilliant success." (Tr. 126).

Grace's chemical division decided not to produce more additive, so ARCO searched for other potential manufacturers. (Tr. 127-28). In 1984, ARCO entered into an agreement with Katalistiks to manufacture commercial-sized quantities of the additive, and ARCO granted Katalistiks a license to produce HRD-276 and HRD-277. (Tr. 128-29, 136; PTX-2). FN2 The HRD-276 and HRD-277 materials were magnesium aluminate spinels having a Mg:Al atomic ratio of 0.5 and 1.0, respectively. Both materials had a surface area greater than 100 m^2/g and were impregnated with 9-12% wt. ceria. (PTX-2 at WRG-10282). As part of the license agreement, Katalistiks was provided with the formula for the materials. (Tr. 137). At that time, Regis Lippert, who is now the president of Intercat, was the president of Katalistiks and signed the license agreement on behalf of Katalistiks. (Tr. 130, 133).

FN2. Toward the end of 1983, Katalistiks had become part of Union Carbide Corporation. (Tr. 868). In 1988, Katalistiks became a business unit of UOP.

Thereafter, ARCO continued to make improvements to the additive. The introduction of vanadium into the formula doubled the effectiveness of the additive. (Tr. 131). The addition of 1% vanadium enhanced the release reaction, allowing the material to release more hydrogen sulfate in the riser reactor. (Tr. 131-32). ARCO named the vanadium-enhanced material HRD-280. (Tr. 131). Later, the HRD-280 material was sold commercially under the name DESOX. (Tr. 140).

In 1985, ARCO decided to close the Harvey Technical Center and to sell its SOx-removing additive technology. (Tr. 137-38). Toward the end of 1983, Katalistiks had become part of Union Carbide Corporation ("Union Carbide"). (Tr. 868). Regis Lippert, who was still president of Katalistiks, advised Robert Kulperger, who was vice president of Union Carbide, that the purchase of ARCO's SOx transfer agent technologywould be a very good idea. (Tr. 139, 870; UF-112). In the summer of 1985, Katalistiks purchased the ARCO additive technology and hired some of ARCO's personnel, including Mr. Powell. (Tr. 139-40; PTX-8).

In late 1985 and early 1986, Regis Lippert left Katalistiks and started a company called Intercat USA, Inc., which was subsequently reincorporated as Intercat, Inc. (Tr. 874, 877). On April 15, 1987, Intercat obtained licenses under several Amoco patents which dealt with SOx-reducing additives. Intercat then began to manufacture an additive called LOSOX. FN3 (Tr. 886).

FN3. LOSOX was comprised of about 12.5% rare earth metal and 2% vanadium on an alumina catalyst support. (Tr. 153).

Meanwhile Katalistiks was producing DESOX. Katalistiks doubled the vanadium content in DESOX in 1987, but otherwise produced the exact same composition that was originally named HRD-280. (Tr. 144, 150). In 1988, Katalistiks became a business unit of UOP.

On January 22, 1993, Grace obtained UOP's additive business, including the DESOX product and the patents-in-suit. (PTX-13). Grace attempted to replace the vanadium present in the DESOX product with iron and various other metals. (Tr. 643). After testing, Grace decided that replacing vanadium with iron would significantly reduce the performance of DESOX. (Tr. 648). Consequently, Grace retained the vanadium.

The testimony at trial indicated that DESOX was far superior to any other additive on the market. As previously mentioned, DESOX was superior to SOXCAT and Grace's Additive R. Other additives which appeared on the market were TRANSOX and LOSOX. TRANSOX, an additive developed by Chevron, showed very little SOx-removal activity. LOSOX, which was developed by Intercat, showed activity similar to SOXCAT; it was approximately one-fourth less active in reducing SOx than DESOX. (Tr. 152-53). By 1989, DESOX controlled 90% of the market, with Additive-R controlling the bulk of the remainder. (Tr. 154).

Regis Lippert testified at trial that he recognized that Intercat's LOSOX was "at best, a marginal product." (Tr. 886). Mr. Lippert testified that although he wanted to develop a new product, he was concerned about the possibility of infringing "the ARCO patents." (Tr. 887). He felt that Intercat needed to develop their own manufacturing process that was outside the scope of the ARCO patents. (Tr. 887). Edward Demmel and Dr. Louis Magnabosco were given the task of developing this new manufacturing process, and they succeeded in doing so. (Tr. 888). The product of that process was called NO-SOX, one of the accused products in this case. Early in 1994, Intercat introduced a new additive, NO-SOX-PC. FN4 (Tr. 902-03). NO-SOX-PC is also accused of infringing the patents-in-suit. In the period between 1993 to 1996, the NO-SOx products captured 15% of the SOx-reducing additive market. (Tr. 66).

FN4. "PC" stands for "partial combustion." (Tr. 903).

III. INFRINGEMENT

A. *DEFENDANTS' MOTION FOR JMOL*

In their motion for JMOL, Defendants claim that Grace has not met its burden to prove that any of the representative claims are infringed either literally or under the doctrine of equivalents. Under Fed.R.Civ.P. 52(c), this court must weigh the evidence, resolve conflicts in the evidence, and decide where the preponderance lies. Wright & Miller, Federal Practice & Procedure: Civil 2d s. 2573.1. Under Rule 52(c), this court is permitted to decline to render any judgment until the close of all evidence. This Court has chosen the latter route and will consider all of the evidence of record to determine whether Grace has proved by a preponderance of the evidence that Defendants are liable for infringement.

B. *CLAIM CONSTRUCTION*

[1] [2] In construing the meaning of patent claims, a court must consider three sources: the claim language, the patent specifications, and the prosecution history. Markman v. Westview Instruments, Inc., 52 F.3d 967, 979 (Fed.Cir.1995), *aff'd,* 517 U.S. 370, 116 S.Ct. 1384, 134 L.Ed.2d 577 (1996). A court may also hear and consider expert testimony, including evidence of how those skilled in the art would interpret the claims. *Id.*

[3] [4] [5] The initial step in claim construction is an examination of the language of the claims at issue. Stiftung v. Renishaw PLC, 945 F.2d 1173, 1177 (Fed.Cir.1991); American Standard, Inc. v. Pfizer Inc., 722 F.Supp. 86, 92 (D.Del.1989). The patent claims are what defines the right to exclude others from making the invention. Markman, 52 F.3d at 980. The words of a claim are normally given their ordinary and accustomed meaning, unless it appears from the specification and prosecution history that they were used differently by the inventor. In re Paulsen, 30 F.3d 1475, 1480 (Fed.Cir.1994).

[6] [7] [8] [9] [10] The patent specification contains a written description of the invention that enables one of ordinary skill in the art to make and use the invention. Markman, 52 F.3d at 979. It is "the single best guide to the meaning of a disputed term." Vitronics Corp. v. Conceptronic, Inc., 90 F.3d 1576, 1582 (Fed.Cir.1996). The specification may act as "a sort of dictionary" which helps to explain the claims. Markman, 52 F.3d at 979. The specification cannot be used, however, to add extraneous limitations into a claim. Hoganas AB v. Dresser Indus., Inc., 9 F.3d 948, 950 (Fed.Cir.1993). Extraneous limitations are those that would be added into a claim from the specification "wholly apart from any need to interpret what the patentee meant by particular words and phrases" in the claims. *Id.* As stated plainly by the Federal Circuit,

"claims are not to be interpreted by adding limitations appearing only in the specification." Electro Medical Sys. S.A. v. Cooper Life Sciences, Inc., 34 F.3d 1048, 1054 (Fed.Cir.1994). On the other hand, when a particular interpretation of the terms of a claim would exclude the preferred embodiment described in the specification from the scope of the claim, such an interpretation "is rarely, if ever, correct and would require highly persuasive evidentiary support." Vitronics, 90 F.3d at 1583.

[11] [12] The prosecution history, which is the record of the proceedings in the Patent and Trademark Office, cannot enlarge diminish or vary the limitations in the claims but should be utilized to interpret the meaning of language used in the patent claims. Markman, 52 F.3d at 980. The prosecution history limits permissible claim construction to exclude any interpretation that was disclaimed during the prosecution of the patent. Southwall Technologies, Inc. v. Cardinal IG Co., 54 F.3d 1570, 1576 (Fed.Cir.1995).

[13] [14] Extrinsic evidence such as expert testimony, dictionaries and learned treatises can be used, at the court's discretion, "for the court's understanding of the patent, [but] not for the purpose of varying or contradicting the terms of the claims." Markman, 52 F.3d at 981. When intrinsic evidence alone is sufficient to resolve the ambiguity in a disputed claim term, it is improper to rely on extrinsic evidence. Vitronics, 90 F.3d at 1583.

1. *Spinel*

[16] The major claim construction dispute involves the term "spinel." Each of the representative claims is directed to a composition, or the use of a composition, which contains a bimetallic spinel within certain size and valence restrictions. (*See, e.g.,* PTX-3, col. 20, lines 17-25). The specification describes what is meant by the term spinel:

The spinel structure is based on a cubic close-packed array of oxide ions. Typically, the crystallographic unit cell of the spinel structure contains 32 oxygen atoms; one-eighth of the tetrahedral holes (of which there are two per anion) are occupied by a divalent metal ion, and one-half of the octahedral holes (of which there are two per anion) are occupied by trivalent metal ions.

(PTX-3, col. 7, lines 44-50). The specification continues, "This typical spinel structure *or a modification thereof* is adaptable to many other mixed metal oxides" of various types. (PTX-3, col. 7, lines 51-53) (emphasis added). The specification includes magnesium aluminate spinel as one example, out of more than fifty examples, of a bimetallic spinel. (PTX-3, col. 8, lines 16, 20). The patent specification explains that alkaline earth metal spinels, "in particular magnesium aluminate spinel," are the "preferred metal-containing spinels for use in the present invention." (PTX-3, col. 8, lines 44-46).

The specification notes that the metal-containing spinels useful in the invention "may be derived from conventional and well known sources." (PTX-3, col. 8, lines 62-64). As a result, detailed descriptions of how to synthesize spinel were omitted from the specification. (PTX-3, col. 8, lines 62-64). The patentees did include, however, "a brief description of the preparation of the most preferred spinel, i.e. magnesium aluminate spinel." (PTX-3. cols. 8-9, lines 67-2) Specifically, the patentees refer the reader to U.S. Patents 2,992,191 and 3,791,992, which include descriptions of how to prepare spinel. (PTX-3, col. 9, lines 5-8, 35-37). The patentees also include 25 examples which disclose how to synthesize spinel. (PTX-3, cols. 15-19). The patentees did not, however, refer to any particular method for analyzing a material to determine whether that material contains spinel.

In contrast to the specification, the prosecution history is relatively unenlightening in regard to the definition of spinel. Defendants urge that the patentees relied upon the classic spinel definition included in U.S. Patent No. 4,233,186 to Duprez in order to overcome the prior art and that the scope of the claims should therefore be limited to that classic definition. It is true that the patentees explained to the PTO that certain materials produced in a prior art example were not spinel, relying in part on the definition of spinel in the Duprez patent. The patentees did not argue, however, that the magnesium aluminate disclosed in that prior art patent was not spinel. Rather, the patentees distinguished the magnesium aluminate disclosed in that prior art patent on the basis of surface size. (DTX 39 at 115; JSPH FN5 at 35-36, 75). This Court finds that there were no representations made in the prosecution history that would limit the scope of claim terms so as to exclude Grace's proposed interpretation of the term spinel. *See* Southwall Technologies, Inc. v. Cardinal IG Co., 54 F.3d 1570, 1576 (Fed.Cir.1995).

FN5. "JSPH" stands for "Joint Statement of Undisputed Facts Regarding the Prosecution Histories of the Patents in Suit and Their Related Applications."

The parties agree that in order to determine the existence of spinel in a composition a person of skill in the art at the time the invention was made would perform X-ray diffraction ("XRD") analysis and compare the resulting pattern of peaks to a standard reference card. The parties have stipulated that XRD is the most reliable method for determining whether spinel is present in a sample. (UF-95). An organization called the International Center for Diffraction Data ("ICDD") archives, collects, and distributes a data file of single-phase FN6 product X-ray diffraction patterns, also known as reference cards. (Tr. 184-85). The general manager and corporate secretary of the ICDD, Dr. Ronald Jenkins, testified on Grace's behalf at trial. (Tr. 183-85).

FN6. A "single-phase" material is one that contains only one component, such as a magnesium aluminate spinel. The accused products contain several different phases, including magnesia, ceria, and a magnesium aluminate material. Each of these components has its own XRD pattern.

Dr. Jenkins explained that the first step in performing XRD analysis is to determine the elemental content of a sample material in order to focus the search toward reference cards for compounds that contain those elements. (Tr. 332). Then, one would perform an XRD analysis of the sample material to compare with the reference cards kept by the ICDD. (Tr. 184-85). A person skilled in the art would identify the three strongest peaks in the XRD pattern of the tested material and would, most likely, consult the Hannawaltindex. (Tr. 222-23). The Hannawalt index is organized so that every permutation of the three strongest peaks from each reference card appears in the index. (Tr. 222). For example, if the three strongest peaks on a reference card were at positions A, B, and C, the material would be listed in the Hannawalt index as ABC, BCA, BAC, CBA, CAB, and ACB. (Tr. 222). The Hannawalt index would refer its user to appropriate reference cards, so that the patterns of the reference card and the XRD analysis of the material could be compared.

Dr. Jenkins testified that the Hannawalt index includes every permutation of the three strongest peaks because "the intensities [of the peaks] are unreliable." (Tr. 1748). Dr. Jenkins explained that "[v]ery commonly one finds that the three strongest lines may be in reverse order or some other combination of orders." (Tr. 224). In fact, even with respect to well-ordered, well-crystallized materials deviations in relative intensities of up to 40% are not uncommon. For a magnesium aluminate spinel that has a high surface area, the relative intensities could deviate by 200-300% from the reference card. (Tr. 433-34, 1752). Rather than being based on the most common real world materials, reference cards are intentionally based on material that is remarkably well crystallized, so that the material gives "very good sharp peaks" which enables the ICDD to determine peak positions with greater accuracy. (Tr. 219).

The dispute between the parties is whether, when comparing a composition's XRD pattern with the magnesium aluminate spinel reference card, a person of ordinary skill in the art would require fairly strict conformity with the peak intensities on the reference card before identifying a material as spinel or whether that person would recognize a particular composition as containing spinel within the definition of the patent if there was substantial variation in the peak intensities, even though the peak positions generally matched the reference card. Grace contends that there can be substantial variation in peak intensity while Defendants assert that the peak intensities must largely match the reference card.

As previously mentioned, the '589, '267, '305, and '304 Patents contain a number of examples for synthesizing spinel. Example I of those patents ("Yoo Example I") provides one method for synthesizing magnesium aluminate spinel. The parties agree that the material produced by following the teaching of Yoo Example I is characterized by the patentees as magnesium aluminate spinel, yet that material does not match the applicable reference card in the relative intensities of the key peaks.FN7 Defendants contend that the patentees have therefore provided a disclosure that is in internal conflict. Grace, on the other hand, argues that a claim interpretation of spinel which would exclude the material of Yoo Example I would run counter to Federal Circuit precedent holding that a claim interpretation that would exclude from the scope of the claim the preferred embodiment described in the specification "is rarely, if ever, correct and would require highly persuasive evidentiary support." Vitronics, 90 F.3d at 1583.

FN7. Grace also argues that materials made in accordance with U.S. Patent Nos. 3,791,992 and 2,992,191 do not match the magnesium aluminate spinel reference card in relative intensities, yet are referred by the patentees as spinel. (D.I. 264 at 11-12). Defendants, on the other hand, contend that the materials made in accordance with these patents are spinels according to their more stringent definition. (D.I. 266 at 4-5 n. 4). Dr. Uhlmann noted that while the relative intensities of the peaks of those materials were not an exact match with the magnesium aluminate spinel reference card, the relative intensities were within 20% deviation. (Tr. 1284, 1287). The magnesium aluminate spinel created by following the teachings of those patents do, therefore, fall within defendants' more narrow definition of spinel.

This Court agrees with Grace. The patentees explain that "the spinel structure is based on a cubic close-packed array of oxide ions." Then, the patentees describe the typical arrangement of the crystallographic unit cell of the spinel structure. The patentees do allow, however, for "a modification" of this typical arrangement. (PTX-3, col. 2, lines 51-53). The patentees use the term spinel in a fairly broad sense. In reading the specification as a whole, the patentees emphasize using the examples of the patent and the prior art to synthesize spinel. In particular, the patentees explain that the product created by Yoo Example I is a spinel. The claim construction urged by Defendants would exclude that preferred embodiment of the invention from the scope of the claims.

This Court finds as fact that the evidence points clearly toward Grace's interpretation of the term spinel. Each of the parties agrees that a person of ordinary skill in the art would utilize XRD analysis to determine the presence of spinel. This Court finds the testimony of Mr. Jenkins to be credible and extremely helpful in understanding XRD technology and the importance of the relative intensities of the peaks. Dr. Jenkins explained that the measurement of the intensities of the peaks in XRD analysis is "unreliable." (Tr. 1748). Indeed, the entire Hannawalt indexing system is designed with this unreliability in mind. This certainly weighs heavily against finding that a person of ordinary skill in the art would reject a phase identification of magnesium aluminate spinel when all of the major peaks are present but differ somewhat from the reference card in their relative intensities.

Defendants point to a text by Klug and Alexander which states that "[t]here must be agreement within experimental error for all lines of the compound's pattern both as to d spacing and relative intensity." (DTX-727). Grace, however, points to testimony from Dr. Jenkins that the Klug and Alexander test is "way, way outdated" and reflects the state of the art in the early 1950's when there were only 100 powder diffractometers in the entire world. (Tr. 1746-49).FN8 Indeed, the above-quoted sentence from Klug and Alexander is directly contradicted by an authoritative text, the Hannawalt search procedure guidelines, which was published only a few years before the invention at issue. (PTX-478). The Hannawalt procedure recognizes that:

FN8. Today there are approximately 30,000 diffractometers. (Tr. 1749).

Because of various factors which frequently quite drastically affect intensity values, the experimental sample intensities may not agree with the File standard. But though the analyst does not know which of the three lines is strongest and which is second strongest, he can still rather quickly locate the entry by trying various combinations.... In the extreme case with enough tries, one could locate the pattern in a *single* entry search manual without *any* data on the intensities of any of the lines of the pattern.

(PTX-478 at iv) (emphasis in original).

Other extrinsic evidence points toward Grace's claim interpretation of spinel. In the Bratton article admitted at trial (PTX-481), Dr. Bratton identified material as spinel when the XRD patterns matched in peak position but not in peak intensity. In contrast to Grace's evidence of Yoo Example I and the Bratton article, Defendants have provided no evidence of a circumstance in which a person skilled in the art declined to call magnesium aluminate a spinel when the peak positions matched the reference card but the relative intensities did not. This leads the court to conclude that Defendants' definition of spinel is litigation-inspired and not in accordance with the practice in the art. Even Dr. Wuensch, a defense witness, candidly admitted that the term spinel is used more loosely in practice than is technically precise.

This Court finds that if a person of ordinary skill in the art, in comparing an XRD analysis of his or her material with the reference cards kept by the ICDD, would be led by the Hannawalt index to a reference card for spinel and would determine that such a material is spinel after comparing the XRD patterns, then that material is spinel within the meaning of the patents-in-suit. This Court finds as fact that a person of ordinary skill in the art would not demand strict compliance, or compliance within some arbitrary amount of acceptable deviation,FN9 with the relative intensities of the major peaks. This Court does not find that relative intensities are unimportant, however. They are important to an identification of the major peaks, and a greater match with relative intensities would yield greater confidence in a particular phase identification.

FN9. Defendants' expert, Dr. Uhlmann, testified that relative intensities must match to within about 20% in order to make an accurate phase identification. (Tr. 1319-1321).

