A "ReCap" on Plant Design

Scott Diaz –   kubit USA
John Bunn –   kubit USA
Buddy Legnon – Autodesk

PD3075   Plant designers are among the earliest adopters of reality capture technologies. With a facility's constant demand for upgrade, repair, and turnaround, highly accurate, yet efficient real-world measurements are an essential foundation for new design and organized asset management. One major technology, laser scanning, is becoming more of a standard rather than luxury within the plant design world. Over the past few years Autodesk has made significant strides in combining reality capture technologies natively into software products such as Autodesk® AutoCAD® software and Autodesk® Navisworks® software. This class provides live demonstrations and real user stories to review the latest enhancements for reality capture in the 2014 product portfolio as well as evaluate how the enhancements affect the AutoCAD plant design workflow. Attendees learn the latest methods for going from scanning, to point clouds, to deliverables such as intelligent plant models, tie-in points, equipment conditions, clash reports, and more.

Learning Objectives

At the end of this class, you will be able to:

- Describe the latest enhancements to Autodesk reality capture technologies and explain how they affect plant design workflows
- Go from field scanning to Autodesk® ReCap™ software to AutoCAD and then to Navisworks
- Generate intelligent plant deliverables from point cloud data with Autodesk® AutoCAD® Plant 3D software
- Apply these new concepts to new workflows at your office

About the Speaker

Scott Diaz: Scott is owner and managing director for kubit USA. Over the past six years he has managed the US headquarters office in Houston, Texas representing kubit software directly for the Americas while establishing a kubit reseller network throughout the US, Canada and Latin America. Scott has a background in business management and marketing with an MBA from Lamar University.
Email: info@kubitusa.com

John Bunn: John is technical sales manager for kubit USA. He has represented kubit for more than three years and is the top technical contact for the software in the Americas. John has more than 14 years of AutoCAD experience as a user and professional programmer with specialty knowledge in the industrial facility/piping design space.

Roland Legnon: Roland "Buddy" Legnon works on the Autodesk Plant Solutions Team. Buddy is an AutoCAD Plant 3D technical specialist and has more than 20 years of user experience in AutoCAD. His previous experience also includes time as a PDS and Autoplant administrator.

Contents

Autodesk Reality Capture for 2014

The world of reality capture is rapidly changing and the ability to keep up with industry trends is often challenging; especially when this is not a core focus of daily work. This class will update Autodesk users working within industrial facility design on the latest trends, methods and workflows for going from laser scanning data collection to typically needed plant deliverables.

Common plant deliverables covered in the class include modeling pipe runs for creation of Plant 3D models/isometrics/orthographics, extraction of structural elements, detection of key tie-in points, clash detection between existing and proposed design, and equipment and tank analysis. The class will also review and demonstrate commonly used point cloud modeling techniques for various objects within an industrial facility.

The Plant Design Suite

The session assumes use of software tools which can be found within the Autodesk Plant Design Suite. Here is a quick review of the products used within the class and their contribution.

AutoCAD Plant 3D

Autodesk's 3D plant layout design software can create catalog driven, parametric 3D plant models within the familiar AutoCAD environment. Designers and engineers use this for asset management, generation of isometrics, orthographic and materials reports. Plant 3D will play a vital role in helping convert objects extracted from the point cloud into intelligent, realistic components.

Autodesk Navisworks

Navisworks is Autodesk's powerful design integration tool for full project review of models and point cloud data. Navisworks will allow for clash detection analysis between existing conditions (collected laser scan data) and newly proposed design in the Plant 3D model.

Autodesk ReCap/ReCap Pro

Autodesk ReCap is the company's latest tool for reality capture management. Including support for both laser scanning and photogrammetry, ReCap is the starting place for projects involving existing conditions survey data. In this session, Autodesk ReCap Pro will be used for properly aligning scan positions to each other (AKA: scan registration). In addition, ReCap will be used to prepare large data sets for use in the AutoCAD Plant 3D environment.

Third Party Software

In addition to native Autodesk software, the class will take advantage of Autodesk third party partner software to help make design from point clouds a more efficient process. Although there are many third party point cloud software packages capable of performing similar workflows from field to finish, the class speakers have the most familiarity with the tools chosen for the workflow in this session.

Faro Scene
Every major laser scanner manufacturer packages a registration or "pre-processing" software with the scanner for basic data management and registration of scan positions. The point cloud data sets collected within this session come from a Faro laser scanner. As a result, traditional scan registration methods will be reviewed within this software to counter methods used within ReCap Pro software.

kubit PointSense Plant
PointSense Plant software is an AutoCAD based tool set from kubit which helps to extract 3D plant models from point cloud data and convert the shapes into AutoCAD Plant 3D objects. Although Autodesk software provides a base tool set for point cloud design, PointSense Plant software will help to more seamlessly close the gap between scan data and intelligent models for industrial facilities.

Laser Scan Data Collection & Preparation

This section will briefly review the laser scanning data collection process but focus most attention during class time towards registration and organization of collected data for use in Autodesk software. Please note differences in scan planning based on the registration method used (traditional vs. scan to scan)

The Faro Focus 3D laser scanner will be used for data sets shown in the images. The device uses phase-based technology which yields a high density result at a lower range distance. Density varies based on the user settings but can range from about 15 million to more than 100 million points per scan position. The scanner range varies based on environmental conditions but maximizes at 120 meters. Typically high quality scan data is collected within 30-40 meters of the scanner position. These numbers can vary based on model/manufacture. Typical time per scan is 2-10 minutes. The time per position varies based on the density settings and whether or not photographs are also collected in addition to scan data. Photographs are used to attach true color (RGB) values on to each collected point. Data for most new scanners is collected directly to an SD card stored within the scanner for easy transfer to PC in the office.

Scanning in the Field

Prior to setting up the scanner in the first position, it is recommended that the surveyor perform a walkthrough of the area intended for data collection. The surveyor should assess the best possible vantage points for reducing the number of overall scan positions, while still collecting the needed data properly. The walkthrough will also help the surveyor visualize the area to be collected from each intended position. This is important when assessing scanner target positioning for quality registration results. Each scan can take 2-15 minutes depending on density

Targets
(Traditional) The traditional laser scanning process, similar to general surveying, requires reference targets. These targets allow the surveyor to accurately tie each position to the next. At least three targets should be visible to the scanner, per scan position. The user should also assess whether these targets are visible from the next intended scan position. Setting out scan targets is a crucial part of the initial scanning process for ensuring accurate data collection. In images provided, spherical targets are used but checkerboard targets as well as known coordinates can also be used to help align scan to scan.

Spherical targets should be distributed at various elevations and distances from the scanner position. The surveyor should avoid setting targets in a linear fashion as this can impair the ability to calculate quality triangulations.

(Scan to Scan) Using scan to scan registration methods, such as ReCap Pro, does not require the use of targets in the field although targets generally are still supported as a means of increasing accuracy in registration. This information is covered later in the document.

Moving Scan Positions
(Traditional) When moving positions, it is important that the scan targets (spheres) which were visible in the first position are visible in the second position. The scanner should offer a self leveling function as well as keep the settings from the previous scan. Once the surveyor is comfortable with the visibility and positioning of each position, the scanner is ready to collect data again. These steps are repeated to each position and new targets can be added as well.

(Scan to scan) When moving positions, it is important that scans have significant overlap from position to position for pattern/point recognition between positions. Since physical targets are not used, the data itself becomes the source of alignment. More overlap allows for more reliable alignment from scan to scan. The need for overlap may result in more scan positions in the overall project compared to using a traditional scanning approach with targets.

**Scan Data Preparation (pre-processing)**
Now that raw data has been successfully collected from the field, it must be organized within a registration software. In its current state, the scan positions have no reference to each other and therefore would create a mess of points all residing at 0,0,0. This class will cover two scan registration methods or "pre-processing software" packages for data alignment; a traditional method from a laser scanner manufacturer's software (Faro Scene) and a targetless scan to scan registration using Autodesk software (ReCap Pro).
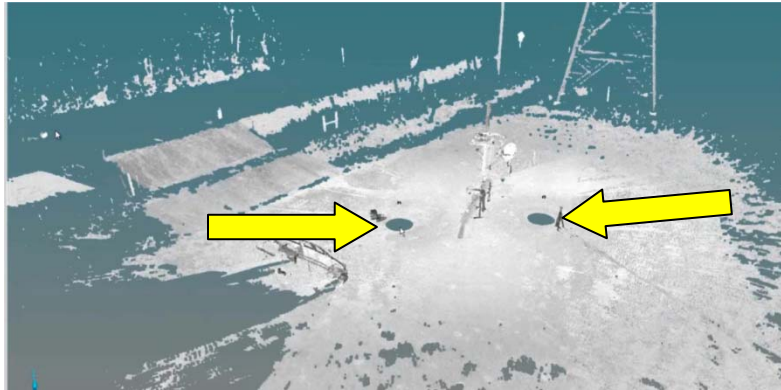
Traditional Registration

Each scanner creates a specific file format per scan position. For the Faro scanner, each raw scan position recorded in the field generates an FLS (Faro Laser Scan) file. We will use Faro's Scene software to walk through the traditional scan registration process.

A new project is started inside of Scene and all raw FLS files are imported. Upon first glance, it is easy to notice that all scans are stacking on top of each other. Because the positions are not yet registered, all scans are sitting at a 0,0,0 coordinate system and overlap with many similar points.

