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Datasheet for the decision of 12 May 2009

Case Number: T 1820/06 - 3.2.03

Application Number: 99945376.4

Publication Number: 1117894

IPC: E21B 10/16, E21B 10/08

Language of the proceedings: EN

Title of invention:
Roller-cone bits, systems, drilling methods, and design methods with optimization of tooth orientation

Patentee:
HALLIBURTON ENERGY SERVICES, INC.

Opponent:
Smith International, Inc.

Headword:
-

Relevant legal provisions:
EPC Art. 123(2), (3), 100(b), 100(a), 52(2), (3), 54, 56

Relevant legal provisions (EPC 1973):
-

Keyword:
"Sufficiency of disclosure (yes)"
"Exclusion from patentability (no)"
"Novelty and inventive step (yes)"

Decisions cited:
-

Catchword:
-

Case Number: T 1820/06 - 3.2.03

D E C I S I O N
of the Technical Board of Appeal 3.2.03
of 12 May 2009

Appellant:
(Patent Proprietor)

HALLIBURTON ENERGY SERVICES, INC.
2601 Belt Line Road
Carrolton, TX 75006 (US)

Representative:

HOFFMANN EITLE
Patent- und Rechtsanwälte
Arabellastraße 4
D-81925 München...(DE)

Decision under appeal:

Decision of the Opposition Division of the European Patent Office posted 15 May 2006 revoking European patent No. 1117894 pursuant to Article 102(1) EPC.

Composition of the Board:

Chairman: U. Krause
Members: E. Frank
K. Garnett

Summary of Facts and Submissions

I. The appeal lies from the decision of the Opposition Division dated 7 April 2006 and posted on 15 May 2006, to revoke the European patent No. 1 117 894 pursuant to Article 102(1) EPC 1973 on the ground of lack of sufficient disclosure. With letter of 20 December 2005 the Opponent withdrew its opposition and the opposition proceedings were continued by the European Patent Office of its own motion under Rule 60(2) EPC 1973. A summons to oral proceedings was sent out on 27 December 2005 and a communication pursuant to Article 101(2) EPC 1973 was faxed on 9 February 2006. The oral proceedings were duly held on 7 April 2006.

II. The Appellant (Proprietor) filed a notice of Appeal on 18 July 2006, paying the appeal fee on the same day. The statement of grounds of appeal was received on 21 September 2006. Together with its grounds of appeal, the Appellant submitted a statement of Mr. James Rodney Hall dated 20 September 2006 as evidence in support of the disclosure of the claimed invention.

III. The Appellant requested that the decision under appeal be set aside, and that the patent be maintained on the basis of claims 1 to 3 and a new description page 7 according to its sole request filed with the grounds of appeal on 21 September 2006, and that oral proceedings be held. Moreover, the Appellant requested that, if oral proceedings did not need to be held, the grounds of novelty and inventive step be also considered by the Board rather than remitting the case to the Opposition Division for further prosecution.

IV. The wording of claim 1 reads as follows:

"1. A method of designing a roller cone bit, comprising the steps of:

adjusting the orientation of at least one tooth on a cone, in dependence on an expected trajectory of said tooth through formation material at the cutting face, in dependence on an estimated ratio of cone rotation to bit rotation for which the torques acting on the cone about its axis sum to zero;

recalculating said ratio, if the location of any row of teeth on said cone changes during optimization;

recalculating the trajectory of said tooth in accordance with a recalculated value of said cone speed; and

adjusting the orientation of said tooth again, in accordance with a recalculated value of said tooth trajectory."

V. The following evidence has been considered for purposes of the present decision:

D1 = The Operational Mechanics of the Rock Bit, Petroleum Industry Press, published in 1996
D2 = CN 2082755 U
D3 = US 5 197 555 A
D4 = Dynamics of Roller Cone Bits, Journal of Energy Resources Technology, December 1985, Vol. 107/543

Statement of James Rodney Hall, dated 20 September 2006; with exhibits 1 to 6 attached to the statement