2. *Minor Amount of Rare Earth Metal Component*

[17] There is a dispute between the parties regarding whether claims 5 and 23 of the '267 patent require a spinel that has within itself a minor amount of at least one rare earth metal component or whether the rare earth metal component is separate from the spinel and is one of the "discrete entities" within the meaning of the patent. In other words, must the rare earth metal be part of the spinel or separate from the spinel. *Compare* D.I. 250 at 10 *with* D.I. 251 at 7. The language of the claim at issue is as follows:

the improvement which comprises: using in intimate admixture with said solid particles *a minor amount of discrete entities having a composition different from said solid particles and comprising at least one alkaline earth metal-containing spinel including alkaline earth metal and a second metal having a valence higher than the valence of said alkaline earth metal,* the atomic ratio of said alkaline earth metal to said second metal in said spinel being at least about 0.25 and said spinel having a surface area in the range of about 25 m^2/gm. to about 600 m^2/gm., *and a minor amount of at least one rare earth metal component,* said discrete entities being present in an amount sufficient to reduce the amount of sulfur oxides in sid flue gas.

(PTX-4, col. 19, line 62, to col. 10, line 8). This Court agrees with Grace that the plain meaning of the claim indicates that the "rare earth metal component" is not a component part of the spinel but of the discrete entities.

Any doubt regarding the correctness of this interpretation is put to rest by the specification which states: "the discrete entities comprise (A) an effective amount of at least one alkaline earth metal containing spinel and (B) a minor amount of at least one rare earth metal component, preferably a cerium component, associated with the spinel...." (PTX-4, col. 6, 4-9). At another point in the specification, the patentees explain that the improvement involves "a particulate material comprising" the cracking catalyst and an effective amount of at least one alkaline metal-containing spinel and "a minor amount of at least one rare earth metal, preferably cerium, component associated with the spinel." (PTX-4, col. 4, lines 31-41). Moreover, to adopt Defendants' interpretation would be to exclude the preferred spinel, the magnesium aluminate spinel (which does not contain a rare earth metal), from the scope of the patent. The spinel and the rare earth metal are, therefore, two components of the discrete entities which are associated with each other. The '267 patent does not require the rare earth metal to be part of the spinel.

3. *Amount Sufficient to Reduce SOx in Flue Gas*

[18] Claim 5 of the '267 Patent requires the "discrete entities" to be "present in an amount sufficient to reduce the amount of sulfur oxides in said flue gas." Defendants seem to argue that Grace was required to produce a witness to testify as to what amount of the discrete entities would be sufficient to reduce SOx emissions and whether those amounts were present in the accused processes. (D.I. 50 at 10). Grace argues that the patent does not require proof that certain numerical thresholds were met. (D.I. 251 at 8).

This claim element is met so long as there is a sufficient amount of the discrete entities to reduce SOx emissions. No particular amount is mandated by the patentees. If there is a sufficient amount of the discrete entities to reduce SOx emissions in the flue gas, there is enough to satisfy this claim element.

C. *Application of Claims to Accused Process and Products*

[19] Proof of infringement includes both the construction of the claims and the application of those claims to the products and processes at issue. Becton Dickinson & Co. v. C.R. Bard, Inc., 922 F.2d 792, 796 (Fed.Cir.1990). Having construed the claims regarding which there was a dispute, the Court will now turn to an application of those claims to the accused processes and products.

1. *Does NO-SOx Contain Spinel?*

[20] Grace contends that NO-SOx contains spinel, which is a claim element in all of the representative claims. More particularly, Grace alleges that NO-SOx contains the spinel most preferred by the patentees, magnesium aluminate spinel. Defendants admit that NO-SOx contains a magnesium aluminate material, but they argue that the material is not sufficiently crystallized to be in the spinel phase. Rather, Defendants argue that the magnesium aluminate of NO-SOx is in a "metastable" phase. The following evidence shows, and this Court finds as fact, that NO-SOx contains "spinel" as that term is used in the patents-in-suit.

a) *XRD Analyses*

The parties agree that a person of ordinary skill in the art at the time the invention was made would perform XRD analysis and compare the resulting pattern to a standard reference card in order to determine the presence of spinel. The parties have stipulated that XRD is the most reliable method for determining whether spinel is present in a sample. If a person of ordinary skill in the art comparing an XRD analysis of NO-SOx with the reference card for magnesium aluminate spinel kept by the ICDD would determine that NO-SOx contains spinel, then that claim element is satisfied.

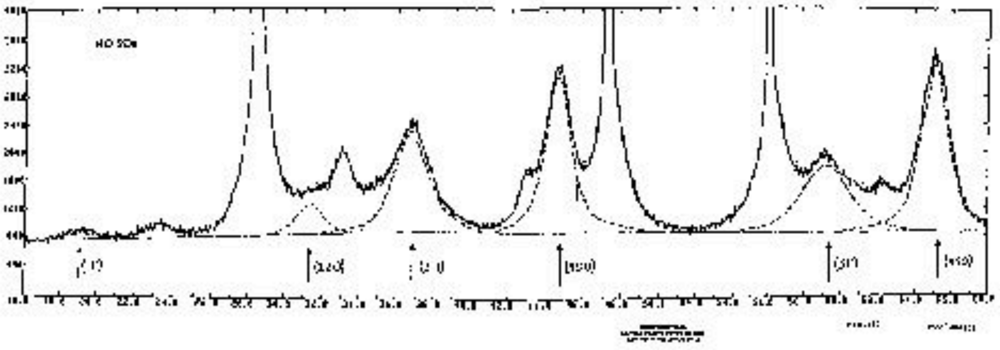
Not surprisingly, the experts do not agree about whether NO-SOx contains magnesium aluminate spinel. Both Dr. Jenkins and Dr. Messing, who testified for Grace, found that the NO-SOx product contained spinel. (Tr. 332, 444). On the contrary, Dr. Uhlmann, who appeared at trial on behalf of Defendants, testified that NO-SOx does not contain spinel. (Tr. 1349). Rather, according to Dr. Uhlmann, NO-SOx contains a "quasi crystalline" magnesium aluminate material, or a metastable phase of magnesium aluminate. (Tr. 1351, 1354). FN10 Although the conclusions of the experts at trial diverged, the XRD patterns elicited by the various experts did not markedly differ. The basic difference between the experts, which led to their divergent conclusions, was whether to ascribe major or minor importance to the relative intensities of the peaks shown in the XRD analysis. (Tr. 1349).

FN10. Spinel would be the "stable" phase of magnesium aluminate. Dr. Uhlmann testified that when the "metastable" magnesium aluminate phase is heated, it becomes more ordered and changes into spinel, a crystalline structure. (Tr. 1352-54).

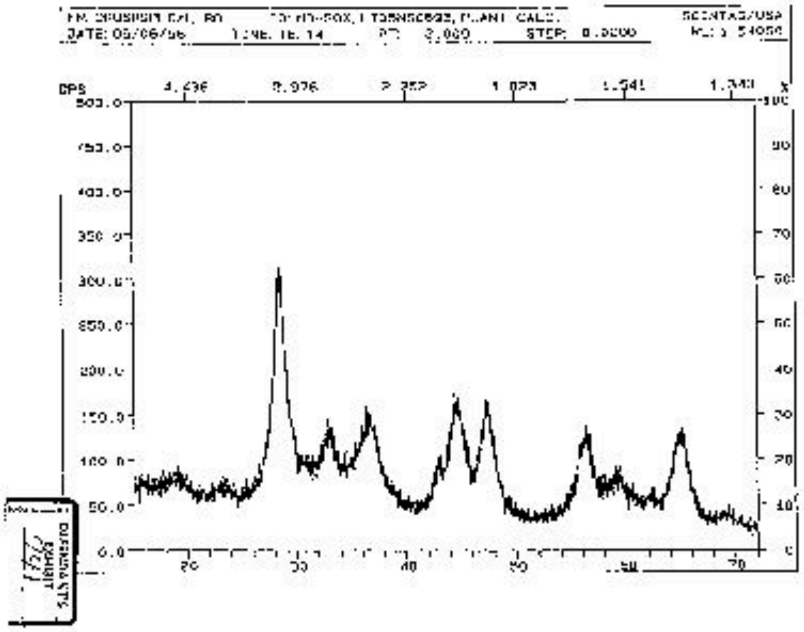
One challenge in the interpretation of the XRD patterns for NO-SOx is that NO-SOx contains more than just the single magnesium aluminate phase alleged by Grace to be spinel and by Defendants to be quasi-crystalline. In addition to the magnesium aluminate phase, Dr. Jenkins also identified magnesium oxide (periclase), and ceria. (Tr. 347-48, 352-53). Defendants agree that NO-SOx contains ceria and magnesium oxide. (D.I. 257 at OF43). Some of the peaks identified in the XRD pattern are attributable to these magnesium oxide and ceria phases.

XRD analyses of the NO-SOx material can be found at PTX-250, PTX-251, PTX-252, and DTX-741. Two of those XRD charts are reproduced below.

***441**



DTX-741



The ceria peaks can be found in the XRD patterns of NO-SOx where one would expect to find them. The three largest peaks for ceria (cerium oxide), according to its reference card, should be at 28.555 (relative intensity 100), 47.479 (relative intensity 52), and 56.335 (relative intensity 42). In addition, there should be another major peak at 33.082 (relative intensity 30). (PTX-266). The three largest peaks in Grace's XRD analysis of NO-SOx (PTX-252) are attributable to ceria. The very large peaks at the 28, 47, and 56 2-theta positions can be ascribed to the presence of ceria in NO-SOx. The ceria peak at 33 2-theta is also easily identified. All of these ceria peaks are also readily identifiable in DTX-741, which is the Defendants' XRD analysis of NO-SOx peaks.

Once the ceria peaks are properly attributed, the magnesium aluminate spinel phase can be identified. The experts agree that the reference card for magnesium aluminate spinel is card number 21-1152. (PTX-54). The XRD pattern for magnesium aluminate spinel is characterized by peaks at 19.029 degrees, 31.272

degrees, 36.853 degrees, 44.833 degrees, 59.371 degrees, and 65.243 degrees. The three highest peaks for magnesium aluminate spinel, according to its reference card (PTX-54), are at 36.853 degrees, 44.833 degrees, and 65.243 degrees. One would expect the highest peak to be at 36.853 degrees, a peak about 65% as high at 44.833 degrees, and a peak about 55% as high at 65.243 degrees. The next three highest peaks listed on the card are at 59.371 degrees with a relative intensity of 45%, at 31.272 degrees with a relative intensity of 40%, and at 19.029 degrees with a relative intensity of 35%. (PTX-54).

In order to be led from the Hannawalt index to the magnesium spinel reference card, one would have to be able to identify the three highest peaks attributable to spinel at 36.853 degrees, 44.833 degrees, and 65.243 degrees. Once the ceria peaks are identified and attributed to ceria, the three largest peaks in the XRD analyses performed by both Grace and the Defendants can be found at the 36-37, 44-45, and 64-65 2-theta positions.FN11 In Grace's analysis, the 64-65 degree peak is the largest, the 44-45 degree peak is the second largest, and the 36-37 degree peak is third in relative intensity. (PTX-252). In Defendants' analysis, the 44-45 degree peak is the largest, followed by the 36-37 degree peak, with the 64-65 degree 2-theta peak placing third in relative intensity. (DTX-741).

FN11. The slight leftward shift in peak position is due to the magnesium-rich nature of the magnesium aluminate in NO-SOx.

Importantly, both Defendants' and Grace's XRD analyses would lead a person of ordinary skill in the art to the reference card for magnesium aluminate spinel through use of the Hannawalt index. Furthermore, it is possible to identify each of the smaller peaks related to magnesium aluminate spinel in the analyses of NO-SOx performed by Grace (PTX-252) and by Defendants (DTX-741). There is a small bump in the pattern at the 19 2-theta position. Dr. Jenkins identified a buried peak at the 31 2-theta position,FN12 and there is clearly a peak at the 59 2-theta position.

FN12. The 31 degree magnesium aluminate spinel peak is "buried" under the convergence of the 28.555 and 33.082 ceria peaks. Once those peaks are attributed to the presence of ceria and removed for purposes of further analysis, a small peak at 31 degrees can be found.

Other peaks in the XRD analyses can be attributed to the presence of magnesium oxide. The reference card for magnesium oxide indicates that there should be major peaks at the 43 and 62 2-theta positions. (PTX-265). The 43 2-theta peak appears in both PTX-252 and DTX-741 as a small peak on the slope of the incline of the 45 2-theta peak attributable to magnesium aluminate spinel. The 62 2-theta peak is a very small peak, but is also recognizable. (PTX-252, DTX-741).

Dr. Uhlmann, in contrast to Dr. Jenkins, did not believe that spinel was present in NO-SOx. Although Dr. Uhlmann recognized that there are peaks in the positions where one would expect to find them for magnesium aluminate spinel,FN13 Dr. Uhlmann testified that the differences in relative intensities between the reference card and the XRD analysis of NO-SOx would preclude a phase identification of magnesium aluminate spinel. (Tr. 1343-49). Defendants do not argue, however, that a person of ordinary skill in the art who was attempting a phase identification would be led by the Hannawalt index to locate a magnesium aluminate phase other than spinel from the reference cards. Although Dr. Uhlmann argues that NO-SOx contains a metastable phase containing magnesium oxide and aluminum oxide, there is no reference card for such a material. Apparently, Defendants believe that a person skilled in the art would conclude that NO-SOx contains a material with the same peaks as magnesium aluminate spinel, but due to the variation in the relative intensities of those peaks, a person skilled in the art would not call that material spinel.

FN13. Dr. Uhlmann explained that one could find a small peak at 31 degrees but one would not have to do so. (Tr. 1345, 1348).

This Court finds that a person of ordinary skill in the art, after performing an XRD analysis of NO-SOx, would conclude that NO-SOx does contain magnesium aluminate spinel. In both Grace's analysis and Defendants' analysis, one can clearly identify the three major peaks of magnesium aluminate spinel. The three minor peaks of magnesium aluminate spinel are also present. After identifying those peaks, and finding no reference card which matches the sample's peaks better than the reference card for spinel, this Court agrees with Grace that persons of ordinary skill in the art would decide that NO-SOx contains spinel.FN14

FN14. The lattice cell parameter chart prepared by Dr. Jenkins also supports a finding that NO-SOx contains spinel. Dr. Jenkins calculated that the magnesium aluminate of NO-SOx had a cubic, face-centered structure, which is the lattice structure of magnesium aluminate spinel. (Tr. 353-56).

b) *XRD Analysis By Amoco*

The finding that NO-SOx contains spinel is supported by Intercat's prelitigation representations and other evidence. Perhaps the most persuasive of this other evidence is an analysis of NO-SOx performed by Amoco. Regis Lippert, as President of Intercat, wrote to Ekkehard Shoettle of Amoco to confirm that NO-SOx fell within the license agreement Intercat had entered with Amoco. (PTX-118). Mr. Shoettle wrote back to Mr. Lippert, stating that the phases observed in the x-ray diffraction patterns of NO-SOx were ceria, magnesia, and magnesium aluminate spinel. (PTX-119). Mr. Shoettle included with his letter the XRD graph of NO-SOx. The only differences between Amoco's graph and the XRD analyses of NO-SOx produced at trial is that the magnesia peaks are somewhat more developed in the Amoco analysis. As explained earlier, in accordance with the reference card for magnesium aluminate spinel, one would expect the highest peak to be at 37 degrees, a peak about 65% as high at 45 degrees, and a peak about 55% as high at 65 degrees. The next three highest peaks listed on the card are at 59 degrees with a relative intensity of 45%, at 31 degrees with a relative intensity of 40%, and at 19 degrees with a relative intensity of 35%. (PTX-54). In the Amoco analysis, the 45 degree peak is the highest, followed by the 37 degree peak and the 65 degree peak which were about equal in relative intensity. Also clearly identifiable were small peaks at 19 degrees and 59 degrees. To the extent that the 31 degree peak existed in the Amoco analysis, it was buried beneath other peaks. Thus, the major peaks for magnesium aluminate spinel were identifiable in the Amoco analysis, but they did not match the reference card in their relative intensities.

Despite the lack of a match with relative intensities, Amoco identified magnesium aluminate spinel as one of the phases present in NO-SOx. This evidence is especially important because Amoco had a financial incentive *not* to find spinel in NO-SOx. Under the license granted by Amoco to Intercat, Intercat was to pay less in royalties to Amoco if NO-SOx contained spinel. (PTX-71). Indeed, Intercat paid royalties to Amoco for sales of NO-SOx under the lower rate of subparagraph 3.1(b) of the license agreement, which was only applicable to materials which contained a spinel. (Tr. 895).

c) *Intercat's Papers and Patents*

In a paper presented to a symposium sponsored by the American Chemical Society, Louis Magnabosco and Edward Demmel, who were working for Intercat, noted that "the commercially successful SOx transfer agents are magnesium aluminum spinels that contain cerium. HRD-280 contains both cerium and a transition metal." (PTX-24 at 3). In their paper, Magnabosco and Demmel noted that magnesium aluminum spinel had been made by the powder method, the gel method, and the slurry peptizing method. (PTX-24 at 4). The authors then introduced a novel processing scheme, which they touted as the "quintessential extension of the Slurry-Peptizing Method to its ultimate physical limitation." (PTX-24 at 5). The authors represented that "[t]he material made according to our processing scheme is named NO-SOx and is used successfully on a commercial scale." (PTX-24 at 6). Magnabosco and Demmel then discuss the "magnesia-rich spinel peak" of NO-SOx. (PTX-24 at 6).

In another paper written by Patrick A. Clark and Edward Demmel, who worked for Intercat, the authors unequivocally stated that "NO-SOx is a magnesia spinel made using a new, proprietary manufacturing process." (PTX-23 at 2). A footnote to that sentence cites U.S. Patent 5,108,479 to Demmel and Magnabosco, which was their patent on the new manufacturing process. (PTX-23 at 4). In yet another paper, Intercat reported that "NO-SOx is a magnesia/alumina spinel, or crystal, made using a proprietary manufacturing process patented by Louis Magnabosco and INTERCAT's Ed Demmel in April, 1992." Again, Intercat cited U.S. Patent 5,108,479. (PTX-47 at 14, 19).

At trial, Grace introduced into evidence U.S. Patent 5,108,979 to Demmel and Magnabosco as PTX-14.FN15 The title of that patent is "Synthetic Spinels and Processes for Making Them." Each claim in that patent relates to a synthetic spinel or to a process for making such a spinel. (PTX-14). Regis Lippert admitted that the Demmel and Magnabosco manufacturing process was used in making NO-SOx. (Tr. 896).

FN15. The authors to the Intercat papers cited U.S. Patent 5,108,479 to Demmel and Magnabosco. The actual number of that patent is 5,108,979.

This Court finds it compelling that, prior to this litigation, Intercat consistently represented that NO-SOx contained magnesium aluminate spinel. It was not until the advent of this litigation that Intercat began claiming that NO-SOx contained not magnesium aluminate spinel, but a metastable phase of magnesium aluminate.

d) *Representations by Intercat Scientists*

In the context of an interoffice memorandum, Dr. Albert Vierheilig, Intercat's resident ceramist, mentioned the 2-theta values for spinel in NO-SOx. (PTX-17). In addition, Mr. Demmel referred to NO-SOx as a magnesium rich spinel in conversations with Dr. Vierheilig. (Vierheilig Dep. at 11-12).

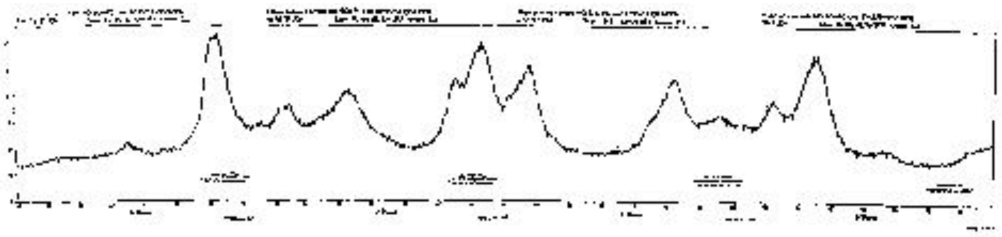
In sum, this Court finds that Grace has proven by a preponderance of the evidence that NO-SOx contains spinel.