Our next operation is to choose the "pre-process" option inside of Scene. Here a user is able to choose from a variety of scan registration methods as noted in the image below. Since spheres were used in the field, this option is selected. The software knows the exact parameters of these targets and will automatically detect/locate them in each scan position. Based on the position of the spheres, the scan positions can be correctly oriented to one another.
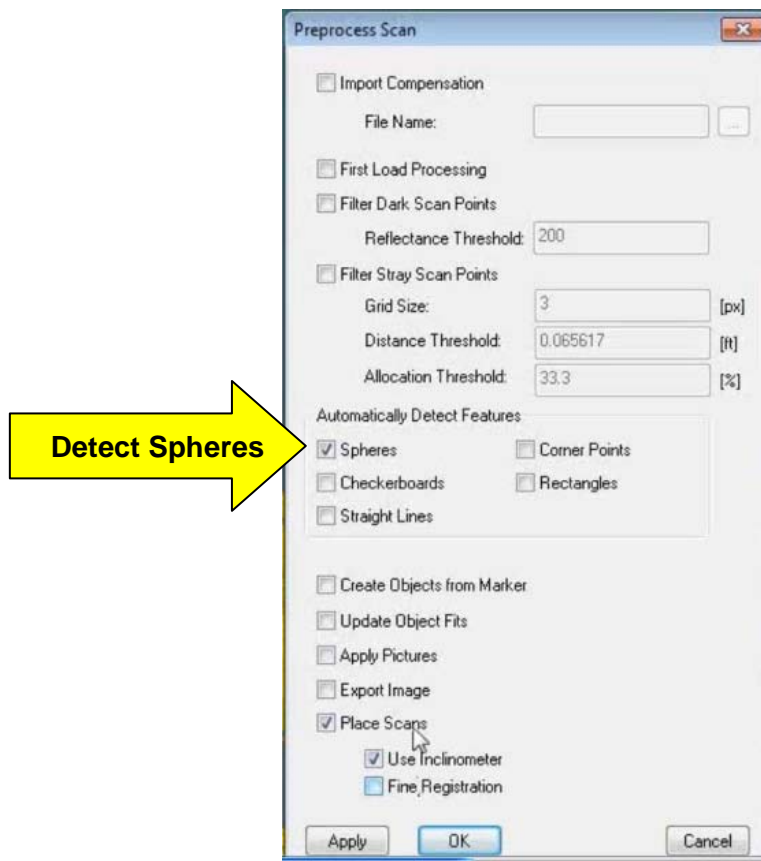

The registration process will create our registered and correctly oriented point cloud. The accuracy report shows an overall standard deviation between scans. When saving the project in Scene, we find a set of registered FLS scan files (now in the revisions folder) along with a project file (FWS and/or LSPROJ) , which references each of the scan positions.

Each scan position now aligned correctly. Empty, circular gaps show scan locations

Applying Color

Either before or after the registration process the color can be added optionally to scan data. The scanner must be set to collect photographs with the scans. The software can then apply an RGB value to each point cloud point.
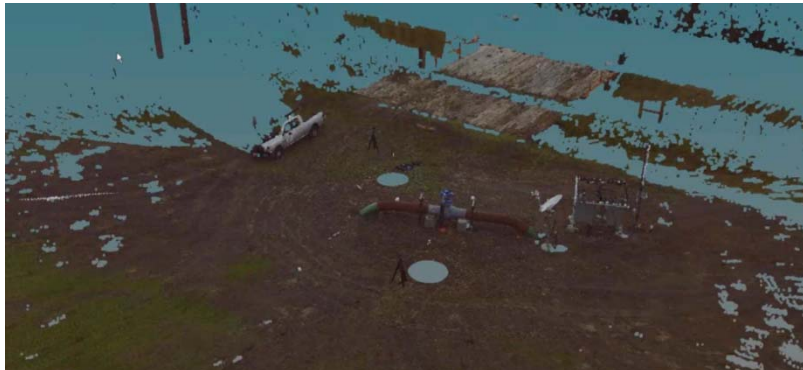
Result of applying true color (RGB) values
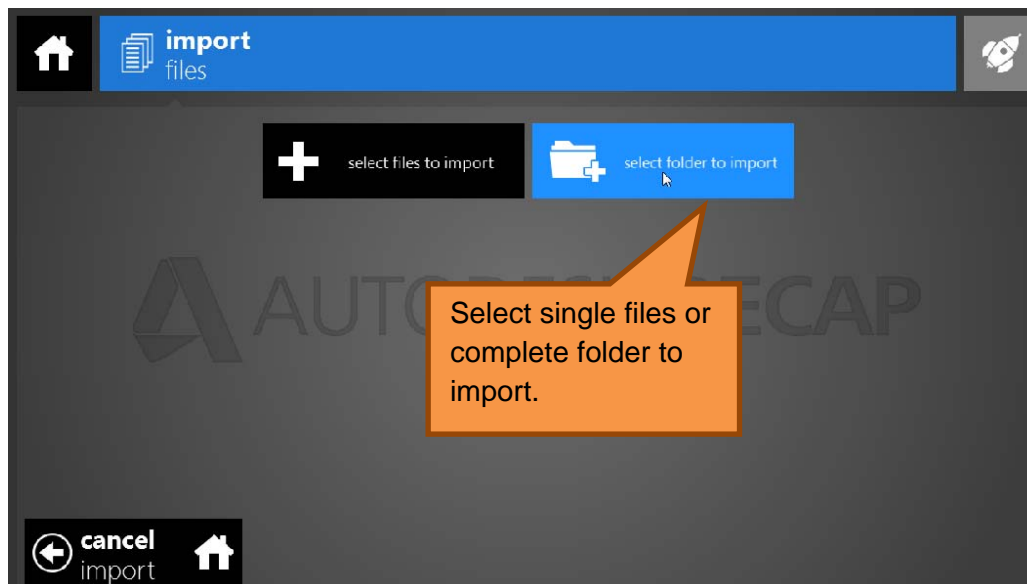
Cloud to Cloud Registration (with ReCap Pro)

ReCap Pro is Autodesk's new software for reality capture by laser scanning. Unlike traditional scanning and registration, Autodesk's ReCap Pro product does not require physical targets in the field. It provides a direct and seamless workflow from raw scan data, to registered, aligned and design ready point clouds usable within various Autodesk products.

ReCap Pro uses so-called cloud to cloud or scan to scan registration to align the scans to each other, thus creating one consistent point cloud of an object scanned from multiple positions. There are no targets required, but they are still supported to improve point cloud accuracy. ReCap Pro also makes it easy to clean, organize and visualize massive point cloud datasets directly on the desktop.

This is how it works:

We will use Autodesk ReCap Pro as one very easy example for cloud to cloud registration and walk through the scan registration process.
You simply start ReCap Pro, create a new project and import the collected FLS files.
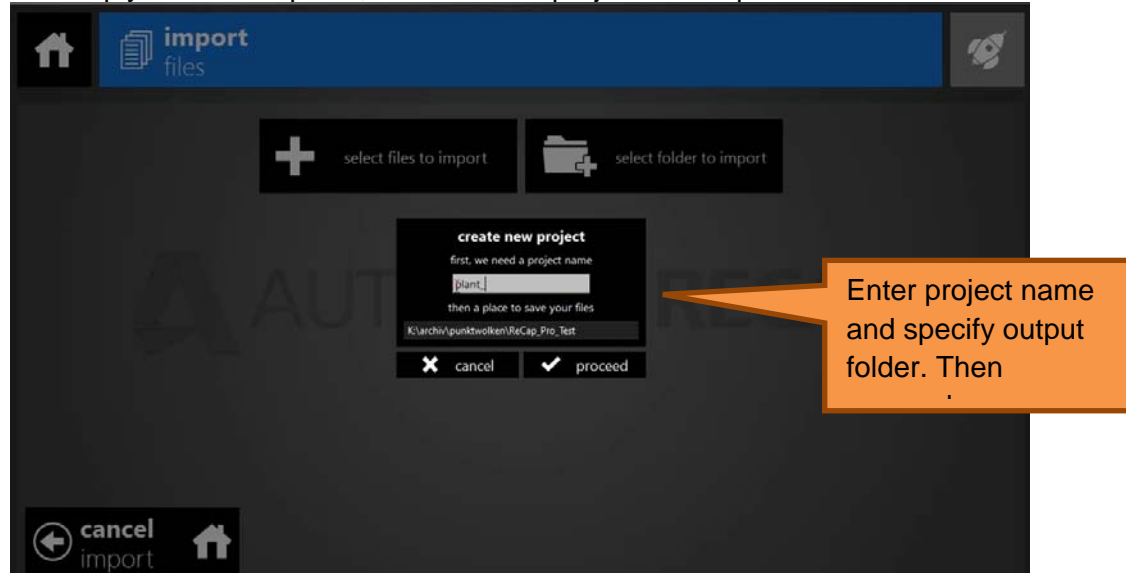
After having imported all scans of the project our next operation is to register the scans by cloud to cloud registration inside of ReCap Pro.
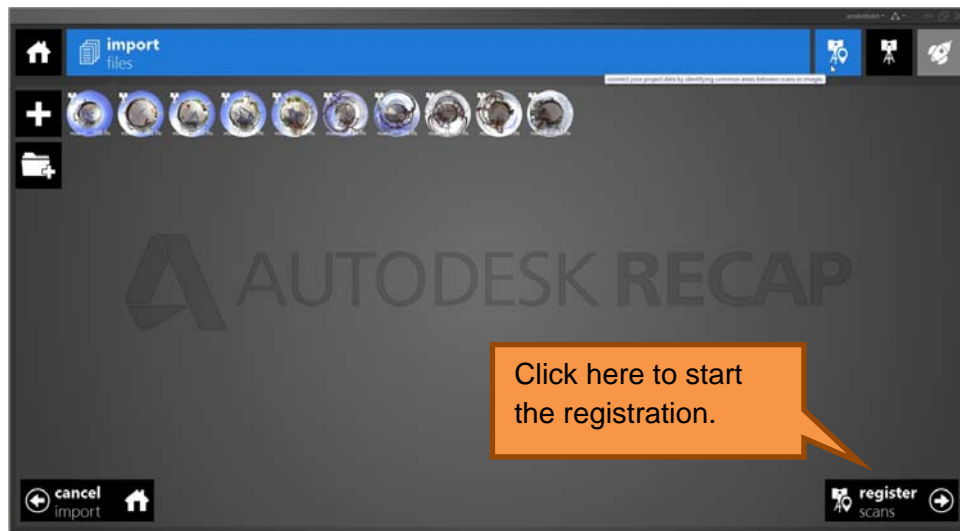
You can choose between two options.
One is using the Scanorama view and clicking three corresponding locations in both scans:

Scanorama View in Recap Pro

The other is using the plan or top view and clicking just two locations in both scans:
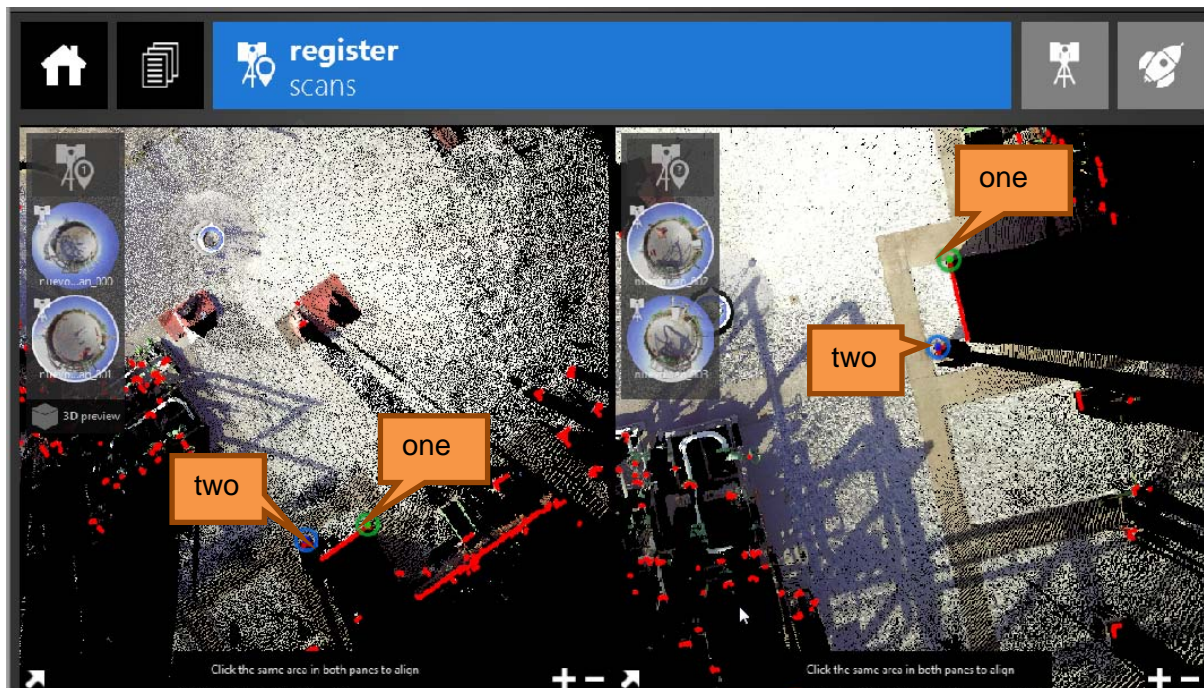
Figure

The registration is done manually scan by scan. The registration process will create our registered and correctly oriented point cloud. A chart with the registration statistics is displayed after each scan to scan registration:
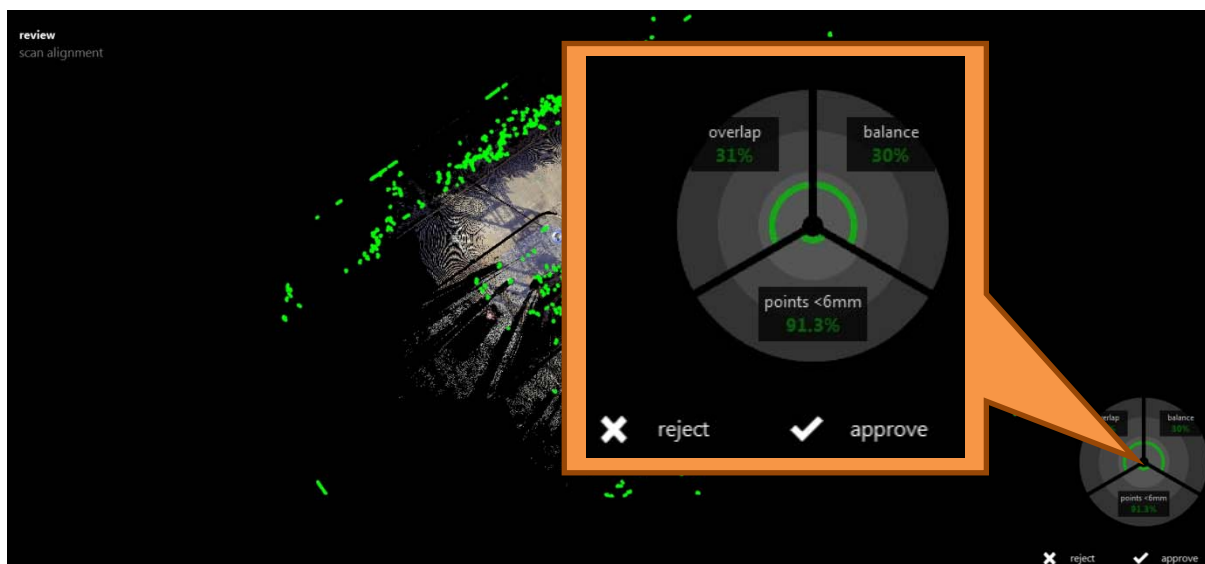
If the statistics are OK you accept the registration by clicking on "approve". In addition there is a "data report" available showing the overall statistics:
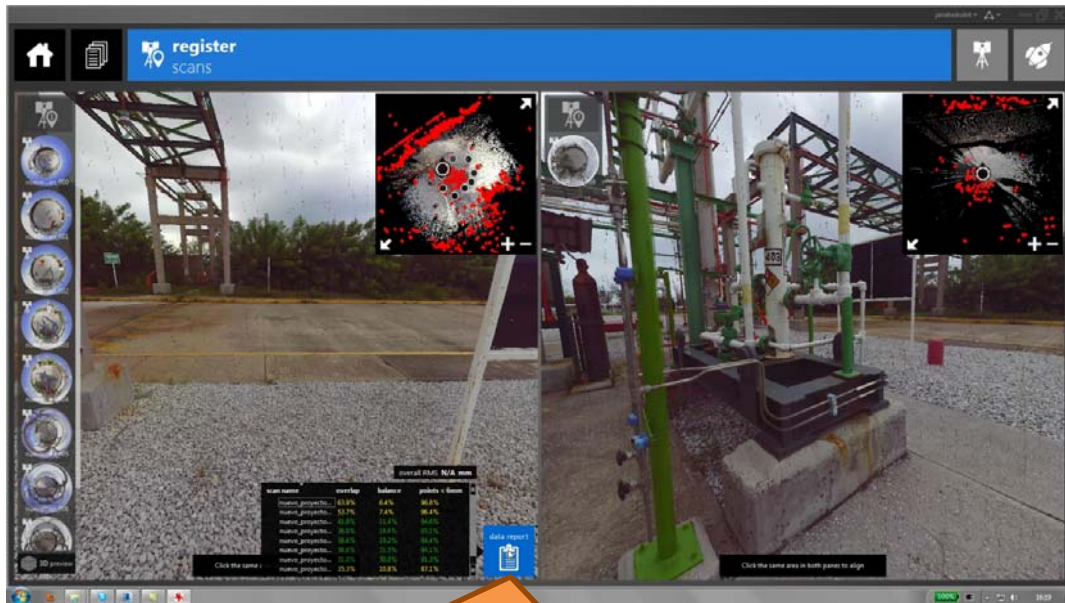
After having finished the registration you index the scans and create the final registered and unified cloud. Indexing is covered in the next section.
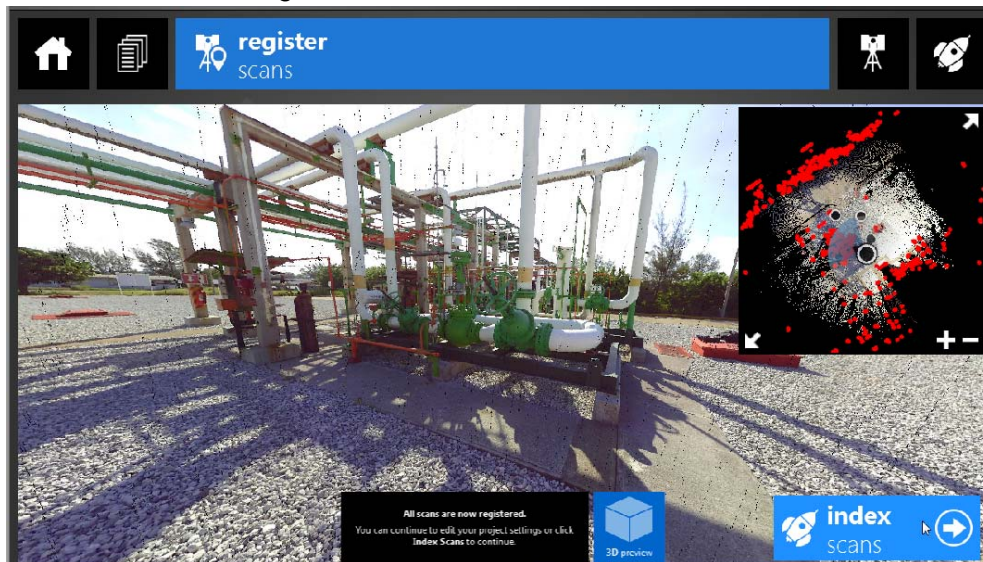
Cloud to Cloud Registration vs. Traditional Methods

Cloud to Cloud Pro's
- no targets needed and thus no additional survey with total station or GPS

ReCap Pro specific:
- easy and intuitive interface
- seamless Autodesk workflow
- meant for immediate registration while still scanning the next positions

Cloud to Cloud Con's
- For good results the scans should overlap sufficiently. This may result in more scan positions than for traditional registration.
- Could be less accurate if you do not add minimal survey control.