VI. The arguments of the Opposition Division and the Appellant were essentially as follows:

The Opposition Division indicated in its communication prior to the oral proceedings that there was no need to discuss the ground of excluded subject-matter, and a provisional opinion on the other grounds of opposition on file was issued, in which D1 to D4 were considered as being highly relevant with respect to claim 1 as granted. In their decision reached to revoke the patent on the ground of insufficiency of disclosure, the Opposition Division held in the first place that, based on the original disclosure or his routine knowledge, the skilled person did not know how to arrive at the estimated ratio of cone rotation to bit rotation as described in claim 1 or how it should be recalculated. No precise calculation was provided, and column 17, paragraphs [0069] to [0072] of the specification failed to describe which sort of torques were meant in claim 1, or why these torques would actually sum to zero. It was also not apparent that only the torques due to the forces acting on the teeth were addressed or whether such forces were available from databases in order to determine in turn the described ratio between the rotational speeds of cone and bit. This ratio was a complex parameter depending on the mechanical strength of the formation, fluid forces, inertia forces, geometry of the bit, slippage etc., and the difficulty of determining the latter was also pointed out in D1:

cf. page 100, second to last paragraph. Moreover, the only evidence to support the argument that the calculation of the ratio belonged to the general knowledge of the skilled person was the witness Mr. J. Hall, who was not available either to make a sworn declaration or to attend the oral proceedings in person. Therefore the invention of claim 1 as granted, and as amended according to the then pending auxiliary request (which corresponds to the now sole request), could not be carried out.

The Appellant agreed with the Opposition Division that at the relevant time no one knew how to accurately calculate the ratio of cone rotation to bit rotation. However, according to claim 1 this was an estimated ratio for which the torques acting on the cone about its axis sum to zero. As explained in paragraphs [0069] to [0072] of the patent, the starting value for the ratio was mathematically checked, i.e. to see whether or not the sum of torques summed to zero. If not, the procedure was repeated iteratively for further ratios, until the ratio was found for which the drag torques, ultimately determined by the drag forces acting on each tooth, summed to zero. In fact, the "estimate" of the ratio in the first step of claim 1 and the "recalculation" of the ratio in the second step of claim 1 were arrived at using the same process. A skilled reader would understand from the patent that the cone to bit ratio was an estimated value and that the reference to "re-calculated" did not contradict this understanding, but merely related to the fact that the ratio was checked for correctness by a torque-balance iterative calculation. Thus, the disclosed method did not involve a direct calculation of the desired ratio but rather an indirect iterative calculation. As to the complex interaction between rock and bit (and bit geometry), the dependency of the cutting action on the nature of the formation material was taken into account by means of "indentation tests" as was explained by Mr. Hall in his evidence with particular reference to exhibit 6. As was also explained by Mr. Hall, the largest contribution to the torques was made by the drag forces acting on the cone teeth. The manner in which the trajectory of each tooth had to be calculated was explained in mathematical terms in the patent and was straightforward for the skilled person to understand.

Furthermore, the fact that D1 mentioned the difficulty of determining the cone to bit speed ratio was irrelevant as regards whether the subject patent met the requirements for sufficiency. Moreover, it was wrong to cast doubt on whether the determination of the ratio was routine knowledge to those skilled in the art simply because Mr. Hall was unable to provide supporting evidence prior to and during oral proceedings, resulting from his serious medical condition. It was accepted by the Appellant that the patent did not give an explanation as to why the (drag) torques acting on each cone would sum to zero. On the other hand, all the patent was required to do was to give a sufficient disclosure to enable the skilled reader to put the invention into effect, which it did, since a clear instruction was given that the drag torques had to be summed and checked to see whether they summed to zero. The reason was in fact based on considerations of mechanics, as explained by Mr. Hall in paragraph 4.14 of his statement, namely that the cones were rotating at a constant speed only if no driving torque was applied to them, i.e. there had to be no net torque acting on each cone. Thus, the requirements of sufficiency of disclosure were satisfied.

Furthermore, since under point 2.6 of the Opposition Division's decision it was stated that there was no need to discuss the ground of excluded subject-matter, the grounds of novelty and inventive step, which were raised by the Opponent and had never been considered by the Opposition Division, remained. As to the prior art cited, D1 only described techniques using special sensors to provide an experimental value for the speed ratio: cf. bridging pages 230 and 231. Moreover, D2 and D3 were concerned with tooth orientation, and D4 merely taught the measurement of mean values of cone and bit speeds experimentally. Thus, the feature that the estimated ratio of cone rotation to bit rotation was that for which the torques acting on the cone about its axis summed to zero was absent from each of D1 to D4, and therefore also inventive in the light of these documents. In the interest of procedural efficiency, therefore, the Appellant requested that the grounds of novelty and inventive step be also considered by the Board, if the amended patent according to the sole request met the requirements for carrying out the invention.