2. *Does NO-SOx-PC Contain Spinel?*

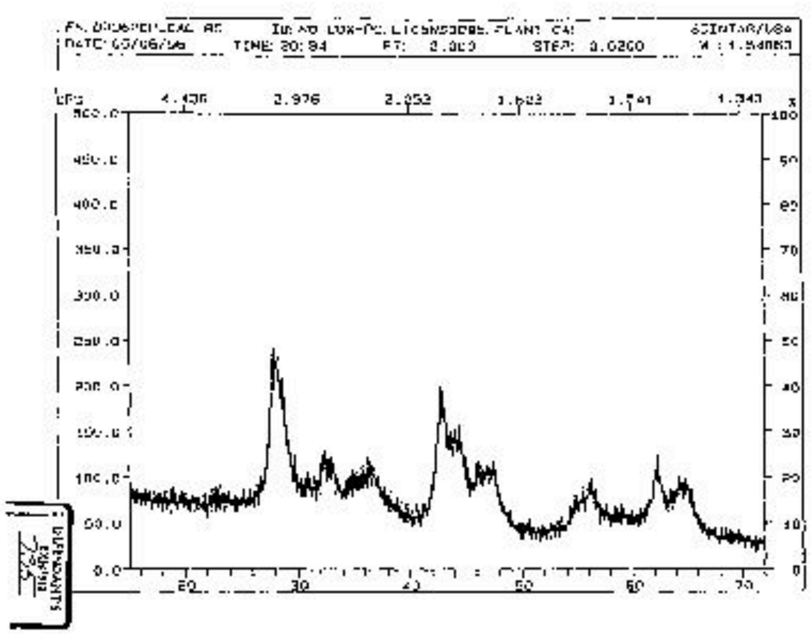
In accordance with the reference card for magnesium aluminate spinel (PTX-54), the XRD pattern for magnesium aluminate spinel is characterized by peaks at 19.029 degrees, 31.272 degrees, 36.853 degrees, 44.833 degrees, 59.371 degrees, and 65.243 degrees. The three highest peaks for magnesium aluminate spinel are at 36.853 degrees, 44.833 degrees, and 65.243 degrees. One would expect the highest peak to be at 36.853 degrees, a peak about 65% as high at 44.833 degrees, and a peak about 55% as high at 65.243 degrees. The next three highest peaks listed on the card are at 59.371 degrees with a relative intensity of 45%, at 31.272 degrees with a relative intensity of 40%, and at 19.029 degrees with a relative intensity of 35%. (PTX-54).

XRD analyses of the NO-SOx-PC material can be found at PTX-296, PTX-297, PTX-298, and DTX-735. Two XRD charts, PTX-296 and DTX-735, are reproduced below:

***445**



DTX-735



In each of the analyses, there are major peaks at 28-29 degrees, 33 degrees, 36-37 degrees, 43 degrees, 44-45 degrees, 47-48 degrees, 56-57 degrees, 62-63 degrees, and 65 degrees. Those same peaks can be found in DTX-735 as the nine strongest peaks.

All the experts agree that NO-SOx-PC contains ceria. The three largest peaks for ceria (cerium oxide), according to its reference card, should be at 28.555 (relative intensity 100), 47.479 (relative intensity 52), and 56.335 (relative intensity 42). In addition, there should be another major peak at 33.082 (relative intensity 30). (PTX-266). The major peaks for ceria are readily identifiable in the XRD analyses of NO-SOx-PC. The peaks located at 28-29 degrees, 33 degrees, 47-48 degrees, and 56-57 degrees can be attributed to ceria.

The experts also agree that NO-SOX-PC contains magnesium oxide. The reference card for magnesium oxide reveals major peaks at the 43 and 62 2-theta positions. (PTX-265). The peaks at 43 degrees and 62-63 degrees can therefore be attributed to the magnesium oxide phase.

Three major peaks remain unassigned, those at 36-37 degrees, 44-45 degrees, and 65 degrees. The three highest peaks for magnesium aluminate spinel, according to its reference card (PTX-54), are at 36.853 degrees, 44.833 degrees, and 65.243 degrees. The existence of these peaks would lead one skilled in the art to the entry for magnesium aluminate spinel in the Hannawalt index.FN16 A person of ordinary skill in the art would then look for the more minor peaks of magnesium aluminate spinel; i.e., the peaks at 59 degrees, 31 degrees, and 19 degrees. A very small peak can be found at 59 degrees. The 31-degree peak is buried, as always, between the 28.555 degree and 33.082 degree ceria peaks. Although the 31-degree peak is buried, a small peak is nonetheless identifiable. At 19 degrees there is a very broad lump that can barely be characterized as a peak.

FN16. This Court rejects Dr. Wuensch's testimony that these peaks are attributable to a gamma alumina-type material rather than to a magnesium alumina spinel. (Tr. 1071, 1163-75). In DTX-632, Dr. Wuensch suggested that the peaks could be attributed to a structure similar to aluminum oxide, the diffraction pattern for which can be found on reference card 10-0425 (PTX-277 at WRG-061827). For gamma alumina, one would expect to find major peaks at 45.901 (100% relative intensity), 67.093 (100% relative intensity), 37.635 (80% relative intensity), 39.524 (50% relative intensity), and 19.466 (40% relative intensity). The peak positions of the spinel reference card simply form a better match with the major peak positions which remain at 36-37 degrees, 44-45 degrees, and 65 degrees. Consequently, a person of ordinary skill in the art would be led through the Hannawalt index to magnesium aluminate spinel but not necessarily to gamma alumina.

Dr. Jenkins testified about how he performed a phase identification of the NO-SOx-PC material. (Tr. 367-372). He made a list of the peaks in terms of decreasing intensity, and starting with the strongest peak attempted to identify the phases. The strongest peak was at 28-29 degrees, which is one of the strong lines of ceria. He consulted the reference card for ceria (PTX-266) and was able to identify the lines of 28.55, 33.08, 47.47, and 56.33. Dr. Jenkins then eliminated the ceria lines from any further analysis.

After eliminating the ceria lines, the next phase Dr. Jenkins identified was magnesium aluminate spinel. Dr. Jenkins found lines at 65.2, 59.37, 44.83, 36.85, and 31.27. Dr. Jenkins also identified the 19.03 peak as "this broad reflection of low angles." (Tr. 371). Then Dr. Jenkins identified the magnesium oxide peaks at 63 degrees and 43 degrees. After eliminating all of those peaks, Dr. Jenkins then found "a small amount of bastnaesite-type material." (Tr. 372). Dr. Jenkins was unable to identify phases other than ceria, magnesium aluminate spinel, magnesium oxide, and the bastnaesite material. (Tr. 378). Dr. Jenkins believed that there was also a small amount of amorphous material present, stating that "there may be a couple percent." (Tr.

379). According to Dr. Jenkins, no free aluminum oxide was present. (Tr. 379). This Court fully credits Dr. Jenkins's testimony.

Dr. Uhlmann located the three major peaks for magnesium aluminate spinel, but noted the discrepancies in relative intensity between NO-SOx-PC and the reference card. (Tr. 1332). The primary problem with the intensity levels of the three major peaks in the NO-SOx-PC sample is that the 37 degree peak is too small. The peaks at 45 degrees and 65 degrees are about right in intensity compared to each other, but one would expect to see the 37 degree peak be two or three times larger than it is. In addition, Dr. Uhlmann testified that there was no clear evidence of peaks at 19 degrees or at 31 degrees. (Tr. 1333).FN17 Although Dr. Uhlmann did not find a peak at 31 degrees, Dr. Uhlmann admitted that one could find a small peak there if one wanted to do so. (Tr. 1335). Dr. Uhlmann's conclusion from his analysis was that there was a magnesium aluminate phase or phases present in the NO-SOx products but that the magnesium aluminate phase was metastable rather than spinel. (Tr. 1633-36).

FN17. Another of Defendants' experts, Dr. Wuensch, did recognize peaks at 19 and 31 degrees. (Tr. 1166-67, 1174).

In addition to the XRD evidence, the parties introduced other evidence regarding the presence or absence of spinel which is of decidedly lesser value. Perhaps the most probative of this other evidence is the lattice cell parameter chart created by Dr. Jenkins. (PTX-307). Using the peaks shown on the XRD analysis, Dr. Jenkins calculated that the magnesium aluminate of NO-SOx-PC had a cubic, face-centered structure, which is the lattice structure of magnesium aluminate spinel. (Tr. 375-76).

The transmission electron microscopy ("TEM") analysis by Dr. Wuensch is of little probative value. First, TEM is a relatively recent technique that was not commonly used before 1990. (Tr. 1198). Moreover, it has been stipulated that a person of skill in the art at the time the patent application was filed would have relied on XRD analysis. If persons skilled in the art at the time the patent application was filed would have understood a material to be spinel based upon XRD analysis, such a material would be spinel within the meaning of the patent even if advanced electron microscopy that was then unavailable, or at least not widely utilized, would demonstrate that those persons of skill in the art to have been erroneous in their phase identification.

Dr. Wuensch's trial testimony regarding the conclusions to be reached from the TEM was shaken by his own deposition testimony. At his deposition, Dr. Wuensch testified that the NO-SOx materials were crystalline and contained no amorphous material. (Tr. 1223-24). At trial, Dr. Wuensch testified that NO-SOx-PC contained 50% amorphous material. (Tr. 1224-25). Dr. Wuensch attempted to explain the discrepancy by stating that at the time of the deposition he had not had a chance to analyze the samples completely. (Tr. 1124-25). This Court is not satisfied by that explanation. In order for the discovery process to work adequately, witnesses (especially expert witnesses) must be prepared to give accurate testimony when deposed. This complete about-face from his deposition testimony lessens considerably this Court's confidence in Dr. Wuensch's conclusions.

Dr. Wuensch's reliance on TEM was also challenged by Dr. Jenkins. Dr. Jenkins testified that TEM is not an appropriate means to determine the amorphous content of a specimen because it focuses on too small an area. (Tr. 1778-79). Dr. Jenkins explained that using TEM to determine a sample's amorphous content would be like focusing a satellite on one square mile of the United States in an effort to survey the topography of the nation. (Tr. 1779). Dr. Jenkins testified that "you can really be fooled by looking at these small areas." (Tr. 1779). Dr. Jenkins testified that an XRD analysis, which looks at several square centimeters of material, "gives a much, much better indication of the amorphous content." (Tr. 1780). This Court credits the testimony of Dr. Jenkins.

To conclude, this Court finds as fact that NO-SOx-PC contains magnesium aluminate spinel.

3. *Do NO-SOx and NO-SOx-PC Satisfy All Other Claim Elements?*

[21] Most of the elements of the claims were not contested by Intercat at trial. Nevertheless, because it is Grace's burden to demonstrate that each claim element is present in the accused processes and products, this Court will determine whether each of the elements of each of the representative claims are met. In doing so, this Court will rely on the claim charts included as Appendix A of D.I. 265.

a) *Claim 5 of '267 Patent* FN18

FN18. Claims 1 and 2 are incorporated into claim 5. The first 13 claim elements are taken from claim 1; the fourteenth and fifteenth claim elements are added by claim 2; and the final claim element is added by claim 5.

The first claim element begins, "In a hydrocarbon conversion process for converting a sulfur containing hydrocarbon feedstock which comprises...." This Court finds as fact that Conoco has used Intercat's NO-SOx and NO-SOx-PC products in Conoco's FCC Unit in Billings, Montana; that the FCC Unit engages in a hydrocarbon conversion process; and that the gas-oil feed to the FCC Unit is a sulfur-containing hydrocarbon feedstock.

The second claim element discusses what the first step in such a hydrocarbon conversion process must include: "(1) contacting said feedstock at hydrocarbon conversion conditions in at least one reaction zone...." This Court finds as fact that Conoco used Vision-59 and/or Vektor 50P cracking catalysts. Both of those cracking catalysts are in the form of solid particles and contain zeolite as the active component. Zeolites promote the conversion of hydrocarbon feedstocks.

The third claim element defines the result of that first step in the process: "to produce at least one hydrocarbon product and to cause deactivating sulfur-containing carbonaceous material to be formed on said solid particles thereby forming deposit-containing particles." The FCC catalyst causes the gas-oil feed to be catalytically cracked into various smaller hydrocarbon products within the riser reactor. This cracking reaction causes deactivating sulfur-containing carbonaceous material ("coke") to be formed on the FCC catalyst.

The fourth and fifth claim elements turn to the second stage of the hydrocarbon conversion process: "(2) contacting said deposit-containing particles with an oxygen-containing vaporous medium at conditions to combust at least a portion of said carbonaceous material in at least one regeneration zone to thereby regenerate at least a portion of the hydrocarbon conversion catalytic activity of said solid particles and to form a regeneration zone flue gas containing sulfur trioxide." With respect to the Billings FCC unit, the coke-containing cracking catalyst particles were contacted with air (which of course contains oxygen) at a temperature that led to the combustion of at least a portion of the coke deposited on the FCC cracking catalyst within the regenerator. The combustion of the coke deposit regenerated the hydrocarbon conversion catalytic activity of the solid FCC catalyst particles. It is undisputed that during this regeneration process sulfur dioxide and sulfur trioxide were formed in the regeneration zone.

The sixth claim element addresses the third step in the hydrocarbon conversion process: "(3) repeating steps (1) and (2) periodically." It has been stipulated that, with respect to Conoco's Billings FCC unit, the admixture of NO-SOx or NO-SOx-PC and FCC catalyst was repeatedly circulated within the FCC unit between the regenerator and the reactor.

At the seventh and eighth claim elements, the patent claim elements turn to the patent's innovations with regard to this hydrocarbon conversion process. The improvement to the hydrocarbon conversion process must comprise "using, in intimate admixture with said solid particles, a minor amount of discrete entities having a composition different from said solid particles." When the patentees refer to "solid particles" they mean the FCC cracking catalyst, such as the Vision-59 and/or the Vektor 50P cracking catalysts, which were used at the Billings FCC unit. When the patentees refer to "discrete entities" they are referring to the SOx-reducing additive, such as the accused NO-SOx and NO-SOx-PC products. When the NO-SOx or NO-SOx-PC is added to the FCC unit it forms a homogenous admixture with FCC cracking catalyst. The NO-SOx and NO-SOx-PC products each have a composition different from the composition of the Vision-59 and the Vektor 50P cracking catalysts. The amount of SOx-removing additive should be considered a "minor amount" because NO-SOx and NO-SOx-PC each have been used in amounts below 12% wt. of the combined weight of the FCC cracking catalyst and the NO-SOx or NO-Ox-PC products.

These discrete entities must, according to ninth claim element, comprise "at least one alkaline earth metal-containing spinel including alkaline earth metal and a second metal having a valence higher than the valence of said alkaline earth metal." This Court has determined that both NO-SOx and NO-SOx-PC contain a magnesium aluminate spinel. Magnesium is an alkaline earth metal having a valence of (+2) and aluminum is a metal having a valence of (+3).

The tenth claim element further requires that "the atomic ratio of said alkaline earth metal to said spinel [must be] at least about 0.25." The magnesium aluminate spinel in NO-SOx has an atomic ratio of magnesium to aluminum (Mg:A1) of about 0.57. The magnesium aluminate spinel in NO-SOx-PC has a MG:A1 atomic ratio of about 0.94.

The eleventh claim element requires the spinel to have "a surface area in the range of about 25 m ^{2}/gm. to about 600 m 61/gm." Dr. Gary L. Messing estimated that the surface area of the magnesium aluminate spinel in NO-SOx is between 82 and 199 m ^{2}/g and that in NO-SOx-PC the surface area of the spinel is between 70 and 176 m ^{2}/g. Dr. Messing made his calculations of the surface area by making high and low estimates of the surface area of the other phases present in the NO-SOx and NO-SOx-PC products. To come up with the high estimate of the surface area of spinel, Dr. Messing assumed that the other phases contributed nothing to surface area, an admittedly unrealistic assumption. To estimate the minimum surface area that could be attributed to spinel, Dr. Messing assumed that the surface area for the other phases was on the order of 300 m ^{2}/gm. Dr. Messing described this assumption as "generous because all of these products have seen high temperatures and it is quite unlikely that any of them will have a surface area even remotely close to that." (Tr. 464-65).

Dr. Uhlmann testified that in his laboratory they often make materials with surface areas of 450 or 500 m ^{2}/g. (Tr. 1391). Dr. Uhlmann testified that if Dr. Messing had assumed a surface area of 500 m ^{2}/g for the other phases, Dr. Messing would have calculated the minimum surface area of the magnesium aluminate phase to be 0 m ^{2}/g. Dr. Uhlmann was quick to clarify that he was not suggesting that the magnesium aluminate phase in NO-SOx and NO-SOx-PC actually had no surface area, only that he found Dr. Messing's approach "inappropriate." (Tr. 1393).

Although Dr. Messing's analysis may be flawed, it is the best analysis in the record on the subject of determining surface area of the magnesium aluminate spinel. Importantly, Dr. Uhlmann did not testify that the other phases were likely to have a surface area that is greater than 300 m ^{2}/g. According to Dr. Messing's calculations, 3% of NO-SOx-PC by weight and 10% of NO-SOx by weight is free MgO, while 13.7% of NO-SOx by weight and 13.9% of NO-SOx-PC by weight is ceria. Dr. Uhlmann's critique would have been more persuasive if he had been able to state that these other known phases likely had surface areas greater than 300 m ^{2}/g. Moreover, Dr. Uhlmann did not attack Dr. Messing's statement that 300 m ^{2}/g is a very generous estimate considering that NO-SOx and NO-SOx-PC are subjected to high temperatures in the manufacturing process. FN19 This Court will therefore accept Dr. Messing's analysis of the surface size of the magnesium aluminate spinel in NO-SOx and NO-SOx-PC.

FN19. One theme that emerged at trial was that, when heated, materials tend to decrease in surface size and increase in crystallinity.

Furthermore, this Court notes that Intercat's own documents show that NO-SOx-PC has a surface area of 160 m ^{2}/g (PTX-86), 163 m ^{2}/g (PTX-111), or 172 m ^{2}/g (PTX-85). According to a different Intercat document, NO-SOx has a surface area of 160 m ^{2}/g (PTX-80). Considering that NO-SOx and NO-SOx-PC are made up mostly of magnesium aluminate spinel, this Court finds these documents to corroborate Dr. Messing's analysis. Consequently, this Court finds that the NO-SOx and NO-SOx-PC products both fall within the scope of the eleventh claim element.

The twelfth claim element requires the discrete entities to also comprise "a minor amount of at least one rare earth metal component." Cerium is a rare earth metal. NO-SOx contains 11.18% cerium, calculated as an elemental metal, equivalent to 13.7% wt. ceria. NO-SOx-PC contains 11.34% cerium, calculated as an elemental metal, equivalent to 13.9% ceria. This Court finds as fact that these amounts of cerium and cerium oxide constitute a "minor amount" of the discrete entities, i.e., NO-SOx and NO-SOx-PC.FN20

FN20. In their JMOL opening brief (D.I. 250 at 10), Defendants contended that Grace's proofs fell short on this element because "[t]here was no testimony, including from Dr. Messing, which identified the amount of cerium oxide in the NO-SOx and NO-SOx-PC products as being a minor amount in the claimed spinel." To the extent that Defendants were arguing that the patent requires the rare earth metal to be part of the spinel rather than part of the discrete entities, this Court has resolved that question against Defendants in the section of this opinion dealing with claim construction. To the extent that Defendants are arguing that the amounts of cerium found by Dr. Messing are not minor, this Court hereby rejects defendants' argument and finds the amounts of cerium to be "minor amounts."

The thirteenth claim element requires the discrete entities to be "present in an amount sufficient to reduce the amount of sulfur oxides in said flue gas." Defendants argued in their JMOL motion that this claim element is not met by the stipulations of the parties which "refer only to the fact that the addition of these products by Conoco to its Billings FCC unit reduce the emissions of sulfur oxides from the flue gas; they do not speak to the sufficiency of the amounts of additive to reduce SOx emissions." (D.I. 250 at 10). Defendants' argument is sophistic. In resolving a claim interpretation disagreement earlier in this opinion, this Court ruled that this claim element is met so long as there is enough additive to reduce SOx emissions in the flue gas, whatever amount that might be. The stipulations of the parties state that "the addition of the [NO-SOx and NO-SOx-PC] products by Conoco to its Billings FCC unit reduced the emissions of the sulfur oxides from the flue gas exiting the regenerator." Because the addition of NO-SOx and NO-SOx-PC reduced the emissions of sulfur oxides from the flue gas, those products were necessarily present in an amount sufficient to reduce the amount of sulfur oxides in the flue gas.

The fourteenth claim element requires the hydrocarbon conversion process to comprise "hydrocarbon cracking in the substantial absence of added molecular hydrogen." With respect to Conoco's Billings FCC unit, it has been stipulated that molecular hydrogen was not added to any section of the FCC unit during its operation with NO-SOx or NO-SOx-PC.