ReCap Pro specific:
- Manual scan by scan process, while registration in FARO Scene with targets runs automatically. This manual process is tedious especially for processing larger projects.
- If you add survey control during registration you have to enter the coordinates manually:

Autodesk Scan Project Management
Now that we registered we need to get the scan data into Autodesk format for design. New formats for 2014, classic supported formats

Creating Autodesk Point Clouds
Native point clouds import have been available since AutoCAD 2011. The traditional workflow for brining data from a scanner manufacturer's format or industry neutral format remains the same today. In addition, Autodesk 2014 products now provide a more centralized, project management approach to reality capture data management with Autodesk ReCap. Below are the steps for creating Autodesk point clouds as well as tips for point cloud management within the AutoCAD environment.

Direct AutoCAD Import
Although new workflows are recommended in 2014+ Autodesk products, users still have the option to convert and create AutoCAD point clouds directly. Here are the steps required.

1. Locate the INSERT Ribbon and select "Create Point Cloud"
   a. Command Line Shortcut: POINTCLOUDINDEX
2. Choose your registered scanner manufacturer's file format (FLS/FWS for the used Faro scanner)
3. Allow the opint cloud data to convert from the manufacturer's format to the Autodesk PCG format
4. When conversion is complete you may ATTACH the point cloud. This command is also available from the INSERT ribbon
   a. Command line shortcut: POINTCLOUDATTACH
5. While attaching point cloud to drawing, take note of the scale factor during import. Most scanner formats collect data in Meters. It may be necessary to scale your point cloud to the desired drawing units. This can be completed within the ATTACH command or with a traditional AutoCAD scale command.
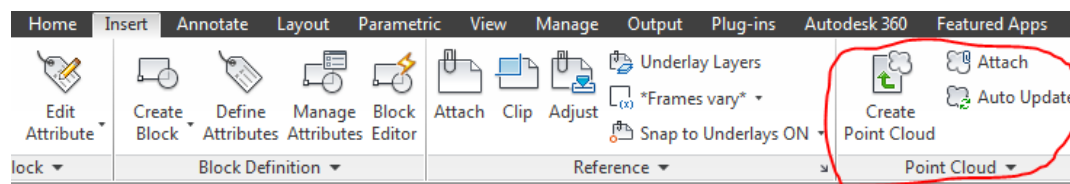
This method is currently recommended for smaller data sets (a few scan positions). It allows users to skip the intermediate step of importing to ReCap and go directly into the AutoCAD environment.

Pros	Cons
Direct import to AutoCAD without intermediate step to ReCap first	Does not generate RCP/RCS files. Standard cloud format for other Autodesk products (Inventor, Navisworks, Revit, etc.)
Best for smaller data sets	Not useful for larger projects. Too many points results in poor viewing quality and difficult

	management of data.

Autodesk ReCap Import

Autodesk ReCap provides a powerful interface for managing reality capture projects throughout the Autodesk product portfolio. The ability to handle billions and billions of points at high resolution makes it the perfect interface for scan management and project planning. ReCap also produces the new standard point cloud formats for Autodesk products. These formats are the RCS (reality capture scans) for individual scan files and RCP (reality capture project) which references all RCS positions.

Importing Already Registered Scans:

If the scanner manufacturer's software is used for scan registration (in this case Faro Scene), the user must import all registered files to the Autodesk ReCap program (in this case FLS/FWS/LSProj) file formats. The program supports most major scanner manufacturer formats as well as many industry neutral/standard formats. ReCap will convert all scan positions from the scanner manufacturer's format to Autodesk's native RCS formats. When conversion is complete, the user should save the newly imported scans as a new RCP project file.

ReCap Pro Import:

Pro has already been discussed above for the registration of scan positions. If a user has already used ReCap Pro for pre-processing of scans the resulting file formats for each scan position will be registered RCS files (Reality Capture Scan). All of these imported RCS scans can be saved within an RCP project file.

Pros	Cons
Creates native RCS/RCP file format. Cloud ready across most of the Autodesk portfolio	Not a direct import to AutoCAD
Handles nearly unlimited data at very high resolution	Conversion from manufacturer format to RCS is a slightly longer import period compared to AutoCAD import.
Able to tag and assign duties for large projects	
Easily manipulate scan data into custom clouds or smaller data sets for use in design programs	
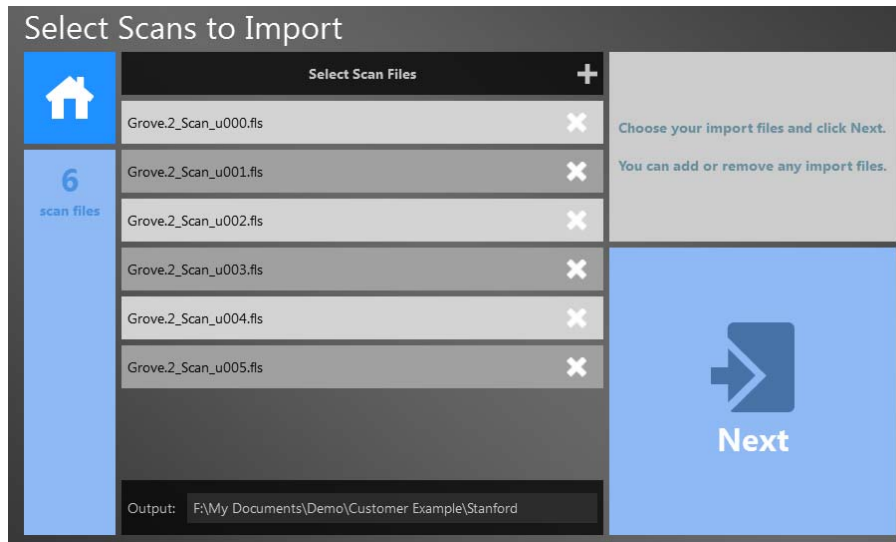
Project Management and Assigning Design Duties:

Within a ReCap project, the user has many options for managing and manipulating data. Organizing scan project duties to a team of designers can be a great way to keep individuals on task and avoid double work. Here are some recommendations for tagging and assigning duties to a team within a ReCap project.

Notes are tagged on various parts of the point cloud, assigning jobs to specific drafters

AutoCAD Point Cloud Settings

The Autodesk graphics engine in AutoCAD 2014 and below is still not optimal for point clouds. Although the environment can handle about 2 billion points, keeping the number of point cloud points lower results in better viewing quality. Currently AutoCAD's graphics engine can only visualize a maximum of 10 million points on the display at one time, but the default setting in AutoCAD is set 1.5 million points. To explain better, let's say a point cloud has one billion points; this means that in every view, after every orbit, pan, or zoom, AutoCAD has to calculate which 1.5 million out of the 1 billion to show (assuming default settings). The result is a longer thinking time (lag) and a point cloud that looks 1% as good as it was intended to look (poor visual fidelity). The rest of the points are still present and are used in calculations for commands, but AutoCAD just can't show them all. This is why it is recommended to work in sections of data.

Autodesk ReCap is the best way to handle larger sets of data. The graphics engine is far superior, and RCP/RCS is the direction that Autodesk is taking with Point Cloud technology, so it is best to adopt the workflow now. Here are some recommendations for preparing a scan project for AutoCAD 2014 as well as helpful settings to improve visual quality within AutoCAD.

Preparing the point cloud for AutoCAD

Breaking a large project into more manageable point clouds is key to having better results in AutoCAD. These steps explain how to create smaller, custom point clouds from a large project.

