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D-49549 Ladbergen
Germany
www.iredes.org

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Germany

IREDES Drill Rigs
Profile Documentation

Version 1.3

2010-09-24

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Goethestr. 52
D-49549 Ladbergen
Germany
www.iredes.org

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1 General Information

1.1 Introduction

As modern mining machinery today is controlled electronically and even operates autonomously, a smooth and cost efficient flow of data in the mining process will be crucial for cost efficient future mine operations. Therefore, the International Rock Excavation Data Exchange Standard (IREDES) was launched by major players in the industry. The task of this initiative is to define a common electronic language for easy and standardized data exchange between mining machines and central computer systems.

This standard is expected to have significant impact on the use of automated mining equipment. Multi vendor installations will be controlled much easier than today as IREDES offers a standardized Interface to all machines. Cost can be reduced as no vendor specific import/export filters have to be developed.

By using IREDES, the mining equipment will become an active part of a mining companies IT-infrastructure. All data produced by IREDES compliant machines can be stored in databases. This will lead to a continuous productivity control and helps improving production planing. The XML technology used in IREDES is widely supported and open for the future.

1.2 Preconditions and Usage

This document is an additional textual documentation to provide documentation which cannot be integrated into the DrillRig XML schema definitions.

In case of ambiguities, the standard's XML schema is the standard's normative basis. It supersedes all other information given in text documents, presentations etc.

As the XML definitions only can contain the formal aspects of the standardization, this document adds all content definitions which base on mutual agreement. Therefore it is an important document for correct interpretation of the standard and for crossover compatibility. An fully IREDES compliant implementation has to fulfill all demands stated in the IREDES XML schema s as well as in this accompanying documentation.

Errors in this documentation as well as in the XML schemes have to be reported to the IREDES office. Thank you for your help!

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Germany
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2 Document History

Date	Version number	Details
2003-02	V1.0	Initial preparation of document
2003-03-12	V1.0	Review by Drill rigs work group
2004-12-29	V1.2	Introduction of changes according to V1.2 Change log spreadsheet
2010-09-24	V1.3	Drill contour related schemes added

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3 Referenced Standards

ISO 8859-1: 1987, Part 1: Latin Alphabet No 1

XML Schema Part 0: Primer: http://www.w3.org/TR/xmlschema-0/

XML Schema Part 1: Structures: http://www.w3.org/TR/xmlschema-1/

XML Schema Part 2: Datatypes: http://www.w3.org/TR/xmlschema-2/

XML Base: http://www.w3.org/TR/xmlbase/

Extensible Markup Language (XML) 1.0: http://www.w3.org/TR/2000/REC-xml-20001006

XML Namespaces: http://www.w3.org/TR/REC-xml-names

RFC1321: http://www.faqs.org/rfcs/rfc1321.html

Please note: The IREDES office is not responsible for the content provided by the above mentioned links. Please let us know if a link is not longer working or if content has changed so it does not relate to the intended purpose any longer.

4 Related Documents

This document is a part of a set of documents describing the different parts of the IREDES standard:

