Research

Sand Control Completion Failures: Can We Talk the Same Language?

Abraham Faga[1*§], Brian T. Wagg[*], and Howard L. McKinzie[*]

Address: C-FER Technologies, 200 Karl Clark Road, Edmonton, T6N 1H2, Alberta, Canada

Email addresses: Abraham Faga - afaga@slb.com: Brian T. Wagg - b.wagg@cfertech.com: Howard L. McKinzie - mckinziehl@aol.com

*These authors contributed equally to this work

§Corresponding author

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Abstract

Several operators have recently launched a new industry-wide initiative on sand control reliability. The aim of the initiative is to gain a better understanding of Sand Control Completion (SCC) systems and equipment performance and reliability in a variety of applications. It focuses on assisting the industry to improve SCC performance and service life through sharing of failure information, operational practices, and other pertinent data. One of the key challenges in this effort is how to achieve consistency in the data collected by several operators.

This paper presents an approach to establish consistent practices for collecting, tracking and sharing SCC reliability and failure information. The approach is based on two key elements: (1) a general and common data set; and (2) a standard nomenclature for coding SCC failure information. The general data set contains basic information on operating conditions, SCC systems and equipment, and the observed failures. While this data set is not overly detailed, in that the information is typically already collected by most operators and relatively easy to obtain, it is comprehensive enough so that meaningful analyses can be performed. The nomenclature standard builds on the International Standard IS0 14224 that stipulates broad definitions and failure attributes related to collection and exchange of reliability and maintenance data for equipment used in the petroleum industry.

The paper also provides a review of past industry efforts to track SCC system reliability in terms of the types of data collected, and the main types of analyses performed with the data. Comments are included on difficult issues such as how to define failure of a sand control completion.

It is hoped that the paper will encourage discussion on the topic, and help the industry share SCC reliability and failure data in a more consistent manner. The ultimate goals of this work are to assist the industry in improving SCC service life; improving the basis for selecting sand control systems and equipment; and better realizing the full potential of SCC technologies.

Introduction

Operators face a major challenge when trying to determine which sand control completion method to choose to provide the best economics over the life of a field. This is especially true because of the increasing cost and complexity of well designs required for hotter and deeper wells. There are now several new options for sand control available with which the industry has

[1] Now with Schlumberger, Algeria

very little experience on which to base these decisions. Operators would like to: have a better understanding of the factors affecting SCC performance in a wide range of applications; be less reliant on a few highly experienced staff for effective SCC decision making; and be able to very quickly climb the learning curve associated with new SCC methods, in both new and existing applications. Unfortunately, while there are many competing forms of sand control performance information, both from service providers and operators, a direct, relatively unbiased comparison between the reliability of sand control types, under a broad range of operating conditions, has been hard to find.

As a result, many operators have identified that having a failure tracking system in place is key to reducing failure rates of SCC systems. Problems with system design, equipment specification, manufacturing, installation, and day-to-day operation could be identified and corrected, contributing to increased service lives, lower operating costs and increased profits. Accordingly, some operators and vendors have set up database systems to track SCC performance, service life and failure information.

Through discussions and communications with numerous operators it is apparent that these efforts have been rewarded with limited success. A review of several tracking systems revealed that they seldom integrate both failure information and a comprehensive set of influential factors, (e.g., operating conditions, and detailed equipment specifications). This limits the ability to understand the influence of several factors on SCC reliability. Other tracking systems also tend to lack sufficient variety in applications to assess SCC service life under different conditions.

These drawbacks impair one's ability to develop general relationships or correlations between types and frequency of failures, field/well conditions and system component or equipment specifications. Without such correlations, service life predictions that are fed into a feasibility study are little more than educated guesses, adding significant uncertainty to a project's economic result. Furthermore, investigating the impact that a change in current practices might make on service life (i.e., conducting "what if" analyses) is also very difficult. For example, how would the service life be affected if we change installation methods, completion fluids or our equipment specification (e.g., by selecting different screens)? Generally, the information required for these types of assessments can not be readily obtained from existing tracking systems. As such, there is often little basis for making such critical decisions. Often, the only option is a "trial-and-error" approach, again with uncertain economic results.