1. Open the saved RCP file
2. Locate a particular area of interest where design/modeling/analysis should occur.
3. Locate the Fence option within ReCap and draw a polygon around the region of interest. Press Enter
4. Choose to clip out everything outside of this region.
5. With only the desired points in view, locate the EXPORT button at the top of the ReCap screen.
6. Choose to export this clipped section as a customer RCS (for 2014 users) or a custom (PCG) for 2013 users.
    a. If using older AutoCAD versions, export PTS and/or E57. A 3rd party import program may be needed to import these formats to older AutoCAD versions (kubit PointSense, LASTools). Please note, PCG exports from Autodesk ReCap are not compatible with AutoCAD 2011/2012.
7. The newly created point cloud file is ready to be attached to AutoCAD. All registration information remains the same for the custom section.
8. This process can be repeated throughout a project. All scan data will align with previously created custom sections due to the data registration remaining constant.
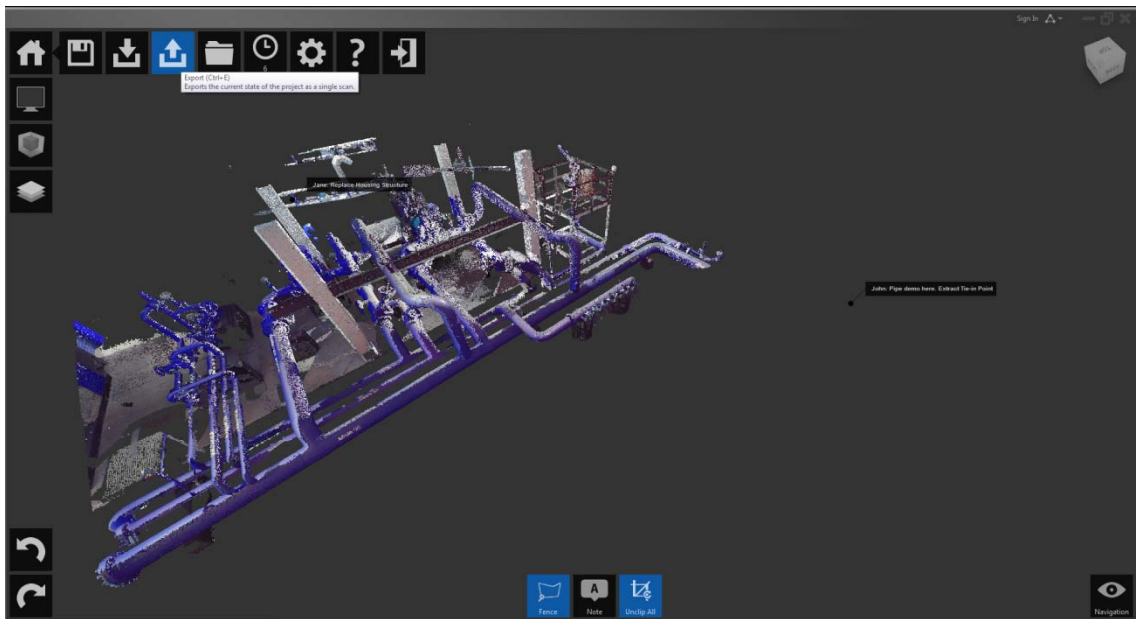
Clipped Section of large RCP project ready for use in AutoCAD. Fewer points will result in better quality

Helpful AutoCAD Settings

Now that a manageable point cloud has been created for AutoCAD, the cloud data can be attached, however, there are still steps that can be taken to improve the viewing experience. Below is a list of commands/tips which will aid the user in this endeavor.

Command / Tip	Notes
No 2D Wireframe	Working in a 2D Wireframe SHADEMODE is never recommended. Cloud data loads very slowly, no color or intensity is present on the cloud data and progress can be very laggy. Switch to any other SHADEMODE.
Hardware Acceleration	Turn on hardware acceleration within AutoCAD to improve visual performance (see color or intensity).Autodesk point clouds are heavily reliant on the quality of the user's video card. Use an Autodesk certified video card for best performance. In addition, ensure that all video card drivers are updated.
POINTCLOUDDENSITY	Sets the % of points viewable on screen based on the point max. For example, a density of 50% with a point max of 2 million will only

	display 1 million points at a time.
POINTCLOUDPOINTMAX	Sets the maximum allowable number of viewable points. Ranges from 1.5 million to 10 million. Careful, a very high point max can result in lag and performance issues based on the user's hardware performance.
AUTO UPDATE	By default, Auto update is turned on. Notice each time an orbit or pan occurs that the point cloud decimates. After the orbit/pan, the cloud regenerates its view from the new location to show the best possible points from that position. This is a good workflow when point max is lower. If point max is high, turn off auto update. User's will experience more fluid movement within AutoCAD but the cloud will not update/Regen to show the best points from a new position. A manual REGEN or RE_ is needed.
Real Time Density	When working with Auto Update on the user may control the amount of decimation that occurs during an orbit/pan. It is recommended to keep this setting low (5-15%) to improve performance in navigation.

Generating Plant Deliverables

Now that the point cloud is successfully imported into AutoCAD, we can begin the process of extracting the information from the cloud. What will we do with this information? Typical deliverables include piping and modeling the point cloud to Plant 3D objects, generating isometric drawings, orthographic images, locating tie-in points for extraction, structural extraction, and analysis of equipment such as tanks. We will also mention additional modeling techniques used for conduit and other equipment. Most basic tasks can be completed using AutoCAD tools but third party software help with the modeling process which is will reviewed.

Design Tools

The tools required to produce these deliverables can be found in your AutoCAD package, third party software, or a combination of both. Working with point clouds requires essential tools but to be more efficient in the industrial world, users will typically have tools that pertain directly to what they are trying to accomplish.

Essential Tools

These basic tools include cropping and slicing of the point cloud, options for manipulating the point cloud, and viewing the cloud at higher resolutions. Cropping the point cloud can help the user eliminate any unnecessary data in the cloud such as noise or background points. Slicing the point cloud at a specific UCS creates simple 2D plans or 2D profiles that can be used for further analysis. Other tools used for manipulating the point cloud include sectioning the cloud for ease of navigation, scaling the cloud to the appropriate drawing units, and manipulating the UCS. Many of these essential tools can be found in Recap and/or AutoCAD.

Recap gives you the ability to crop, slice, manipulate the scan data, change the density of the point cloud, set the point maximum, and reduce the number of points in the point cloud in a high resolution easy to navigate 3D view. Some of these tools can also be found in AutoCAD by simply clicking the point cloud. Notice the ribbon change to the point cloud tools menu.

Many people benefit from this high resolution view as well as Autodesk Recap Pro's Scanorama views and third party software such as kubit's VirtuSurv. These views image based (bubble) or planar views can be used as an alternative to working with the raw scan data and are extremely helpful in navigation and design. You can compare your raw data to a 2D map and your image view as a 3D "Google street" type of view.

Shape Extraction/Pattern Recognition

More advanced tools will use pattern recognition to generate the desired models. These tools are based on algorithms that recognize pre-defined patterns from point data. In the plant world, these algorithms should be geared towards common plant objects (pipes beams) and at times can be combined with commands that make them catalog/plant driven. The resulting extractions create results that follow the final design software while staying as close to the as-built data as possible. In our case, we will be using a catalog based on standard piping design standards and export the models to its final format, Plant 3D objects.
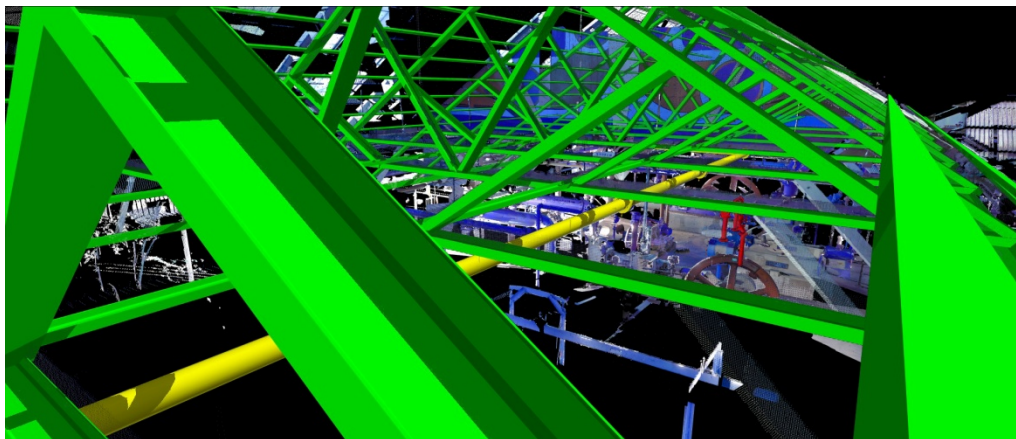
Extracted solids overlaid with a point cloud

Automatic shape extraction is used most commonly for shapes such as primitive lines, polylines, boxes, cylinders and cones. More advanced routines and algorithms allow for specific parts such as beams and pipe fittings to be detected within the cloud. Shape extraction is the most efficient when searching for the best-fit of a pre-defined 3D object. For example, a piping designer could be looking for a 90 degree elbow which is derived from standard piping catalogs and specs that are already being used in Plant 3D. In our demonstration, the kubit team will show how kubit PointSense Plant software will automatically import the user's catalog/specs from AutoCAD Plant 3D into the pattern recognition library. The software will then search for the same patterns that the user is familiar with and would use for a new design.