The fifteenth claim element requires the solid particles and discrete entities to be "fluidizable and circulating between said reaction zone and said regeneration zone." The parties stipulated that, with respect to Conoco's Billings FCC unit, the admixture of the FCC cracking catalyst and NO-SOx or NO-SOx-PC was repeatedly circulated between the regenerator and the reactor. Defendants contend that it would be error to rely on this stipulation alone because the claim element requires two characteristics, fluidization and circulation, and the stipulation addresses only circulation. (D.I. 250 at 11).

Mr. Hartley Owen testified that a "fluidized solid" is a finely divided powder ranging from roughly 1 micron to 150 microns with an average of about 60 microns. (Tr. 746). According to Intercat's own documents, NO-SOx-PC has an average particle size of 80 microns (PTX-111) or 95 microns (PTX-86), while NO-SOx has an average particle size of 95 microns (PTX-80). Mr. Owen was asked if SOx-reducing additives are fluidized through the FCC unit along with the cracking catalyst. (Tr. 746). Mr. Owen replied, "It is presently practiced, yes." (Tr. 747). Defendants' own witness, Dr. John G. Gott, testified that the cracking catalyst is a solid and "when you fluidize it with air or another gas or a hydrocarbon gas, it behaves like a liquid and flows." (Tr. 806). In Intercat's license with Amoco, the term "Emission Control Material," which referred to Intercat's SOx-reducing additives, was defined as "the fluidized catalytic cracking sulfur oxide-reducing additive of licensee...." (Tr. 952). Indeed, the totality of the evidence has proven that NO-SOx, NO-SOx-PC, and the cracking catalyst are all fluidizable. Intercat has pointed to no persuasive evidence to the contrary. Consequently, this Court finds that the fifteenth claim element is satisfied.

The sixteenth claim element requires the discrete entities to "contain at least about 70% by weight of said spinel." NO-SOx contains about 72% by weight of magnesia aluminate spinel, while NO-SOX-PC contains about 74% by weight of magnesia aluminate spinel. (Tr. 398-401). These amounts are "about 70%."

Consequently, this Court holds that Conoco directly infringes claim 5 of the '267 Patent through its use of NO-SOx and NO-SOx-PC in its Billings, Montana, FCC unit.

b) ***Claim 23 of '267 Patent*** FN21

FN21. Claims 1, 2, and 7 are incorporated into claim 23.

This Court has already held that the first fifteen claim elements of claim 23 of the '267 Patent are infringed by the use of NO-SOx and NO-SOx-PC in Conoco's FCC facilities. There is no sixteenth claim element, due apparently to an omission in the claim chart.

The seventeenth claim element mandates that the "solid particles are separate from said discrete entities and the relative amounts of said solid particles and said discrete entities are in the range of about 80 parts to about 99 parts, and about 1 part to about 20 parts by weight, respectively." This claim element requires the additive to be between 1-20% of the combined weight of the additive and the cracking catalyst. It has been stipulated that NO-SOx has been used in Conoco's Billings FCC unit in amounts between about 5 and 7 percent by weight of NO-SOx and the FCC cracking catalyst together and that NO-SOx-PC has been used in Conoco's Billings FCC unit in amounts up to about 12 percent by weight of the total weight of NO-SOx-PC and the cracking catalyst together. (UF-147, UF-158). This stipulation is accepted, and the seventeenth claim element is therefore satisfied.

The eighteenth claim element requires that the "discrete entities further comprise about 0.1% to about 25% by weight of free magnesia, calculated as MgO." Dr. Jenkins testified that NO-SOx contains about 10% by weight free magnesia, while NO-SOx-PC contains about 3% by weight free magnesia. (Tr. 393-95). This Court accepts Dr. Jenkins's testimony and finds this claim element, and consequently this claim, to be infringed.

c) *Claim 31 of '267 Patent*

Each of the claim elements of claim 29, which are incorporated into claim 31, have been resolved except for the requirement that NO-SOx and NO-SOx-PC each contain a major amount of spinel. This Court has already found that NO-SOx contains about 72% by weight of magnesium aluminate spinel and that NO-SOx-PC contains about 74% by weight of magnesium aluminate spinel. Those amounts should be considered a "major amount" of spinel.

The claim element that is added by claim 31 mandates that the "hydrocarbon feedstock contains about 0.01% to about 5.0% by weight of sulfur." It has been stipulated that the gas-oil feed to Conoco's FCC units while Conoco was using NO-SOx contained 2-3% by weight of sulfur. Hartley Owen testified that he never saw a gas-oil feed with less than .1% or more than 5% by weight of sulfur.FN22 (Tr. 743). Defendants argue that Grace's proofs are insufficient to show that the gas-oil feed contained .01% to 5% by weight of sulfur during the period in which Conoco used NO-SOx-PC. This Court disagrees. There is no evidence that Conoco changed its gas-oil feed when it switched from NO-SOx to NO-SOx-PC. No evidence has been submitted that would suggest that Conoco would have had any reason to convert to a different gas-oil feed. A reasonable inference from the evidence is that the gas-oil feed in the Conoco Billings FCC unit contained, throughout the entire period relevant to this lawsuit, about 2-3% sulfur by weight. If Defendants had wished for this Court to find as fact that the gas-oil feed had less than .01% or more than 5% by weight of sulfur, which according to the testimony of Mr. Owen would have been a truly extraordinary circumstance, they should have presented some scintilla of evidence to support their position. The weight of evidence clearly supports finding this claim element, and consequently this claim, to be satisfied.

FN22. Mr. Owen is a patentee on over 100 patents relating to FCC technology and has been working in the field since the 1950's.

d) ***Claim 39 of*** **'*267 Patent*** FN23

FN23. Claims 29, 30, and 31 are incorporated into claim 39.

This Court has already found Conoco to have directly infringed all of the claim elements in claims 29, 30, and 31, which are incorporated by reference into claim 39.

Claim element 39 adds only one additional limitation, that "at least one of said solid particles and discrete entities further comprise a minor, catalytically effective amount of at least one additional metal component capable of promoting the conversion of sulfur dioxide to sulfur trioxide at the conditions of step (2)." Defendants do not dispute that the NO-SOx and NO-SOx-PC contain vanadium. Indeed, Defendants stipulated that "vanadium is intended to function as an oxidation catalyst, and is present in the NO-SOx and NO-SOx-PC products in an amount that is intended to be catalytically effective to promote the conversion of SO_2 to SO_3." (UF-130). Moreover, Edward Demmel, Intercat's Head of Technology, testified in his deposition that ceria dioxide and vanadium pentoxide both act as an oxidation catalyst to catalyze the reaction of sulfur dioxide to sulfur trioxide in NO-SOx.

Defendants fault this evidence, stating that "there is no testimony that vanadium *actually* functions *in the accused products in use* to oxidize SO_2 to SO_3." (D.I. 250 at 13). Defendants argument is not well taken. This claim requires that the discrete entities contain a "catalytically effective amount" of an additional metal component that is "capable" of promoting the conversion of sulfur dioxide to sulfur trioxide. There seems to be no real dispute that vanadium is capable of promoting the chemical conversion of sulfur dioxide to sulfur trioxide. There is also no dispute that the accused products contain vanadium in an amount that is intended to be catalytically effective to promote this oxidation reaction. Moreover, Mr. Demmel stated that vanadium oxide does act as an oxidation catalyst in NO-SOx, converting SO_2 to SO_3. These proofs are more than sufficient, especially in light of the fact that there is absolutely no countervailing evidence in the record, to find that Grace has met its burden on this claim element, and consequently, this claim.

e) ***Claim 7 of*** '589 Patent

The first fifteen claim elements in this claim are identical to the first fifteen claim elements in claim 5 of the '267 Patent and have therefore been resolved.

Claim 7 also requires, however, that the "spinel comprises alkaline earth metal-containing spinel and the atomic ratio of said first metal to said second metal in said spinel is at least about 0.2." This Court has found that NO-SOx and NO-SOx-PC each contain a magnesium aluminate spinel. This Court has already found that the magnesium aluminate spinel in NO-SOx has an atomic ratio of magnesium to aluminum (Mg:A1) of about 0.57 and that the magnesium aluminate spinel in NO-SOx-PC has a MG:A1 atomic ratio of about 0.94. Consequently, the atomic ratio is greater than 0.2.

f) ***Claim 21 of*** '589 Patent

The first fifteen claim elements in this claim are identical to the first fifteen claim elements in claim 5 of the '267 Patent and have therefore been resolved. The next two claim elements are identical to claim elements 17 and 18 of claim 23 of the '267 Patent, which have also been resolved in Grace's favor. Therefore, Grace has proven this claim to be infringed.

g) *Claim 33 of* '589 Patent

All of the claim elements in this claim have been resolved through the analysis of other claims. Conoco has directly infringed this claim through its use of NO-SOx and NO-SOx-PC in its Billings FCC Unit.

h) *Claim 34 of* '589 Patent

All of the claim elements in this claim have been resolved through the analysis of other claims. Conoco has directly infringed this claim through its use of NO-SOx and NO-SOx-PC in its Billings FCC Unit.

i) *Claim 3 of* '305 Patent

This is the first of the composition claims to be analyzed. The first claim element requires there to be "a composition of matter comprising in intimate admixture...." This Court has already found that the cracking catalyst and the NO-SOx and NO-SOx-PC products are intimately admixed.

The second claim element requires as part of the composition of matter "a major amount of solid particles capable of promoting hydrocarbon conversion at hydrocarbon conversion conditions." It has already been decided that the FCC catalyst, which consists of solid particles, is capable of promoting hydrocarbon conversion at hydrocarbon conversion conditions. The cracking catalyst does comprise the major amount of the admixture, with the additive contributing less than 12% of the total weight of the composition.

The third claim element requires the solid particles to contain "at least one crystalline aluminosilicate capable of promoting said hydrocarbon conversion." This Court has already found that the cracking catalysts used by Conoco contained a zeolite, or crystalline aluminosilicate, that is capable of promoting hydrocarbon conversion.

All but one of the other claim elements in claim 3 of the '305 Patent have been found to be met in other claims. Claim 3 also requires a major amount of the solid particles, or cracking catalyst, to have diameters in the range of about 10 microns to about 250 microns. Mr. Powell testified that the cracking catalyst has a particle size of 20 to 120 microns in diameter. (Tr. 82). This Court accepts Mr. Powell's testimony and finds that this claim element is satisfied.

j) *Claim 15 of* '305 Patent

All elements of this claim have been addressed in other claims. Conoco directly infringes this claim through the use of NO-SOx and NO-SOx-PC in its Billings FCC unit.

k) *Claim 30 of* '305 Patent

All elements of this claim have been addressed in other claims. Conoco directly infringes this claim through the use of NO-SOx and NO-SOx-PC in its Billings FCC unit.

l) *Claim 35 of* '305 Patent

All elements of this claim have been addressed in other claims. Conoco directly infringes this claim through the use of NO-SOx and NO-SOx-PC in its Billings FCC unit.

m) ***Claim 6 of*** '304 Patent

All elements of this claim have been addressed in other claims. Conoco directly infringes this claim through the use of NO-SOx and NO-SOx-PC in its Billings FCC unit.

n) ***Claim 20 of*** '304 Patent

All elements of this claim have been addressed in other claims. Conoco directly infringes this claim through the use of NO-SOx and NO-SOx-PC in its Billings FCC unit.

o) ***Claim 40 of*** '304 Patent

All elements of this claim have been addressed in other claims. Conoco directly infringes this claim through the use of NO-SOx and NO-SOx-PC in its Billings FCC unit.

p) ***Claim 32 of*** the '982 Patent FN24

FN24. Defendants' claim chart (D.I. 250, exhibit A) is wrong. It includes claim elements from claim 1, which is not part of claim 32, the only claim in suit.

The '982 Patent involves a process claim, similar to the asserted claims from the '267 Patent. The first nine claim elements in claim 32 are the same as the first nine claim elements in claim 5 of the '267 Patent. As has been previously held, those claim elements are satisfied.

Claim 32, in its tenth claim element, requires that the discrete entities include "a third metal other than said first and second metals effective to promote the oxidation of sulfur dioxide to sulfur trioxide at sulfur dioxide oxidation conditions." NO-SOx and NO-SOx-PC each contain cerium, which is different from the first metal (magnesium) and the second metal (aluminum). The cerium present in NO-SOx and NO-SOx-PC functions to promote the oxidation of sulfur dioxide to sulfur trioxide.

The eleventh claim element requires that the discrete entities also include "a fourth metal other than said first, second and third metals effective to promote the reduction of a sulfate of the first metal at first metal sulfate reduction conditions." The parties agree that NO-SOx and NO-SOx-PC contain vanadium, which is different from the first metal (magnesium), the second metal (aluminum), and the third metal (cerium). In order to meet this claim limitation the vanadium in NO-SOx and NO-SOx-PC must be effective to promote the reduction of magnesium sulfate. Mr. Powell and Mr. Roberie testified that one function of vanadium in the DESOX additive is to promote the reduction of magnesium sulfate. (Tr. 132; 642-43). Grace argues that this testimony creates an inference that it serves the same function in NO-SOx and NO-SOx-PC. Defendants decry the absence of specific proof.

There is no reason to believe that vanadium works any differently in NO-SOx and NO-SOx-PC than it works in DESOX. This Court finds that vanadium is effective as a reductant in SOx-reducing additives, including NO-SOx and NO-SOx-PC.

The twelfth claim element requires the third metal to be "selected from the group consisting of Group IB metals, Group IIB metals, Group VIA metals, the rare earth metals, the Platinum Group metals and mixtures thereof." Cerium, a rare earth metal, is the third metal in both NO-SOx and NO-SOx-PC.

The thirteenth claim element requires the fourth metal to be "selected from the group consisting of iron, nickel, titanium, chromium, manganese, cobalt, germanium, tin, bismuth, molybdenum, antimony, vanadium and mixtures thereof." NO-SOx and NO-SOx-PC each contain a minor amount of vanadium as the fourth metal.

The fourteenth claim element requires that the "third metal component and said fourth metal component are present in amounts effective to promote the oxidation of SO_2 to SO_3 and the subsequent reduction of the sulfate of the first metal formed by reaction with the metal-containing spinel, to H_2S and the original spinel and in amounts effective to promote the reduction of nitrogen oxides at nitrogen oxide conditions." Cerium, which is the third metal in the accused products, functions to promote the oxidation of sulfur dioxide to sulfur trioxide. Vanadium, which is the fourth metal in the accused products, functions to promote the reduction of the metal sulfate. Defendants do not dispute the sufficiency of the cerium and vanadium in NO-SOx and NO-SOx-PC to promote the reduction of nitrogen oxides at nitrogen oxide conditions.

[22] Because NO-SOx and NO-SOx-PC meet every claim element of each of the patents-in-suit when used in Conoco's FCC Unit, this Court finds that Conoco has directly and literally infringed the patents-in-suit.FN25

FN25. Grace also argues that Conoco directly infringes under the doctrine of equivalents. Grace contends that even if the Court accepts Intercat's argument that its products contain a metastable phase of magnesium aluminate, rather than a magnesium aluminate spinel, the metastable phase works in exactly the same way, to perform the same function, to achieve the same result as the spinel. *See* Graver Tank & Mfg. Co. v. Linde Air Prods. Co., 339 U.S. 605, 608, 70 S.Ct. 854, 94 L.Ed. 1097 (1950) (patentee may invoke doctrine of equivalents if the accused product performs substantially the same function in substantially the same way to obtain the same result as the patented invention). Grace argues that any distinction between the metastable phase and the spinel is insubstantial. According to Grace, the patentees identified materials, such as Yoo Example 1, whose XRD patterns match the reference card in peak position but not intensity as being equivalent to spinel.Although this Court agrees with Grace that the magnesium aluminate in NO-SOx and NO-SOx-PC meets the function-way-result test identified in *Graver Tank,* a finding of equivalents is precluded by prosecution history estoppel. *See* Warner-Jenkinson Co. v. Hilton Davis Chem. Co., 520 U.S. 17, 117 S.Ct. 1040, 1049-50, 137 L.Ed.2d 146 (1997). In the course of an interference action by Bertolacini, the patentees represented that spinel is "clearly a distinct chemical composition ... from non-spinel $MgAl_2O_4$, and is patentably distinct." (DTX 80 at 13). The patentees also represented that non-spinel $MgAl_2O_4$ was "not directed to the same patentable invention" as were the spinel claims. (DTX 80 at 14). The patentees further explained that their invention was "exclusively directed to spinel." (DTX-80 at 15). To the extent that the magnesium aluminate in NO-SOx and NO-SOx-PC is not spinel, but is only similar to spinel, this Court finds that the patentees clearly disclaimed patent protection for such a material. Of course, this discussion in no way changes this Court's finding on literal infringement. The NO-SOx and NO-SOx-PC products do indeed contain spinel within the meaning of the patents-in-suit.

D. *CONTRIBUTORY INFRINGEMENT AND INDUCEMENT OF INFRINGEMENT*

[23] Having established that Conoco directly infringes the patents-in-suit, the question becomes whether Intercat contributed to and induced Conoco's direct infringement. The doctrine of contributory infringement is codified at 35 U.S.C. s. 271(c):

> Whoever offers to sell or sells within the United States ... a component of a patented machine, manufacture, combination or composition, or a material or apparatus for use in practicing a patented process, constituting a material part of the invention, knowing the same to be especially made or especially adapted for use in an infringement of such patent, and not a staple article or commodity of commerce suitable for substantial noninfringing use, shall be liable as a contributory infringer.

[24] In order to hold Intercat liable for contributory infringement, Grace was required to prove that Intercat knew that NO-SOx was especially made for an infringing use and that there were patents prescribing that use. Hewlett-Packard Co. v. Bausch & Lomb Inc., 909 F.2d 1464, 1469 (Fed.Cir.1990). Actual intent to cause or contribute to infringement is not necessary to establish contributory infringement. *Id.*

[25] [26] The patent laws also explicitly prohibit the inducement of infringement: "Whoever actively induces infringement of a patent shall be liable as an infringer." 35 U.S.C. s. 271. One induces infringement by actively and knowingly aiding and abetting another's direct infringement. Water Technologies Corp. v. Calco, Ltd., 850 F.2d 660, 668 (Fed.Cir.1988). Actual intent to cause the acts which constitute the infringement is a necessary prerequisite to a finding active inducement. Hewlett-Packard, 909 F.2d at 1469.

Intercat presented only one defense to Grace's charges of contributory infringement and inducement of infringement: if Conoco does not directly infringe, then Intercat cannot be found to have contributed to or induced that infringement. (D.I. 266 at 26 n. 25). While Intercat's legal argument is valid, its factual premise is flawed. Conoco does directly infringe. It is clear from the record that Intercat sold its NO-SOx products to Conoco for use in Conoco's Billings, Montana, FCC unit. Intercat intended for Conoco to add NO-SOx and NO-SOx-PC to the Billings FCC unit to reduce SOx. As will become more clear in this Court's discussion on willfulness, Intercat knew that the use of the NO-SOx products in the FCC unit would violate the patents-in-suit. Moreover, the NO-SOx products were unsuitable for any substantial non-infringing use. Intercat designed the NO-SOx products for use in an FCC Unit to reduce SOx emissions and intended that they be used to reduce SOx in the Billings FCC unit in a manner that violated the patents-in-suit. That is the purpose for which NO-SOx and NO-SOx-PC were sold to Conoco, and that is the purpose for which they were used. As such, Intercat is liable for contributory infringement and the inducement of infringement.

IV. INVALIDITY

[27] Defendants contend that the patents-in-suit are invalid for obviousness, for failing to distinctly claim the subject matter of the invention, and for inequitable conduct before the Patent and Trademark Office ("PTO"). Each claim of a patent is presumed valid. 35 U.S.C. s. 282. The party asserting invalidity has the burden to prove it by clear and convincing evidence. Loctite Corp. v. Ultraseal, Ltd., 781 F.2d 861, 872 (Fed.Cir.1985). The clear and convincing standard of proof is "an intermediate standard which lies between 'beyond a reasonable doubt' and a 'preponderance of the evidence.' " Buildex, Inc. v. Kason Indus., Inc., 849 F.2d 1461, 1463 (Fed.Cir.1988). Each of Defendants' invalidity claims will be resolved *seriatim*.

