# Selection of Centralizers for Primary Cementing Operations

API TECHNICAL REPORT 10TR4
FIRST EDITION, MAY 2008

# Selection of Centralizers for Primary Cementing Operations

Upstream Department

API TECHNICAL REPORT 10TR4
FIRST EDITION, MAY 2008

## Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

## Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, D.C. 20005, standards@api.org.

# Contents

Page



Tables

# Selection of Centralizers for Primary Cementing Operations

## Acknowledgment

API Subcommittee 10 acknowledges the assistance from industry manufacturers in compiling this document. Many of them provided photos of their centralizers, and those illustrations are included in this document.

## 1 Introduction

The proper centralization of the casing for primary cementing has long been a critical step in quality cementing. Lack of proper centralization can lead to severe cementing problems, including lack of zonal isolation and improper casing support. The goal of this document is to provide the petroleum industry with information for three types of centralizers, their selection and application, and their advantages and limitations.

## 2 Benefits of Centralization

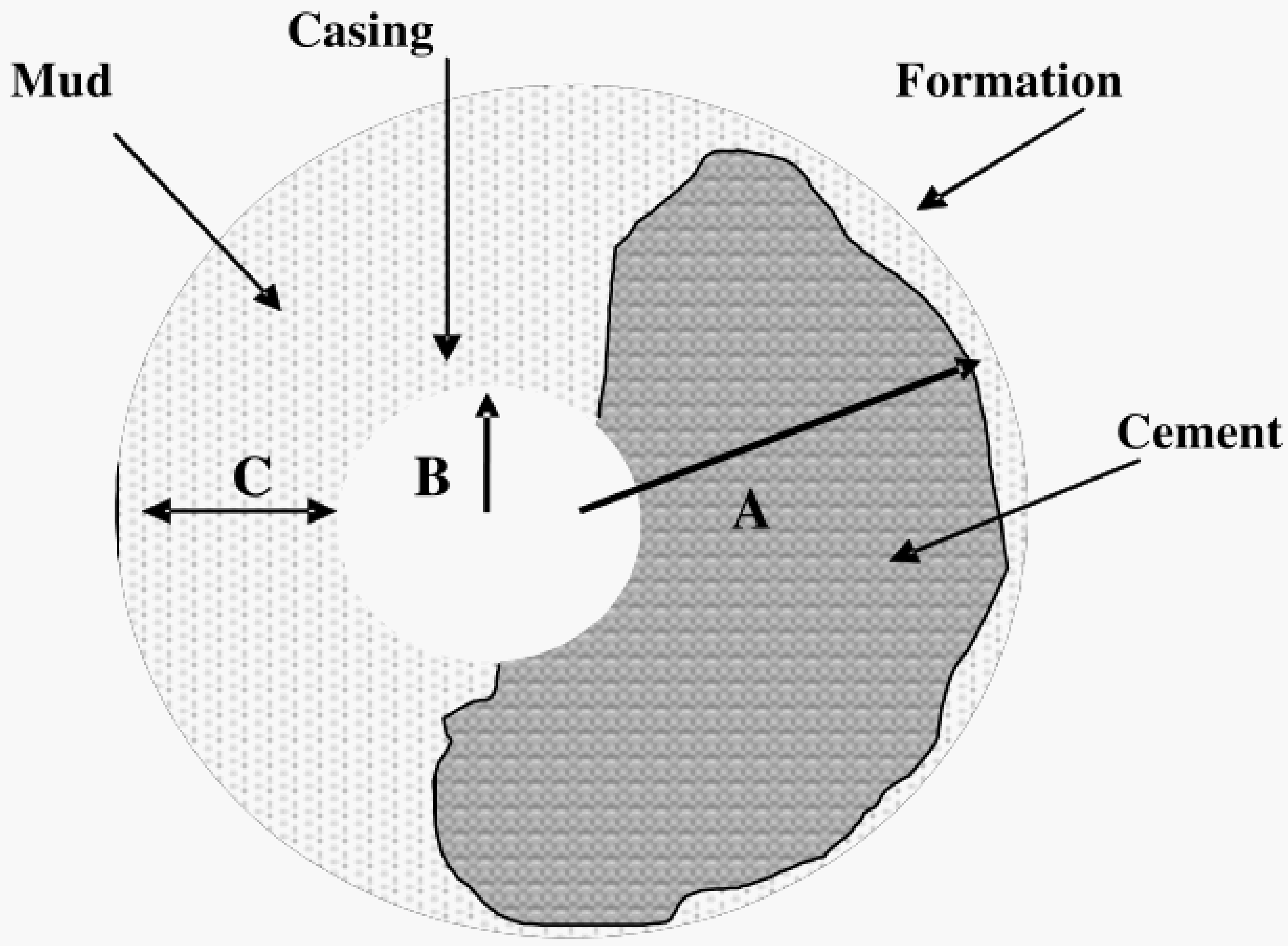
When performing primary cementing jobs, the casing should be centralized in the wellbore for three reasons:

1. to help get the casing to bottom (this includes reduction of the potential for sticking of the string);
2. to help move the casing during mud conditioning and during the cementing job;
3. to provide an optimal path for fluid flow during mud conditioning and cementing allowing for effective mud removal to achieve zonal isolation.

Field experiences, numerous large-scale experiments and computer simulations have shown that poor casing centralization can be detrimental to the cement job, particularly in narrow annuli. Therefore, a good centralization program should aim for high levels of standoff, which produces improved mud removal, particularly across critical areas of the wellbore, that is, those areas where isolation is required. It is imperative the user investigate the standoff at all points, especially between the centralizers.

### 2.1 Definition of Standoff

Standoff is defined by API/ISO documents (e.g. ISO 10427-2) as the smallest distance between the outside diameter of the casing and the wellbore. The standoff ratio is defined by the same documents as the ratio of standoff to the annular clearance for perfectly centered casing expressed as a percentage (%). Annular clearance for perfectly centered casing is the wellbore diameter minus the casing outside diameter divided by two. Figure 1 illustrates standoff and annular clearance.




$$\% \text{ Standoff} = \frac{C}{A - B} \times 100$$

**A = Distance from center of Wellbore to Formation**
**B = Distance from center of Casing to OD of Casing**
**C = Smallest distance from OD of Casing to Formation**

NOTE Failure to place cement completely around the casing, as portrayed in the figure, is a likely result of inadequate standoff (centralization) and results in failure to achieve isolation.

**Figure 1—Definition of Standoff**

## 2.2 Casing Centralization and Centralizing Devices

Casing centralization requires mechanical devices (centralizers) to keep the casing away from the wellbore and/or from the cased sections of the well.

Significant issues include:

1. the centralizer must provide enough load support to overcome the normal forces tending to lay the casing against the formation wall, particularly in deviated holes, horizontal holes and through doglegs;
2. enough centralizers should be used to provide good casing centralization over the needed intervals (including at points between the centralizers);
3. it is normally assumed (however not always the case) that the formation can provide enough support for the tools (minimum centralizer embedment).

# 3 General Discussion

## 3.1 Centralizer Types Available

The industry has developed three main types of centralizers: bow-spring, rigid, and solid.

### 3.1.1 Bow-spring Centralizer

The bow-spring centralizer is composed of flexible spring bows (heat-treated steel springs) attached to two collars. By design the bows are flexible enough to allow passage of the centralizer through restrictions but are also expected to provide standoff in enlarged hole sections. The springs come in various shapes and dimensions. The uncompressed outside diameter (OD) of a bow-spring centralizer may be much larger than the nominal hole (bit) diameter; thus, this type of centralizer can potentially "centralize" the pipe in moderately washed-out zones. Double-bow centralizers are also available. The double-bow centralizers can provide good restoring forces with low starting and running forces. Double-bow centralizers have a lesser maximum OD than conventional bow-spring centralizers and might sacrifice standoff in enlarged holes. Double-bow centralizers may also be considered semi-rigid, as will be discussed later in this document.

**Figure 2—Example of a Bow-spring Centralizer**

**Figure 3—Example of a Double Bow-spring Centralizer**

### 3.1.2 Rigid Centralizer

Rigid centralizers are made using non-flexible bands attached to collars. The bands are not designed to flex, and therefore, tend to maintain a constant OD. The centralizers exhibit minimal (or no) flexibility, but may have some ability to deform in hole restrictions, depending on their construction. Several types of rigid centralizers are available from manufacturers.