Reasons for the Decision

1. The appeal complies with the provisions of Articles 106 to 108 EPC and of Rule 99 EPC and is, therefore, admissible.

2. Amendments
(Articles 123(2) and (3) EPC)

Claim 1 differs from claim 1 as granted in that the estimated ratio of cone rotation to bit rotation has been further specified by the newly added feature "for which the torques acting on the cone about its axis sum to zero".

This amendment is derivable from page 16, last paragraph (as published). Moreover, the description has been adapted with a newly filed page 7 in accordance with Article 84 EPC.

Thus, in the Board's view, the patent as amended in accordance with the current request fulfils the requirements of Articles 123(2) and (3) EPC.

3. Sufficiency of disclosure
(Article 100(b) EPC)

As for the requirements of sufficiency of disclosure laid down in Article 100(b) EPC, at the date of filing, i.e. in the present case at its priority date, the requested patent must disclose the invention in a manner sufficiently clear and complete for it to be carried out by a skilled person in the technical field of drill bit design, with knowledge of the patent and on the basis of a drill bit designer's common general knowledge.

3.1 As is described by the sample embodiment of a bit design process in column 9, paragraph [0034] of the patent specification, firstly the bit geometry, rock properties and bit operational parameters are input, and then are displayed as a 3D tooth shape, cone profile, cone layout, 3D cone, 3D bit, and 2D hole. Then, as described in paragraphs [0035] and [0036] of the patent, the teeth trajectories and the teeth force on the bottom hole are calculated. The teeth force is projected into cone and bit coordinates, thus ultimately yielding the total cone and bit forces and moments (torques). This is also derivable from the design process shown in figure 1A (steps 102 and 104), figure 1B (step 124) and figure 1C (step 146). The Board notes that prior to the calculation of the transformation matrices from cone to bit coordinates (cf. patent, column 9, lines 27 to 30 and lines 46 to 48; figure 1A, step 106 and figure 1C, step 128) a given ratio of cone rotation to bit rotation has to be assumed. In the end, the specific energy of the bit, i.e. the ROP (rate of penetration: cf. patent, paragraph [0023]) depending on the bit features, but also on the rock properties, can be determined.

3.2 Based on his general knowledge at the relevant time, in the Board's view the skilled reader would have appreciated that the properties of rock formations, and also the interaction forces between contacting teeth and the hole bottom were to be retrieved from available databases and that the geometric two- or three-dimensional analysis of the hole formation in question and the respective bit were based on complex models, which had to be mathematically implemented into computer software to carry out, e.g., a finite element analysis: cf. D1; page 15, second main paragraph, to page 17. Several models are addressed in the patent specification, e.g., in column 12, lines 32 to 36, the modelling of the (hole) formation by multiple stepped horizontal planes is described. Moreover, from column 10, paragraph [0039] and figure 13 a three-dimensional grid, i.e. the model, of a non-axisymmetric tooth tip is derivable, which apparently corresponds to a "solid-body" tooth model as described in column 17 at lines 14 and 15 in context with the calculation of the cone to bit ratio. As to the interaction between a tooth in cutting and a particular rock formation, generally known "crater models" (cf. D1, page 232, lines 3 to 9) are addressed in the specification (cf. column 10, lines 2 to 4; figures 1B (step 124) and 1C (step 146)). Thus, the volume of craters of spalled rock is taken into account caused by the brittle fracture of the formation.