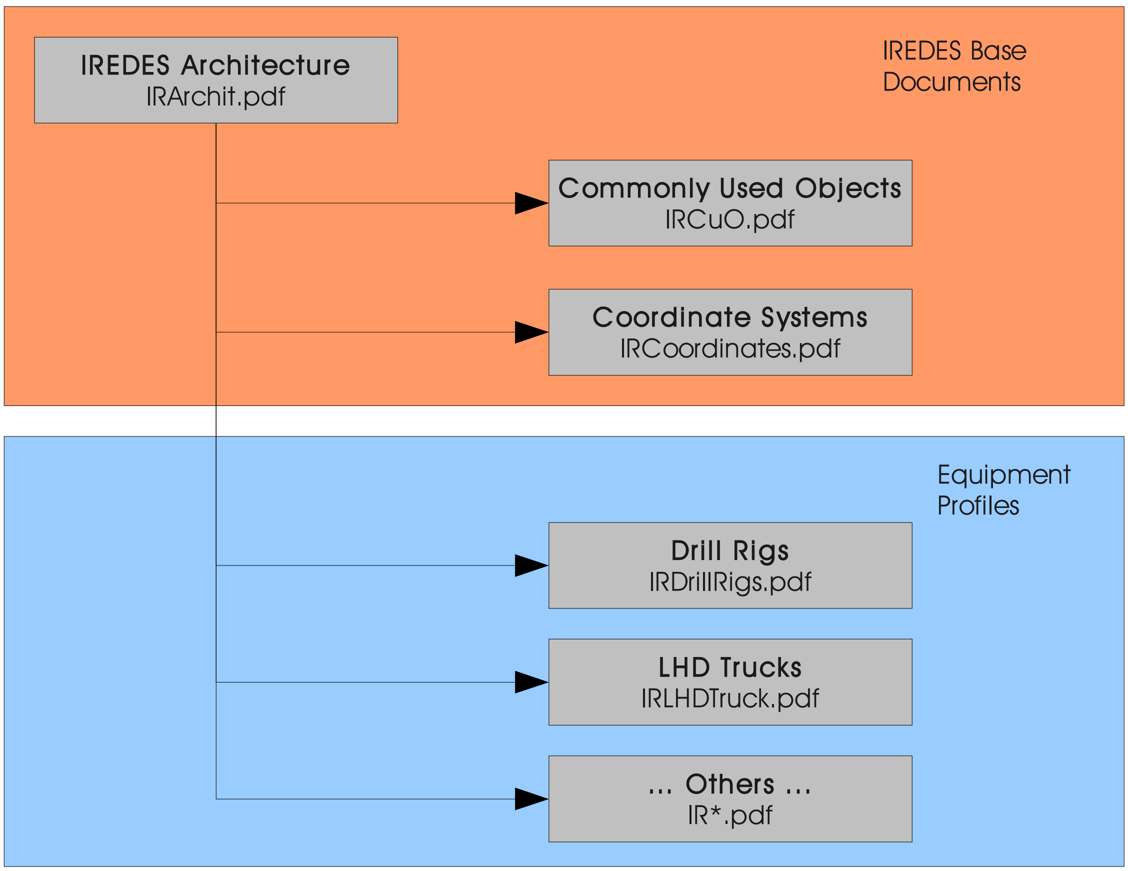

Figure 1: IREDES documentations

The uppermost document is the IREDES Architecture description explaining the general setup and collaboration of the different parts of the standard. The "IREDES Architecture" document will be the best choice to start with as it gives an overview and basic information needed to understand the structure of IREDES.

Detail information about single parts of the IREDES standard are available from separate documents. Readers of these documents should be familiar with XML, XML schemes and implementation relevant issues.

Standard definitions used in common throughout multiple equipment profiles are covered by the corresponding documentation of the "General Objects"

(Application Profiles, General Data Types etc) and "Commonly used Objects" (CuO's).

All standard information concerning a particular equipment type (Drill Rigs, LHD's,...) is contained in a separate document related to the equipment profile.

Beside the textual descriptions, the entire standard is available as XML schemes as they contain the formal description of the standard. In case of ambiguities, the definitions in the XML schema override all definitions made in the accompanying textual documentation. Textual description available for different IREDES profiles is additional information mainly containing parts of the standards not definable in XML schemes. Implementors should take care of these documents as they may contain important information which must be defined basing on "mutual agreement" to make the standard work.

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5 General Handling of the Drill Rigs Profile

5.1 Object Relationships

For the Drill Rigs equipment profile, the following rules are set up for the exchange of data sets and their relation among each other.

5.1.1 DRPlan – DRPQual

The relation in handling the DRPPlan and DRPQual profiles is in line with the general description for handling of the Production Plan - Production Quality reporting relationship as described in the *IRArchit.pdf* document.

One **DRPQual** Quality report normally matches one single **DRPPlan** planning object. In exceptional situations (the machine is exchanged in the middle of one round) also multiple DRPQual objects may be used to report the work of one single Drill plan. Therefore, implementors shall take care of planning for an 1:n relationship between *DRPPlan* Drill Plan and *DRPQual* Quality reporting.

Potential problems of interpreting split DRPQual profiles are not covered by the standard definition itself! These issues have to be handled properly by the applications.

Users shall take care to organize work that a logical working sequence in normal operation is not split between multiple machines.

5.1.2 DRPPlan – MWD

The MWD log is regarded as another Quality reporting Data Set. Therefore it is also derived from the general Quality Reporting Application Profile. Consequently, the Plan-Quality relationship is also applicable.

There is a 1:1 - Relationship between a Drill Plan and a corresponding MWD log (if the machine is able to supply such a protocol). Each MWD log bases on a DRPPlan Data Set previously supplied to the machine.

5.1.3 Laserline – Tunnel Line

The aim of the tunnel line is to aid and simplify the excavation of curved tunnels by calculating the tunnel laser position based on a table of coordinates which define the tunnel centerline.

The coordinate points of the tunnel centerline (see Figure 5-1) should coincide with the origins of the drill plan.

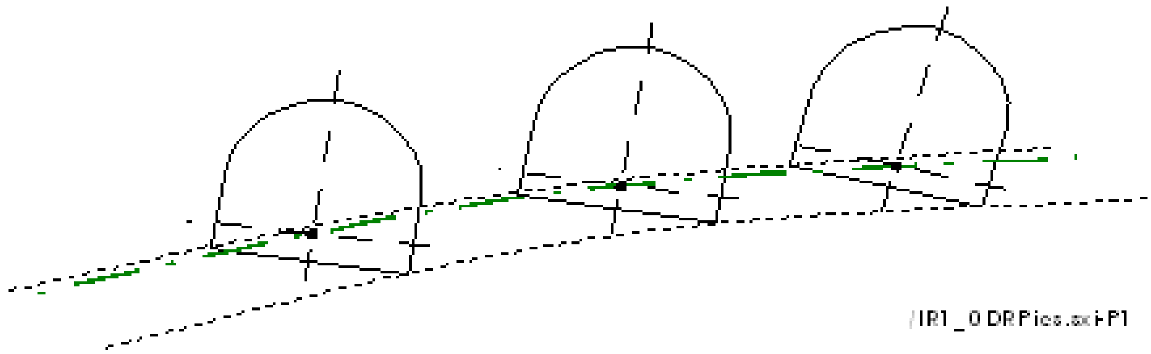

Figure 2: An example of a tunnel line

For each point in the *CurveTable* the following information is given,

- *CurvePointId* (not mandatory)
- *PointDepth* (not mandatory*)*
- *X, Y, Z* coordinates
- *PointG* (amount of degrees by which the tunnel is inclined)

The *PivotPoint* defines a point in the drill plan around which the drill plan is rotated. The positive rotation direction is clockwise.