A. *OBVIOUSNESS*

[28] [29] A patent may be found invalid for obviousness in accordance with 35 U.S.C. s. 103. Under s. 103, a Court must determine whether "the subject matter as a whole would have been obvious at the time the invention was made." FN26 Obviousness is a question of law based upon factual inquiries established by the United States Supreme Court in Graham v. John Deere Co., 383 U.S. 1, 17, 86 S.Ct. 684, 15 L.Ed.2d 545 (1966). Arkie Lures, Inc. v. Gene Larew Tackle, Inc., 119 F.3d 953 (Fed.Cir.1997); Panduit Corp. v.

Dennison Mfg. Co., 810 F.2d 1561, 1566-68 (Fed.Cir.1987). The factors to consider in determining whether obviousness is present include: 1) scope and content of the prior art; 2) differences between the prior art and the subject patent; 3) level of ordinary of skill in the art at the time of the invention; and 4) secondary considerations such as commercial success, long felt but unresolved need, and failure of others. Graham, 383 U.S. at 17, 86 S.Ct. 684; Arkie Lures, 119 F.3d at 955.

FN26. Section 103 provides in pertinent part:A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.

35 U.S.C. s. 103.
[30] When performing an obviousness analysis, "[f]ocusing on the obviousness of substitutions and differences, instead of on the invention as a whole, is a legally improper way to simplify the often difficult determination of obviousness." Gillette Co. v. S.C. Johnson & Son, Inc., 919 F.2d 720, 724 (Fed.Cir.1990). The Court may not, with 20-20 hindsight, utilize the claims as a template and reconstruct the invention willy-nilly by picking and choosing elements at will from the prior art. *See* In re Gorman, 933 F.2d 982, 987 (Fed.Cir.1991). The "critical question, as s. 103 makes plain, is whether the invention as a whole would have been obvious to one of ordinary skill in the art at the time it was made." Perkin-Elmer Corp. v. Computervision Corp., 732 F.2d 888, 894 (Fed.Cir.1984).

1) *Scope and Content of the Prior Art*

[31] The scope of the relevant prior art is defined as that which is "reasonably pertinent to the particular problem with which the inventor was involved." Stratoflex, Inc. v. Aeroquip Corp., 713 F.2d 1530, 1535 (Fed.Cir.1983) (quoting Application of Wood, 599 F.2d 1032, 1036 (Cust. & Pat.App.1979)).

a) *Bertolacini Patents*

Much of the technology of the patents-in-suit was disclosed in three patents granted to Ralph J. Bertolacini, et al.FN27 Each of these patents was disclosed to the PTO during the patent prosecution.

FN27. These patents include U.S. Patents 4,369, 103 (" '103 Patent"); 4,369,108 (" '108 Patent"); and 4,381,991 (" '991 Patent").

Defendants particularly rely on the '108 Patent. The '108 Patent disclosed that magnesia was a somewhat more efficient SOx remover than alumina, but that magnesia had certain problems not possessed by alumina:

In the practice of this invention, at least one inorganic oxide is employed which is selected from the group consisting of the oxides of aluminum, magnesium, zinc, titanium, and calcium, and preferably at least one inorganic oxide selected from the group consisting of alumina and magnesium oxide is employed. **Magnesium oxide is generally somewhat more efficient in absorbing sulfur oxides than is alumina but does not release absorbed sulfur oxides as readily as alumina upon contact with a hydrocarbon in the presence of a cracking catalyst. In addition, when fluidized solids are employed, particles comprising large amounts of magnesium oxide frequently have poor attrition properties relative to particles**

containing large amounts of alumina. In view of the desirable attrition and sulfur oxide releasing properties of alumina, the inorganic oxide most preferably comprises alumina. Although the use of any form of alumina is contemplated for use in the practice of this invention, gamma-alumina and eta-alumina are preferred because of their usually large surface area.

(DTX 158, col. 9, lines 37-56) (emphasis added). The '108 Patent therefore explains that magnesia is better than alumina at absorbing SOx but is less attrition resistant and does not release SOx as readily as does alumina.

Example 10 of the '108 Patent discloses a mixture of MgO, $Ca_3Al_{10}O_{18}$ and $MgAl_2O_4$, which was impregnated with cerium, as a SOx-absorbing additive. Although the patent does not state whether the magnesium aluminate of Example 10 was spinel, because the magnesium aluminate was calcined at a high temperature (540 degrees Celsius for three hours and 1,200 degrees Celsius for another three hours), the magnesium aluminate would have been spinel. (Tr. 1496). Defendants contend that the patents show that the SOXCAT-like cerium on alumina composition of Example 2 of the '108 Patent and the composition disclosed in Example 10 have similar SOx pick-up activity, even though the composition of Example 10 would have had a lower surface area. Dr. Uhlmann testified that a person of ordinary skill in the art would have realized that Example 10 had a lower surface area than Example 2 and would deduce that if the calcination temperature in Example 10 were decreased, thereby increasing the surface area, that Example 10 would have been a more effective SOx-reducing additive than Example 2. (Tr. 1494-96). Dr. Uhlmann stated that when faced with an attrition-resistance problem for magnesia, in a case where alumina was known to be attrition resistant, a person of ordinary skill in the art would have turned to spinel because it is a very hard ceramic material. (Tr. 1496).

Dr. Uhlmann further testified that a person of ordinary skill in the art would not have been concerned about the attrition resistance of spinel or its ability to pick up SOx, but would wonder whether the reaction would be reversible; i.e., whether the metal sulfate could be reduced within the riser reactor thereby releasing the sulfur in the form of hydrogen sulfide.FN28

FN28. Dr. Uhlmann contends that this question is answered in another prior art reference, the Okutani article. *See infra* Part IV(A)(1)(d).

Grace counters that the Bertolacini patents do not disclose the particular spinel-containing additives claimed in the patents-in-suit. Although Example 10 of the '108 Patent includes a spinel, the spinel in the patents-in-suit have a surface area of at least 25 m^2/g or alternatively the spinel constitutes a major amount of the additive. The Bertolacini patents disclose only a small surface area spinel which was a minor part of the additive. During the prosecution of the patents-in-suit, Dr. Mooi submitted affidavits stating that the magnesium aluminate spinel of Example 10 had a surface area of no more than 16 m^2/g and comprised only 6% by weight of the composition.

Importantly, the specification of the '108 Patent does not suggest using spinel in an SOx-removal additive. The specification states that gamma-alumina and eta-alumina are preferred for use in the practice of the invention because of their usually large surface area. This Court agrees with Grace that the relative insignificance of magnesium aluminate spinel in Example 10 makes it unlikely that a person of ordinary skill in the art would have focused on spinel as a catalyst support in a SOx-removal additive. The Bertolacini patents identify two problems with using magnesia as a SOx-removing additive: its difficulty releasing SOx and its poor attrition properties. The Bertolacini patents do not suggest using spinel as a solution to either of those problems. Rather, the Bertolacini patents suggest using alumina, despite its slightly lower ability to absorb SOx.

b) *Fischer Patent*

The Fischer patent (DTX-163, DTX-712) FN29 discloses the use of a high surface cobalt-molybdenum impregnated magnesium aluminate spinel to remove the sulfur, among other things, from oil stock. The Fischer patent relates to "hydroprocessing" or "hydrotreating" processes to remove sulfur from the oil itself. In other words, the patents address a composition and process to remove sulfur from the oil stock before it ever enters an FCC unit.

FN29. The Fischer Patent admitted at trial is U.S. Patent 3,867,282.

Defendants argue that the Fischer patent discloses the use of high surface area spinel to remove sulfur, which was an important component of the patents-in-suit. It is true that the Fischer patent discloses the use of magnesium aluminate spinel to remove sulfur in a hydrotreating process. The primary question, which will be addressed below, is whether there is some suggestion in the prior art or the general knowledge in the field of catalysis to use this high surface area spinel in an FCC unit, and with the other components described in the patents-in-suit, to remove SOx.

c) *Erickson/Mooi Patents*

As discussed previously, the research resulting in the patents-in-suit was undertaken in an effort to remedy the deactivation of ARCO's SOXCAT SOx-removing additive. The "process research group" headed by Dr. Mooi was instrumental in that effort. Working for Dr. Mooi was a research chemist named Dr. John Jaecker. Dr. Jaecker and his co-worker, Marvin Johnson, agreed that placing an ion into the alumina to prevent the possible movement of cerium into the lattice might prevent the deactivation of SOXCAT.

On November 26, 1979, Dr. Jaecker had a discussion with Dr. Mooi about SOXCAT. (DTX-13 at 38565). Dr. Mooi suggested microspheres of silica as a substrate. Dr. Jaecker also noted that Dr. Mooi "liked the spinel idea" especially with magnesium aluminate "which was used before." Dr. Jaecker wrote that Dr. Mooi "said it [magnesium aluminate spinel] prevented Co (cobalt) from penetrating alumina." (DTX-13 at 38565).

In a meeting held on December 3, 1979, Dr. Jaecker suggested cerium on magnesium aluminate spinel as a potential additive. Notes from that meeting indicate that Dr. Jaecker believed that the "spinel structure may prevent Ce from becoming buried" in the alumina. (PTX-204).

Defendants argue that Dr. Jaecker's idea to use magnesium aluminate spinel as a catalyst support in order to prevent the migration of cerium into the alumina lattice was obvious in light of Dr. Mooi's prior patents. In 1977, Dr. Mooi and Henry Erickson were granted U.S. Patents 3,974,255 and 4,049,582. (DTX-41; DTX-42). Erickson and Mooi utilized magnesium aluminate spinel, in combination with a metal which is less basic than magnesium, to reduce the amounts of hydrocarbons, carbon monoxide, and nitrogen oxides in the exhaust gases of internal combustion engines. The Erickson/Mooi patents recognize that in the high temperature environment of an internal combustion engine the catalyst metal may migrate into the interior of the catalyst support, thereby preventing the catalyst metal from performing its oxidation and/or reduction functions. (DTX-41, col. 2, lines 1-13; DTX-42, col. 2, lines 1-12). At trial, Dr. Uhlmann testified that the Erickson/Mooi patents teach that when "faced with a problem of migration of a catalyst ion into the interior of a support body that one would look to spinel, in particular, magnesium aluminate spinel, to decrease that migration or diffusion." (Tr. 1450).

Grace argues that the problem faced by Dr. Jaecker was actually different than the problem addressed in the Erickson/Mooi patents. According to Grace, the Erickson/Mooi patents do not disclose that cerium would migrate into the alumina lattice in the same way that the metals addressed by the Erickson/Mooi patents migrated into the catalyst support. Grace asserts that the Erickson/Mooi patents dealt with the migration of metals which have a valence of +2 while cerium has a valence of +3 or +4. The theory of the Erickson/Mooi patents, according to Grace, was that the magnesium +2 ion would occupy a place in the alumina lattice that would have allowed a +2 metal (like cobalt or platinum) to migrate into the interior of the alumina lattice. One would not think that cerium, with a valence of +3 or +4, would migrate into the alumina lattice. For that reason, argues Grace, a person of ordinary skill in the art, after reading the Erickson/Mooi patents, would not think that the deactivation problem in SOXCAT, which dealt with cerium, was the same as the deactivation problem addressed in the Erickson/Mooi patents. At his deposition, Dr. Mooi supported Grace's theory.

It is important to note that the relevant prior art is the Erickson/Mooi patents themselves. Dr. Mooi's theories behind his patents are not prior art unless they are disclosed in the patent. Similarly, Dr. Jaecker's theory of how to solve the SOXCAT deactivation problem is not prior art.FN30 The Erickson/Mooi patents note only that there is a problem, in certain instances, with the catalyst metal migrating into the interior of the support and thus becoming less active. The Erickson/Mooi patents do not explicitly state that the use of magnesium aluminate spinel solves that problem or how it solves that problem, although the Erickson/Mooi patents do employ magnesium aluminate spinel as the catalyst support.

FN30. Dr. Uhlmann candidly noted that "the principal sense in which I have addressed ... the '255 patent was the knowledge internal to ARCO, although under the usual approach that I suggest to my classes in terms of the reading of patents, I would suggest that one of ordinary skill in the art would read that and take it as a teaching that in order to block migration [,] going to spinel would be very helpful." The knowledge internal to ARCO is irrelevant as prior art. The Erickson/Mooi patents are the relevant prior art. This Court takes Dr. Uhlmann's testimony to mean that one of ordinary skill in the art would read the patent as teaching that spinel may be useful to block the migration of some catalyst metals into the catalyst support.

After reading the Erickson/Mooi patents, a person of ordinary skill in the art would be on notice that one potential cause of deactivation is the migration of a catalyst metal into the catalyst support. A person of ordinary skill in the art might attempt to solve his or her deactivation problem in the same way that the Erickson/Mooi patents solve it, i.e., by using magnesium aluminate spinel as the catalyst support.

Even if it were obvious to try spinel as a catalyst support to solve a deactivation problem, however, the use of spinel by the inventors of the patents-in-suit was not necessarily obvious. "Obvious to try" does not equal obviousness under 35 U.S.C. s. 103. In re Deuel, 51 F.3d 1552, 1559 (Fed.Cir.1995). The Federal Circuit has held that

An 'obvious-to-try' situation exists when a general disclosure may pique the scientist's curiosity, such that further investigation might be done as a result of the disclosure, but the disclosure itself does not contain a sufficient teaching of how to obtain the desired result, or that the claimed result would be obtained if certain directions were pursued.

In re Eli Lilly & Co., 902 F.2d 943, 945 (Fed.Cir.1990). Obviousness requires something more. Although obviousness does not require absolute predictability of success, there must be a reasonable expectation of success based on the disclosure of the prior art. In re O'Farrell, 853 F.2d 894, 903 (Fed.Cir.1988).

In essence, Grace argues that the inventors of the patents-in-suit would not have had a reasonable expectation of success because they understood that the ability of magnesium aluminate spinel to prevent the migration of the catalyst metal was related to the valence of the catalyst metal. Because cerium is not a +2 metal, asserts Grace, the Erickson/Mooi patent would not lead one to expect that the deactivation of SOXCAT was caused by cerium migration into the alumina lattice.

This Court agrees with Grace. The Erickson/Mooi patents vaguely suggest, but do not teach, that magnesium aluminate spinel is a potential solution to the migration of catalyst metals into the catalyst support which causes deactivation of the catalyst. Due to the valence of cerium, however, one would not reasonably expect that the particular deactivation problem was related to the migration of cerium or that the use of magnesium aluminate spinel as a catalyst support would solve that problem. Although the prior art may have led the inventors to magnesium aluminate spinel as a potential solution to their deactivation problem, Defendants have failed to clearly convince this court that the inventors would have reasonably expected the magnesium aluminate spinel to solve their particular deactivation problem.

Moreover, Defendants' argument regarding the Erickson/Mooi patents relates only to the use of magnesium aluminate spinel as a solution to the deactivation problem, rather than to the use of magnesium aluminate spinel to improve the initial absorption of SOx. The usefulness of the invention for the initial absorption of SOx is not, in any way, disclosed or suggested by the Erickson/Mooi patents. Consequently, even if the Erickson/Mooi patents disclose spinel as an obvious solution to the deactivation problem, there would still be no indication from the Erickson/Mooi patents that magnesium aluminate spinel is amazingly effective at removing SOx when used as directed by the patents-in-suit.FN31

FN31. The effectiveness of the present invention for the initial absorption of SOx will be discussed in more detail in the section of this Opinion which addresses unexpected results. *See infra* Part IV(A)(4)(a).

d) *Okutani Article*

Defendants contend that an article by Takeshi Okutani, Ryusabro Furuichi, and Tadao Ishii in the Journal of the Japan Chemical Society (DTX-165, the "Okutani Article") taught that magnesium aluminate spinel could pick-up SOx by forming magnesium sulfate. According to defendants, the article also taught that $MgAl_2O_4 + SO_2 \longleftrightarrow MgSO_4 + Al_2O_3$ is a reversible reaction. These contentions are supported by the testimony of Dr. Uhlmann. (Tr. 1500-1502).

Grace counters that the Okutani Article does not teach that the step of sulfur release and regeneration of the spinel by decomposition of the $MgSO_4$ (the "reverse" or "reduction" reaction) can occur under the conditions present in the riser reactor section of an FCC unit. Indeed, Dr. Messing testified that the Okutani Article indicated that the reverse reaction did not occur at temperatures below 1,832 degrees Fahrenheit. (Tr. 1589-90). Other witnesses testified that the temperature of the riser reactor, where the reverse reaction takes place, is generally around 1,000 degrees Fahrenheit. (Tr. 79, 743). For that reason, Grace argues that the Okutani Article actually teaches away from the use of spinel as a SOx pick-up agent in an FCC Unit.

In rebuttal, Defendants argue that "the Okutani article teaches the regeneration and reversibility of the SOx reaction with spinel *under any conditions*." (D.I. 261 at 13) (emphasis in original). This rebuttal argument is unpersuasive. Much of the Okutani Article is devoted to the temperatures at which the reactions occurred. Yet, Grace's argument goes too far as well. The Okutani Article teaches neither that the reverse reaction can occur under the conditions of the riser reactor in an FCC unit nor that the reverse reaction cannot occur under those conditions.

e) *Yoo Patents*

Defendants allege that claim 32 of the '982 Patent, which was issued several years after the other patents-in-suit, is obvious in light of the patents-in-suit and two prior art patents issued to Jin Yoo and others. Those two other prior art patents are U.S. Patents 4,492,677 ("Yoo '677 Patent") and 4,522,937 ("Yoo "7 Patent"). Both of these references were cited to the patent examiner in the prosecution of the '982 Patent.

Defendants assert that the '982 Patent's use of a fourth metal selected from the group consisting of iron, nickel, titanium, chromium, manganese, cobalt, germanium, tin, bismuth, molybdenum, antimony, and vanadium to improve the sulfate reduction step was obvious from the Yoo patents.

According to Dr. Uhlmann, the significance of the Yoo '677 Patent lies in claim 21. In claim 21, the patentees claimed a process for the production of a composition which includes a spinel and an additional metal such as rare earth metals (like cerium), vanadium, and mixtures thereof. Grace correctly points out, however, that the Yoo '677 Patent suggests the use of rare earth metals and/or vanadium solely to promote oxidation, not reduction. (D.I. 161, col. 8, lines 13-32).

The more relevant of the two prior art patents is the Yoo "7 Patent. Table I of the Yoo "7 Patent disclosed the ability of spinel, alone or with combinations of several transition metals, to pick up SOx and to release sulfate. The experimental results for Examples I-IV in Table I are especially important. The patentees disclosed that:

> a small amount of iron (Examples II and III) greatly improved the effectiveness of the spinel base, both for pickup of SOx and for subsequent release of sulfur, as, for example, in the reactor section and catalyst regeneration section, respectively, of a fluid bed hydrocarbon catalytic cracking unit. Other transition metal [sic] also exhibited improvement over the spinel alone, whether employed alone or in combinations.

(D.I. 162, col. 10, lines 3-12). The results also indicate that spinel in conjunction with a cerium-iron combination (Example IV) was more effective than the use of spinel with iron alone (Examples II and III) at initial SOx removal. Yet, the cerium-iron combination (Example IV) was less effective in sulfate reduction than was spinel with iron alone (Examples II and III).

Dr. Yoo, in a letter which does not constitute prior art, noted that "example IV in this patent teaches the novel effect of a combined catalyst of Ce with iron on the spinel matrix." (D.I. 623 at WRG-059963). Dr. Yoo further explained that the Yoo "7 Patent "revealed the catalytic function of iron and other transition metals added to spinel or Ce/spinel for both the oxidation of SO2 to SO3 and for the reduction of sulfate for the first time." (D.I. 623 at WRG-059963).

The Yoo "7 Patent therefore discloses the use of vanadium alone or in combination with other metals to promote the oxidation and reduction steps of the process. Yet, because the results of the testing showed that iron, which has a similar chemistry to vanadium, had a lower reduction effect when used with cerium than it had when used alone, the Yoo "7 Patent does not suggest that a combination of cerium with vanadium would be particularly effective at improving the reduction function.FN32

FN32. In claim 14 of the Yoo "7 Patent, the patentees claimed a process for the production of a spinel composition which includes an additional metal selected from the group consisting of bismuth, rare earth metals, antimony, chromium, copper, iron, manganese, vanadium, tin, and mixtures thereof. (D.I. 162, col. 12, lines 3-6).