With respect to the general knowledge of the interaction between rock and bit at the date of filing of the patent, in particular reference is made to document D1, chapter 5, "The Experimental Study On The Interaction Between Bit And Rock", pages 171 to 226. Beside the complex properties of rocks, the special features of the teeth of roller cone bits and how the teeth work in the bottom hole are described in great detail. To start with, under point 5.1 (W.C. Maurer's axial penetration test of a single tooth), test data of tooth load with respect to US and Chinese typical rocks of the vertical indentation of single teeth are described: cf. in particular figures 5-1 to 5-6, and tables 5-1 and 5-2. Moreover, transformation from a brittle breaking process to a plastic breaking process with a single tooth was tested by J.B. Cheatham and P.F. Gnirk: cf. page 184 and table 5-3. After 60 years of applying the pressing single tooth test to investigate the high pressure impact on breaking rock, experimental frames with full size roller cone bits to simulate bottom hole conditions were implemented: cf. point 5.2 on page 185. The first test frame for simulating bottom hole conditions was built in Salt Lake city in 1975. Thus, measurable dynamic parameters, such as torque, were determined. Another well-known test frame for simulating bottom hole conditions was built in 1985 by Schlumberger Cambridge Co. at Cambridge, England: cf. page 187. This frame can simulate the pressure and temperature at a 5000m depth hole, and the simulated data are captured by a computer system, i.e. are stored in data bases. If the rock sample is too big, it is necessary to estimate the influence of the boundary stress on the rock sample by the finite element method: cf. page 191, figure 5-8 and 5-9. The experimental device is used to simulate the real motion of the teeth of each teeth row and their crater making process on the rock sample. Finally, the combination of all this information can be used to calculate the mutual influence between bit and rock. From page 194 onwards under point 5.3, a so called "multi-motion breaking rock test machine" from the 1980s is described which could, amongst other things, simulate a series of tooth crater-forming processes of a test teeth row on the bottom surface. Data is sent to a computer to collect the required test data. On page 202, from the first main paragraph onwards, it is explained that the breaking action on the bit for all kinds of cone rows can be simulated, the rotary speed can be adjusted and the ratio of the bit rotary speed to the cone speed can be selected in eight grades as well as in a free state. The measured data are, inter alia, the drilling weight and torque: cf. figure 5-18. The crater depth, breaking area and crater volume are measured by an advanced photoelectric device: cf. figures 5-4, 5-5 and table 5-6. Moreover, reference is also made to the statement of Mr. Hall (which was not available to the Opposition Division), who refers explicitly to "the knowledge of the skilled person as of the filing date of the patent", although, rather than the priority date of the patent (31 August 1998), he regards the filing on the 31st of August 1999 with the European Patent Office as the filing date of the patent: cf. paragraph 2.1. However, Mr. Hall's statement is convincing in that for any given rock formation and tooth geometry, apparently any skilled person at the priority date of the patent could also determine the drag forces (cf. exhibits 5 (see drawings) and 6 (see first page, abstract and figs. 1 and 2)) at a given depth from experimental data, such as the "indentation test data", because they had been available since the 1970s: cf. paragraphs 4.20 to 4.28.

Thus, the teeth forces on a roller cone drill bit caused by a particular rock formation could be derived by the skilled person from various databases of models known in the art at the date of filing, even though this is not specifically disclosed in the patent, and in fact no "detailed force calculations" (cf. column 17, lines 7 and 8) are described therein. In the Board's view, in any case the knowledge of

W.C. Maurer's old model of the vertical indentation of a single tooth described in D1, or the drag force model based on the "indentation test data" of the 1970s described by Mr. Hall, would be sufficient for the skilled person to be able to acquire data for the determination of the tooth force described in column 10, lines 1 to 8 of the patent.

3.3 As to the iterative determination of the correct ratio of cone rotation to bit rotation, when adjusting the orientation of a tooth according to the invention of method claim 1, this is based on column 17, paragraphs [0069] to [0072] of the specification. In paragraph [0069] a "given" ratio is described, which is determined by the defined geometry of the roller cone bit (cf. paragraph [0009], lines 41 to 43) and can be based, e.g., on a simplified known model (cf. paragraph [0071]) by assuming that the gage row (outermost row of the cone: cf. column 3, lines 30 and 31) is the "driving row", which has no tangential slippage against the cutting face. However, in paragraph [0069] it is stated that in the context of the detailed force calculations, the rotational speeds of cone and bit can be checked by simply calculating the torques about the cone axis. Based on the generally known models of interactions between a particular type of rock and tooth as discussed under point 3.2 above, the skilled person would determine the teeth force and project it into cone and bit coordinates as is taught in column 9, paragraph [0036] (cf. in particular lines 5 to 7) and figure 1C, step 146. Thus, the Board agrees with the Appellant that the torques acting on a cone could be readily obtained, and that apparently the largest contribution to the torques is made by the drag forces acting on the cone teeth. However, in the Board's view, whether or not additional forces would be taken into consideration, such as the influence of drilling fluids, inertia caused by acceleration and deceleration of the cones, etc., would depend on the input parameters of the model for the approximation for the interaction between bit and hole which was used, and thus would have no impact whatsoever on the iterations taught in the patent, according to which at a given ratio of cone and bit speed the torques acting on each cone are to be balanced, i.e. sum to zero about its axis.