A subclass within the rigid centralizer category can be made for certain type centralizers. For example, the double bow-spring centralizer is considered a bow-type but may also be considered a "semi-rigid" centralizer. This is because the bows of these centralizers flex, but after small deflection, they become essentially rigid.

**Figure 4—Example of a Rigid Centralizer**

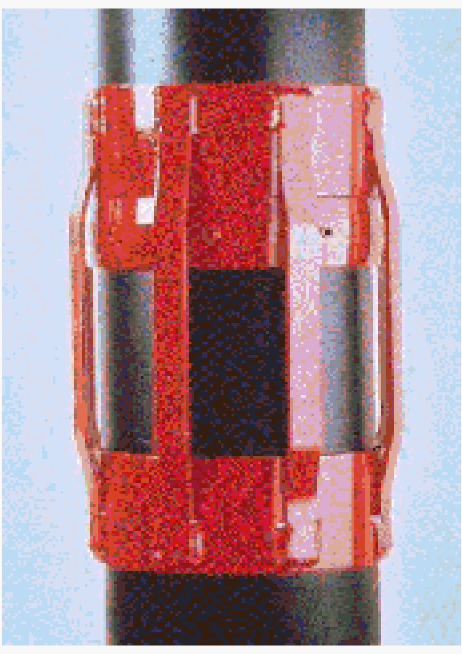


**Figure 5—Example of a Rigid Centralizer—a Slim-hole Centralizer**

**Figure 6—Example of a Rigid Centralizer**

### 3.1.2 Rigid Centralizer

Rigid centralizers are made using non-flexible bands attached to collars. The bands are not designed to flex, and therefore, tend to maintain a constant OD. The centralizers exhibit minimal (or no) flexibility, but may have some ability to deform in hole restrictions, depending on their construction. Several types of rigid centralizers are available from manufacturers.

A subclass within the rigid centralizer category can be made for certain type centralizers. For example, the double bow-spring centralizer is considered a bow-type but may also be considered a "semi-rigid" centralizer. This is because the bows of these centralizers flex, but after small deflection, they become essentially rigid.