Several operators have recently recognized that in order to get a better understanding of the factors affecting SCC service life, and reduce the uncertainty in predicting service life for new applications, one needs access to reliability information derived from as large and consistent a data set as possible. They have also recognized that such a large data set of SCC reliability data can only be achieved by pooling and sharing their individual data sets through a joint industry initiative.

Early on, the companies involved acknowledged that there were many challenges in such an effort, one of them being how to achieve consistency in the data collected by several operators scattered around the globe. This paper describes a common set of guidelines developed through the first phase of an industry initiative to achieve such consistency. It includes two key elements: a general data set of quantitative and qualitative parameters, and a standard nomenclature for coding SCC failure information.

Brief Review of Existing Tracking Systems

Despite the recent increase in discussions about sand control reliability, most of the information that can be found in existing literature relates to sand control performance rather than reliability. The few reported sand control reliability studies often have widely different objectives.

In the early 80's a number of oil companies operating in the North and the Adriatic Seas started a collaborative project to survey the reliability of important well equipment under 'real life' operational conditions. This study [1] led to the development of a database of completion equipment and reliability information (Wellmaster). The database covers a wide range of completion tubing accessories and other completion equipment including gravel pack screens. Hother and Hebert [2] presented a Failure Modes Effects and Criticalities Analysis (FMECA) of sand control completion technology aimed at identifying and ranking critical issues and potential improvements. George King [3] presented a paper discussing an inter- and intra-company cooperation that led to the development of an Excel™ database of sand control reliability/failure information on over 2000 wells. The database contains information regarding general reliability and has production and reservoir data from many wells including: cumulative production; maximum rates; drawdown; skins; pay deviation; screen length; pay interval sorting; fines content; depth; and length. Several operators have also implemented in-house reliability tracking systems.

Most of the literature addresses well or field specific performance issues (discussed in relation to skin, productivity index, flow efficiency, etc.) often with some comparisons of performance among a few sand control methods. From the literature, and through discussions and communications with numerous operators, it has become apparent that most of the existing databases and tracking systems do not include much of the data (such as drilling data, reservoir characteristics, operational/installation data, and production data) that would provide a better understanding of the factors affecting SCC reliability in a comprehensive tracking system.

Data Quality

Confidence in the data collected for reliability studies, and hence any analysis, is strongly dependent on the quality of the data collected [4]. However, ensuring that good quality data is collected is also one of the main challenges in sharing failure data through a common, industry-wide tracking system [5]. This was of particular concern in this case because of the potentially large data sets that would be required to account for influential factors from: well and completion design; reservoir characteristics; equipment and fluids selection; drilling and completion operations; production and servicing history, etc.

In this initiative, data consistency is promoted by defining both the parameters (quantitative and qualitative) that this common data set should consist of, as well as how the SCC failures would be described.

A common data set is essential for establishing meaningful relationships among the types of failures observed; the equipment used; the produced fluids; the operating practices; and other factors. Its primary role is to enable operators to collect a common set of parameters. To forestall the potential difficulty of collecting and handling an excessively large data set, this common data set is limited to parameters that: (1) will have immediate or potential use in the analysis; and (2) are readily available from the existing tracking systems, databases and field records of most operators. At the same time, the data set must be comprehensive enough so that meaningful analyses can be performed. Hence, defining the list of parameters is challenging because it must satisfy these two, often-opposing, objectives.

A common terminology and format for classifying the failures is also necessary; it ensures that all users have similar interpretations of a failure event, and that data collection and analyses are performed in a consistent manner. Establishing a common set of terminologies is a challenge however, because failures are generally described in qualitative terms, strongly influenced by the experience and background of the observer. Interpretation of the failure tracking guidelines has accounted for the largest proportion of data quality problems in other similar failure data collection efforts [6].

Common Data Set

The Common Data Set for the SCC failure tracking system currently contains a total of 400 parameters in the following categories:

- Field/Well/Fluid/Reservoir data
- Operational drilling/installation data
    - Such as drill-in/ completion/ workover fluids, wellbore cleanup Preparation (i.e., mud displacement), installation techniques etc.
- Service life information
    - Install, Start, Stop, final suspension dates, etc.
- Production and Operating Information
    - Producing rates, gas oil ratio, Wellhead Pressure and Temperature, etc.
- Equipment data
    - Model, dimensions, materials, etc.
    - Manufacturer “Catalogue” information
- Failure information
    - Mode, Item(s), Descriptor(s), Cause, Effects, and associated comments

