ES11269

The "Realities" of Today's Plant Design Projects

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Learning Objectives

- Learn how to adopt point-cloud workflows within the 2016 Plant Design Suite software
- Gain insight from user experiences regarding what to expect with new Autodesk technology
- Understand the recommended steps for preparing laser scan projects within your Autodesk design package
- Discover how to extract typically needed plant deliverables from point clouds, such as intelligent models, tie-ins, and more

Description

How are inventive plant designers capitalizing on the power of Autodesk, Inc.'s, reality-computing platform? This class will examine real Autodesk user experiences regarding how companies are successfully implementing point cloud data for plant design. Listen to your peers and gain insight into the latest software used, the common barriers experienced in introducing new technology, and the workflows adopted to help users get from the field to completed design. This class will also recommend the latest laser scanning workflows within the Plant Design Suite software for 2016. Discover how to achieve typically needed plant deliverables such as catalog piping and structural design, tie-in point extraction, clash reporting, and field to shop and back—all from native Autodesk point clouds.

Your AU Experts

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***Isabel Suarez** has 19 years of AutoCAD experience; 10 years of professional CAD design experience, and 3 years of experience in Reality Computing. She has worked as a designer in various industries including construction, precast concrete design, civil, manufacturing, structural, and heavy-lift and transport. As an experienced CAD user with a passion for teaching and assisting others she developed many of those positions into instructional roles and she is currently the Technical Support & Training Manager of FARO 3D Software in North America.*

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Reality Computing: Capture, Compute, Create

Autodesk defines Reality Computing with three simple terms; Capture, Compute, Create. What does this mean and how does this translate to the world of industrial facility and plant design?

Capture

Capture has a similar definition across most industries and refers to collecting existing field conditions with the use of tape measurement, surveying instruments and/or digital cameras (photogrammetry). In the plant design world these survey instruments are commonly terrestrial laser scanners. The image below demonstrates the terrestrial laser scanning process. The laser scanner is capable of collecting hundreds of thousands of points per second via a laser beam. As the beam makes contact with the surface the laser is projected back to the instrument allowing the instrument to record the object’s distance and angle from the scanner. The scanner’s rotating mirror spins vertically combined with the scanner’s horizontal rotation allowing thousands of laser measurements to occur per second.