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6 Equipment Profile Wide DrillRigs Objects

This section covers comments on parameters and data types used universally throughout the DrillRigs equipment profile. These elements are defined in the file DRbaseClasses.xsd.

6.1 DRigRefType

Purpose: Provide reference data for drill rig positioning and setup as well as user information

Use in: DRPQual, DRPPlan

6.1.1 ScreenInfo

Purpose: Reinforcement by screening is typically used in underground mining, but also at construction sites together with bolting and sprayed concrete. In screening, a wire mesh is installed on the rock surface either manually or using a dedicated screening manipulator.

6.2 DRpositionType

Purpose: Provide position (or origin in coordinate system) information for the plan where the rig is going to drill

Use in: DRPPQual, DRPPlan

Please refer also to the Coordinate System / Navigation documentation for details!

6.2.1 PositionID, PositionName

These parameters are both optional. However: One of those values always has to be stated! Either the PositionID or the PositionName.

This is a mutual agreement, as it is not possible to express in the XML schema (up to now).

6.2.2 PlanIDref

If no plan has been stated, the value "VOID" shall be used to intentionally state

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that no plan reference has been available.

6.3 DRholeType

6.3.1 HoleID

Hole id code used to uniquely identify each hole in the drilled round.

This parameter links the Hole ID in a DRPQual Data Set to a specific hole in the corresponding DRPPlan Data Set.

If a new DRPQual Data Set is initialized, the value of all HoleID objects will be directly copied from the corresponding DRPplan value to setup the link between both information sets.

If more holes are drilled than specified in the plan, the further ID's are to be defined by the automation system (e.g. by increasing the number).

If no DRPPlan is used to copy the ID from the hole numbering is freely defined by the machine (e.g. in the order of hole drilling)

6.3.2 StartPoint

The start point of the hole according to the IREDES coordinate system definitions.

Use in DRPPlan: Planned start point as defined by the planning program.

Use in DRPQual: Real start point at rock contact

Initialization if DRPPlan used: Corresponding value copied from DRPPlan

Initialization if DRPPlan not used: Zero values

During work, the initialization values are replaced by the real position info after boom positioning to the hole and after finishing drilling the hole.

Start point as planned for drilling the hole. This is the theoretical start point as it was used for drilling the hole. This start point will differ from the planned point due to positioning errors or problems in adjusting the boom on the rock surface. If due to such deviations the drill rig does a recalculation of the start point, the value has to be modifies accordingly.

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6.3.3 EndPoint

The end point of the hole according. to the IREDES coordinate system definitions.

Use in DRPPlan: Planned end point as defined by the planning program.

Use in DRPQual: Real end point at rock contact

- Initialization if DRPPlan used: Corresponding value copied from DRPPlan
- Initialization if DRPPlan not used: Zero values

During work, the initialization values are replaced by the real position info after boom positioning to the hole and after finishing drilling the hole.

The end point always remains a calculated value basing on real start point, the drilling direction and the drilled length.

6.3.4 TypeOfHole

Enumeration of hole types. Valid types with their definitions are:

Use in DRPPlan: Value as defined by the planning program.

Use in DRPQual:

- Initialization if DRPPlan used: Corresponding value copied from DRPPlan, if machine supports the optional element.
- Initialization if DRPPlan not used: "Undefined" if machine supports parameter, element unused if machine does not support parameter.

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Hole type	Definition and use
Reference	
CutHole	
ReamingHole	To be drilled "two times". First normal diameter, second time reaming diameter. Drill bit stated in DRPPlan is the the bit used for the final diameter. To be reported as two holes in DRPQual: Pilot and Reaming hole separately.
EasersHole	
BoltHole	
InjectionHole	
SecondContour	
Bottom	
Contour	
Casing	
Probe	
Grout	
Others	
Undefined	Used, if parameter is used in the profile, but no definition has been made (e.g. because value has not been entered manually by the operator)

6.3.5 DRbitType

Enumeration of drill bit types.

Use in DRPPlan: Value as defined by the planning program.

Use in DRPQual:

- Initialization if DRPPlan used: Corresponding value copied from DRPPlan, if machine supports the optional element.

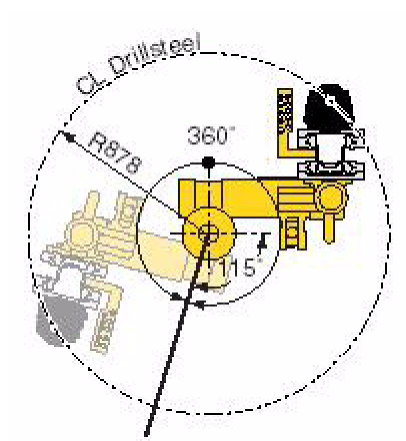
- Initialization if DRPPlan not used: "Undefined" if machine supports parameter, element unused if machine does not support parameter.

Valid type values with their definitions are:

Drill Bit Type	Definition and use
Button	
Cross	
Reaming	
Others	
Undefined	Used, if parameter is used in the profile, but no definition has been made (e.g. because value has not been entered manually by the operator)

6.3.6 RollAngle

Rolling angle of boom. Given in degrees 0-360°. Defined as 180° when the drill steel is direct above the feed. Positive rotation direction is clockwise viewed from behind the feed. See Drill Rigs Profile documentation!