Piping the Point Cloud

Catalog Loading
Using third party software such as kubit's PointSense Plant, the user is able to step through a pipe run in the point cloud. Since this process is catalog driven, the first step is to select the catalog that we will be using for modeling. This catalog, as we mentioned previously, is based on standard piping design standards. Plant 3D also provides several catalogs and specification that we can choose to include. After importing the catalog we can see the rating, the diameter, the type of fitting, and the standard displayed.
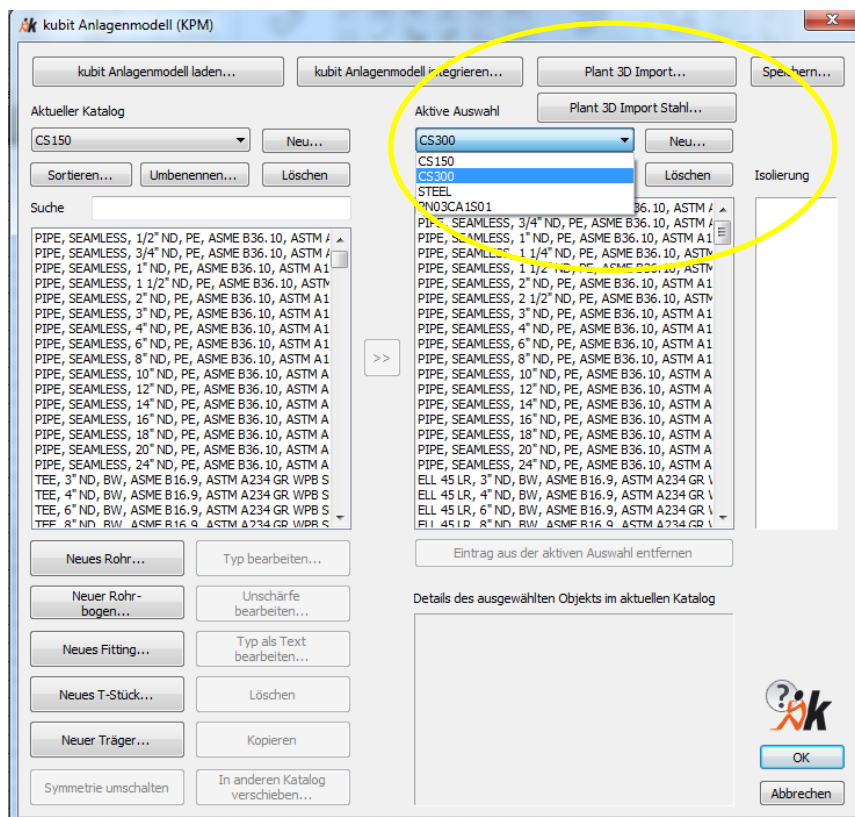
An AutoCAD Plant 3D Catalog is used within kubit PointSense for shape extraction

Modeling the Pipe Run

After selecting the catalog we wish to use, we can begin using kubit's "Walk the Run" routine found in PointSense Plant software. Each component is detected along the line and the use can confirm or override the pattern recognition. This flexibility offers a semi-automatic way of modeling the pipe run. "Walk the Run" applies the standard components derived from the Plant 3D catalog to the point cloud data. This process is meant for quick and local modeling of the pipe, elbow or inline fitting along a run. Local pattern recognition is the first step towards a fully modeled pipe run.
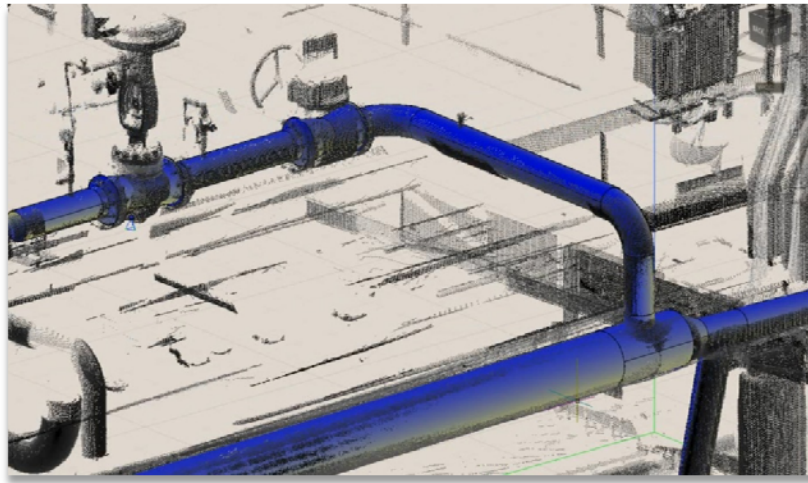
Adhering to Plant Design Software Rules

After modeling a section of the pipe run with "Walk the Run" routine, we notice small gaps between components and a lack of co-linearity between items. This is where applying design constraints becomes essential. The pattern recognition software used for this process helps close the gaps between the point clouds and parametric objects. The Design Software is made more for Greenfield situations, not Brownfield. These programs typically expect:

· Connected objects,

· Coaxial cylinder axis,

· Coplanar cylinder axis,

· 90° angles and

· Standard objects.
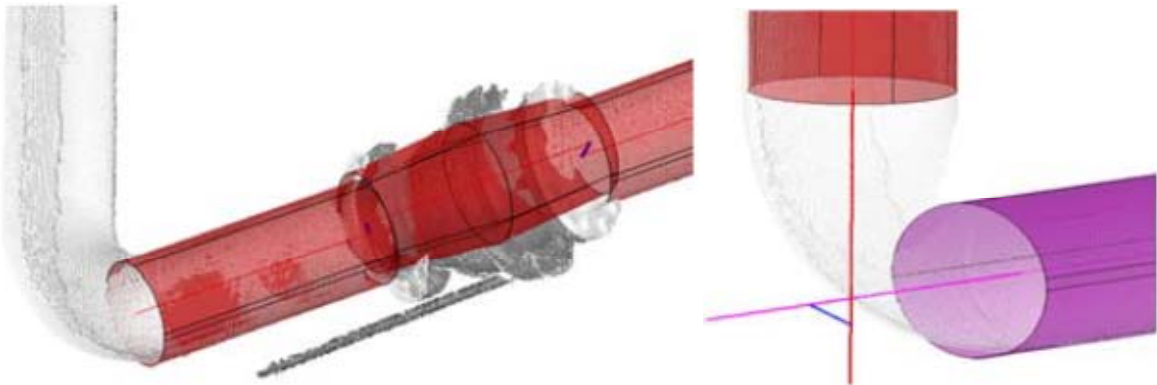
The screenshots above show the need for coaxial and/or coplanar axes at elbows and branches

By using "Apply Constraints" we can correct these gaps and have coaxial and/or (at elbows and branches) coplanar axes.

PointSense Plant's "Apply Constraints" can be used to correct the gaps by prioritizing the specifications in the catalog or by prioritizing their location in the point cloud. In this case, we need to prioritize the catalog specifications in order to generate the Plant 3D intelligent objects.

During the constraints process, we want to stay as close as possible to the points in the cloud and apply as few changes as possible to individually modeled objects while still meeting the rules of the design software. Another important objective is that the sequence of our modeling actions must not have any influence on the final result.

For example, if we begin the modeling of a long piperun with a very short cylinder fit along this piperun, the fitting of this initial cylinder axis will have a small error with respect to the full length of the pipe. Perhaps the pipe is bent or perhaps strong noise is present in the point cloud. As a result, every additionally connected piece will be inserted colinear to this first cylinder or at 90° angles with respect to the initial – short – axis of the first cylinder extracted.

In order to avoid this issue, we need an interactive workflow that which includes global optimization for an overall best fit for all objects rather than just following the constraints of the initial modeled object.
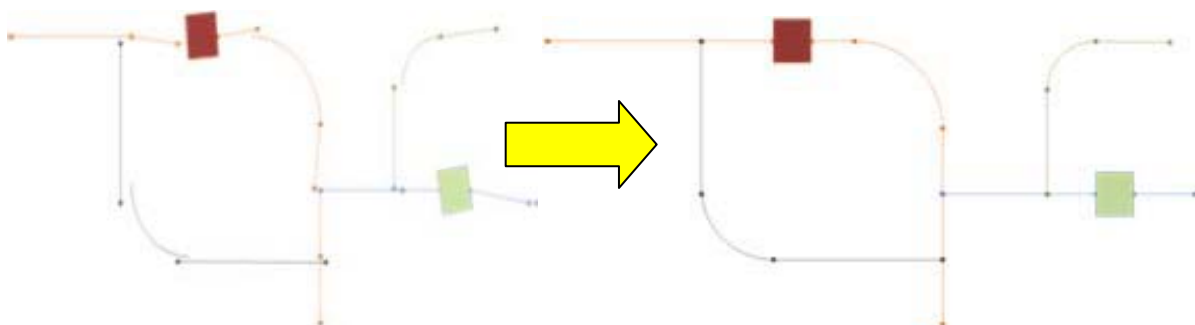
Applying design constraints globally through the entire pipe run ensures the model stays as close as possible to the cloud while still meeting the needs of design software like Plant 3D

Creating Intelligent Plant Objects

We have now modeled a pipe run and applied the necessary design constraints. The global optimization allowed the constraints to be applied to the design in order to meet the Plant 3D guidelines. The data is ready for conversion to Plant 3D objects.

There are different methods for converting the modeling route to Plant 3D objects but the kubit team has integrated this approach into a simple routine. By selecting the "Export as Plant 3D Objects" in the "Export" dialog we can instantly create an intelligent Plant 3D model. Alternative methods include the extraction of an overall best-fit routing line from detected runs. Many piping design products include "line to pipe" routines which can be used to complete design.

Now that the intelligent Plant 3D model is created, the Autodesk team provides automatic isometrics and/or orthographic drawing extraction. The "Quick Iso" routine was used during the session to convert our 3D model into an isometric with bill of materials listed.

Structural Extraction

Similar to piping the point cloud, structural modeling from point clouds uses:

- Pattern recognition algorithms

- Defined catalog components (known standards, AISC, etc.)