2) *Differences Between Prior Art and Patents-in-Suit*

The prior art does not disclose that a composition consisting of magnesium aluminate spinel and a rare earth metal, such as cerium, would be effective as a SOx remover in an FCC unit. Example 10 of the Bertolacini patents did not disclose to a person of ordinary skill in the art that magnesium aluminate spinel would be an important component in a SOx-reducing additive. The Bertolacini patents do not suggest using spinel as a solution to the two major problems associated with the use of magnesia as a catalyst support: its difficulty releasing SOx and its poor attrition properties. The Bertolacini patents suggest using alumina, despite its slightly lower ability to absorb SOx.FN33

FN33. It should be noted that the Bertolacini patents were extremely recent prior art to the patents-in-suit. One would think that if the answer to the problems suggested in Bertolacini were obviously answered by the use of magnesium aluminate spinel as a catalyst support, then the Bertolacini patents would have suggested the spinel solution rather than the use of alumina.

The Fischer patent does disclose the use of magnesium aluminate spinel with a high surface area to remove sulfur in a hydrotreating process. As noted earlier, however, that process is substantially different than the use of a sulfur reduction additive within the FCC unit itself.

The Erickson/Mooi patents would give notice to a person of ordinary skill in the art that one potential cause of deactivation of a SOx-reducing additive is the migration of a catalyst metal into the catalyst support. The Erickson/Mooi patents use magnesium aluminate spinel as a catalyst support. Erickson and Mooi did not explain that magnesium aluminate spinel was the solution to the migration of the catalyst metal into the catalyst support, and they certainly did not explain how magnesium aluminate spinel acted to solve the problem of catalyst metal migration into the support. Due to the valence of cerium, one would not have reasonably expected that the deactivation problem was related to the migration of cerium or that the use of magnesium aluminate spinel as a catalyst support would cure the deactivation of SOXCAT. Importantly, the Erickson/Mooi patents do not teach that magnesium aluminate spinel increases the initial activity of an additive in removing SOx when used as directed by the patents-in-suit.

The importance of the Okutani Article is that it shows that magnesium aluminate spinel can pick-up SOx by forming magnesium sulfate. The Okutani Article also taught that $MgAl_2O_4 + SO_2 \text{<-->} MgSO_4 + Al_2O_3$ is a reversible reaction. The Okutani Article does not disclose whether or not the reverse reaction can occur under the conditions of a riser reactor in an FCC unit.

None of the references, singly or in combination, suggest that magnesium aluminate spinel in combination with a rare earth metal such as cerium would be an effective additive in an FCC unit. Based on the prior art, a person of ordinary skill in the art would not find the use of such a combination in an FCC unit to be obvious.

[32] Importantly, there is no suggestion in the prior art that these references should be combined in order to achieve the claimed invention. There must be some suggestion to combine the prior art references, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art. Motorola, Inc. v. Interdigital Tech. Corp., 121 F.3d 1461, 1473 (Fed.Cir.1997); In re Jones, 958 F.2d 347, 351 (Fed.Cir.1992). As recently stated by the Federal Circuit, "It is insufficient to establish obviousness that the separate elements of the invention existed in the prior art, absent some teaching or suggestion, in the prior art, to combine them." Arkie Lures, 119 F.3d at 957. Defendants have not proven by clear and convincing evidence that a person of ordinary skill in the art would have combined these prior art references in such a way as to render obvious the present invention.

The differences between the prior art and the '982 Patent is a separate issue. The question is whether the prior art disclosed or suggested that the use of a fourth metal, such as vanadium, is an especially efficient catalyst for the reduction reaction when used in conjunction with a third metal, such as cerium. During the prosecution of the '982 Patent, the attorneys responded as follows to an obviousness rejection:

In order to more fully appreciate the importance of the present invention, it should be clearly understood that only recently has it become recognized by the applicants that a spinel with rare earth metals, such as that taught by Yoo '267 and '589, do not yield a complete SOx abatement catalyst. Indeed, it had only recently been determined that the fourth metal component, *e.g.,* vanadium, is necessary in order to catalyze the reaction (1), and to help in the regeneration of the catalyst. $MSO_4 + 4H_2$ MO $+H_2S + 3H_2O$ ... (1) The effect of the presence of the fourth metal thus serves to enhance the overall activity of the catalyst system.

(JSPH, p. 92). Dr. Uhlmann similarly yet cogently stated the asserted novelty of the '982 Patent: "The suggested improvement is that it makes a more effective SOx reduction material by promoting the reduction stage." (Tr. 1474-75).

The '982 Patent makes clear that the third metal is chosen to promote the oxidation of sulfur dioxide to sulfur trioxide and that the fourth metal is included to promote the reduction of the first metal sulfate, such as magnesium sulfate. (PTX-25, col. 9, lines 44-68). The data in the '982 Patent disclosed that the vanadium-cerium (Example 10) and iron-cerium (Example 13) combinations were more effective at removing sulfur oxides, both initially and over time, than was cerium alone (Example 2), iron alone (Example 6), or vanadium alone (Example 9). (PTX-25, col. 13, lines 17-32; col. 14, line 30 to col. 15, line 2). Thus, while the prior art disclosed the use of a spinel with a rare earth metal and iron, which is a transition metal that is similar to vanadium, the prior art did not disclose that such a combination was more effective at removing SOx in conjunction with spinel than the rare earth metal alone or the transition metal alone in conjunction with spinel.

The improvement of claim 32 of the '982 patent relates solely to the use of vanadium as the fourth metal component.FN34 Claim 32 is the only claim from the '982 Patent that is at issue in this case. DESOX, NO-SOx, and NO-SOx-PC all use vanadium as a fourth metal component. The prior art simply does not indicate that vanadium is especially good at promoting the reduction reaction when combined with the third metal, such as cerium. As a result, the invention of the '982 Patent is not obvious in light of the prior art.

FN34. The composition must contain vanadium as a fourth metal in the range of about 0.001% to about 10% by weight.

3) *Level of Ordinary Skill in the Art*

[33] A decision regarding obviousness is made from the viewpoint of a person of ordinary skill in the field of the invention. Arkie Lures, 119 F.3d at 956. At oral argument, this Court asked defense counsel if they would agree "that the person skilled in the art is a person with substantial experience in the field of chemistry, a degree in chemistry, ... and an application in catalysis." (D.I. 272 at 31). Defense counsel responded affirmatively. Grace has not disputed this characterization of the person of ordinary skill in the art. Indeed, it is consistent with Grace's position on the issue. (*See* D.I. 260 at 4).

4) *Secondary Considerations*

[34] [35] Evidence of secondary considerations such as unexpected results, commercial success, failure of others, and long-felt need, if present, must be considered in determining obviousness. Minnesota Mining & Mfg. v. Johnson & Johnson, 976 F.2d 1559, 1573 (Fed.Cir.1992); E.I. DuPont De Nemours & Co. v. Monsanto Co., 903 F.Supp. 680, 761 (D.Del.1995). The secondary considerations provide evidence of how the patented invention is viewed by the interested public. Arkie Lures, 119 F.3d at 957. In addition to those secondary considerations previously mentioned, copying is evidence of nonobviousness. *See id.*

[36] Analysis of secondary considerations is not "secondary" at all; such considerations may be highly probative or even the most probative evidence in the record regarding the question of obviousness. Arkie Lures, 119 F.3d at 957; Stratoflex, Inc. v. Aeroquip Corp., 713 F.2d 1530, 1538-39 (Fed.Cir.1983); *see also,* Hybritech, Inc. v. Monoclonal Antibodies, Inc., 802 F.2d 1367, 1380 (Fed.Cir.1986) (secondary considerations are "not merely 'icing on the cake' ").

a) *Unexpected Results*

Grace argues that the high level of initial activity of the present invention was unexpected by the inventors, and would have been unexpected by anyone of ordinary skill in the art. Grace contends that this unexpected initial activity is compelling evidence of nonobviousness. The Federal Circuit has noted that even for inventions that "seem quite obvious" there remains "at least a possibility of unexpected results, that would then provide an objective basis for showing that the invention, although apparently obvious was in law nonobvious." O'Farrell, 853 F.2d at 903. Unexpected results exist when "the claimed invention exhibits some superior property or advantage that a person in the relevant art would have found surprising or unexpected." In re Soni, 54 F.3d 746, 750 (Fed.Cir.1995). The Federal Circuit has explained the rationale for finding that unexpected results rebuts a contention of obviousness: "that which would have been surprising to a person of ordinary skill in a particular art would not have been obvious." *Id.*FN35

FN35. The Federal Circuit has also explained that the doctrine of unexpected results "applies most often to the less predictable fields, such as chemistry, where minor changes in a product or process may yield substantially different results." Soni, 54 F.3d at 750.

Grace has produced highly persuasive evidence that the initial activity of the spinel composition was far beyond the expectations of those of ordinary skill in the art. Mr. Powell testified about the pilot plant testing of a sample of cerium-impregnated magnesium aluminate spinel:

> The cerium spinel test results were really amazing in the results that came back. We had been used to testing the SOXCAT material and whereas the baseline emission level for our little pilot plant was, maybe, 500 ppm, 5 percent concentration of SOXCAT, we would maybe take that emission level down to 250.
>
> When we first did the initial activity test of the spinel material, the engineer came back and told me that they got almost no SOx coming out of the flue gas of the little pilot plant unit. It was like eight, nine, ten ppm, almost within the scatter of the data that we had for our analysis.

(Tr. 108-09). Mr. Powell was so astounded by the results that he instructed his employees to recalibrate the pilot plant unit to make sure that the results were correct. (Tr. 109-10).

Mr. Powell testified that he was "so amazed" he personally went to the pilot plant just to look at the material. The real surprise of the experiment was the initial activity of the spinel composition:

> And the shock was that we-a lot of this work was aimed at improving the stability of SOXCAT, but the surprise was that this was the initial activity test, not the stability test. We were yet to do a stability test. And so that was a complete surprise. We weren't expecting initial activities that were much higher than SOXCAT. And that's what I remember. That was quite an exciting time.

(Tr. 110). It is undisputed that Mr. Powell is a person of ordinary skill in the art. Dr. Mooi, who also meets the criteria for one skilled in the art, was also surprised at the initial activity of the magnesium aluminate spinel composition. (Mooi Dep., March 1995, at 8-10).

This Court finds that Grace has proven unexpected results. Such results must be "shown to be unexpected compared with the closest prior art." In re Baxter Travenol Labs., 952 F.2d 388, 392 (Fed.Cir.1991). The evidence indicates that SOXCAT was the state of the art in sulfur reduction additives at the time of the invention. The spinel material, which was the subject matter of the patents-in-suit, was far more effective than SOXCAT. SOXCAT reduced the pilot plant's SOx emissions from 500 ppm to 250 ppm. The spinel material reduced the SOx emissions from 500 ppm to 10 ppm. These results were nothing short of shocking to those of ordinary skill in the art. Defendants have failed to rebut Grace's evidence of unexpected results in any meaningful way.

Grace also argues that the use of vanadium as a fourth metal to promote reduction produced unexpected results. In the course of developing a commercial SOx-removing additive, ARCO had tested a material called HRD-277. HRD-277 consisted of magnesium aluminate spinel which was impregnated with 9-12% wt. ceria. The ARCO researchers also tested a material called HRD-280, which was the same as HRD-277 except for the addition of 1% vanadium. (Tr. 131). Dr. Powell testified that the HRD-280 material was "probably at least twice as effective" as the HRD-277 material. (Tr. 131). Dr. Powell explained that the HRD-277 had been releasing only a portion of the sulfate in the reactor. The addition of vanadium enhanced the release reaction. (Tr. 132). After Grace purchased the rights to the DESOX product, Grace tried to eliminate vanadium from the SOx-removing additive because it is toxic. (Tr. 643). Grace found that iron was somewhat less effective in promoting the reduction reaction than was vanadium. (Tr. 643-49).

The prior art did not disclose the particular utility of vanadium as a fourth metal when used in conjunction with a rare earth metal such as ceria. The evidence of unexpected results for the use of vanadium, however, is thin. Even though Grace has shown that the use of vanadium in conjunction with cerium was twice as effective as using cerium alone, there is no persuasive testimony that a person of ordinary skill in the art would have been surprised that vanadium would produce such an increase in the reduction function.

b) ***Copying***

Previously, in considering the issue of willful infringement, this Court found that Grace had submitted substantial evidence of copying. DESOX, which is the commercial embodiment of the present invention, was the preeminent SOx abatement additive on the market when Intercat's NO-SOx was being developed. Despite the solutions that Intercat claimed were obvious in the prior art, Intercat had failed to gain any significant market share with its LOSOX or TRANSCAT additives which were admittedly inferior to DESOX. Intercat's later product, NO-SOx, is practically identical to DESOX. They both contain magnesium, aluminum, cerium, and vanadium as their four primary metallic components. Both contain magnesium aluminate spinel, rather than a simple mixture of magnesium oxide and aluminum oxide. Moreover, the XRD patterns for DESOX and NO-SOx are practically identical. (*See* PTX-470). This copying constitutes substantial evidence of nonobviousness.

c) ***Failure of Others***

The evidence submitted at trial showed indisputably that DESOX was the preeminent SOx-removal additive on the market. Other companies, including Grace, had tried and failed to develop a commercially successful additive. SOXCAT, Additive R, TRANSOX and LOSOX must be considered failures when compared to the patented invention. This Court therefore finds that others failed where the patented invention succeeded.

d) ***Commercial Success***

The testimony at trial indicated that DESOX was far superior to any other additive on the market, both in terms of effectiveness and sales. DESOX was superior to SOXCAT and Grace's Additive R. Intercat's LOSOX showed activity similar to SOXCAT; it was approximately one-fourth less active in reducing SOx than DESOX. (Tr. 152-53). Regis Lippert testified at trial that he recognized Intercat's LOSOX to be "at best, a marginal product." (Tr. 886). TRANSOX, an additive developed by Chevron, showed very little SOx-removal activity. Prior to the introduction of DESOX, Additive-R had controlled nearly 100% of the market. By 1989, DESOX controlled 90% of the market, with Additive-R controlling the bulk of the remainder. (Tr. 154). At its peak in 1993, DESOX controlled as much as 95% of the worldwide market for SOx abatement additives. (Tr. 65).

Defendants urge that the commercial success of DESOX should be ignored because Grace failed to prove that DESOX satisfies the claims of the patents-in-suit. This Court rejects that argument. The evidence of record shows that DESOX is the same, in all relevant respects, as NO-SOx. NO-SOx infringes the patents-in-suit. Because DESOX is the same as NO-SOx, DESOX also comes within the scope of the patents-in-suit. Moreover, an examination of the evidence of record, including the XRD analyses of DESOX, shows that there is no substantial question that DESOX meets the claim elements of the patents-in-suit.

Defendants further argue that the evidence of commercial success should be disregarded because Grace failed to show a connection between the patented features of the invention and the commercial success of

DESOX. It is true that a "nexus is required between the merits of the claimed invention and the evidence [of commercial success] offered, if that evidence is to be given substantial weight enroute to a conclusion on the obviousness issue." Stratoflex, Inc. v. Aeroquip Corp., 713 F.2d 1530, 1539 (Fed.Cir.1983). In *Stratoflex,* the Federal Circuit declined to consider the patentee's success in licensing the invention because the patentee had failed to show either a nexus between the merits of the invention and the licenses or a "recognition and acceptance of the patent" from which the licenses arose. *Id.*

In the present case, there is some circumstantial evidence that the commercial success of DESOX was related to the effectiveness of the patented features of the invention. The use of a spinel with a high surface area as a catalyst support in lieu of alumina was shown to increase both SOx absorption and the stability of the additive to a marked degree. Indeed, the evidence of record shows that DESOX was far more effective than any other SOx-removing additive on the market. It is also evident that Intercat recognized the utility of the present invention. In a paper presented to a symposium, Louis Magnabosco and Edward Demmel, who were working for Intercat, noted that "the commercially successful SOx transfer agents are magnesium aluminum spinels that contain cerium. HRD-280 contains both cerium and a transition metal." (PTX-24 at 3). The commercialization of HRD-280 was DESOX. Regis Lippert, the President of Intercat, also recognized the value of DESOX and the patented technology when he encouraged their purchase in 1985 and considered their purchase in 1992. (Tr. 139, 870, 902; UF-112).

This Court further finds that the commercial success of NO-SOx, which falls within the scope of the patented invention, demonstrates the great utility of the invention. Intercat had been unable to garner any significant market share with its LOSOX product. When it introduced NO-SOx, which directly infringes the patents-in-suit, Intercat was able to capture 15% of the market from Grace. In the presentation of the Magnabosco and Demmel paper to a symposium, Magnabosco and Demmel stressed the value of spinel, and Intercat's use of spinel, to reduce SOx. (PTX-24). *Cf.* Gambro Lundia AB v. Baxter Healthcare Corp., 110 F.3d 1573, 1579 (Fed.Cir.1997) (prominence of patented technology in infringer's advertising creates inference linking invention to infringer's commercial success). This Court finds that the totality of the evidence of commercial success is strong evidence of nonobviousness.

e) *Long-Felt Need*

The evidence showed that in the late-1970's, ARCO was operating its Watson FCC unit near Los Angeles, California. The Watson FCC unit was subject to the regulations imposed by SCAQMD, which compelled ARCO to reduce the SOx emissions to a specified level by 1981 and to a much lower level by 1985. (Tr. 105-06).

ARCO considered the options of a hydrotreater or a flue gas scrubber, but in order to avoid the large capital investments involved in both of those options (and in order to avoid a solid waste problem that would have resulted from the use of a flue gas scrubber), ARCO sought to develop a SOx-removing additive as a viable way to reach the emission standards without making a huge capital investment.

Although several companies were experimenting with SOx abatement additives, there is not evidence of a long felt need for an effective additive in the petroleum industry. The evidence indicates that there was, rather than a long-felt need by the industry as a whole, an intense need for a viable SOx-removing additive by one company. While other companies may have faced similar pressure to develop a viable additive, the record does not show that to be true. Based on the limited evidence submitted on this issue at trial, this Court cannot conclude that the industry had a long-felt need for an effective SOx-removing additive.

5) *Conclusion-Obviousness*

As explained earlier, the "critical question" in determining obviousness is "whether the invention as a whole would have been obvious to one of ordinary skill in the art at the time it was made." Perkin-Elmer Corp. v. Computervision Corp., 732 F.2d 888, 894 (Fed.Cir.1984). Considering the foregoing analysis, this Court finds that Defendants have not met their burden to prove by clear and convincing evidence that using a major amount of a high surface area spinel, in conjunction with a rare earth metal, to reduce SOx in an FCC unit would have been obvious in light of the prior art. Similarly, this Court finds that Defendants have not met their burden to prove that using vanadium as a fourth metal, in conjunction with a bimetallic spinel and a third metal, to promote the reduction reaction and to therefore create a more effective SOx abatement additive was obvious in light of the prior art. The elements of the patented invention cannot all be found in the prior art, and for those elements that do exist separately, there is generally no suggestion to combine them to create the patented composition and to use that composition in the patented process.

The secondary considerations, especially, weigh heavily against a finding of obviousness. The commercial success of DESOX, the unanticipated results in the initial activity of the spinel composition, the copying of DESOX by Intercat, as well as the failure of others in the industry to create a commercially viable SOx-removing additive and Intercat's own praise of the patentees' invention, are compelling evidence of non-obviousness.

B. *DEFINITENESS*

[37] [38] [39] [40] The patent laws require the specification to "conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention." 35 U.S.C. s. 112.FN36 A claim is sufficiently definite when it "reasonably apprises those of skill in the art of its scope." In re Warmerdam, 33 F.3d 1354, 1361 (Fed.Cir.1994). A person skilled in the art must be able to "understand what is claimed when the claim is read in light of the specification." Morton Int'l, Inc. v. Cardinal Chem. Co., 5 F.3d 1464, 1470 (Fed.Cir.1993). The degree of precision mandated by s. 112 depends upon the nature of the subject matter of the patent. Miles Labs., Inc. v. Shandon, Inc., 997 F.2d 870, 875 (Fed.Cir.1993); Hybritech Inc. v. Monoclonal Antibodies, Inc., 802 F.2d 1367, 1385 (Fed.Cir.1986). Defendants bear the burden to prove by clear and convincing evidence that the claims are invalid for indefiniteness. North American Vaccine, Inc. v. American Cyanamid Co., 7 F.3d 1571, 1579 (Fed.Cir.1993); Morton, 5 F.3d at 1470.