Use in DRPPlan:

- Value as defined by the planning program.

Use in DRPQual:

- Initialization if DRPPlan used: Corresponding value copied from DRPPlan, if machine supports the optional element.

- Initialization if DRPPlan not used: "Undefined" if machine supports parameter, element unused if machine does not support parameter.

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7 Drill Rigs Production Performance Profile

The Drill Rigs production performance profile is produced by the machine to report on the machine's work within the expired reporting interval.

One data set consists of all information of one single reporting period as defined in the header object. A separate data set has to be created for each reporting period.

7.1 Data Set Exchange Timing

Production Performance Data Sets are exchanged on a fixed time interval basis. This time basis has to be configurable in the implementing application. Recommended time bases are e.g. per shift or per day (24hrs).

For data set initialization and finalization, the following rules apply:

1. Each reporting period starts with an "empty" profile with all parameters set to their defined initial values. Initial values other than "zero" are specified in the parameter documentation.

2. After a reporting interval expires, the complete Drill Rigs production performance data set generation is closed and the profile is written to memory media. A new reporting period is started immediately with the initialization of a new data set.

7.2 Profile Implementation

To generate an IREDES compliant production performance report, the individual implementation has to assure the following function(s):

- In case of power loss, the implementation has to assure intermediate storage of all values to prevent from data loss.

7.3 Profile Parameter Comments

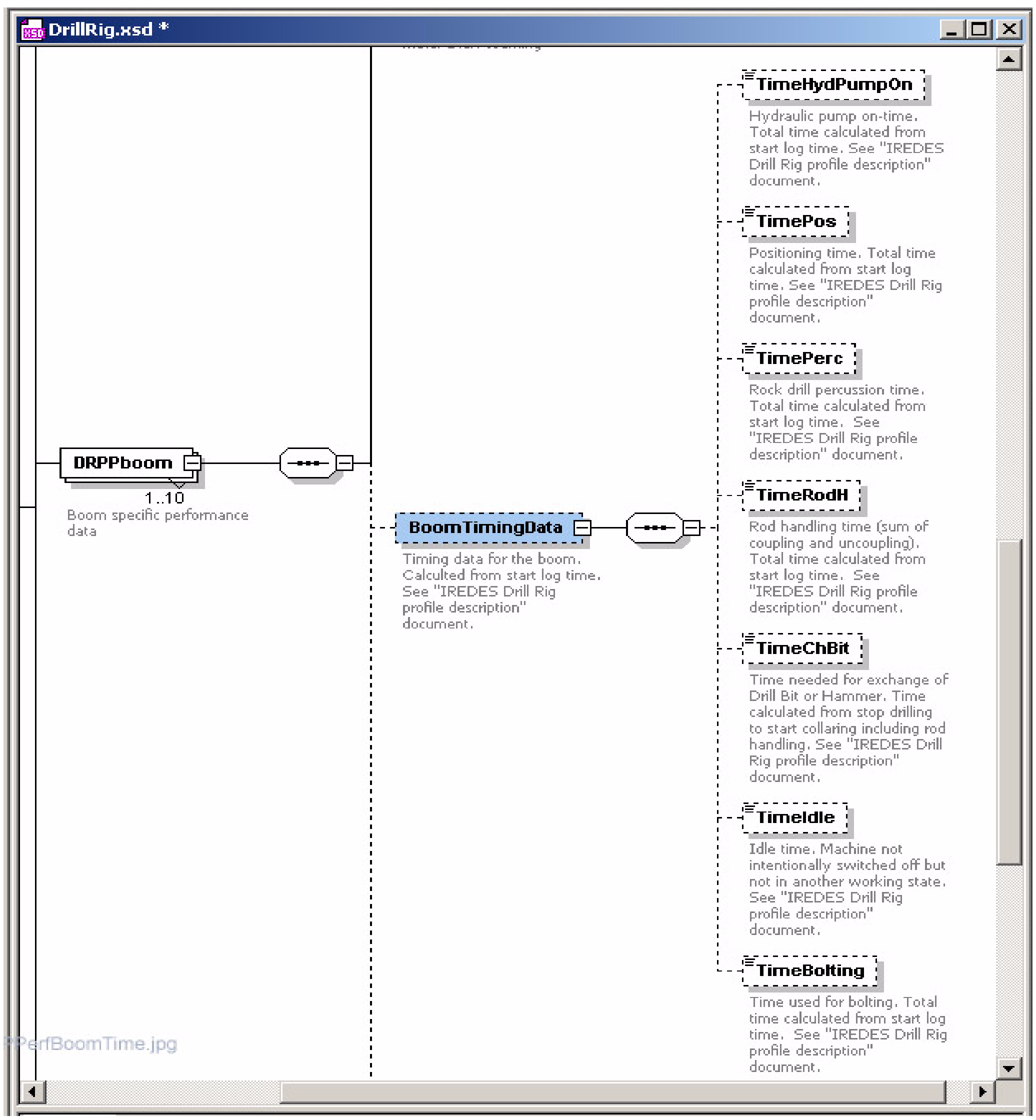
This chapter contains additional documentation and definitions on the parameter content of the Drill Rigs production performance profile. Please note: This documentation only supplements the XML schema documentation. In the case of ambiguities, the comments in the XML schema always supersede the annotations made in this document. Please note: In this documentation only parameters are mentioned that require additional documentation or illustration to explain their use. All other definitions are made in the schema file exclusively.