3.4 Finally, the calculations of the projections of the tooth trajectories on the hole bottom, in order to arrive at a desired bottom-hole pattern for the "action on bottom", are also based on a model, namely the "equivalent tangent and radial scraping distances": cf. columns 13 to 16 of the specification, and figures 2, 5, 15A to 15D and 16A to 16D, in particular paragraphs [0052] to [0057]. The manner in which the trajectories are planarized and how this is explained in mathematical terms has not been objected to by the Opposition Division and also the Board has no reason to doubt that the tooth orientation as dependent on an expected trajectory of this tooth as claimed in present claim 1 can be carried out by the skilled person.

The skilled person therefore would be aware that the model computer analysis of a hole formation and a suitable bit, designed to interact with the hole, cannot be based on a "precise calculation", as objected to by the Opposition Division under point 5.2 of its decision. Rather, according to the invention of claim 1, because there are too many parameters, iterative calculations with the aid of approximations based on models are provided. In the view of the Board, the use of these models is either described in detail, or is generally known and hinted at in the patent, and thus can be carried out by the skilled person.

3.5 Having regard to the subject-matter of claim 1, in the view of the Board, the skilled person would understand from the specification in column 17, paragraph [0069] lines 9 to 12, that the "given" cone to bit speed ratio is an estimated value, and that unless the torques about the cone axis of a cone sum to zero, an iterative calculation has to be performed to find the correct ratio. Thus, the method according to claim 1 comprises a first iteration loop, starting from an estimated cone to bit speed ratio. The trajectories for each tooth of a cone are calculated (as a function of the cone speed, i.e. of the cone to bit speed ratio), and the orientation of at least one tooth as a function of its trajectory is adjusted for an optimized performance of the drill bit. The teeth forces on the cone based on the cutting depth of the scraping actions of the teeth are determined, and the torques acting on the cone are calculated and checked whether they sum to zero. If not, the estimated ratio is corrected and the iteration will be continued, so as to finally arrive at a ratio for which the torques acting on the cone are balanced, and the first iteration loop will be stopped. In the next step of method claim 1, it is checked to see whether the location of any row of teeth on the cone has to be changed because of the new tooth orientation, which may affect the width of uncut rings or the tooth clearances: cf. column 16, paragraph [0064],[0065] and column 17, paragraph [0072]. If the location of any row of teeth on said cone changes during optimization, a second iteration loop is started, and the ratio is "recalculated", i.e. re-estimated, and again the trajectories of each tooth are recalculated, and the orientation of the at least one tooth is adjusted in accordance with the recalculated value of the tooth trajectory. Again the torques on the cone are determined and checked for balance. The cone to bit speed ratio may then be corrected, and also the second iteration loop of the claimed method ends when the torques acting on the cone about its axis sum to zero.

Finally, contrary to the Opposition Division's view, since the torques acting on each cone can be determined and then readily summed by the skilled person, the claimed ratio can be put into practice, and therefore in the present case an explanation as to why the torques in fact would sum to zero is immaterial for carrying out the invention. However, for the sake of completeness, a plausible explanation for the torque summation to zero is given in paragraph 4.14 of Mr. Hall's statement: On the basis that no driving torque is applied to the cones, and they are rotating at a constant speed, there would be no net torque acting on each cone.

The disclosure of the invention according to the subject-matter of claim 1 therefore meets the requirements of Article 100(b) EPC.

4. Exclusion from patentability
(Article 100(a) EPC: see Article 52(2) and (3)

The Board agrees with the opinion of the Opposition Division indicated prior to the oral proceedings that the method of claim 1 complies with Article 52(2) and (3), since a technical effect, i.e. the optimized adjustment of the orientation of at least one tooth on a cone of a roller cone bit, is thereby achieved.