The kubit software offers the pattern recognition algorithms for recognizing steel members. The standard AISC steel catalog along with any user defined pattern can be extracted from the point cloud data. We can select this catalog through kubit's "Edit KPM" dialog. Similar to the pipe catalog, we can view the size, shape and standard of each beam.
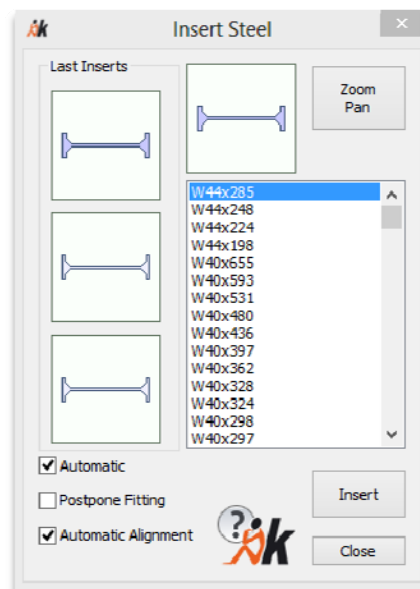
After selecting our steel catalog, we can begin be using kubit's "Fit beam" function and select the profile we choose to model. Next, the user will select two points on the member and allow the software to search the region for the most desired placement. We can speed up this process by selecting the "batch fit" option which will fit multiple beams at one time. The user also has the option of editing the member before continuing to the next object or waiting until after fitting all desired members.

Now, the beams can be extended, refit, and modified according to the orientation of the other beams. Similar to "Apply Constraints" for pipes, steel also has the option of filing the gaps between each of the members that lie on the same plane or axis (coplanar/coaxial). After editing the beams, a standard AutoCAD solid is derived with the proper centerline.
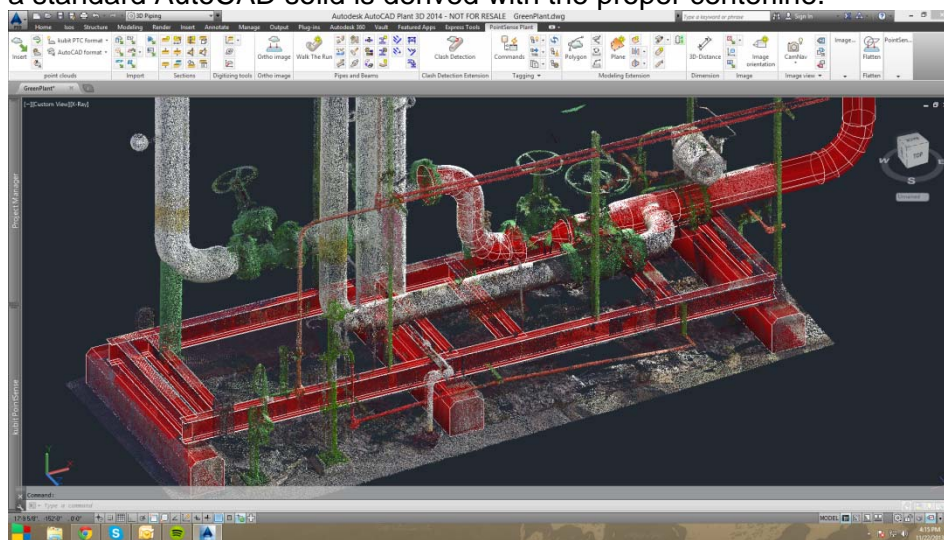
Extracting Tie-in Points

standard AISC steel catalog along with any user defined pattern can be extracted from the point cloud data.

Sometimes modeling a piperun and steel structures can be very time consuming especially if a designer only needs to derive specific tie-in points from specific pipe runs in the field. Why bother modeling everything in the point cloud in order to extract a few key points? There are different workflow options for users that have this need.

The user needs multiple options for deriving the tie-in points along a run. Based on the scan position, the user may only be able to see a flange or may only have scan data for the flange from a specific angle. For this reason, software must allow flexibility in calculating the internal tie-in points.

Typically, you can select 3 points on the front of the face, 3 on the back of the face, and 3 on the hub. Another option is to select a single point on the front face, on the back face or on the hub and then detect the cylinder axis.

3 on front of face → ← detect cylinder axis + point on face

3 on back of face → ← detect cylinder axis + point on back of face

3 on hub → ← detect cylinder axis + point on hub
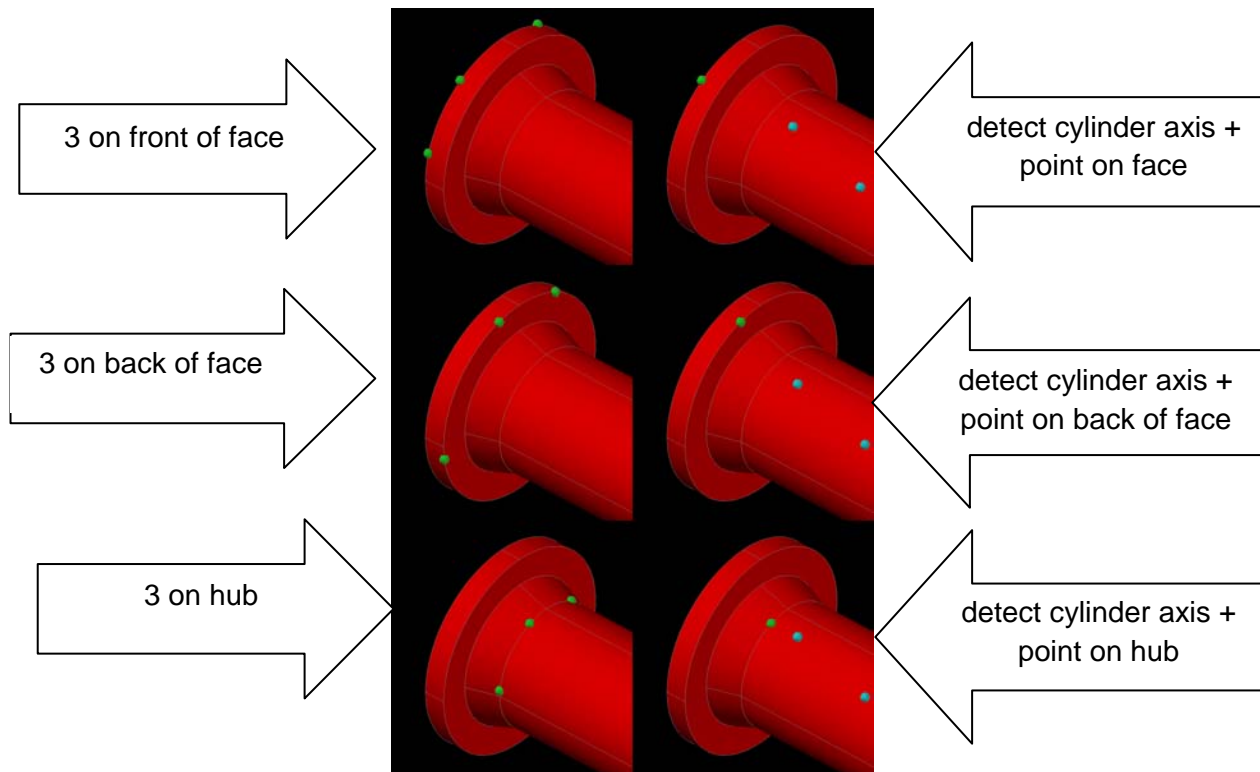
Clash Detection

Verifying and testing for interference between existing field conditions and new proposed design has never been more efficient. In this case, a clash detection tool is extremely valuable. Fortunately, Autodesk provides this functionality directly in Autodesk Navisworks Manage software. Please read the recommended instructions below for clashing between model point cloud with Manage.

Workflow options:

1. APPEND a DWG to Navisworks which includes the finished drawing objects. The user may remove the point cloud from the DWG before appending.
2. Append the RCP or RCS point cloud file in Navisworks 2014
3. If needed, scale the point cloud object to match the units of the DWG objects by selecting the "reality capture" cloud, right clicking and choosing "units…"
4. Click the CLASH DETECTIVE icon in Navisworks Manage which opens up two columns
5. On the left column, choose the point cloud data referenced in the DWG. Make sure that
6. the clash setting is marked for POINTS.
7. On the right column, choose the solids/surfaces referenced in the DWG. Make sure that
8. the clash setting in the column is marked for SURFACES
6. Set an appropriate tolerance for the clash searching between points and solids
7. Set the clash type to CLEARANCE and Run the clash detective
8. Visualize the clashes detected in Navisworks. You will notice the highlighted solids/surfaces which clash with the point cloud data within the desired tolerance set.
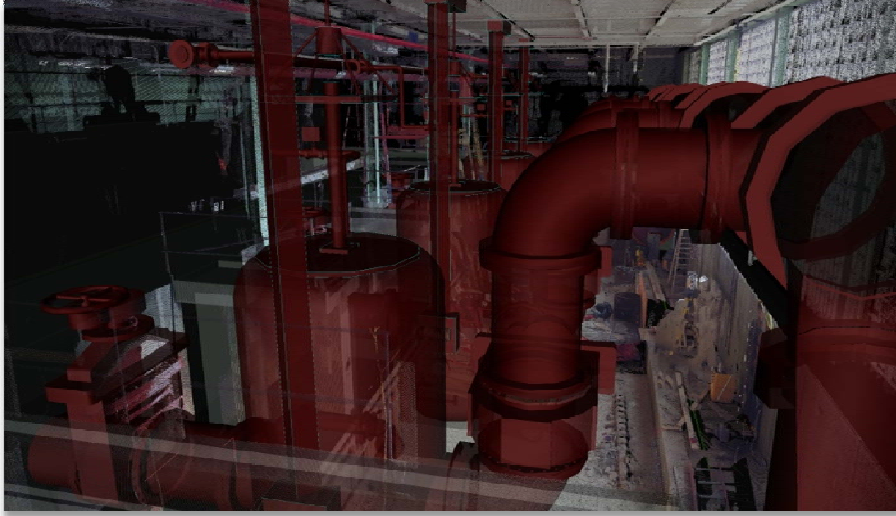
New equipment placed within existing facility; ready for clash detection in Navisworks

Tank/Equipment Analysis

Some third party software also provide more advanced tools for further analysis of modeled objects created from the point cloud. PointSense Plant offers a tool that allows the user to calculate volumes, create a deviation chart, and generate a 3D model of tanks, cylindrical objects and other equipment.