DRPPerf/DRPPBoom/BoomTimingData

This time reporting is entirely production performance related. Further time reporting is carried out in the Production Quality reporting (see separate chapter). In the production performance reporting different sequences are accumulated and reporting is boom related.

This reporting helps to analyze machine usage for optimization of operation and maintenance purpose.

The Time reporting per boom covers the following parameters:



All parameters cover time values accumulated during the entire reporting interval. The parameters are defined as follows:

Parameter	Start Counting	Stop Counting
TimeHydPumpOn	When main power supply of the drill boom (eg. hydraulic pump) is started, or (if there is one sinlge supply for the entire rig) if the boom’s hydraulic system is set under pressure	If the boom’s main power supply is switched off or if the boom's hydraulic system is deactivated.
TimePos	Any time the boom is moved e.g. for positioning to another hole	When movement finally stops after new position is reached and the boom is readily anchored to the hole (intermediate stops during positioning are also accumulated under TimePos
TimePerc	Percussion time including collaring time. Starts any time the percussion of the rock drill is switched on	When percussion of the rock drill is switched off.
TimeRodH	As soon as percussion stops for rod handling (adding rods or removing rods)	As soon as: • Rod coupling starts • Removal of last rod from the drill string is finished
TimeChBit	When last rod (or hammer) is in the boom position to start drill bit exchange	When new bit is readily mounted to the string in order to restart rod assembly to continue drilling
TimeIdle	Time the drill rig is usable (not in an error condition) and the	When another operation mode is selected or restarted.
TimeBolting	As soon as the boom is put into bolting mode	After bolting is finished

The relation between the timing reporting paramters is illustrated in the following

Per Hole	Per Boom	AutoMode
TimeIdle	TimeIdle	Idle
TimePos	TimePos	Positioning
TimePos	TimePos	Anchoring
TimePerc	TimePerc	Collaring
TimePerc	TimePerc	Drilling
TimeRodH	TimeRodH*	RodHandling
	TimeChBit**	ChangeBit Stop on Error
	TimeIdelError	IdleError
		Operator activity

Sum of all times reported per boom = Time Run
* Excluding percussion during rod handling. Percussion to be counted as "TimePerc"
** Time for bit change under ongoing hole drilling from stop drilling to start newly collaring

The implementation has to assure that only state transitions illustrated by errors are valid for IREDES compliant reporting.

The accumulated time of all phases has to be identical to the time reported by the TimeHydPumpOn parameter.

A reporting period starts at StartLogTime. It ends at EndLogTime. The total time elapsed between those time stamps is the duration of the reporting period, which is the total time available for reporting. How this time is used is reported by the parameters above. There is no time overlap between the times accumulated by the different parameters.

DRPPerf/DRPPBoom/NumHFAuto - NumHFErr - NumHMan

These parameters report on the rig's performance in different operation modes and how many holes the particular boom completed in full automatic mode or in manual mode.

NumHFAuto

The paramter reports the number of holes completed in full automatic operation mode during the reporting period. Full automatic modes means:

- Automatic boom positioning to the hole
- Automatic anchoring
- Automatic hole collaring
- Automatic hole drilling
- Automatic rod handling

In none of the sequences stated above, operator assistance is allowed to report a hole as "completed in Automatic mode" using the parameter NumHFAuto. If any operator action is made, the hole automatically has to be counted as NumHFMan.

NumHFErr

Number of holes started in automatic mode but terminated on error. An user action was required either to restart the automatic mode or to complete the drilling manually.

NumHFMan

Number of holes started in manual mode or completed in manual mode. Also holes partially run by automatic sequences are accounted as run in manual mode using this parameter.

7.4 Parameter Dependencies

In this section, dependencies between parameters and their content are illustrated.

DRPPBoom/LengthDrilled

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Parameter represents the accumulated length of all holes drilled during reporting period. In practice, this is the sum of all bore meters reported separately for each hole in the DRPQual sections DrilledInRock parameter.

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8 Drill Rigs Production Quality Profile

The Drill Rigs production quality profile is produced by the machine to report on the quality of work during the working sequence covered by the report.

8.1 Profile Exchange Timing

A production quality profile is not related to a fixed reporting time but to the working sequence carried out. For a drill rig a working sequence is typically characterized by "ONE round" or "one fan", which is defined as a set of holes drilled from one single machine setup position.

A Production Quality profile may be set up either as a stand alone report or as a report basing on a DRPPlan data set a machine uses for setting up the (automatic) machine's operating parameters.

If a quality report profile is related to a particular plan, it has to be assured by the implementation that one of the main sub-object of DRPQual always matches exactly one single corresponding DRPPLan object. The matching relationship is as follows:

Object in DRPPlan	Matching Object in DRPQual
DRPLrefData	ReferenceData
DrillPosPlan	PositionQuality
DrillPlan	DrillQuality

When starting preparation of a DRPQual data set, the data set content is initialized with the content from the corresponding objects available in DRPPlan.

A valid DRPQual report is finalized ("closed") and the corresponding data set is written to memory media when:

- The planned sequence is finished
- The planned sequence is finally terminated before having been entirely completed

Upon interruption of work of any reason, the quality reporting has to restart exactly at the situation before the interruption occurred.