5. Novelty and Inventive Step
(Article 100(a) EPC: see Articles 54 and 56 EPC)

The document D1 describes, on page 231, second last main paragraph, under point 6.1.2.2, that there was a patented program for optimizing the tooth (or insert) crest direction, however without a reference to any particular method steps as to how the orientation of a tooth had to be determined or had been implemented into this software. In the Board's view, the "diagram of the tooth track" under point 6.1.2.2, third main paragraph, is based on another computer program, namely that which is described on page 103 and shown on page 104 and 105 as a flow chart. This iterative calculation is based on the fundamental equations of bit geometry mentioned in Chapter 2.2: cf. page 103, third main paragraph, point "(2)". The description of these equations under chapter 2.2 on page 34, in particular from chapter 2.2.2 on page 38 onwards, however, does not describe any iterations for taking the tooth orientation into account, and also the determination of the teeth tracks based on teeth trajectories under chapters 3.4 and 3.5, pages 94 to 103, gives no clue as to the tooth orientation (at least not explicitly), let alone to a plurality of detailed iterative steps in the context of the ratio of cone to bit rotation such as described in method claim 1.

However, in the view of the Board, since the first paragraph of chapter 2.2.2 on page 38 and page 43 last paragraph state that the position of any points of teeth in the moving coordinates can be determined in the space and tooth tracks on the bottom hole as determined in chapters 3.4 and 3.5, it appears that, whilst the tooth crest direction is optimized, the dependency of tooth orientation on both an expected tooth trajectory and a ratio of cone to bit rotation is implicitly disclosed by D1 on page 231, second last main paragraph. As for the determination of the ratio of cone rotation to bit rotation, the Board agrees with the Appellant that document D1 only says that the rotational speed ratio of each roller to the bit is measured by sensors on a test frame. The test and corresponding bit data are stored and can be used to design new similar bits. A computer simulation program may be used, if no similar bit data are available in the database. However, D1 does not disclose any information about this simulation program (cf. D1, bridging paragraph of pages 230 and 231). In particular, no iteration, starting from an estimated ratio of cone to bit speed which is then checked for torque balance, so as finally to arrive at a corrected ratio, for which the torques acting on a cone about its axis sum to zero, is derivable.

Moreover, in order to determine the average speed of the bits and cones, the document D4 explains that it is easy to establish the rotational speed of the bit, either in the lab or in the field, whereas the speed of the cones must be measured in the lab. These results are then to be fed into a computer program, but again no details as to the program to be used are given: cf. D4, page 547, right column, point 2. Finally, the documents D2 and D3 concern tooth orientation: cf. the abstracts. Although D2 also refers to a formula for the orientation angle depending on the angular speeds of the drill bit and the roller cone, it merely states that the parameters of the formula, i.e. the angular speeds, can be theoretically and experimentally determined, cf.D2, page 2, first paragraph.

Thus, in the Board's view, none of the known prior art documents D1 to D4 disclose the two iterative loops according to the subject-matter of claim 1.

Starting from D1 as closest prior art, since it provides the most detailed disclosure for the design of a roller cone bit by means of tooth orientation of non-axisymmetric teeth, the problem underlying the method steps of claim 1 can be seen in an improved optimization of the tooth orientation of a roller cone bit. The skilled person faced with that problem would not get any incentive, either from his ordinary common technical knowledge or from the disclosure of D2 to D4, to arrive at the claimed solution. Through the method of claim 1, in particular the impact on the cone to bit speed ratio because of changes in tooth orientation is iteratively considered: cf. patent, paragraph [0072]. Moreover, the speed ratio is checked for torque balance during iteration, to find the correct value of cone rotation to bit rotation.

Therefore the subject-matter of claim 1 fulfills the requirements of novelty and inventive step.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the Opposition Division with the order to maintain the patent on the basis of:

   - Claims, No.:
     1 to 3 as filed with the grounds of appeal
     on 21 September 2006,

   - Drawings, figures:
     1A to 1C,2,3A to 3D,4A,4B,5,6,7A,7B,8A,8B,9A to 9C,10 to 14,15A to 15D,16A to 16D as granted,

   - Description, pages:
     2,3,6 to 10 as granted,

     and pages 4 and 5 of the printed patent as granted, as amended in accordance with page 7 as filed with the grounds of appeal.

The Registrar | The Chairman

A. Wolinski | U. Krause