**Figure 4—Example of a Rigid Centralizer**

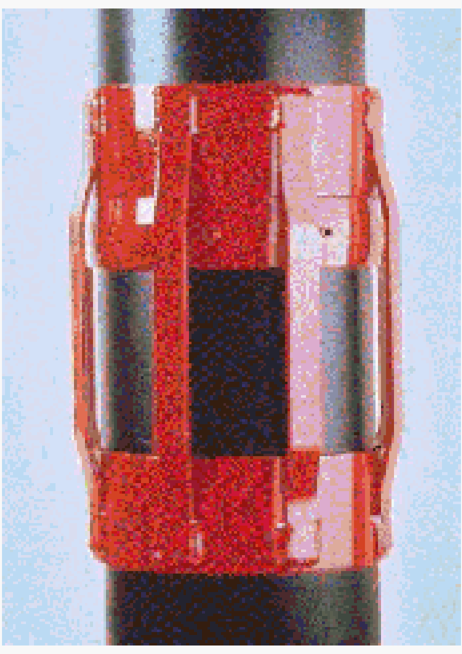


**Figure 5—Example of a Rigid Centralizer—a Slim-hole Centralizer**

**Figure 6—Example of a Rigid Centralizer**

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

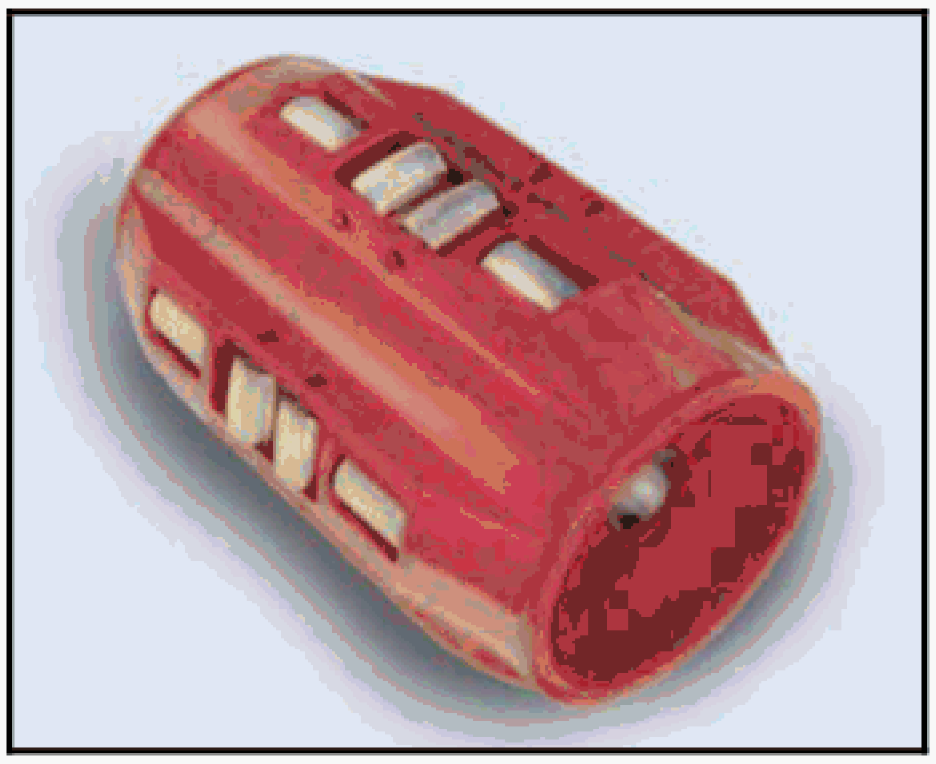


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

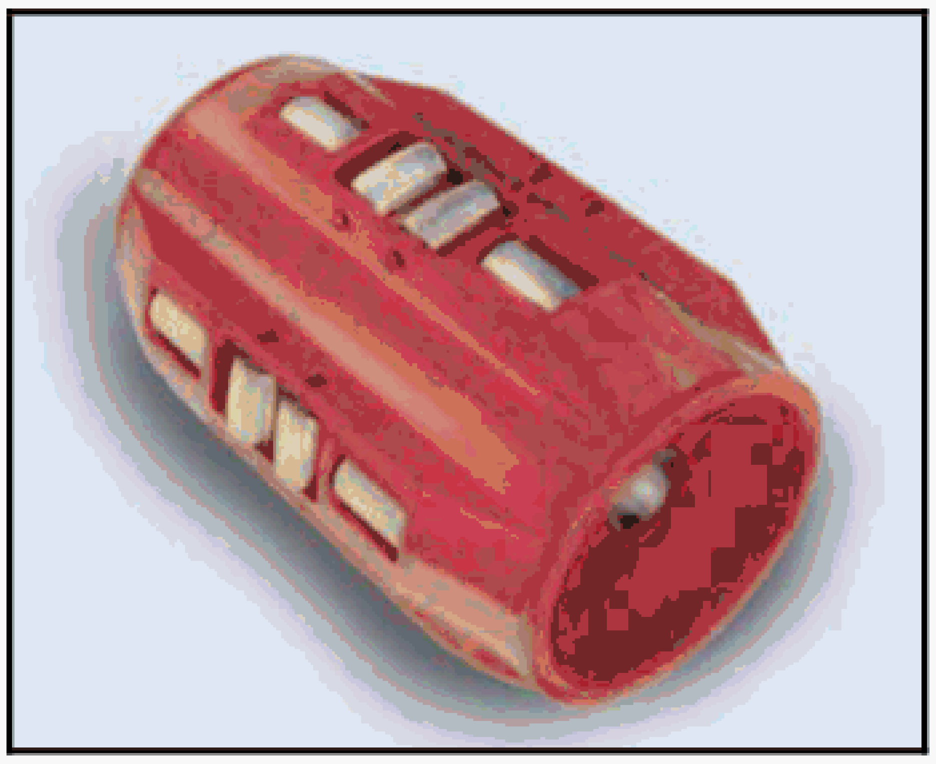


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

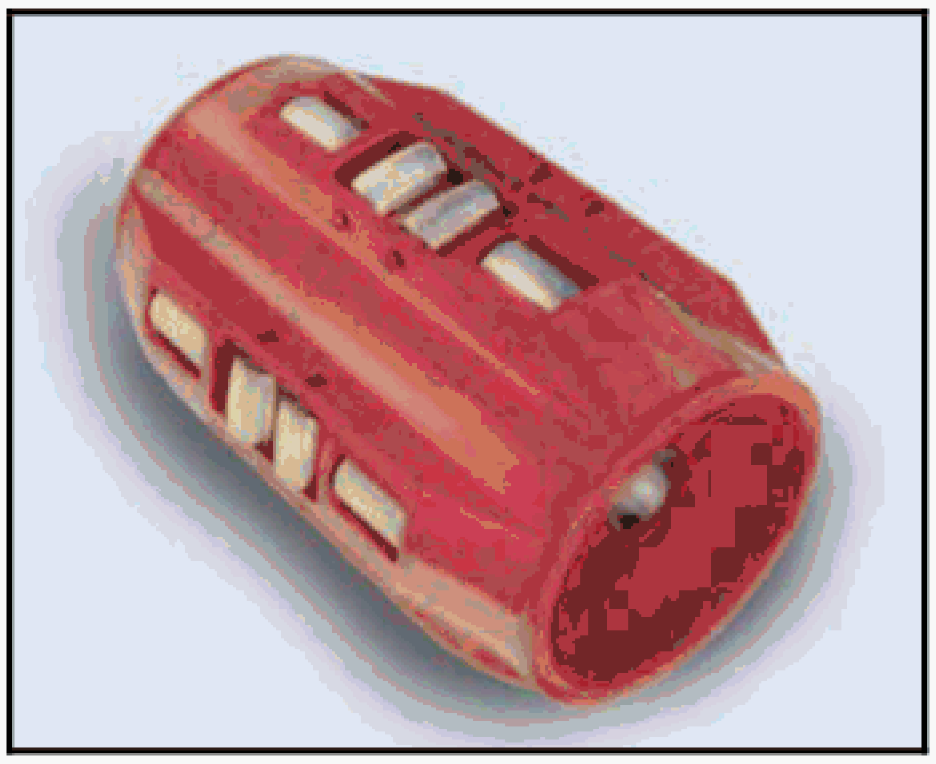


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

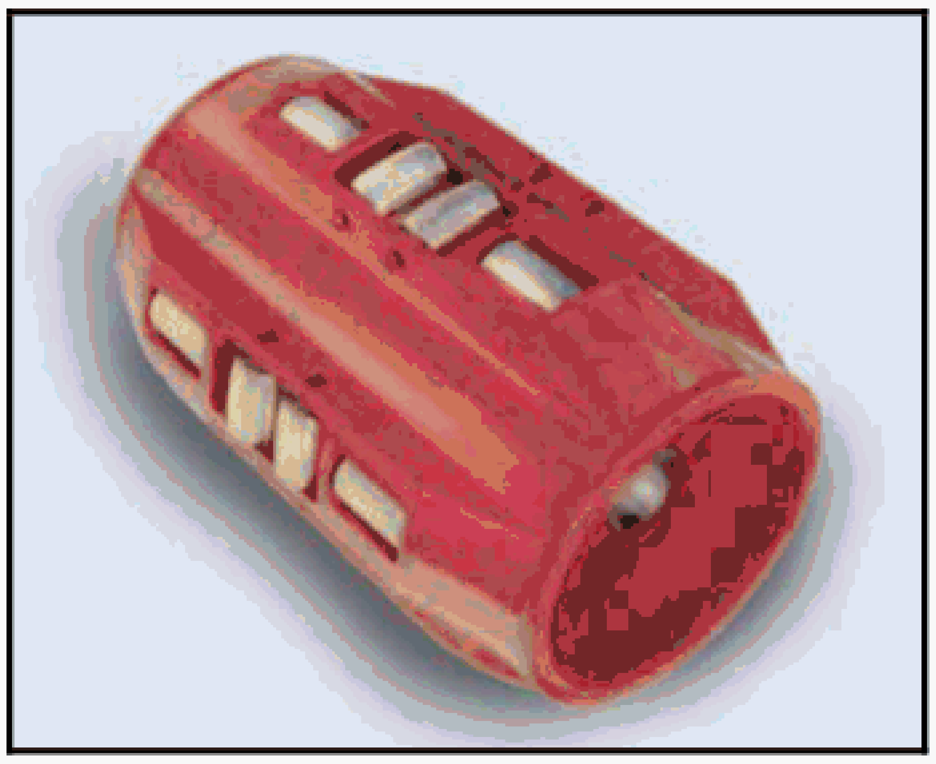