8.2 Profile Implementation

To generate an IREDES compliant production quality report, the individual implementation has to assure the following functions:

At least one of the - all optional - sub objects has to be covered by a valid Quality Reporting Profile.

When a new plan is activated for use, all corresponding reporting parameters in the DRPQual sub-objects have to be set to their initial values. Initial values can be: zero or the corresponding planning data set's value which is initially copied over to the corresponding DRPQual parameter.

8.3 Profile Parameter Comments

This chapter contains additional comments on the parameter content of the Drill Rigs production quality profile. Please note: This documentation only supplements the XML schema in line documentation. In the case of ambiguities, the comments in the XML schema always supersede the annotations made in this document. Please note: In this documentation only parameters are mentioned that require additional documentation or illustration to explain their use.

8.3.1 DRPQual/HoleQualityData

Reports the Drill quality separately for each hole drilled from the current setup position.

8.3.2 DRPQual/BoomID

From left up-down to right up-down seen from the cabin including basket booms and others

8.3.3 DRPPQual/HoleQualityData/Jamming

If drifter is automatically drawn back during ongoing drilling operation a jamming event has to be registered.

8.3.4 DRPQual/HoleQualityData/HoleTimingData

The information reported in this section covers all single hole related timing information to be used for analysis of a single hole's drill procedure.

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A hole drilling job starts at StartHoleTime. It ends at EndHoleTime. The total time elapsed between those time stamps is the duration used for hole drilling, waiting time etc. In most cases users wish to know details about how this time was used. This is explained by the detail reporting parameters. All of these parameters cover a specific part of the total duration.

The accumulated time of all phases is part of the time elapsed between HoleStartTime and HoleEndTime. If it is less than this value, the remaining difference is the time the machine was intentionally switched off or unavailable due to external reasons not caused by any drilling procedure related errors (which are reported as TimeStop).

Parameter	Start Counting	Stop Counting
TimePos	Start boom movement for positioning to the new hole.	Position reached and boom anchored at drilling position
TimeCollaring	End of TimePos to start with hole collaring	When collaring mode is finished, identified by starting full percussion pressure
TimePerc	Percussion time including collaring time. Starts any time the percussion of the rock drill is switched on	When percussion of the rock drill is switched off.
TimeRodH	As soon as percussion stops for rod handling (adding rods or removing rods)	As soon as: • Rod coupling starts • Removal of last rod from the drill string is finished
TimeCoupling	when rod is moved into drill center	rod is coupled to the drill string and percussion restarts (continue with accumulation of TimePerc)
TimeUncoupling	when drill string is in uncoupling position and grippers start movement in order to fasten string for rod breaking	when drill rod is uncoupled from the string. Rod handling for removal of rod is ready to start. Time counting continues with TimeRodH
TimeChBit	When last rod (or hammer) is in the boom position to start drill bit exchange	When new bit is readily mounted to the string in order to restart rod assembly to continue drilling
TimeStop	Time the drill rig is stopped due to errors in the drilling process. These errors result from machine stops due to internal, procedural reasons. NOT due to external reasons as e.g. lack of resources (water, electricity,...)	When another operation mode is selected or restarted.

8.3.5 DRPQual/HoleQualityData/DrillSequ

The drilling boom's sequence number of the hole.

If no changes are made during drilling operation, this number is identical to the number stated in DRPPlan/DrillPlan/BoomSequ/Sequence/SequNum.

The parameter is not initialized with the value from the DRPPlan data set. It is always filled in first, if one boom in reality starts anchoring to the hole.

9 DRContour Definition Profile

Different from schemes explained in the previous sections, DRContour definition profile is defined for describing the contour shape of tunnels. With the data regulated by the contour schema, computer systems can simulate 3D view of drilled tunnels without further interpretation. This section gives an explanation to the IREDES contour definition.

An IREDES contour consists of an ordered list of node points forming a closed path. The coordinates of the last point should be equal to those of the first so that the path is closed. If not, an extra point should be inserted by the system. In the rest of this chapter it is assumed that this condition is fulfilled.

9.1 Technical Terms

9.1.1 Curved Lines

It is sometime useful to be able to model a curved line. A curved line between two node points can be achieved in two different ways:

9.1.2 Inverted Radius

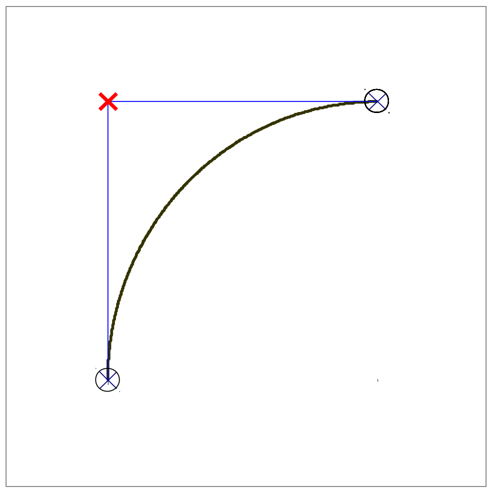
Each node point has an element called *Inverted Radius*. This value represents the inverse of the radius of the curve between the node point and the node point following it. A value of zero indicates a straight line, intuitively interpreted as an infinite radius.

9.1.3 Control Points

Control points enable us to model more general curved lines, namely those expressible by Non Uniform Rational B-Splines, NURBS in the following. This includes circular and elliptical curves. This means that a contour using the inverted radius format can med translated in to control point format, but not vice-versa.