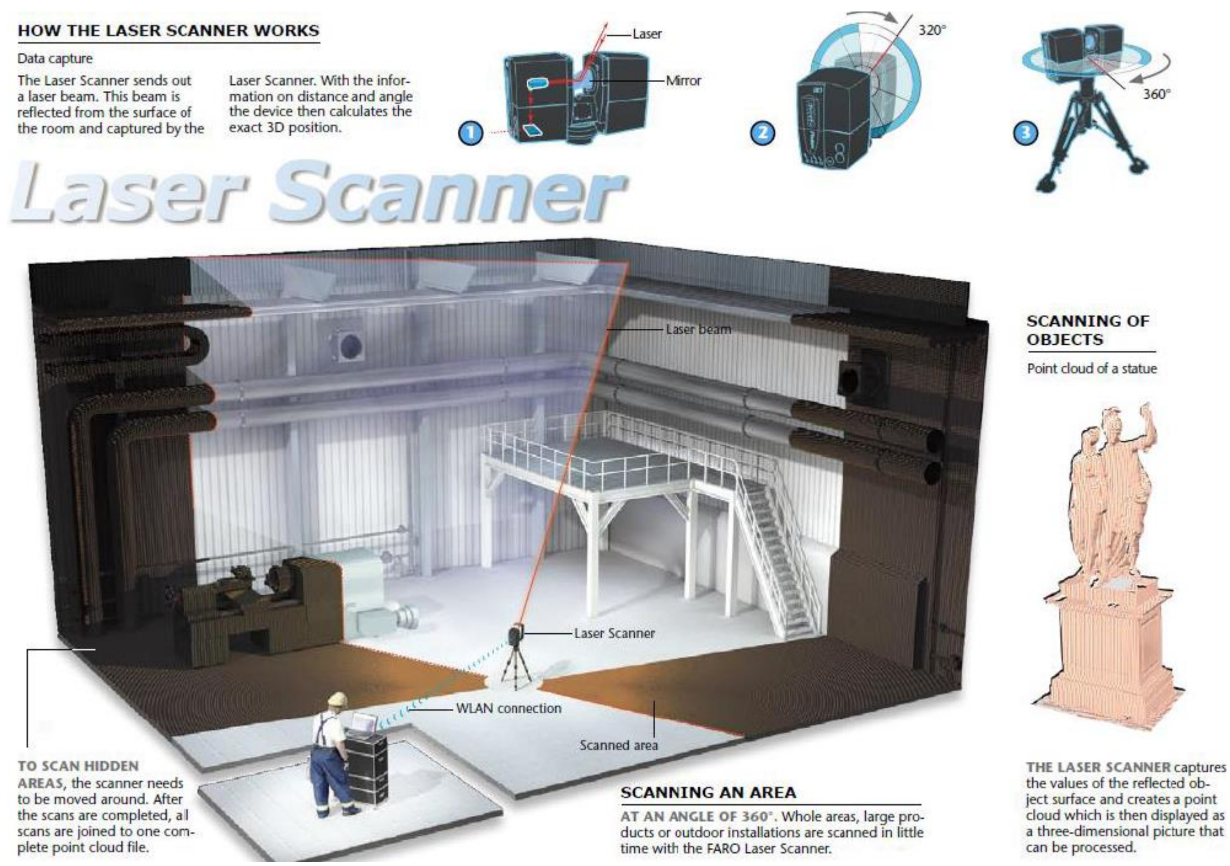

FIGURE 1

Terrestrial laser scanners have become an accepted means of data collection within industrial facilities. Under the “3D Data Capture: What’s New” section, we will explore new technologies which complement this traditional approach.

Compute

The computing portion of Reality Computing refers to processing acquired data into a useful form. For plant design this means first registering the data into an organized structure and coordinate system. Afterward users begin the post-processing phase which converts organized data to typically needed design deliverables.

Pre-processing and Registration

After scans are taken in the field, registration is the process of aligning them in a common coordinate system. In the field, scan points are recorded and saved in a coordinate system which is relative to the scanner. The point of origin for this scan coordinate system is the position where the laser meets the mirror. The coordinates of this point are x = 0, y = 0, z = 0. If you have two or more scans taken at different locations in a room, right after scanning they will only know their own scan coordinate systems. In reality the origins of these scan coordinate systems have been at different positions in the room, and therefore it is necessary to determine the spatial relationship between them. This is called registering the scan, and the step from the scan coordinate system into the overall coordinate system is called transformation.

Post-processing

In the first half of the post processing phase, the proprietary laser scan data is converted into a format that is useable in an Autodesk environment. While Autodesk has provided the ability to create the RCP/RCS point cloud formats directly from the scanner manufacturer’s registration software only a few like FARO SCENE and LFM Gateway have taken advantage of this. The reality of this portion of the post-processing phase is that it is most often completed using Autodesk Recap for ease of use, its ability to convert various file formats, and its speed in processing.

The second half is completed in AutoCAD (or one of its many verticals) and/or Revit. Pattern recognition is used to extract linework, geometry and information from the cloud. This data will then be organized and used in the “create” step to form final and typical as-builts.

Create

The “create” step of the process is where the point cloud data becomes one of many standard deliverables in the engineering and plant design world. This can mean anything from simple 2D drawings to complex, intelligent 3D models.