A “minimum” data set, which is a subset of the Common Data Set, defines a smaller minimum list of parameters that serves as a measure of the level of completeness of a record. The Common Data Set is a more comprehensive data set that indicates the information a record should have to enable investigation of more potential ‘influential factors’ and generation of additional results and conclusions. Minimum Data Sets differ depending on the SCC system type (e.g. Frac Pack system, Sand Consolidation system, etc.). Some of the main differences between the data sets are in the equipment/system component data and operational/installation practices. The Minimum Data Sets are limited to parameters that are readily available to most operators and yet are sufficiently detailed to allow a reasonable level of analysis. The Minimum Data Sets currently contain between 149 and 190 parameters depending on the SCC system type.

SCC Failure Nomenclature Standard

SCC failure information is currently classified and recorded in a number of very different formats and codes. While operators and vendors have standard sets of codes used in their internal tracking systems, these "standards" are not common and widely accepted across the industry.

The SCC Failure Nomenclature Standard attempts to establish a consistent terminology and structure for classifying, recording and storing the various attributes of an SCC failure. It is primarily based on one key industry guideline, the ISO 14224 [4], "Petroleum and Natural Gas Industries – Collection and Exchange of Reliability and Maintenance Data for Equipment". Unfortunately, there is currently no common and widely accepted "standard" across the industry for the nomenclature for components, parts of sand control systems and equipment. It is partly in response to this that the International Standards Organization (ISO) has formed a task group to develop a standard nomenclature for sand exclusion systems (ISO 17824) [7].

Failure Definitions. In line with ISO 14224, the following failure definitions are used:

- *Failure:* the termination of the ability of an item to perform a required function;
- *Failure Mode:* the observed manner of failure;
- *Failed Item:* any part, component, device, subsystem, functional unit, equipment or system that can be individually considered;
- *Failure Descriptor:* the apparent, observed cause of failure (of a Failed Item);
- *Failure Cause:* the circumstances during design, manufacture or use which led to a failure; and
- *Failure Effects:* the consequences of a failure mode on the operation, function, or status of an item.

Failure. Failure occurs when an item has lost its ability to perform a Required Function. (Note that reliability is defined as the probability of an item to perform a required function, under given conditions, for a given time interval). Implicit in this definition is the recognition that the Required Functions have been clearly established, which involves identifying both the functions necessary for providing a given service and the desired level of performance for each function. The desired level of performance defines the boundary between satisfactory and unsatisfactory operating conditions; it will generally be different between operations, applications and even within the same application as conditions change with time.

The Boundary and Functional Block Diagrams for an Internal Gravel Pack (IGP) system indicating their main components and corresponding Required Functions are shown in **Figs. 1** and **2**, respectively. Similar functional block diagrams have been developed for other SCC System configurations.

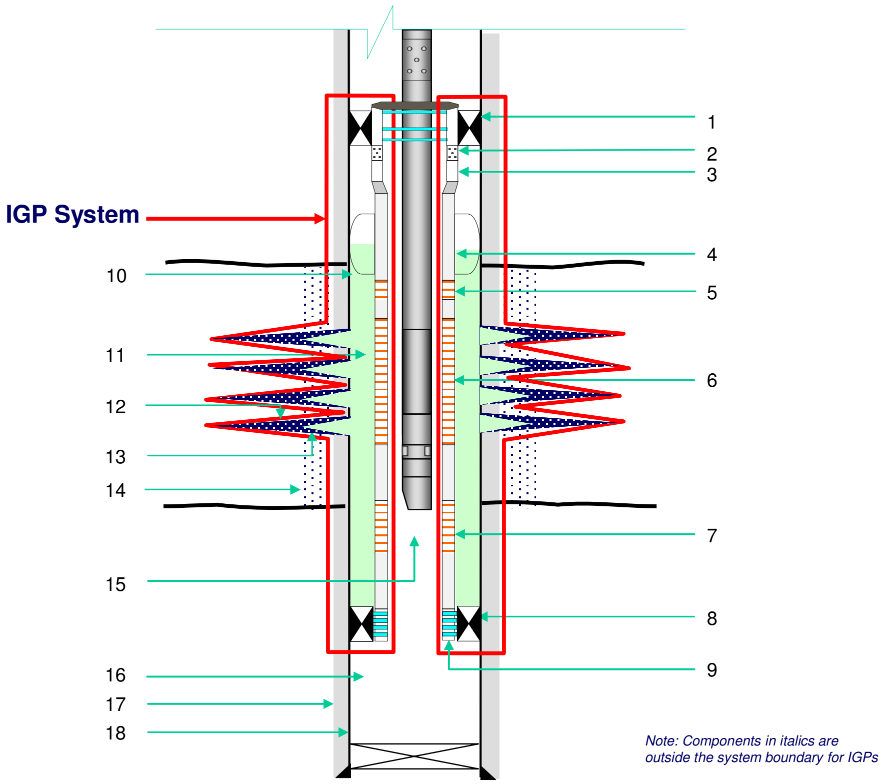
In general, the primary Required Function of an SCC System is to minimize production of load bearing reservoir sand while allowing hydrocarbon production at/or above a target rate. However, prevention of sand movement is generally incompatible with unrestricted flow of fluids; consequently, some degree of compromise between this objective and sand control is often required. Practical limits for tolerable sand production are set by the well operator based on economic, technical, operational, safety and environmental considerations.