Control points are inserted between the node points in the contour table. The contour line does not necessarily pass through a control point, but the contour line bends towards the control point. Associated with the control point is a weight that defines how much the control point attracts curve.

When a control point is placed adjacent to an ordinary node point in the contour table the tangent of the contour line in the node point is directed towards the control point.



The first and last point in the contour table must be of type node.

The use of *Inverted Radius* and the use of control points should not be mixed in the same contour definition.

9.2 Interpretation of Contours Using Control Points

When calculating the exact contour from an IREDES contour definition containing control points, the contour table is first translated into a 2nd degree NURBS-curve. A full description of NURBS-curves is not within the scoop of this document, but a short overview is given here.

9.2.1 NURBS Overview

A NURBS-curve is defined by a list of control points defining a control polygon consisting of straight lines between the control points. A 1st degree NURBS-curve coincides with the control polygon. A 2nd degree NURBS-curve is a smooth curve that touches the control polygon somewhere between each pair of consecutive control points. IREDES contours are modeled using 2nd degree NURBS-curves.

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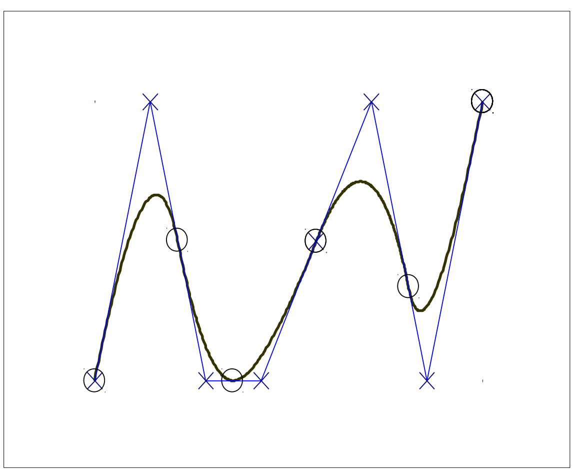
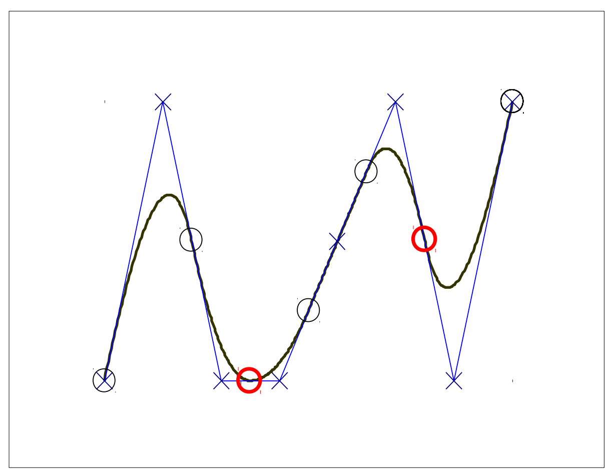
Sharp corners can be represented by placing two consecutive control points on the same coordinate. This is how an ordinary node point in the contour modeled using NURBS.

The coordinate of a point somewhere along a NURBS-curve is given by a function *C(u)*. The function is defined for an interval of *u* which is determined by the knot vector *K*. The knot vector is a sequence of parameter values that decides which control points influence the curve for a specific parameter value. The number of knots is equal to the degree of the curve plus the number of control points plus one. The following examples have 8 control points, marked with crosses, and thus a knot vector of length 11. The blue lines designate the control polygons. The knot vector of the left curve is
K = <0, 0, 0, 1, 2, 3, 3, 4, 5, 5, 5> and the knot vector of the right curve is *K = <0, 0, 0, 1, 2, 3, 4, 5, 6, 6, 6>*. Thus, the left curve is defined for parameters between 0 and 5, whereas the right curve is defined for parameters 0 to 6. The small circles mark the points where the curve touches the control polygon. Parameter values between two knot values define the curve between two such circles. This is called a knot span. When a knot value is repeated a span of zero length is created and two circles are moved together to the control point in between. In this way it is possible to force the curve to touch the control polygon on a control point. See the left curve.





The NURBS control points also have a weight associated which influences how much the control point influence the curve. Using weighted control points makes it possible to represent circles and ellipses. An arc with an angle span of less than 180°can be modeled using three control points where the middle control points has a weight $w = \frac{1+\cos^2\beta - \sin^2\beta - 2\cos\beta}{2\cos\beta - 2}$, where β refers to the half the angle span of the arc.

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Goethestr. 52
D-49549 Ladbergen
Germany
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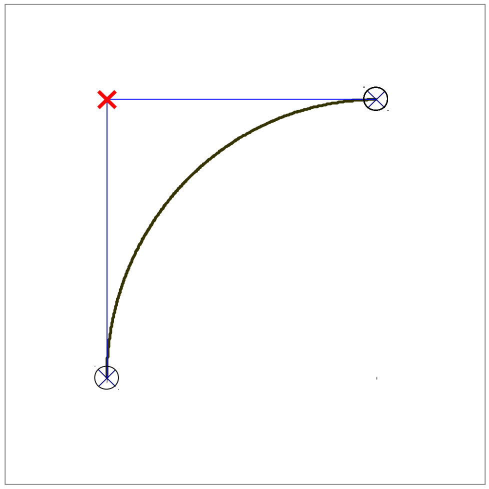
An arc with a 90° angle span has a control point with the weight $\sqrt{\frac{1}{2}}$.