FN36. Although Defendants confuse, to some extent, the question of enablement under the first paragraph of s. 112 with the definiteness requirement under the second paragraph of s. 112, this Court finds that Defendants have raised only the issue of indefiniteness.

Defendants assert that, upon reading the patent claims, one of ordinary skill in the art would be unable to determine whether a material contained a spinel as that term is used in the patents. Defendants argue that Grace should have provided XRD patterns for the non-stoichiometric and imperfect spinels claimed, since the ICDD does not have standard reference cards for such materials. Grace counters that those skilled in the art could, without difficulty, identify the non-stoichiometric and imperfect spinels claimed simply by referring to the ICDD reference cards for the stoichiometric and well-defined spinels. The great weight of evidence supports Grace's position.

The specification describes what is meant by the term spinel:

> The spinel structure is based on a cubic close-packed array of oxide ions. Typically, the crystallographic unit cell of the spinel structure contains 32 oxygen atoms; one-eighth of the tetrahedral holes (of which there are two per anion) are occupied by a divalent metal ion, and one-half of the octahedral holes (of which there are two per anion) are occupied by trivalent metal ions.

(PTX-3, col. 7, lines 44-50). The specification continues, "This typical spinel structure *or a modification thereof* is adaptable to many other mixed metal oxides" of various types. (PTX-3, col. 7, lines 51-53) (emphasis added). The specification includes magnesium aluminate spinel as one example, out of more than fifty examples, of a metal-containing spinel. (PTX-3, col. 8, lines 16, 20).

Not only does the specification tell one of ordinary skill in the art what a spinel is, but is also refers to prior art patents which explain how to make spinel. The specification notes that the metal-containing spinels useful in the invention "may be derived from conventional and well known sources." (PTX-3, col. 8, lines 62-64). Specifically, the patentees refer the reader to U.S. Patents 2,992,191 and 3,791,992, which include descriptions of how to prepare spinel. (PTX-3, col. 9, lines 5-8, 35-37). The patentees also include 25 examples which disclose how to synthesize spinel. (PTX-3, cols. 15-19).

The parties agree that in order to determine the existence of spinel in a composition a person of skill in the art at the time the invention was made would perform X-ray diffraction ("XRD") analysis and compare the resulting pattern of peaks to a standard reference card. The parties stipulated that XRD is the most reliable method for determining whether spinel is present in a sample. (UF-95).

With the exception of Defendants' post-litigation efforts, those skilled in the art have had no problem determining that non-stoichiometric and imperfect spinels are indeed spinel and fall within the claims of the patent. Dr. Bratton identified material as spinel when the XRD patterns matched in peak position but not in peak intensity. (PTX-481). In Amoco's analysis of NO-SOx, the Amoco scientists had no difficulty identifying magnesium aluminate spinel despite discrepancies from the reference card in the relative intensities. (PTX-119). Moreover, in their symposium paper, Louis Magnabosco and Edward Demmel were able to determine that NO-SOx and DESOX contained spinel. (PTX-24). In another paper written by Patrick A. Clark and Edward Demmel, who worked for Intercat, the authors were able to find that "NO-SOx is a magnesia spinel" despite some variance in the relative intensities of the peak positions. (PTX-23 at 2). In yet another paper, Intercat reported that "NO-SOx is a magnesia/alumina spinel, or crystal, made using a proprietary manufacturing process patented by Louis Magnabosco and INTERCAT's Ed Demmel in April, 1992." (PTX-47 at 14, 19). In light of Intercat's own ease, prior to this litigation, in determining the presence of spinel, the s. 112 defense is especially unavailing. *See* Rosemount, Inc. v. Beckman Instruments, Inc., 727 F.2d 1540, 1547 (Fed.Cir.1984) (weighing defendant's ease in applying term to prior art against the merits of a s. 112 defense).

Defendants have identified no instance in which a person skilled in the art was unable to identify whether a material was spinel when the peak positions matched the reference card but the relative intensities did not. Indeed, Dr. Wuensch admitted that the term spinel is used more loosely in practice than is technically precise. Defendants have failed to meet their burden to show by clear and convincing evidence that one of ordinary skill in the art would be unable to understand the scope of the claims when they are read in light of the specification.

C. *INEQUITABLE CONDUCT*

[41] Defendants allege that the patents are invalid due to inequitable conduct based upon the patentees' failure to disclose to the patent examiner the Yoo '677 and "2 Patents; the '582 and '255 Erickson/Mooi Patents; and the Fischer '282 Patent.

Grace has moved for JMOL, claiming that Defendants have not met their burden to prove inequitable conduct by clear and convincing evidence. Under Fed.R.Civ.P. 52(c), this court must weigh the evidence, resolve conflicts in the evidence, and decide where the preponderance lies. Charles A. Wright & Arthur R. Miller, Federal Practice & Procedure: Civil 2d s. 2573.1. Under Rule 52(c), this court is permitted to decline to render any judgment until the close of all evidence. This Court has taken Grace's motion under advisement and will consider all of the evidence of record to determine whether Defendants have proven by clear and convincing evidence that the patentees engaged in inequitable conduct before the PTO.

[42] [43] Inequitable conduct includes the affirmative misrepresentation of a material fact, the failure to disclose material information, or submission of false material information to the patent office, coupled with an intent to deceive. Kolmes v. World Fibers Corp., 107 F.3d 1534, 1541 (Fed.Cir.1997); Molins PLC v. Textron, Inc., 48 F.3d 1172, 1178 (Fed.Cir.1995). The burden of proof on the party asserting inequitable conduct is a high one:

One who alleges inequitable conduct arising from a failure to disclose prior art must offer clear and convincing proof of the materiality of the prior art, knowledge chargeable to the applicant of that prior art and of its materiality, and the applicant's failure to disclose the prior art, coupled with an intent to mislead the PTO.

Molins, 48 F.3d at 1178. The withholding of information must meet thresholds of materiality and deceptive intent. *Id*. If those thresholds are met, the Court must weigh the findings of materiality and deceptive intent to determine if the equities warrant a finding of inequitable conduct. *Id*.

[44] Information is material if a reasonable patent examiner would have considered it important to the patentability of a claim. Regents of the Univ. of Cal. v. Eli Lilly & Co., 119 F.3d 1559, 1569 (Fed.Cir.1997). A reference that simply replicates another reference already before the examiner is not material. Gambro Lundia AB v. Baxter Healthcare Corp., 110 F.3d 1573, 1580 (Fed.Cir.1997); Molins, 48 F.3d at 1179.

[45] The Federal Circuit has noted that the term "intent" generally means, "Design, resolve, or determination with which [a] person acts[; a] state of mind in which a person seeks to accomplish a given result through a course of action." Molins, 48 F.3d at 1180 (quoting *Black's Law Dictionary* at 810 (6th ed.1990)). Intent is most often proved not by direct evidence, but by showing acts the natural consequences of which are presumably intended by the actor. Molins, 48 F.3d at 1180. Yet, "[g]iven the ease with which a relatively routine act of patent prosecution can be portrayed as intended to mislead or deceive, clear or convincing evidence of conduct sufficient to support an inference of culpable intent is required." *Id*. at 1181 (quoting Northern Telecom, Inc. v. Datapoint Corp., 908 F.2d 931, 939 (Fed.Cir.1990)). In examining the evidence on intent to deceive, a court must weigh all of the evidence, including evidence of good faith. Gambro Lundia, 110 F.3d at 1580. If the information withheld or misrepresented is particularly material, less evidence of intent is necessary to establish inequitable conduct. *Id*.

1. *Yoo '677 and "7 Patents*

Defendants contend that the failure to disclose the significance of the Yoo '677 Patent and the Yoo "7 Patent constituted inequitable conduct. Dr. Yoo sent letters to Norman Balmer (DTX-623) and Frank Uxa, Jr. (DTX-624), in which he explained his belief that the Yoo '677 Patent and the Yoo "7 Patent disclosed much of the utility of the invention of the '982 Patent. In light of these disclosures, Defendants claim that the representation that the reduction function of vanadium had been only recently discovered was designed to mislead the PTO.

This Court has little doubt that the threshold test of materiality is met for the Yoo "7 Patent. Table I of the Yoo "7 Patent is significant prior art. The Yoo '677 Patent, however, does not meet the threshold test of materiality because it is cumulative of U.S.Patent 4,469,589, which was disclosed to the PTO. Dr. Uhlmann himself acknowledged that the Yoo '677 Patent taught nothing of substance that was not included in U.S. Patent 4,469,589. (Tr. 1661-62).

Although the "7 Patent meets the threshold test of materiality, Defendants have failed to show knowledge chargeable to the applicant of the "7 Patent. Mr. Balmer, who is the chief patent counsel for Union Carbide testified that he did not recall receiving Mr. Yoo's letter during the prosecution of the '982 Patent and that his affidavit (PTX-499) was accurate. He also testified that his role in the prosecution of patent applications in 1986 was "[v]ery much from a supervisory standpoint." Defendants attempt to counter Mr. Balmer's testimony by showing that an invoice was included with Dr. Yoo's letter and that Mr. Balmer testified that he did not recall an instance in which Dr. Yoo was not paid. A fair inference from this evidence is that someone at Union Carbide, perhaps Mr. Balmer, received Dr. Yoo's letter. The evidence presented by Defendants fails to clearly and convincingly show, however, that Mr. Balmer received and actually apprehended the materiality of the Yoo "7 Patent.FN37

FN37. When denying the cross motions for summary judgment based on inequitable conduct, this Court stated:The briefs of the parties reveal numerous factual issues that will be key in determining whether the thresholds of materiality and intent are met and, if so, whether the equities favor non-enforcement of the patent based on inequitable conduct. Perhaps most important is the question of who received Dr. Yoo's letter and whether they were in a position to recognize its importance to the patent prosecution. That factual question is not clear from the record on summary judgment.

(D.I. 229). Defendants did not submit evidence to answer this basic factual question.

Moreover, to the extent that there is any evidence of intent to mislead the PTO, it is very weak. One might speculate, merely from the fact that the letter was sent to Mr. Balmer, that he received the letter, read the letter, appreciated the materiality of the Yoo "7 Patent to the pending '982 application, yet consciously decided not to submit the letter to the PTO in an effort to mislead the PTO. But to support a finding of inequitable conduct, there must be clear and convincing evidence, not supposition and speculation. Defendants simply failed to meet their burden of proof.

2. *Erickson/Mooi '582 and '255 Patents*

Defendants contend that Mr. Frank Uxa engaged in inequitable conduct before the PTO by not citing the prior art Erickson/Mooi '582 and '255 Patents. Grace responds that the disclosure of those patents is substantively identical to the teachings of U.S.Patent 2,992,191 (PTX-463) to Erickson which was cited to the examiner on numerous occasions. Moreover, Grace asserts that there is no proof of an intent to deceive.

An initial question is the materiality of the '582 and '255 Patents. There are essentially two theories as to why these patents are material. First, the Erickson/Mooi patents disclose the problem of the migration of a catalyst ion into the interior of a support body causing deactivation of the catalyst metal. Grace responds that this does not make the Erickson/Mooi Patents material, because this disclosure was also made in the '191 Patent which was cited to the examiner. As previously stated, it is well established that there is no duty to disclose a cumulative reference. *See* Gambro Lundia, 110 F.3d at 1580; Molins, 48 F.3d at 1179; Litton Indus. Prods. v. Solid State Sys. Corp., 755 F.2d 158, 167 (Fed.Cir.1985).

The '191 Patent explains that spinel is a more effective base than alumina when used with cobalt and molybdenum because "they do not dissolve in or react with my base to the same degree as they are dissolved in other bases such as alumina" and are "retained near the surface of my base and are more readily available for affording the desired catalytic effect." Dr. Messing testified that the '191 Patent and the '255 Patent contain the same teaching. (Tr. 1593).

Although the references are similar, the '255 Patent explains that the metal migration into the interior of the support is related to the high temperature environment. In addition, the patent examiner may have found the use of the terms "diffusion" and "migrate" in the Erickson/Mooi patents, compared to the word "dissolved" in the '191 Patent, to indicate different theories of what happens to the catalyst metal. A reasonable patent examiner may have considered the distinction important in assessing patentability. For this reason, and despite Dr. Messing's testimony, the Erickson/Mooi patents meet the threshold test of materiality.

There is also a second theory of materiality. Mr. Uxa prosecuted the Erickson/Mooi '255 and '582 Patents, as well as the '589 Patent (PTX-3), the '267 Patent (PTX-4), the '305 Patent (PTX-5), and the '304 Patent (PTX-6). FN38 It is undisputed that in drafting the patent specification for the patents-in-suit, Mr. Uxa copied sections of the specifications of the Erickson/Mooi '255 and '582 Patents. The following language, with minor alterations, exists in the specification to the Erickson/Mooi '255 and '582 Patents and in the specification for four of the patents-in-suit:

FN38. Mr. Uxa did not prosecute the '982 Patent.

The magnesium aluminate spinel suitable for use in the present invention can be prepared, for example, according to the method disclosed in U.S. Pat. No. 2,992,191. The spinel can be formed by reacting, in an aqueous medium, a water-soluble magnesium inorganic salt and a water-soluble aluminum salt in which the aluminum is present in the anion. Suitable salts are exemplified by the strongly acidic magnesium salts such as the chloride, nitrate or sulfate and the water-soluble alkali metal aluminates. The magnesium and aluminate salts are dissolved in an aqueous medium and a spinel precursor is precipitated through neutralization of the aluminate by the acidic magnesium salt. Excesses of acid salt or aluminate are preferably not employed, thus avoiding the precipitation of excess magnesia or alumina. Preferably, the precipitation is washed free of extraneous ions before being further processed.

The precipitate can be dried and calcined to yield magnesium aluminate spinel. Drying and calcination may take place simultaneously. However, it is preferred that the drying take place at a temperature below which water of hydration is removed from the spinel precursor. Thus, this drying may occur at temperatures below about 500 (deg.) F., preferably from about 220 (deg.)>> F. to about 450 (deg.) F. Suitable calcination temperatures are exemplified by temperatures ranging from about 800 (deg.) F. to about 2000 (deg.) F. or more. Calcination of the spinel precursor may take place in a period of time of at least about one half hour and preferably in a period of time ranging from about 1 hour to about 10 hours.

(DTX-41, col. 3, lines 39-68; DTX-42, col. 3, line 40 to col. 4, line 2; PTX-3, col. 9, lines 5-34; PTX-4, col. 8, lines 18-48; PTX-5, col. 8, lines 18-48; PTX-6, col. 9, lines 5-34).FN39 The sections copied relate to the synthesis of spinel. A reasonable patent examiner would not find this section of the '255 patent to meet the threshold test of materiality. The means to prepare spinel that were copied into the patent specification were well known in the prior art and were not part of the patentees' invention. The act of copying background material into a specification from a prior patent does not transform that background information into material information. Information is material only if a reasonable patent examiner would have considered it important to the patentability of a claim. Regents of the Univ. of Cal. v. Eli Lilly & Co., 119 F.3d 1559, 1569 (Fed.Cir.1997). The copied information would not have affected the invention's patentability.

FN39. This language was not included in the '982 Patent specification. *See* PTX-25.

The next question is whether Mr. Uxa knew of the materiality of the Erickson/Mooi patents, yet withheld them from the examiner. Obviously, Mr. Uxa knew about the existence of the Erickson/Mooi patents. There is no proof, however, that he appreciated their materiality to the patents-in-suit. Dr. Mooi may have recognized the materiality of his prior patents, but as conceded by Defendants, Dr. Mooi was not an applicant or prosecuting attorney on the patents-in-suit (D.I. 254 at 19), so his level of knowledge lacks relevance. Perhaps Dr. Jaecker recognized the materiality of the Erickson/Mooi patents. Dr. Jaecker noted after a November 1979 discussion with Dr. Mooi that Dr. Mooi "liked the spinel idea" especially with magnesium aluminate "which was used before." (DTX-13 at 38565). Dr. Jaecker wrote that Dr. Mooi "said it [magnesium aluminate spinel] prevented Co [cobalt] from penetrating alumina." (DTX-13 at 38565). There is no indication, however, that Dr. Jaecker realized that the idea that "was used before" had been disclosed in one of Dr. Mooi's patents. In sum, although the problem of certain metals migrating into the catalyst support was disclosed in the '582 Patent and the '255 Patent, it is unclear if anyone with a duty of candor had knowledge of the materiality of the Erickson/Mooi Patents.

The next question is whether Mr. Uxa possessed an intent to deceive the PTO. Without question, there is no direct evidence of an intent to deceive. As the parties recognize, the issue is whether the circumstantial evidence merits, by clear and convincing evidence, an inference that Mr. Uxa intended to deceive the PTO. The only circumstantial evidence of an intent to deceive is the failure to disclose itself. It must be stressed that the patentees did cite the '191 Patent, which contained a disclosure that is quite similar to the disclosure of the '255 Patent. Although the applicants did not highlight that aspect of the '191 Patent, it was nonetheless before the examiner. To disclose a patent with such a similar disclosure seems inconsistent with a motive to hide the materiality of the Erickson/Mooi patents. It would be odd, indeed, if Mr. Uxa risked a finding of inequitable conduct on several very valuable patents in order to hide a reference that was so similar to a disclosed reference.

[46] This Court finds that Defendant has failed to prove by clear and convincing evidence that Mr. Uxa, or anyone else with a duty of candor, intended to deceive the PTO.FN40 At most, the evidence submitted by Defendants shows that Mr. Uxa was negligent in failing to disclose the Erickson/Mooi '255 Patent. Even gross negligence, however, does not by itself justify inferring an intent to deceive. Halliburton Co. v. Schlumberger Technology Corp., 925 F.2d 1435, 1442-43 (Fed.Cir.1991).

FN40. Interestingly, none of the important actors in the alleged inequitable conduct (Mr. Uxa, Dr. Jaecker, and Dr. Mooi) was called to the stand to testify.

Even if Defendants' proof of deceptive intent could be considered clear and convincing, and even if someone with a duty of candor knew of the materiality of the Erickson/Mooi patents, this Court would still be required to weigh the findings of materiality and deceptive intent to determine if the equities warrant a finding of inequitable conduct. Molins, 48 F.3d at 1178. The balance of the equities in this case weighs heavily toward enforcing the patents-in-suit. The materiality of the Erickson/Mooi patents is slight in light of the disclosure of the '191 Patent which was cited to the examiner. The evidence of intent is thin, even if this Court were to accept all of Defendants' contentions. In sum, the conduct of the applicants and their attorney was not so culpable that the patents should be deemed unenforceable.

3. *Fischer* '282 Patent

The Fischer '282 patent discloses the use of magnesium aluminate spinel with a high surface area to remove sulfur in a hydrotreating process. The asserted materiality of the Fischer '282 Patent relates to the use of a high surface area spinel, i.e., in excess of 50 m^2/g, as a catalyst support. During the patent prosecution, the applicants distinguished their invention from others based on the high surface area of the spinel. Consequently, argue Defendants, the Fischer '282 Patent was a material reference.

Grace counters that U.S. Patent 3,791,992 to Feldwick (PTX-456) discloses magnesium aluminate spinel in excess of 50 m^2/g. The Feldwick '992 Patent is identified in the specification to the patents-in-suit and was cited to the PTO on numerous occasions. To this argument, Defendants have no response.

There is no duty to disclose a cumulative reference. Gambro Lundia, 110 F.3d at 1580; Molins, 48 F.3d at 1179. Defendants have not shown by clear and convincing evidence that the Fischer '282 Patent is material.Indeed, after reviewing the Feldwick '992 Patent, especially Tables I and II, this Court finds that the disclosure of the Fischer '282 Patent would have been cumulative.

Moreover, Defendants have presented a dearth of evidence regarding an intent to deceive. Defendants summarily argue that it is "clear from a consideration of all the circumstances" that the Fischer '282 Patent was intentionally withheld. (D.I. 254 at 21). Apparently, those circumstances are the applicants' failure to disclose the Fischer '282 Patent and the applicants' distinguishing some prior art references because the spinel utilized had inadequate surface area. Because the applicants did cite other prior art that disclosed a high surface area spinel, this Court does not find that Defendants have proven by clear and convincing evidence that the applicants had an intent to deceive the PTO.