Other functions such as permitting mechanical/hydraulic through-bore access may also be considered "required" depending on the SCC configuration and application.

It is important that all of the Required Functions (and desired levels of performance) be clearly defined and understood to allow operational personnel to identify Failures.

It is recognized that an SCC System failure may or may not be a complete failure (i.e. the failure might not have caused the complete lack of a required function). For instance, an SCC System that has been choked back due to excessive sand production may not be considered a complete failure if the well is able to produce at an acceptable rate until the failed component is repaired. In addition, an SCC System may degrade with respect to its Required Functions in a gradual manner or it may fail suddenly (partially or completely). The nomenclature standard allows for these scenarios to be accounted for.

Failure Mode. The Failure Mode is the main evidence of the downhole equipment failure. It is usually a result of an abnormal operating condition identified by the operator through surface instruments, a monitoring/control system, or a well test. A Failure Mode can be established once the operator has determined that the downhole equipment has "Failed". Usually, at this point, the interval completed with the SCC System may be suspended to inspect and repair the faulty SCC component(s). Table 1 lists several possible Failure Modes for an SCC installation. Since SCC systems may be suspended for reasons other than an SCC equipment or component failure, there may be "reasons for suspension" other than the Failure Modes indicated in Table 1.



Item	Description
1	GP Packer
2	GP Extension with sliding sleeve
3	Shear out safety sub
4	Blank Liner
5	Upper tell-tale
6	**Screen Assembly**
7	Lower Tell-tale
8	Sump Packer
9	Seal Assembly
10	Centralizer
11	Gravel Pack
12	Crushed zone
13	Perforations
14	Damaged formation
15	*Completion Tubing and Accessories*
16	Sump
17	Cement
18	Casing