9.2.2 Translation Procedure

In order to generate the control polygon and knot vector for the NURBS-curve given an IREDES contour follow the following procedure:

Assume the contour table holds *n* elements each element has the properties:

- *Type:* node or control.
- *Weight:* NURBS control point weight (only valid for points of type control).
- *Coordinates:* The coordinates of the point.

For each point, p_i, in the contour table, look up a row in the table below based on the index *i* and the type of the current and previous point. The third column describes how to generate the knot vector. K_{last} represents the current last parameter value in the knot vector so far. The fourth column states how many times the point should be repeated in the NURBS control polygon. Remember that duplicated is needed to model sharp edges.

i	Type(p_i)	Type(p_{i-1})	Generation of knot vector (K)	Multiplicity(p_i)
i=1	node	n/a	K = append(K, <0, 0, 0>)	1
1<i<n	control	node or control	a = K_{last}, K = append(K, <a+1>)	1
1<i<n-1	node	control	a = K_{last}, K = append(K, <a>)	1
1<i<n-1	node	node	a = K_{last}, K = append(K, <a+1, a+1>)	2
i=n-1	node	node	a = K_{last}, K = append(K, <a+1, a+2>)	2
i=n-1	node	control	a = K_{last}, K = append(K, <a, a+1>)	2
i=n	node	node or control	a = K_{last}, K = append(K, <a, a>)	1

9.2.3 Example

Given the following contour definition:

Index	X	Y	Type	Weight
1	0	0	Node	1
2	0	1	Node	1
3	0	2	Control	1
4	1.5	1.8	Node	1
5	3	1.6	Control	1
6	3	1	Node	1
7	3	0	Node	1
8	0	0	Node	1

1. Looking up the first point in translation table tells us to append <0, 0, 0> to the initially empty knot vector. *K = <0, 0, 0>*.

2. The second point gives us the instruction $a = K_{last}$, K = append(K, $<a+1, a+1>$), i.e.,
   $a = 0$, K = append(K, $<a+1, a+1>$) = <0, 0, 0, 1, 1>. The multiplicity of 2 tells us to duplicate the point in the control polygon.

3. Next point is of type *control* and results in
   $a = 1$, K = append(K, $<a+1>$) = <0, 0, 0, 1, 1, 2>

4. When there are no more elements to process we have a knot vector *K = <0, 0, 0, 1, 1, 2, 2, 3, 3, 4, 5, 5, 5>* and a NURBS control polygon with the following points:

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D-49549 Ladbergen
Germany
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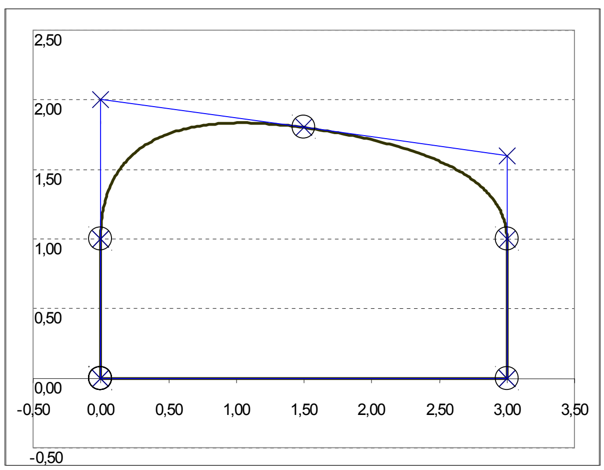
Original Index	x	y	weight
1	0	0	1
2	0	1	1
2	0	1	1
3	0	2	1
4	1.5	1.8	1
5	3	1,6	1
6	3	1	1
7	3	0	1
7	3	0	1
8	0	0	1

The result contour is shown in the figure below:



Appendix 1: Time and Duration Reporting Drill Rig Equipment Profile

Time Reporting in DRPQual/HoleQualityData/	Operation Sequence	**Parameter** in DRPQual/HoleQualityData/HoleTimingData	**Accumulation** in DRPQual/HoleQualityData/HoleTimingData / TimePerc	**Accumulation** in DRPQual/HoleQualityData/HoleTimingData/ TimeDrill	**Parameter** in DRPPboom/ BoomTimingData	**Accumulation** in DRPPerf/DRPPboom/ BoomTimingData/ HydPump On	**Accumulation** in DRPPerf/DRPPboom /BoomTimingData/ TimePerc
	Positioning	TimePos	-	-	TimePos	Yes	
	Anchoring		-	-		Yes	
StartHoleTime							
	Collaring	TimeCollaring	Yes	Yes		Yes	Yes
	Drilling		Yes	Yes		Yes	Yes
	Jamming		Yes ?	Yes		Yes	Yes ?
	Rod Handling	TimeRodH	-	Yes	TimeRodH	Yes	
	Rod Coupling	TimeCoupling	-	Yes	?TimeRodH?	Yes	
	Rod Uncoupling	TimeUncoupling	-	Yes	?TimeRodH?	Yes	
	Rig stopped	TimeStop				until timeout	
EndHoleTime							
	Change Bit	TimeChBit		-	TimeChBit	Yes	
					TimeIdle	if pump on	
					TimeBolting		