V. WILLFUL INFRINGEMENT

[47] [48] [49] [50] [51] Grace alleges that Intercat's infringement was willful.FN41 A party seeking to establish willful infringement must prove the bad faith of the infringer by clear and convincing evidence. E.I. DuPont De Nemours & Co. v. Monsanto Co., 903 F.Supp. 680, 740 (D.Del.1995), *aff'd,* 92 F.3d 1208, 1996 WL 403285 (Fed.Cir.1996). The test for willful infringement is "whether, under all the circumstances, a reasonable person would prudently conduct himself with any confidence that a court might hold the patent invalid or not infringed." Hall v. Aqua Queen Mfg., Inc., 93 F.3d 1548, 1555 (Fed.Cir.1996). The Federal Circuit has held that there is an "affirmative duty to use due care in avoiding infringement of another's patent rights." Jurgens v. CBK, Ltd., 80 F.3d 1566, 1570 (Fed.Cir.1996). This duty usually includes "seeking

and obtaining competent legal advice before engaging in activity that may result in infringement." Stryker Corp. v. Intermedics Orthopedics, Inc., 96 F.3d 1409, 1414 (Fed.Cir.1996) (quoting Electro Med. Sys. S.A. v. Cooper Life Sciences, 34 F.3d 1048, 1056 (Fed.Cir.1994)). There is, however, no "absolute requirement" for a would-be defendant to obtain its own opinion letter in order to avoid a finding of willful infringement. Hall, 93 F.3d at 1555.

FN41. Under 35 U.S.C. s. 284, a court "may increase the damages up to three times the amount found or assessed." In exercising its discretion under this section, a court should apply a two-step analysis. First, the court should determine whether an infringer is guilty of conduct that would justify an award of increased damages. Second, the court should determine whether, and to what extent, to increase damages. Jurgens v. CBK, Ltd., 80 F.3d 1566, 1570 (Fed.Cir.1996). This Court will, at this point, resolve only the first of those questions. The second question is more appropriately determined in the damages phase of this litigation.

The question is whether, under the totality of the circumstances, a potential infringer acted reasonably in avoiding the infringement of a valid patent. The following are among the relevant considerations:

(1) the infringer's deliberate copying of the ideas of another; (2) the infringer's knowledge of the patent rights of another; (3) any good faith belief of invalidity or non-infringement formed by the infringer after an investigation of the patent rights of another; (4) the infringer's behavior as a litigant.

E.I. DuPont De Nemours & Co. v. Monsanto Co., 903 F.Supp. 680 (D.Del.1995). FN42

FN42. Although the infringer's behavior as a litigant is normally a relevant factor in deciding the question of willfulness, it is of decidedly secondary importance. In the circumstances of this particular case, that final factor is of no value in showing either willfulness or the lack of willfulness.

It is undisputed that Regis Lippert, the President of Intercat, was well aware of the patents-in-suit. It is also undisputed that Intercat did not obtain a written opinion of counsel. The primary areas of dispute are whether Intercat copied the ideas of the patent and whether, despite his failure to obtain a written opinion of counsel, Regis Lippert formed a reasonable belief that the NO-SOx products did not infringe the patents-in-suit or that the patents-in-suit are invalid.

Regis Lippert testified that he had received a letter dated September 3, 1991, from Mr. Robert Anderson, who was the general manager of the Katalistiks International divisionof UOP. (Tr. 897; PTX-26). At that time, UOP owned the patents-in-suit. Mr. Anderson brought the patents-in-suit to Mr. Lippert's attention and asked Intercat to review the patents and assure UOP that NO-SOx would neither infringe nor induce others to infringe the patents. (PTX-26). Mr. Lippert testified that he was surprised to get the letter from Mr. Anderson and had not considered that NO-SOx might infringe the patents-in-suit. (Tr. 898). Following correspondence clarifying the identity of one of the patents, Regis Lippert wrote back to Mr. Anderson, and made the following representation:

We have had our patent counsel review the U.S. Patents listed in your letters of September 3 and September 17. It is counsel's opinion that NO-SOx, as manufactured by INTERCAT and used by our customers, is not covered by the U.S. patents that you brought to our attention.

All of INTERCAT'S products are covered by our proprietary technology and/or technology received from third parties. Our NO-SOx SOx emission control agent is covered by this policy.

(PTX-29).

Mr. Lippert explained at trial the basis for his letter to UOP:

we had sent his [Mr. Anderson's] letter, of course, to our patent attorney and various other people in our company. And it was our opinion that it just did not cover-was not covered by the ARCO patents or the Katalistiks patents, if you will. We were completely comfortable with our position on that.

(Tr. 900). Assuming that "our opinion" includes the opinion of Intercat's patent counsel, that opinion was oral and not written.FN43 Oral opinions are not favored to establish competent advice of counsel. Minnesota Mining & Mfg. Co. v. Johnson & Johnson Orthopaedics, Inc., 976 F.2d 1559, 1580 (Fed.Cir.1992). Oral opinions carry less weight because they have to be proved years later against the challenges of faded memories and "the forces of contemporaneous litigation." *Id.*

FN43. Curiously, Mr. Lippert testified in his deposition that he neither sought nor received an opinion from Jack Sloan, Intercat's patent attorney, regarding the patents. (Lippert Dep. at 388-89).

The oral opinion of patent counsel in this case, if indeed there was one, carries very little weight in demonstrating Mr. Lippert's good faith. An unsupported opinion means nothing; obtaining a *competent* opinion of counsel is what matters. There is no proof in the record that the opinion of counsel and others at Intercat was based on even the most cursory examination of the patents, the prosecution history, and the NO-SOx product. The Federal Circuit has rejected written opinions of counsel that do not contain a reasoned analysis based on an examination of the file histories and a comparison of the patents to the allegedly infringing product or process. *See, e.g.,* Underwater Devices, Inc. v. Morrison-Knudsen Co., 717 F.2d 1380, 1390 (Fed.Cir.1983). Here, there is no evidence of an analysis of the patents or prosecution histories whatsoever and no real proof that any opinion of counsel, let alone a competent one, was ever rendered.

Intercat argues that other evidence shows that Regis Lippert acted in good faith. Intercat offers its decision to enter into a license agreement with Amoco before producing NO-SOx, and its general policy of entering into patent licenses, as evidence that it does not willfully infringe the patent rights of third parties. While this evidence tends to show that Intercat normally follows a prudent course in dealing with the patent rights of others, it does not explain the total absence of even the most basic precautions to ensure that NO-SOx did not infringe the patents-in-suit. To the extent that Mr. Lippert believed that the license with Amoco somehow shielded Intercat from liability for infringing the patents-in-suit, which were never owned by Amoco, Mr. Lippert's belief was objectively unreasonable.

Intercat also asserts that when Mr. Lippert was at Katalistiks, he was led by Union Carbide's patent group to believe that the patents-in-suit were not strong. (D.I. 266 at 28). Mr. Lippert testified that he received an opinion from Mr. Norman Balmer and the Union Carbide patent group that the patents-in-suitwere very useful for treating stack gas emissions from power plants but that for use in the FCC process the patents-in-suit had "severe problems with the Amoco and Chevron patents." (Tr. 965-66). Mr. Balmer testified that he gave Mr. Lippert no such opinion. (Tr. 1736-38). Mr. Balmer also testified, however, that he could not shed any light upon what was said to Regis Lippert by any other Union Carbide employee. (Tr. 1742).

Mr. Lippert also testified that the Union Carbide patent counsel informed him that the Amoco patents were "quite strong." (Tr. 885; 966). Of course, even if the Amoco patents were strong, it does not necessarily follow that the patents-in-suit were not also strong.

Mr. Lippert further attempted to establish his good faith by testifying about other evidence of invalidity of which he was aware. Mr. Lippert apparently knew that Dr. Magnabosco claimed that he was the true inventor of the Yoo/Jaecker patents. Mr. Lippert testified that Dr. Magnabosco believed that he was the inventor of the technology of the patents-in-suit and that Mr Lippert "tended to agree with him." (Tr. 907). Mr. Lippert, who is admittedly a marketing person rather than a technical person (Tr. 903), did not explain why he tended to agree with Dr. Magnabosco or whether his tendency to agree with Dr. Magnabosco was anchored in fact. Mr. Lippert did not contend that he ever received an objective, competent opinion from counsel that the patents-in-suit were invalid for failing to name Dr. Magnabosco as an inventor.

According to Mr. Lippert, an article by Dr. Hirschberg (DTX 618), combined with subsequent conversations with Dr. Hirschberg, led Mr. Lippert to believe that the Grace patents were not valid because spinel is inactive as a SOx-reducing additive. Mr. Lippert testified that in September of 1987 he attended a presentation by Dr. Hirschberg and Mr. Bertolacini, the content of which was also presented in a written article (DTX-618). (Tr. 908-09). In that presentation and article, Hirschberg and Bertolacini stated that their research showed that stoichiometric spinel was inactive for SOx absorption. During his testimony, Mr. Lippert quoted the following excerpt from the Hirschberg and Bertolacini article:

> Recently, high capacity additives, based on magnesia and alumina, have been suggested as SOx additives. Patent literature identifies the active material in these systems as spinel. Our work has shown, however, that magnesia is the active material being at least an order of magnitude more active than alumina. The stoichiometric spinel, $MgAl_2O_4$, appears to be inactive for SO2 absorption. The role of the alumina and role of the excess magnesia in this system should be clarified.

(Tr. 909; DTX-618).

This Court finds Mr. Lippert's contention that he relied on the Hirschberg and Bertolacini presentation and article in forming an objectively reasonable belief that the patents-in-suit were invalid to lack credibility for several reasons. First, in 1992 Mr. Lippert entered into negotiations to purchase the DESOX technology, which was based on spinel as a SOx remover, for a considerable sum of money. (PTX-31). Second, Louis Magnabosco and Edward Demmel, who were working for Intercat to produce a manufacturing process for NO-SOx, noted in a paper presented to a symposium in 1993 that "the commercially successful SOx transfer agents are magnesium aluminum spinels that contain cerium." (PTX-24 at 3). Indeed, the "novel processing scheme" for manufacturing NO-SOx devised by Magnabosco and Demmel was designed to minimize free magnesia and maximize the production of a magnesium-rich spinel. FN44 Of course, it would be ridiculousto patent a process designed to minimize the production of free magnesia and to maximize the production of spinel if one truly believed that magnesia was the active component and that spinel was inactive for SOx absorption.FN45

FN44. For example Magnabosco and Demmel stated their "data show convincingly that a transfer agent based on magnesium aluminum spinel is superior to other competitive materials, *even though* free magnesia is present." (PTX-24 at 176) (emphasis added). At another point, Magnabosco and Demmel explain that the

XRD pattern for the product of their novel process "is devoid of a shoulder [on the magnesium aluminate spinel peak at the 65 2-theta position] that would indicate presence of undesirable free magnesium oxide." (PTX-24 at 176). Magnabosco and Demmel further state thatNO-SOx is both more active and more stable than Agent A which has "free MgO". Note that NO-SOx has no "free MgO". Its magnesia-rich spinel peak is similar to that shown in Figure 6.

(PTX-24 at 176). Interestingly, Mr. Demmel was with Mr. Lippert at the Hirschberg presentation in New Orleans in 1987. (Tr. 909). Although Mr. Lippert claims that he believed that spinel was inactive for SOx absorption and that magnesia was the active material based on the New Orleans presentation, it is clear from the article (PTX-24) that, at least by 1993, Mr. Demmel, who was the lead technical expert at Intercat and who was intimately involved in the creation of both NO-SOx and NO-SOx-PC, no longer held that impression, if he ever did. Mr. Lippert admitted on cross-examination that there is nothing in the Magnabosco and Demmel article with which he does not agree. (Tr. 919). Perhaps Mr. Lippert could have rid himself of his lingering doubts about the validity of the patents-in-suit by reading his company's own publications or by speaking to his own Director of Technology.It should also be noted that defense counsel contended at oral argument that:

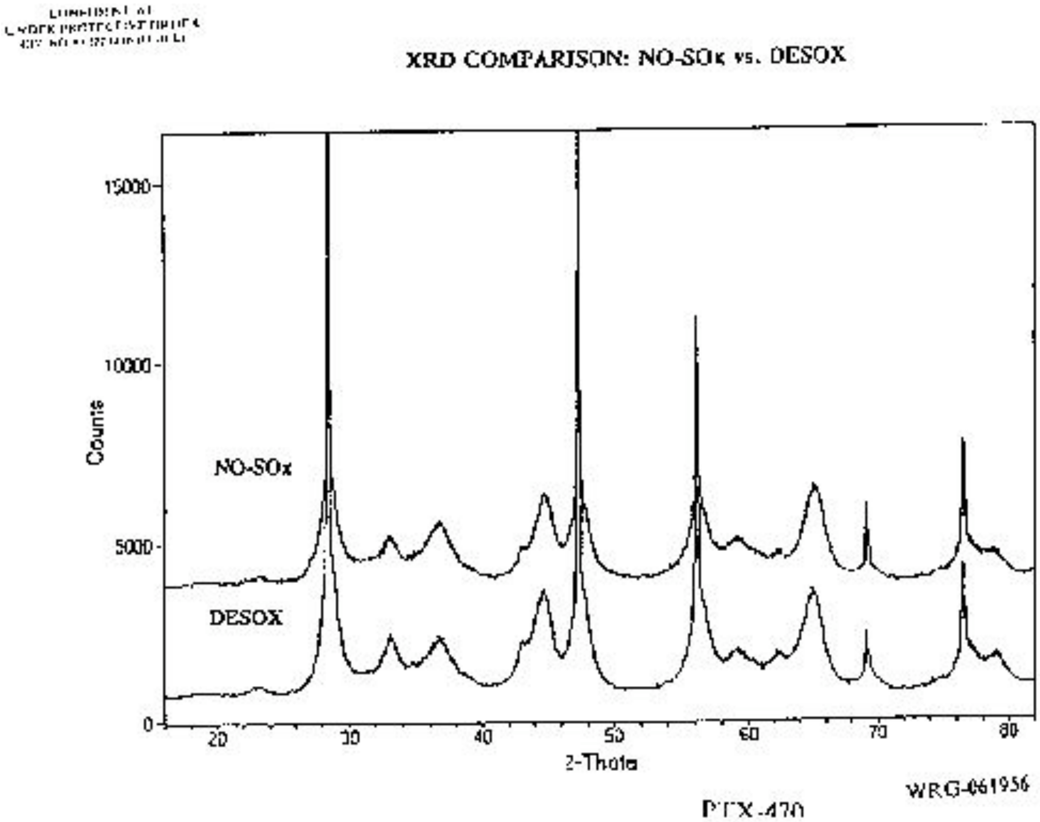
Intercat's products are based upon Amoco's technology. They are based upon the finding that magnesia is what is necessary. You don't need a spinel. They are intentionally made so that a spinel won't be formed.

(D.I. 272 at 64). Counsel's argument is totally contradicted by the Magnabosco and Demmel article and by the patent issued to Magnabosco and Demmel for the NO-SOx manufacturing process.
FN45. It should also be noted that based on the XRD analyses produced in this case, there is substantial doubt that Intercat was successful in minimizing free MgO in NO-SOx. It is clear that NO-SOx contains free MgO. The XRD analyses of NO-SOx resemble Figure 4, not Figure 6, from the Magnabosco and Demmel article (PTX-24).

Mr. Lippert did not have a good reason to believe that the patents-in-suit were invalid. Indeed, the evidence of record casts a dark shadow of doubt over Mr. Lippert's testimony. Mr. Lippert discussed "the possibility of acquiring the entire technology package covering DESOX" from Katalistiks in 1992. (Tr. 902). Furthermore, if it had not been for Regis Lippert, Katalistiks might not have owned the rights to the patents-in-suit and the DESOX product. In 1985, when Regis Lippert was president of Katalistiks, he advised Robert Kulperger, who was vice president of Union Carbide, that the purchase of ARCO's SOx abatement technology would be a very good idea. (Tr. 139, 870; UF-112). Mr. Lippert's pursuit of the patents-in-suit belies any claim that he thought the patents were not strong or were invalid.

There is also substantial evidence of copying. DESOX was the preeminent SOx abatement additive on the market when NO-SOx was developed. Intercat had failed to gain any significant market share with its LOSOX or TRANSCAT additives. When attempting to create a new product, Intercat enlisted the help of Dr. Magnabosco, who was involved in the development of the original ARCO materials which resulted in the issuance of the patents-in-suit and in the commercialization of DESOX. Although there is evidence that Intercat attempted to design around the process for making DESOX, the plain fact is that when Intercat put its new product, NO-SOx, on the market it was practically identical to DESOX. Both DESOX and NO-SOx contain magnesium, aluminum, cerium, and vanadium as their four primary metallic components. Moreover, each contain magnesium aluminate, rather than a simple mixture of magnesium oxide and aluminum oxide. Most importantly the XRD patterns for DESOX and NO-SOx are practically identical. This point was made abundantly clear by the comparison of XRD analyses of the two materials in PTX-470, which is reproduced below.

XRD COMPARISON: NO-SOX VS. DESOX



This Court finds as fact that NO-SOx is a copy of DESOX.

Although the discussion thus far has centered on the willfulness of Intercat in regard to NO-SOx, there is also clear and convincing evidence that Intercat willfully infringed the patents-in-suit by selling NO-SOx-PC to Conoco for use in its FCC units. Amazingly, even though this litigation had already commenced, Intercat failed to obtain a written opinion of counsel regarding whether NO-Sox-PC infringed the patents-in-suit or whether the patents-in-suit were invalid. Mr. Lippert explained, "With the advent of the lawsuit, we reviewed our position, felt comfortable with it, and, in fact, our expert in this case advised us that it [NO-Sox-PC] contained no spinel, so that we moved ahead and introduced it." (Tr. 906). Yet, on cross-examination, when asked if he "never believed that [his] compositions [NO-Sox and NO-Sox-PC] contained a spinel," Mr. Lippert responded, "I never believed or disbelieved." (Tr. 937). When asked if he had obtained a formal opinion on invalidity before introducing NO-Sox-PC, Mr. Lippert stated that because Intercat is a small company they make decisions fairly quickly. Intercat discussed the question with counsel; counsel gave a verbal opinion; and Intercat did not request a written opinion. To not request a written opinion of counsel before introducing the NO-Sox-PC product after the advent of this litigation constituted a reckless disregard of Grace's patent rights. When combined with Mr. Lippert's lack of credibility and the insubstantial nature of his investigation into the patent rights of Grace, Intercat's failure to obtain a competent, written opinion of counsel before introducing NO-Sox-PC into the marketplace was unreasonable and constituted willful infringement of the patents-in-suit.

In sum, Grace has proven by clear and convincing evidence that Intercat did not act reasonably and prudently to avoid infringement of Grace's patent rights. Intercat deliberatelycopied the invention of the patents-in-suit and the highly successful DESOX product. Regis Lippert, the President of Intercat, plainly had knowledge of Grace's patent rights, yet failed to obtain competent advice of counsel before initiating or continuing infringing activities. Although Mr. Lippert claims to have formed a good faith belief that NO-Sox and NO-Sox-PC did not infringe the patents-in-suit and that those patents were invalid, he formed his belief (if indeed he actually held such a belief) without performing an adequate investigation into the scope of Grace's patent rights. As a consequence, this Court finds as fact that Intercat willfully infringed the patents-in-suit.

VI. CONCLUSION

Conoco directly infringes all of the asserted claims of each of the patents-in-suit through its use of NO-Sox and NO-Sox-PC in its Billings FCC unit. Intercat has induced and contributed to that infringement. Intercat failed to act reasonably in an effort to avoid the infringement of the patents-in-suit, so Intercat's inducement of infringement and contributory infringement constitutes willful infringement. As a consequence of these findings, Intercat's motion for JMOL on the issue of infringement will be denied, and a finding of infringement will be entered.

After reviewing the record, this Court holds that Defendants have failed to prove any claim of the patents invalid by clear and convincing evidence. The patents are not obvious in light of the prior art. In addition, the patent claims specifically claim the invention and are sufficiently definite to apprise those of ordinary skill in the art of the scope of the patent. Moreover, the patentees and their representatives did not engage in inequitable conduct before the PTO. Grace's motion for JMOL will be granted on the issue of inequitable conduct, and a finding that the patent claims are not invalid will be entered.

Although the parties have also disputed whether this is an exceptional case which would justify an award of attorneys fees, that decision will be reserved for the damages phase of this litigation. An appropriate Order shall issue.

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