Fig. 1 Internal Gravel Pack System Boundary

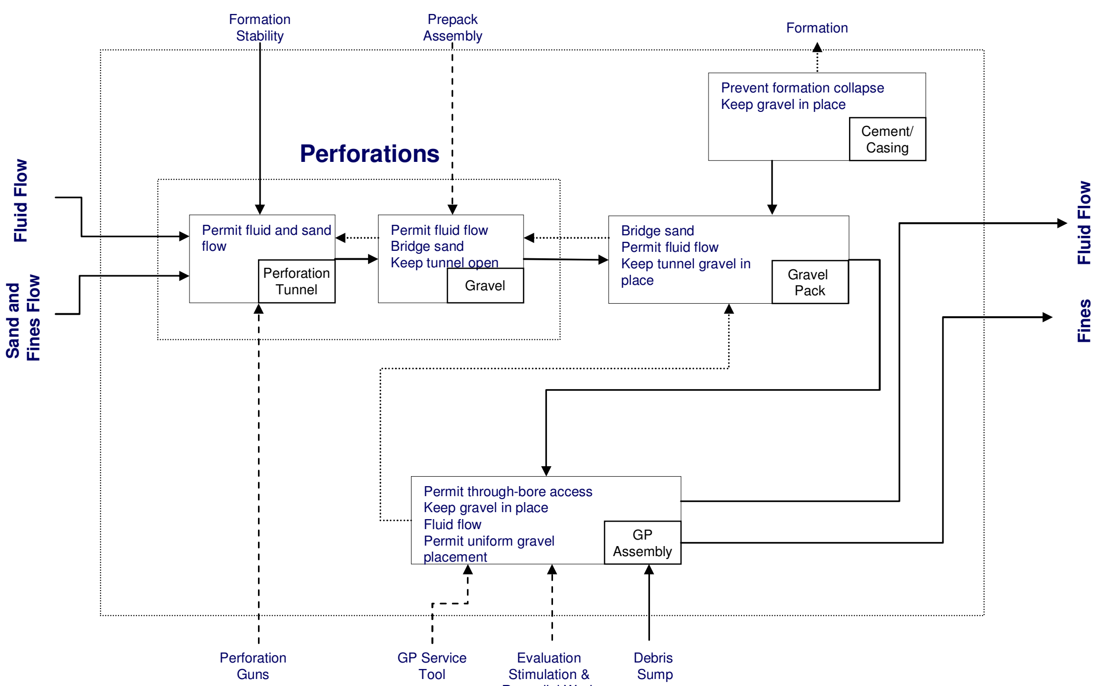


Fig. 2 Internal Gravel Pack System Functional Block Diagram

Table 1 Failure Modes

General Failure Mode	Specific Failure Mode	Comments
Sand Production	High sand production	Observed at surface Observed via sand monitoring devices
Productivity	Low productivity	Production lower than target rate As per well test
Access	Impaired access	As per indications during planned interventions
Other	Other	
Unknown	Unknown	

Table 2 Failed Items

IGP Components				
Failed Item	**Perforations**	**GP Assembly**	**Gravel Pack**	**Casing/ Cement**
Associated Parts/Sub-Components	• Perforation Tunnel • Gravel • Crushed Zone	• GP Packer • GP Extension sliding sleeve • Shear out safety sub • Blank Liner • Upper tell-tale • Screen Assembly • Lower Tell-tale • Sump Packer • Seal Assembly • Centralizers	• Gravel Pack	• Cement • Casing

Failed Items. As per the definition of Failure above, a Failed Item (i.e., either a main component, such as a gravel pack assembly, or part of a component, such as a screen or packer) has lost its ability to perform a certain function. In some cases, the item has been tested or inspected in situ and has failed to meet the required specifications. Table 2 lists the main downhole components and many associated parts for an IGP system, as an example, that may be identified as Failed Items.

Failure Descriptors. A Failure Descriptor is an apparent or observed cause of failure of Failed Items. These observations are usually made during the SCC downhole equipment inspection. They are the main symptoms, or perceptible signs of damage to the SCC components or their parts, that may have resulted in the system failure. Table 3 lists possible Failure Descriptors for the main SCC components and associated parts. Note that some Failure Descriptors may not be applicable to some parts (e.g. a packer may not be “burned”). Where possible, Primary and Secondary Failure Descriptor are assigned to each failed item to describe the most prominent and secondary features, respectively.

Failure Cause. The Failure Cause is associated with the circumstances during design, manufacture or use, which have led to a failure. As noted in the ISO 14224, identification of the Failure Cause normally "requires some in-depth investigation, to uncover the underlying human or organizational factors that were influential in the failure of the system, component or part, and the technical explanation and sequence of events leading up to the observed mode, item and descriptors of the failure". Table 4 lists several possible Failure Causes for an SCC system. It is recognized that it can be very difficult to uncover root causes for SCC systems because SCC equipment and components are seldom pulled to surface for investigation and in situ investigations are seldom performed. Therefore, the SCC failure tracking system is configured to capture key word searchable failure related comments (such as "installation failure", "operation failure" etc.) to provide perspective regarding each failure record. Notwithstanding, Failure Causes can be specified whenever it is feasible.