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

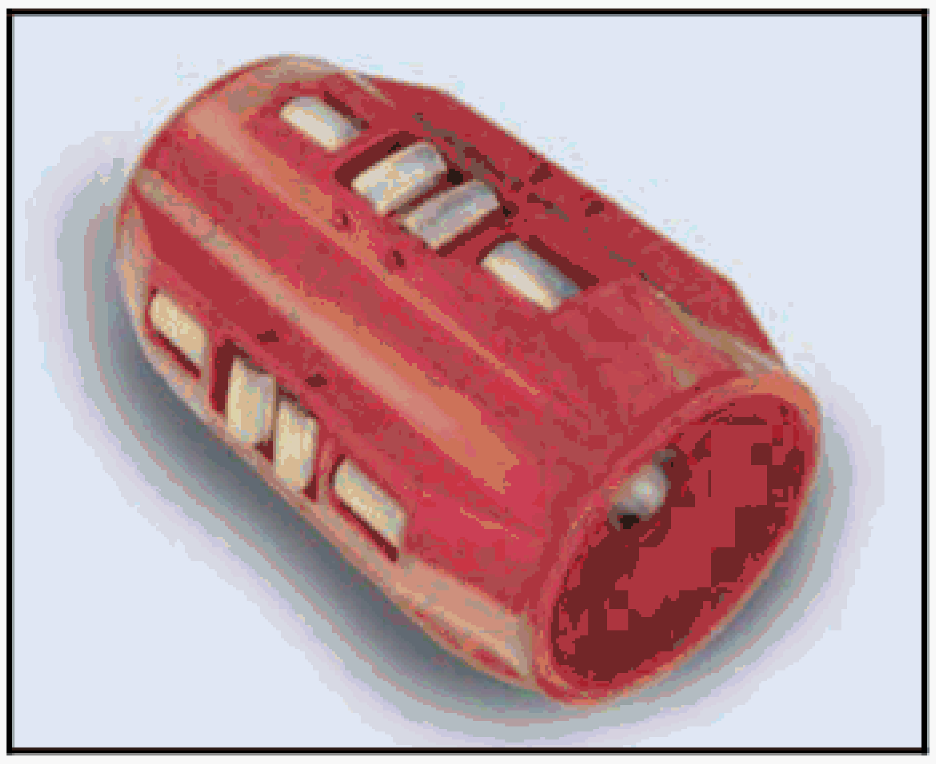


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

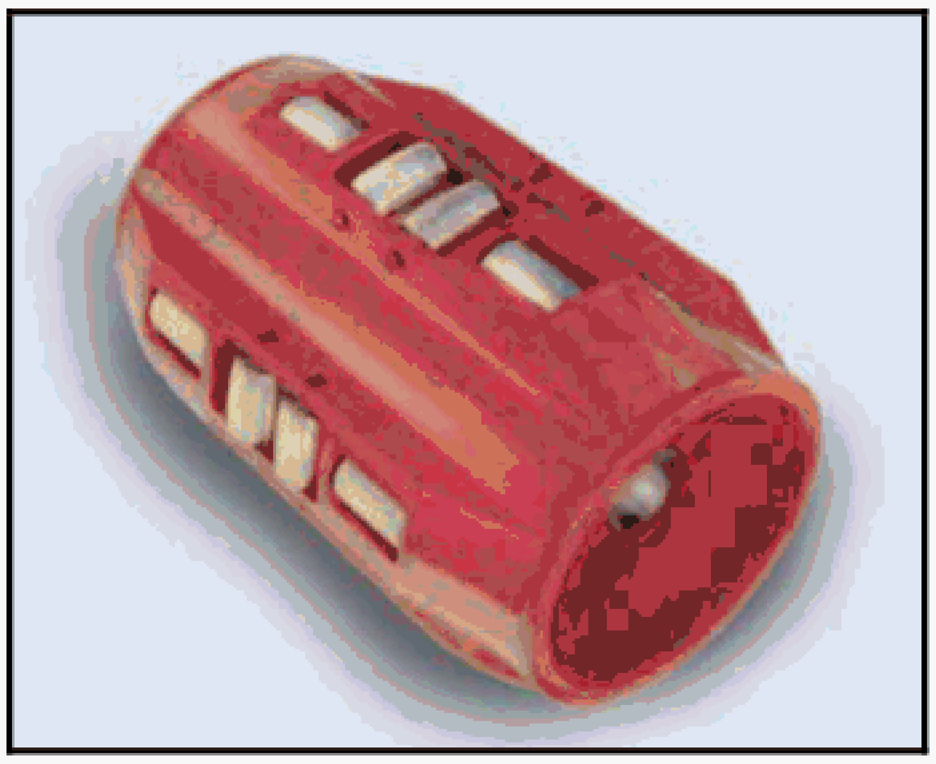


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

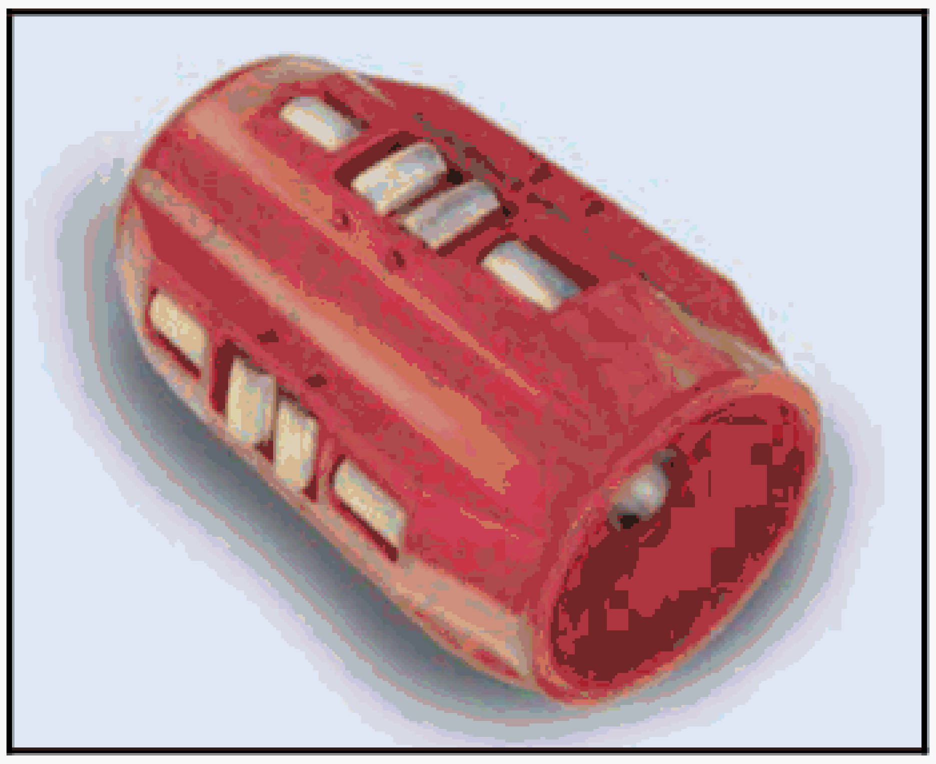


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

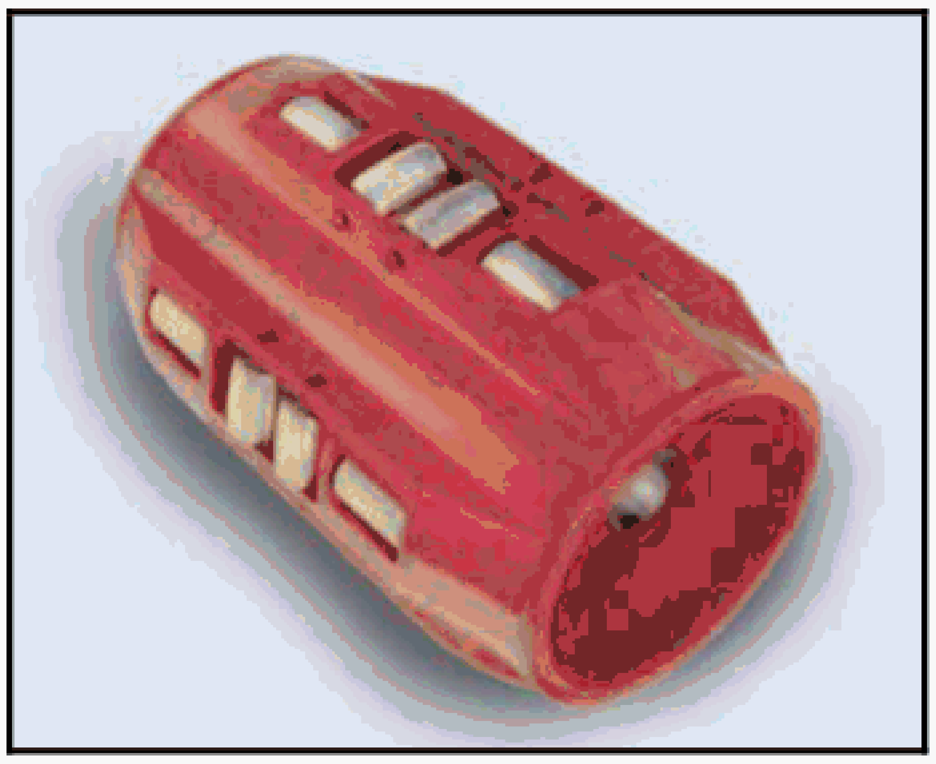


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

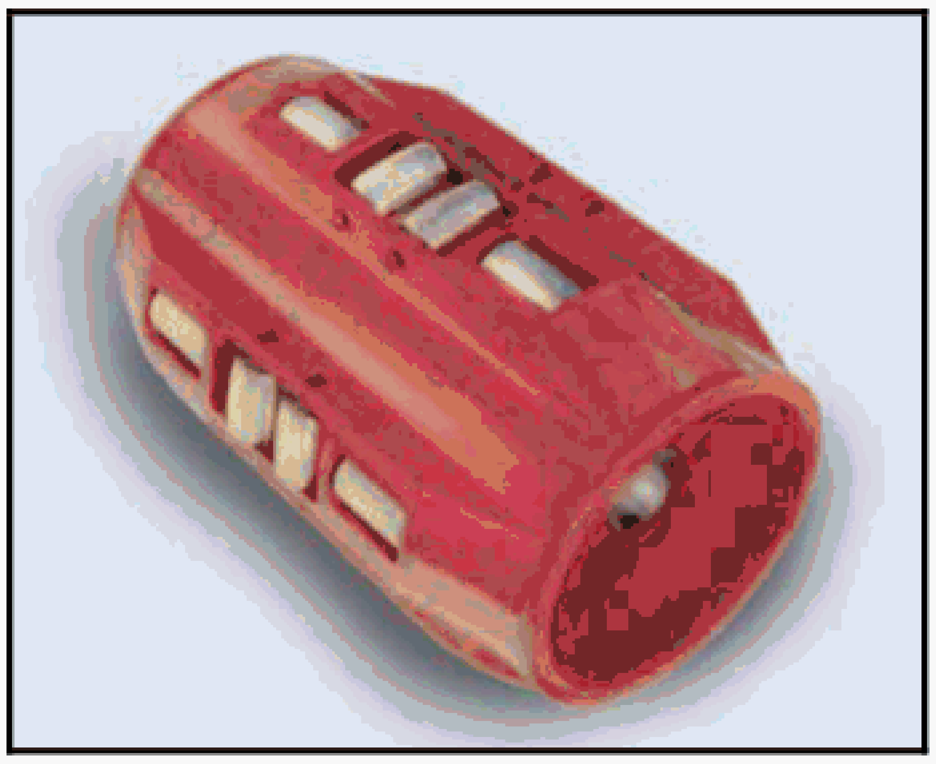


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

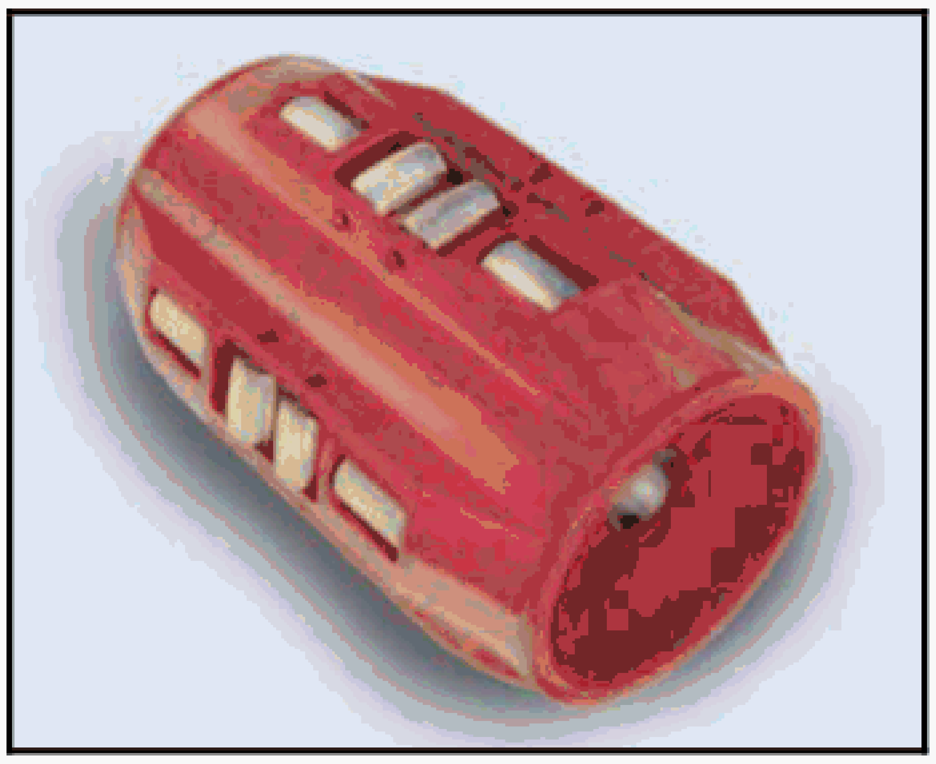