The user can start by fitting a cylinder to the desired object in the point cloud. This tool works best when cropping out undesired points and leaving only the area of interest. The cylinder will use the points in the point cloud to fit the best possible cylinder. Now we can use this cylinder to generate a 3D model.

The PointSense Plant command being used is "PCCYLINDERANALYSIS". In the Cylinder Analysis dialog, we can specify all of our constraints including the option of reducing volume due to undesirable objects in the equipment (deadwood), the maximum deviation expected from the point cloud to the generated cylinder, wall thickness if that value is known and other advanced options.

From this dialog we can generate a database of points (Create points list), a table of volumes (Create Table), a 3D solid, polylines, and a point cloud of the unwrapped cylinder.

After executing we will view the generated 3D solid and a deviation table. The deviation table shows us where the point cloud crosses beyond the generated cylinder and where it is located within the cylinder. A perfectly round and symmetrical point cloud cylinder would generate values close to or equal to zero since the cylinder is fit exactly.

By inserting the generated point cloud of the unwrapped cylinder, we can overlay this information with the deviation table to see a more graphic representation.
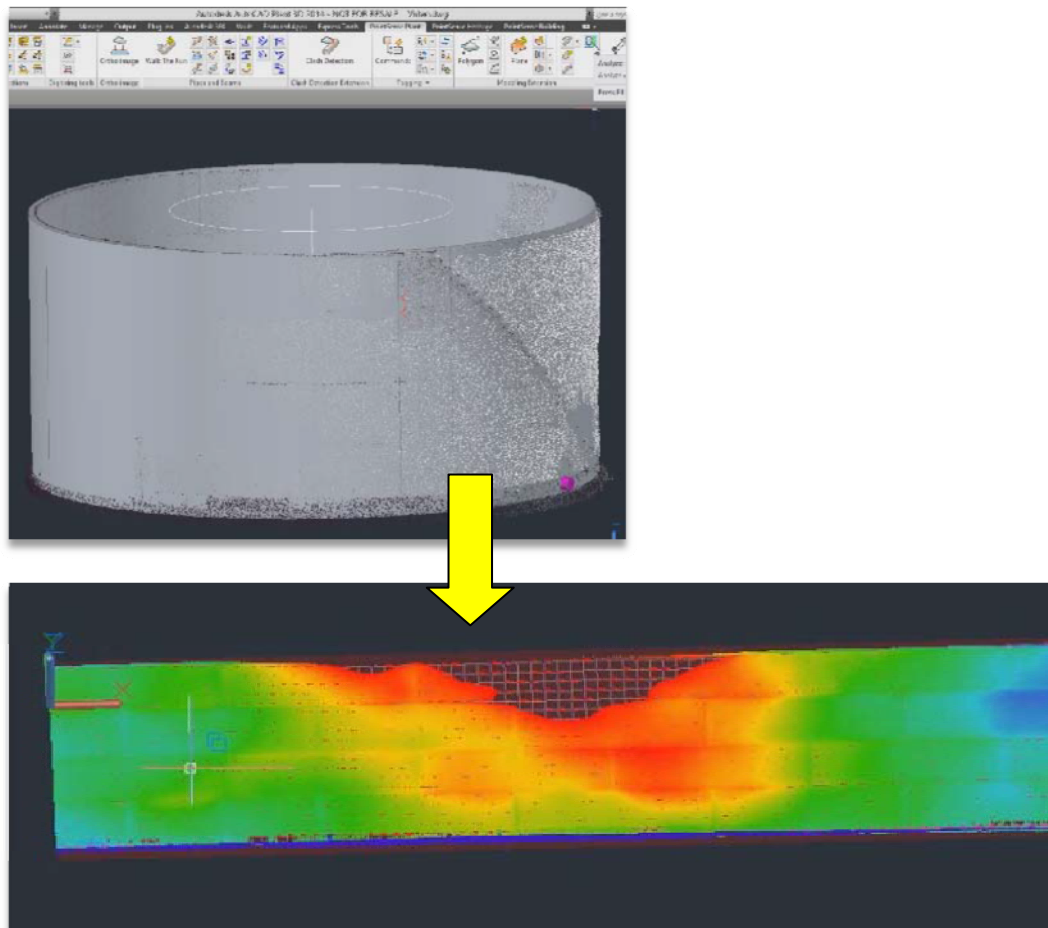
Unwrapped tank is color mapped to show deviation from a perfect cylinder

For further analysis, we can combine our results with Microsoft Office's Excel and view our points list. From this list, the minimum and maximum deviation can be taken and applied to the deviation chart in AutoCAD to create a deviation map.

Using kubit's Section Manager, the deviations can be categorized by color. The maximum and minimum points found using Excel can be specified in the Section Color->Elevation map section. This map can also be accompanied by a Legend which can be found in the Section Manager.

Lastly, the table of volumes that was generated can be viewed in Microsoft Office's Excel. The volume is given at each elevation, and if a reducing volume was specified in the previous Cylinder Analysis dialog, it will also give the total reduced volume. Selecting each volume at each elevation will generate a graphic representation of the cylinder's volume capacity.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
le	1.363°	4.088°	6.813°	9.539°	12.26°	14.99°	17.71°	20.44°	23.17°	25.89°	28.62°	31.34°	34.07°
ength	6	18	30	42	54	66	78	90	102	114	126	138	1
-183.5	3.119091	3.19577	3.375525	3.230472	3.140588	3.180353	2.955865	3.095502	2.719374	2.696468	2.697995	2.57557	2.9390
-171.5	1.453874	1.435584	1.545365	1.291093	0.922242	0.88661	0.575488	0.451946	0.305564	0.201863	0.191535	0.17642	0.3515
-159.5	1.468682	1.35774	1.268383	0.995841	0.703618	0.776011	0.396043	0.193029	-0.0283	-0.15286	-0.06081	0.093672	0.2842
-147.5	1.395523	1.145676	0.922194	0.657353	0.410889	0.529533	0.032071	-0.24541	-0.42165	-0.42814	-0.28742	-0.12473	0.0876
-135.5	1.018005	0.73907	0.475837	0.238106	0.022045	0.186351	-0.39057	-0.72976	-0.92875	-0.94405	-0.83694	-0.57028	-0.217
-123.5	0.478022	0.272445	0.058659	-0.15179	-0.27947	-0.2225	-0.68513	-1.11943	-1.40375	-1.51128	-1.51847	-1.32691	-0.806
-111.5	0.575006	0.428975	0.261081	0.098733	-0.02056	-0.11792	-0.37006	-0.65249	-0.89142	-1.0465	-1.18931	-1.2919	-1.145
-99.48	0.584133	0.439244	0.306021	0.182241	0.094818	0.034161	-0.13169	-0.30107	-0.49584	-0.66531	-0.86461	-1.08715	-1.147
-87.48	0.602058	0.451877	0.321274	0.231711	0.197794	0.211512	0.098712	-0.01825	-0.16866	-0.34398	-0.59085	-0.88975	-1.059
-75.48	0.468748	0.327693	0.195891	0.132274	0.154224	0.274395	0.233295	0.115059	0.05044	-0.06425	-0.33003	-0.62953	-0.779
-63.48	0.876838	0.726789	0.572764	0.444765	0.355147	0.527156	0.562294	0.607421	0.598974	0.480779	0.248219	0.037254	-0.136
-51.48	0.934047	0.773899	0.650785	0.512254	0.414066	0.637805	0.623785	0.711674	0.673761	0.542392	0.392051	0.2733	0.1170
-39.48	0.713302	0.563661	0.490184	0.40459	0.361847	0.722357	0.55172	0.587672	0.466938	0.288399	0.182535	0.117607	0.0085
-27.48	0.512278	0.365353	0.345723	0.355801	0.422906	0.800915	0.557672	0.391549	0.228618	0.078473	0.007618	-0.00101	-0.019
-15.48	-0.01248	-0.14952	-0.10547	0.087239	0.273837	0.52427	0.228705	-0.02646	-0.20603	-0.2982	-0.32947	-0.26601	-0.134
-3.477	-0.64775	-0.70914	-0.67852	-0.43887	-0.15607	-0.15022	-0.42324	-0.75604	-0.93703	-0.98165	-1.04695	-1.12145	-0.982
8.523	-0.34646	-0.39795	-0.36231	-0.21896	-0.10092	-0.06472	-0.28483	-0.58035	-0.82886	-0.92161	-0.98313	-1.13653	-1.107
20.52	-0.18189	-0.28794	-0.22616	-0.08574	0.032976	0.027554	-0.19759	-0.52572	-0.76892	-0.88021	-0.9201	-1.01239	-0.95
32.52	-0.09614	-0.10587	-0.06404	0.014824	0.105419	0.11889	-0.10335	-0.38805	-0.67513	-0.8386	-0.91683	-0.9341	-0.888
44.52	0.070029	0.049737	-0.00115	0.040323	0.008442	-0.01267	-0.14789	-0.38414	-0.63331	-0.79997	-0.9215	-1.0064	-1.072

Detailed reporting in Excel shows volumetric and deformation from the tank