Table 3 Failure Descriptors

Failure Descriptors		**Comments**
• Bent • Broken/Fractured • Buckled • Collapsed • Cracked • Damaged • Dented • Disconnected • Failed Pressure Test • Failed Vibration Test • Faulty Clearance or Alignment • Leaking	• Loose/Spinning • Low efficiency • Low head • Punctured • Burst/Ruptured • Scratched • Squashed/Flattened • Stuck • Torn • Twisted • Vibration marks/Rub marks • Unbalanced/Vibration	Usually the result of force, pressure, or torque
• Brittle • Burned • Corroded • Discolored • Eroded / Pressure Washed	• Hardened • Melted • Overheated • Swollen • Worn	Usually related to the physical characteristics of the material such as colour, hardness, finish, etc.
• Contaminated • Plugged • Coated - External • Coated - Internal	• Stuck closed • Stuck open	Failures caused by external events or substances, e.g. paraffin, asphaltene, scale, sand, iron sulfide
• Missing • Maintenance Discard	• Other	

Table 4 Failure Causes

General Failure Cause	Specific Failure Cause	Comments
Fabrication Related	• Manufacturing problem	• Damage during manufacture
Design Related	• Equipment selection – size selection • Equipment selection – fluid design • Defective design • Operating procedure	• Inadequate size (Gravel size is too large, Blank liner is too short, Screen OD is too large, screen slots tool large/small) • Poor placement fluid design • Excessive pump rate during packing • Damage during handling or storage • Packer / seal unit not set (or sealing) • Corroded screens
Installation Related	• Installation – field service	• Damage during installation • Improper installation
Operation Related	• Production strategy	• Increased volume of fines due to pore pressure decline
Reservoir or fluids related	• Reservoir conditions	• Unexpected reservoir conditions (grain-size, permeability, high volume of fines, etc) leading to (1) selection of larger gravel size than optimum (2) early screen out due to high injectivity (3) screen erosion by fines

Failure Effects. Failure Effects are the consequences of a Failure Mode on the operation, function, or status of an item. One of the following Failure Effects (assessed at the SCC system level) would be reported when a failure is deemed to have occurred:

- Curtailed production – production rate is reduced for that specific completion interval.
- Minor intervention – typically through-tubing workover operations, e.g., using coiled tubing, snubbing or slickline equipment, conducted to complete treatments or well service activities that avoid a full workover where the tubing is removed. The operation should save time and expense compared to a full workover within the operators field experience.
- Major intervention – a full workover, e.g., any well treatment or work that requires the production tubing to be pulled (including through tubing recompletions), typically requiring the services of a workover rig.

Plug and abandon – the specific completion interval is abandoned.

Applying the Nomenclature Standard. Most of the time, in the existing industry systems, the various components of a failure record or event (i.e., mode, item, descriptors and cause) are erroneously lumped into one or two failure classes; for instance "reason for suspension: low productivity due to plugging of the SAS screens with fines". In line with the proposed Standard, this failure record would be described as the following: Failed Item: screens; Failure Mode: low productivity; Failure Descriptors: plugged; and Failure Cause: reservoir or fluids (assuming the failure investigation reveals these as the root causes).

Conclusions and Recommendations

1. Although there are many competing forms of sand control performance information, both from service providers and operators, a direct, unbiased comparison between the reliability of sand control types, under a broad range of operating conditions has been hard to find;
2. Several operators have now implemented in-house reliability tracking systems but are yet to report any major successes. Only a few industry-led implementations of SCC reliability databases and other sand control reliability studies have been reported in literature. These systems vary widely in scope and content; seldom integrate both failure information and a comprehensive set of influential factors; tend to be field and/or operation specific; and typically lack sufficient breadth to assess SCC service life under different conditions. As a result, it is often difficult to develop predictions of SCC failure rates based on field/well conditions and equipment specifications, thus adding significant uncertainty to a project's economic result;

3. To reduce the uncertainty in predicting service life, reliability information should be derived from as large and consistent a data population as possible. One of the main challenges facing this effort however, is how to achieve consistency in the wide range of data currently being tracked by operators and vendors. Two key guidelines were presented to assist in this task: a common data set of quantitative and qualitative parameters; and a standard nomenclature for coding SCC failure information;
4. The common data set must be limited to parameters that will have immediate or potential use in the reliability analysis, while being comprehensive enough to enable meaningful analyses;
5. An SCC system failure can be described by a failure mode, failed item(s), failure descriptor(s), failure cause and failure effects, consistent with the SCC Failure Nomenclature Standard and ISO 14224.

Nomenclature

ISO =International Organization for Standardization
IGP = Internal Gravel Pack
FMECA = Failure Modes Effects and Criticalities Analysis
SCC = Sand Control Completion
SAS = Stand Alone Screens

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