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

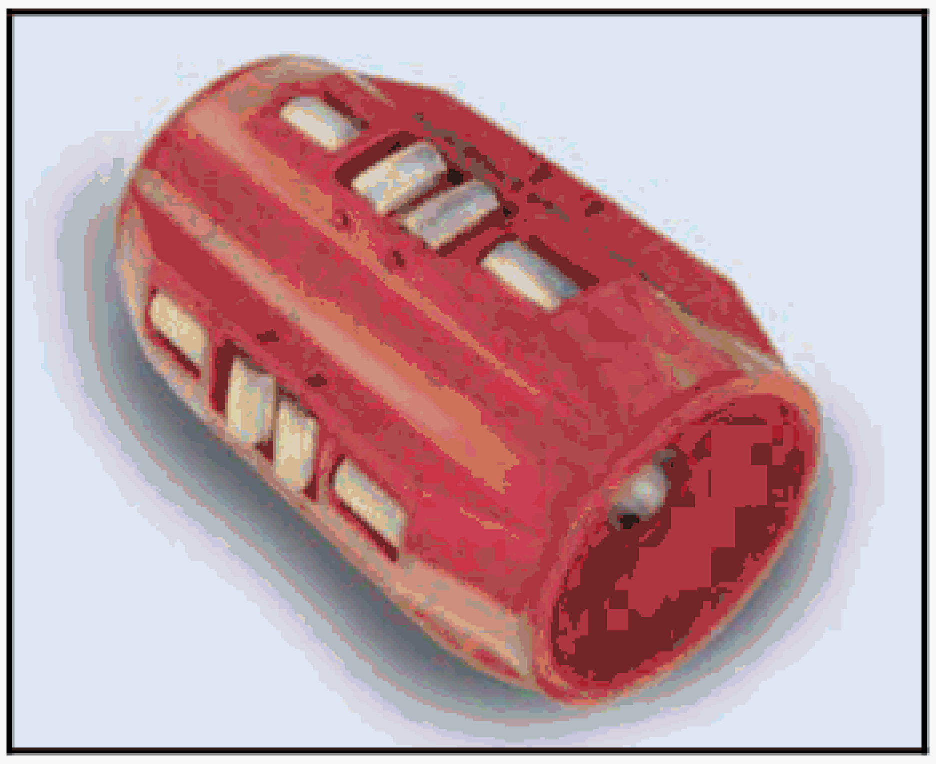


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

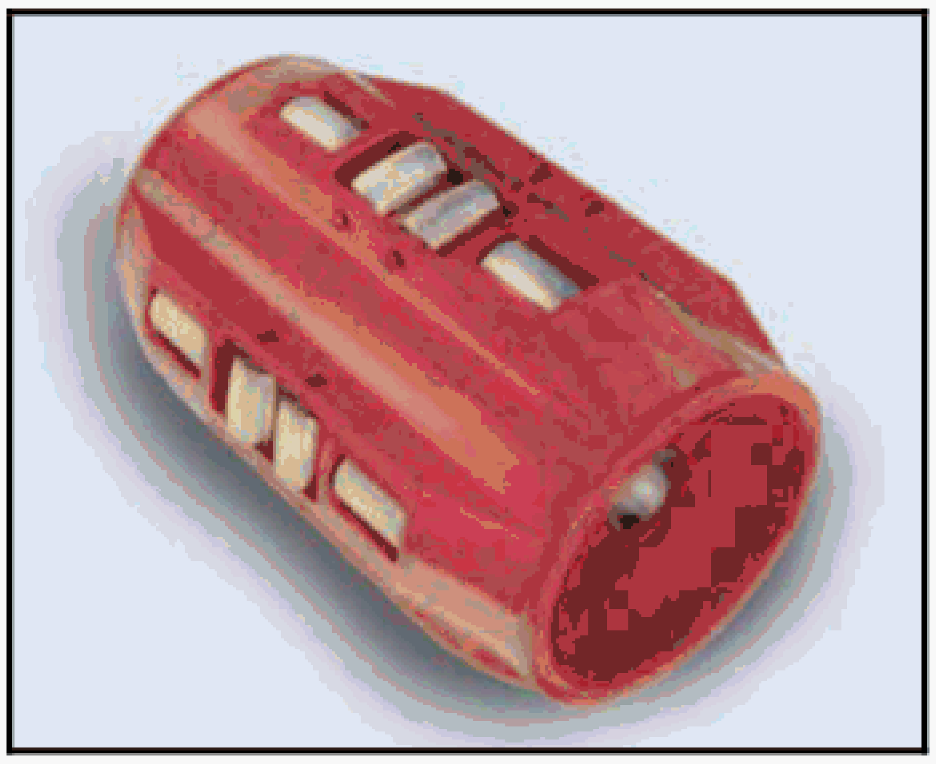


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

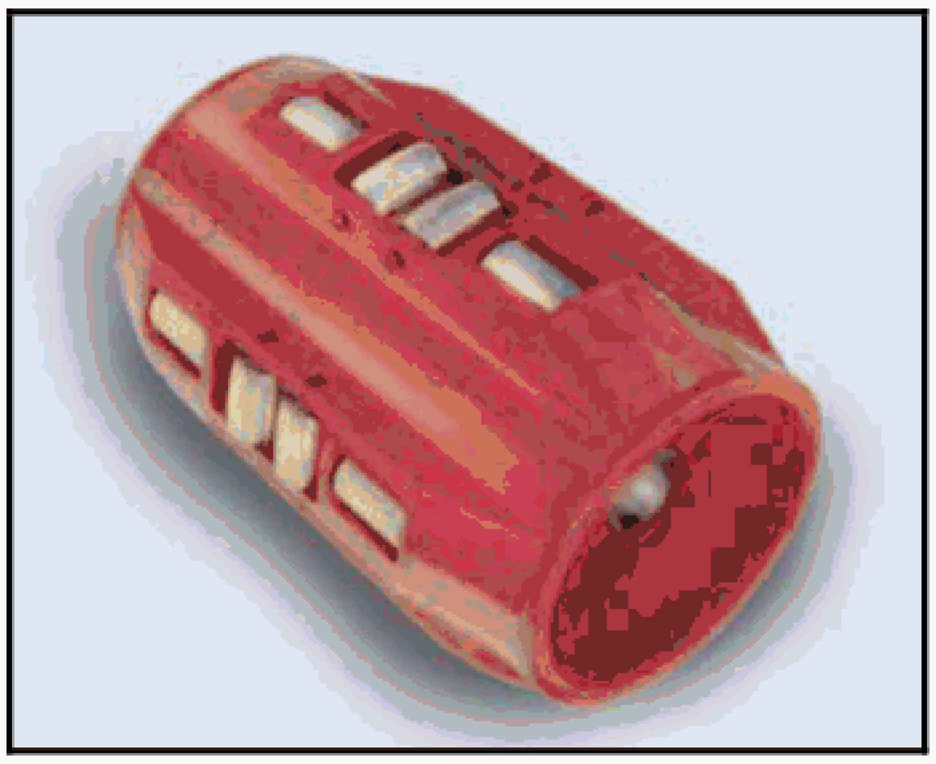


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

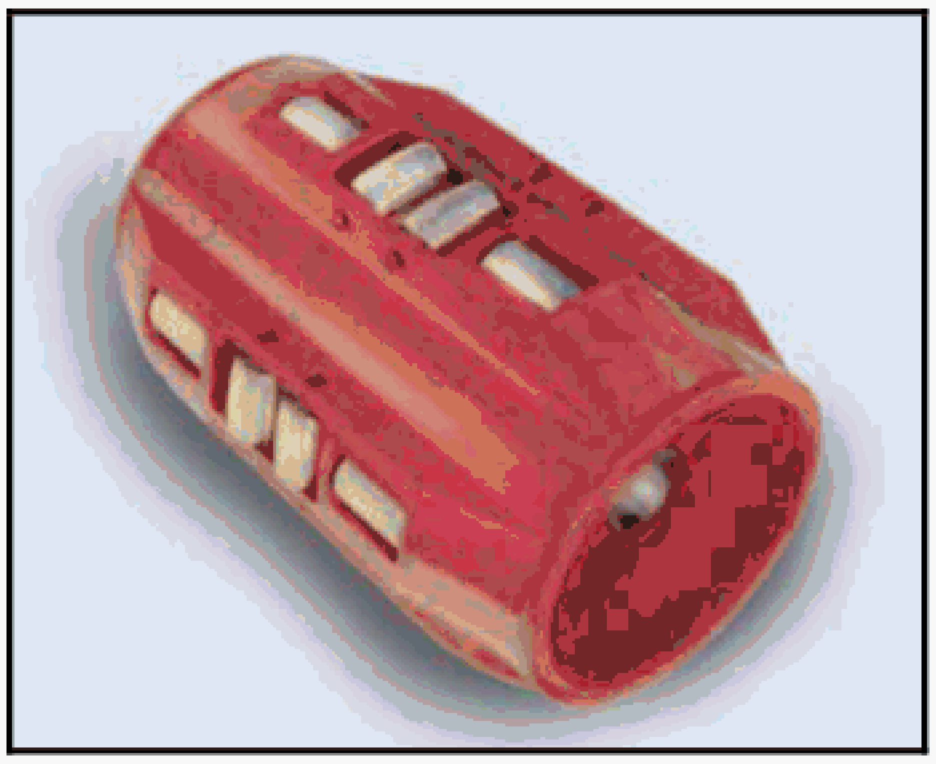


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

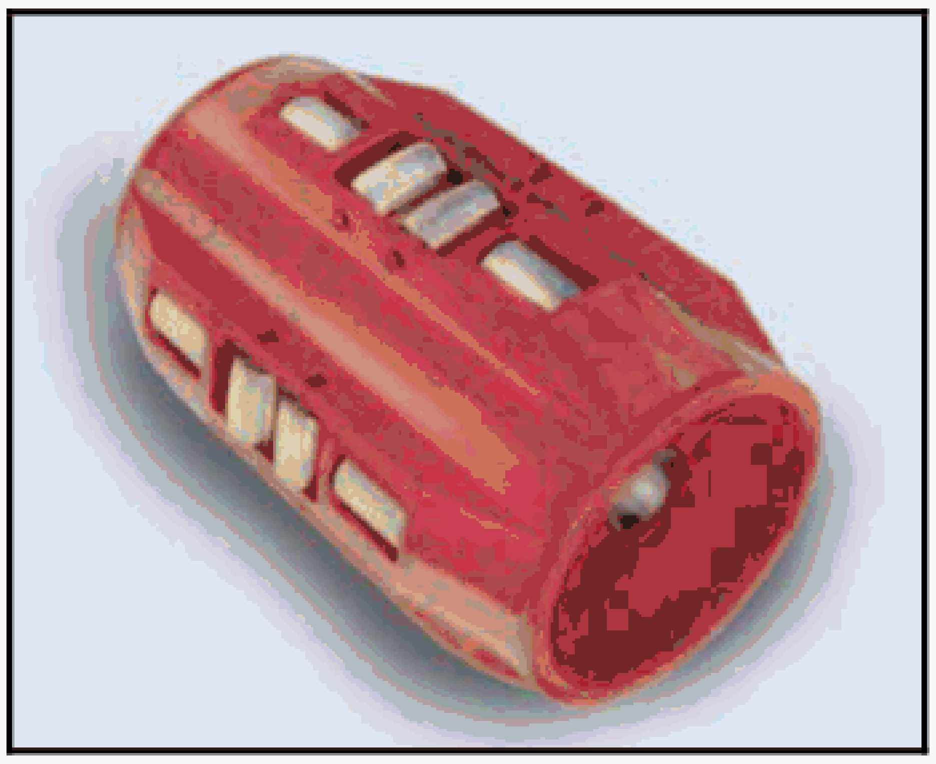


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

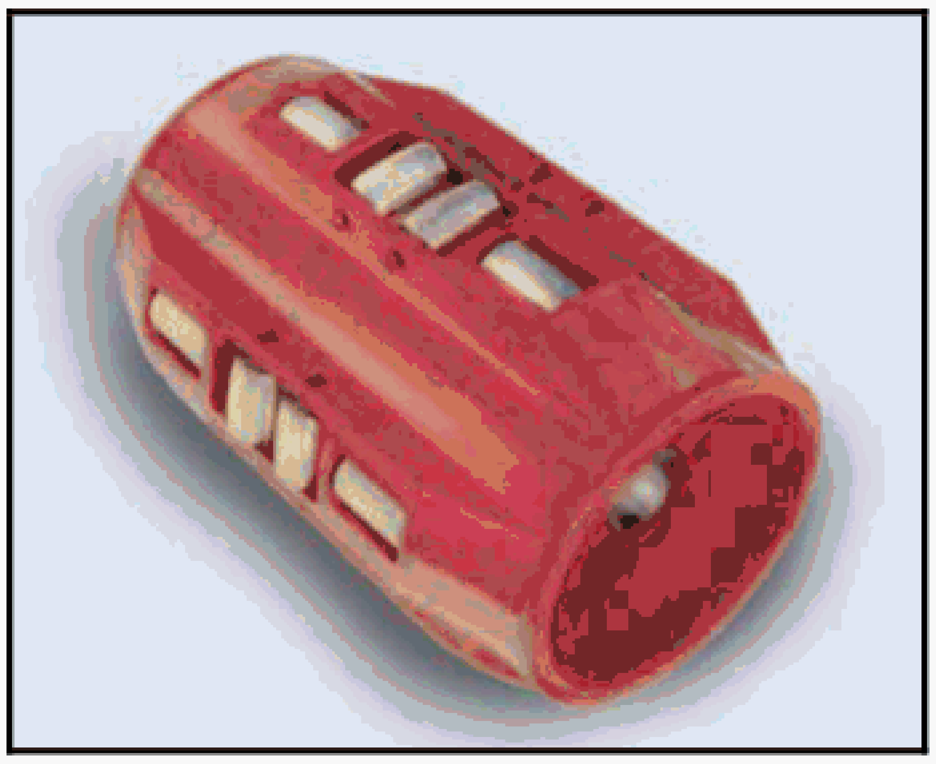


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

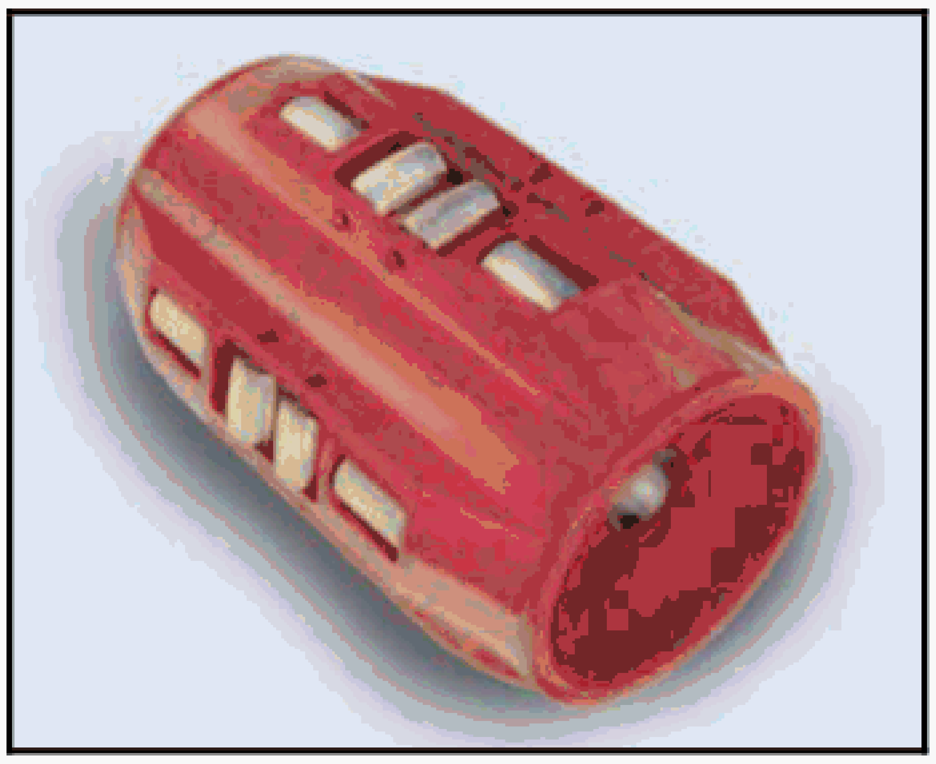


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

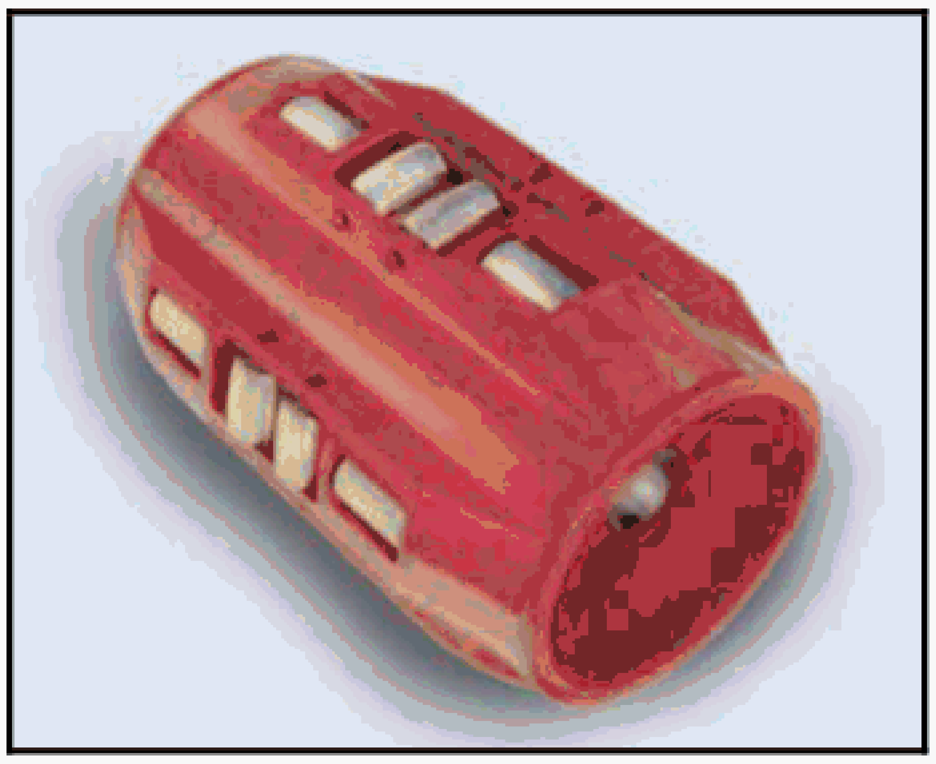


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

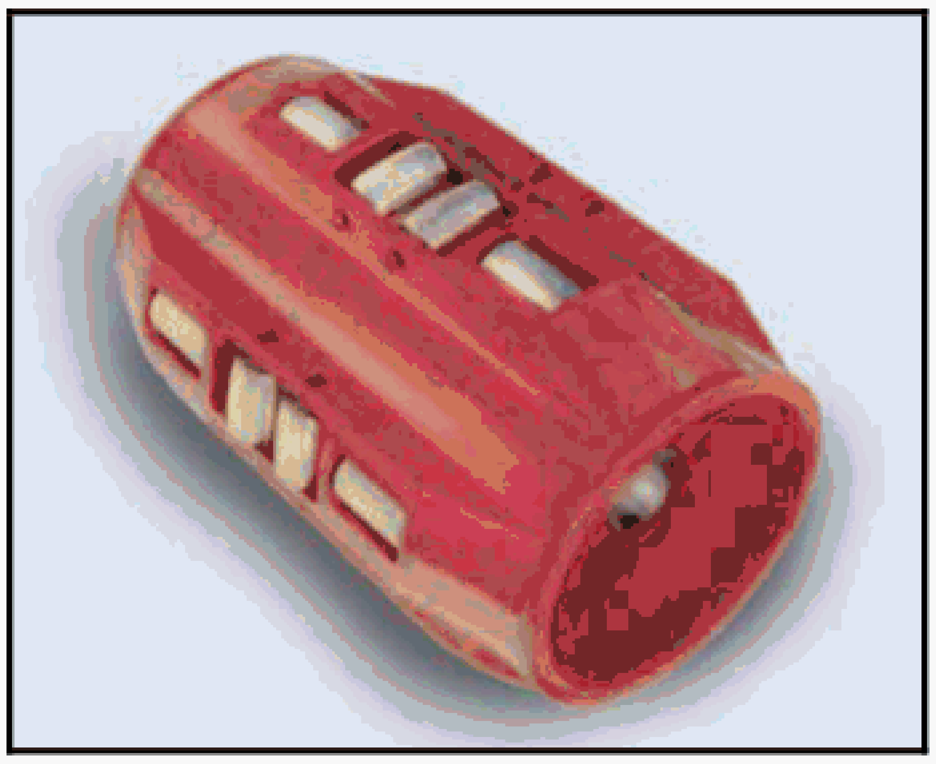


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

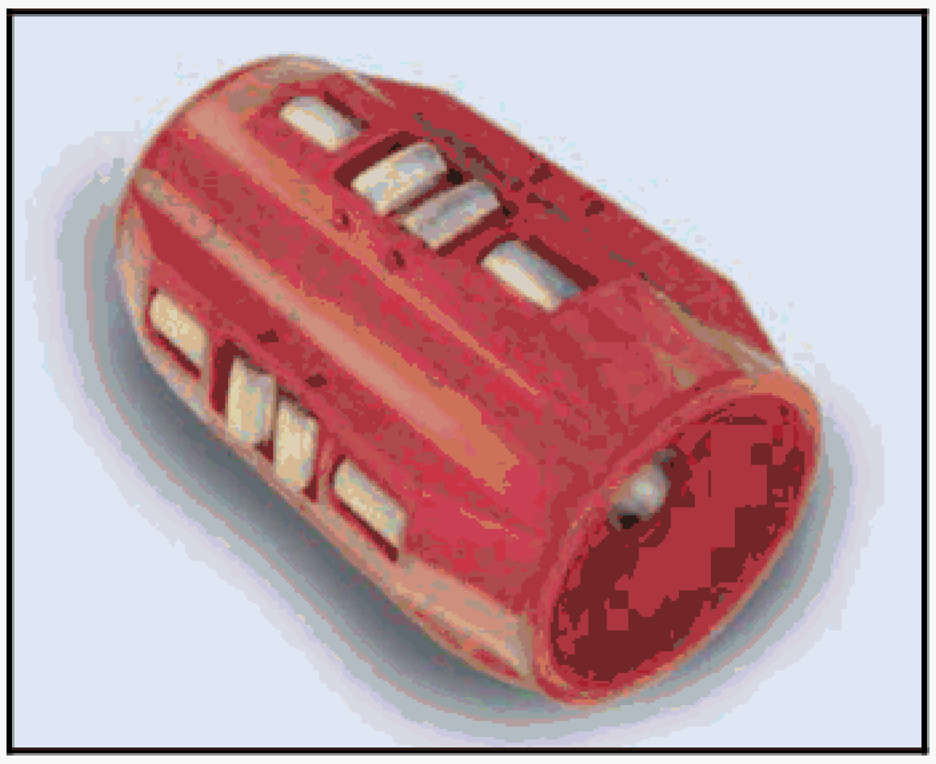


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

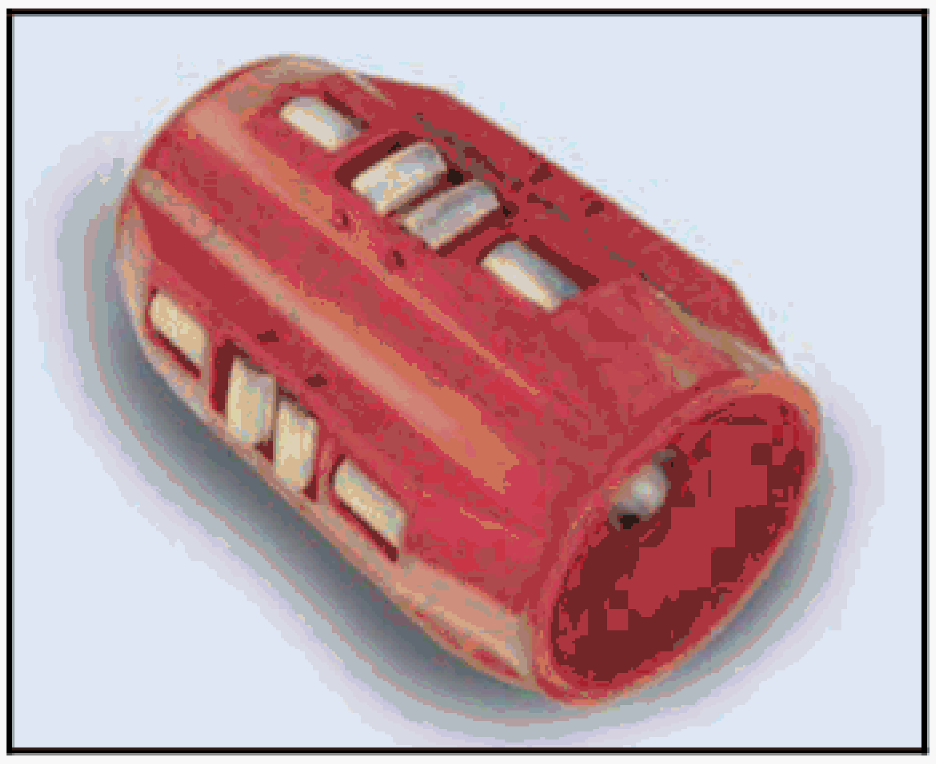


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

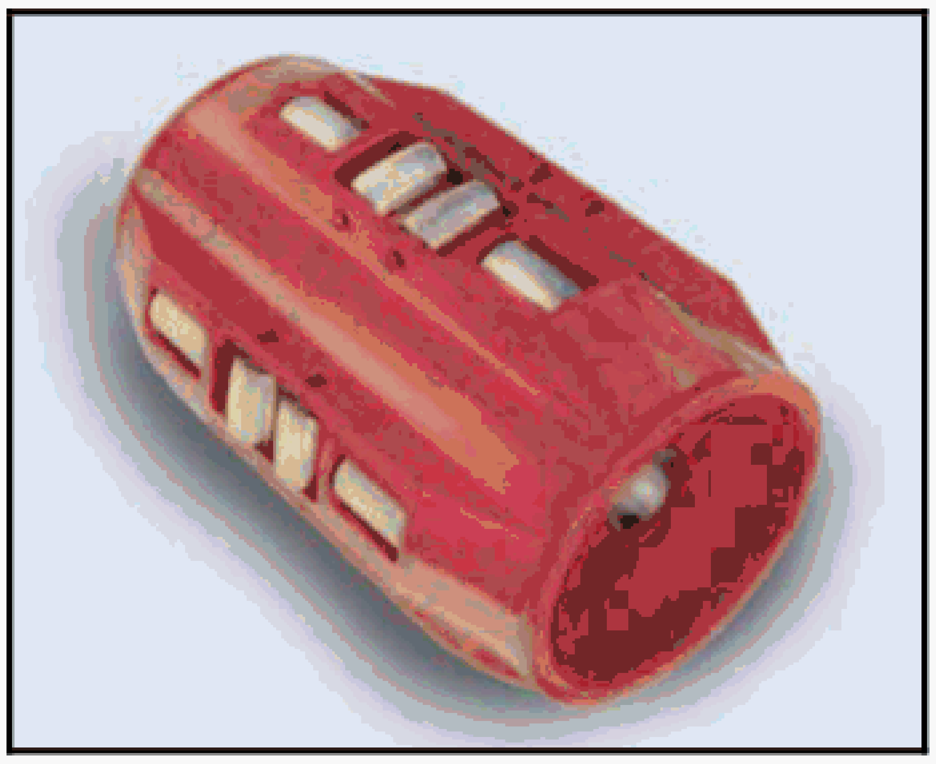


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.

### 3.1.5 Roller Type Solid Centralizer

Roller blade-type centralizers may greatly assist running the casing in extended-reach wells. The rollers have been shown to substantially reduce the drag and torque. Designs of roller centralizers are available for running the casing and also for allowing rotation of the string. Figure 10 shows a running-rotating combination.

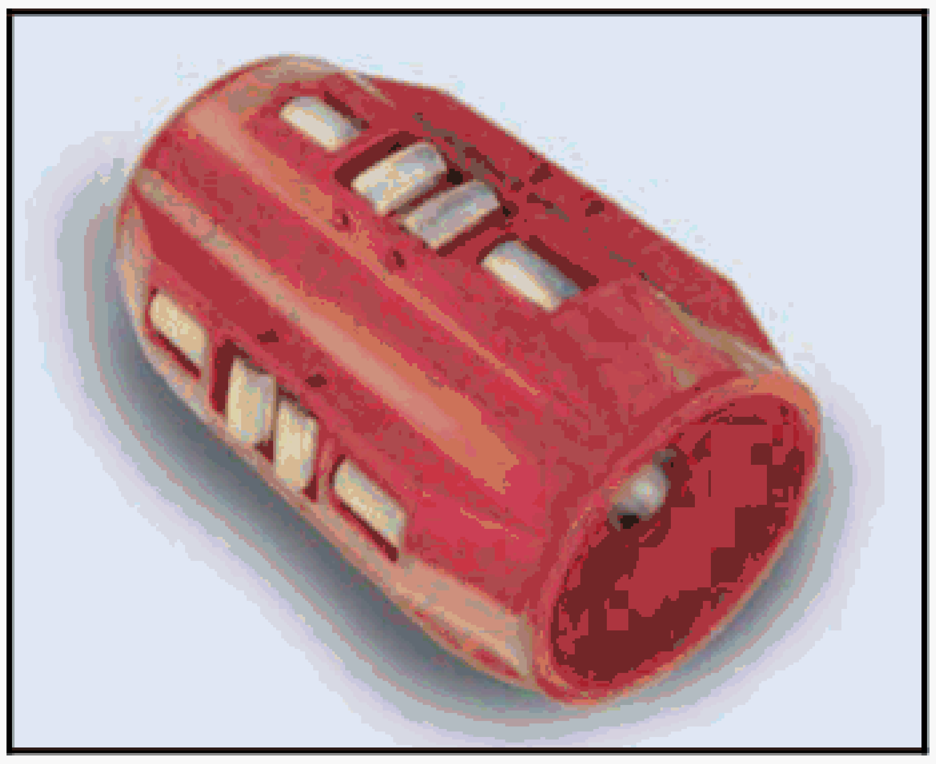


**Figure 10—Example of Solid Roller Centralizer for Running and Rotating of the Casing**

### 3.1.6 Centralizers Bonded onto the Pipe

A recently-introduced centralizer is designed for use in slim-type well configurations. The centralizers are formed and bonded directly onto the pipe. The centralizers are made from composite material consisting of carbon fibers and ceramics. Figure 11 illustrates this type of centralizer.

**Figure 11—Example of Centralizers Bonded Directly onto the Pipe**

### 3.1.7 Modified Bow-spring Centralizer

A modified bow-spring centralizer with a reduced OD and bows that meet the API specification has been introduced. The centralizer has lower starting and running forces because of the smaller OD compared to conventional bow-spring centralizers.