Create for Plant Design

Create for plant design means considering the needs of both internal and external customers and generating useful deliverables to those ends. This can include but is not limited to:

- Accurate 2D Drawings
- Intelligent 3D Models
- Isometrics
- Tie-In Point Extraction
- Fabrication Drawings

- Existing equipment condition reporting
- Collision detection reports between proposed and existing structures

All of these results and more can be derived from laser scan data and represent CREATE for reality computing in plant design. Discussed later are methods for generating these results

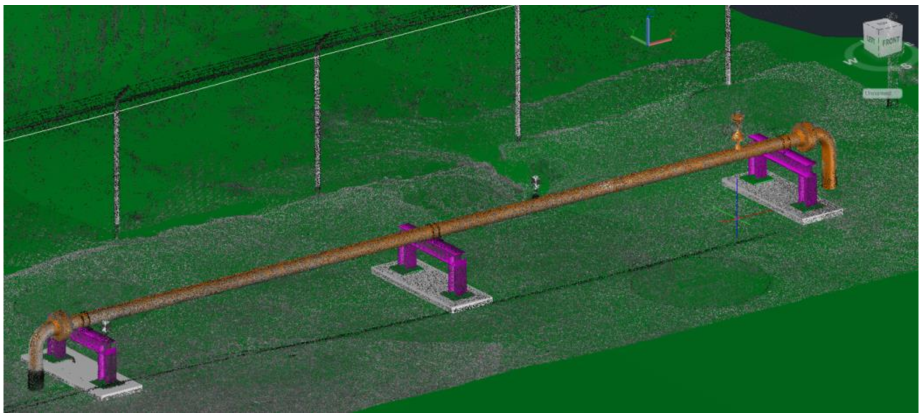

FIGURE 2

From Field to CAD

Since 2011 Autodesk has supported point clouds natively. The best workflow for inserting point clouds to the design environment and managing data sets has changed slightly each year. With the release of Autodesk 2015 and 2016 products, the recommended workflow has reached a consistent point and will remain so into the future. This is a relief for current users and trainers. The following steps describe the recommended workflow from field to AutoCAD.

Importing Data to AutoCAD

In the next steps we will examine the process from scanning in the field to inserting the acquired data into AutoCAD 2016.

Scan in the Field:

No change to this process. The user scans in each position where data is required. Scan strategy based on desired object capture is discussed later in the document.

Registration:

See “pre-processing and registration” section above. Plant users may also transform data to a plant north coordinate system or real world coordinates at this time. Laser scanners typically come with their own manufacture’s software for data registration. As an alternative, Autodesk users may choose to use Autodesk ReCap 360 Ultimate. In addition to standard target-based registration and user guided registration via matching points from scan to scan, the Ultimate extension of ReCap is now beginning to experiment with fully automatic registration with little user input.

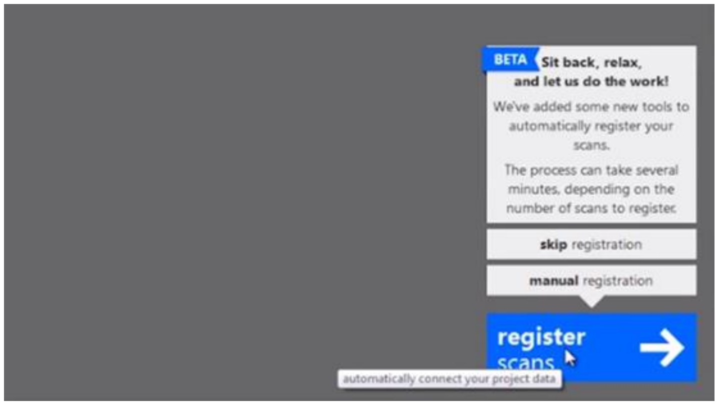

FIGURE 3

Converting to Autodesk Point Cloud Format:
Once the data has been registered, users may import the resulting set into Autodesk ReCap. This program accepts scan data from the majority of major scan manufacturers as well as common, open formats and converts the files into Reality Capture Scans (RCS files). It is recommended to use a file format which allows for individual scan position control after import to the Autodesk world. As an example, if the surveyor scanned 10 positions in the field, 10 RCS files should be created upon import to Autodesk ReCap. For this reason, PTS and ASCII or other unified data sets are not recommended. This import process converts each scan position to an RCS file and the project saves as a Reality Capture Project (RCP) which references each RCS scan position. These files are now ready for use throughout the Autodesk design products which support point clouds (AutoCAD, Revit, 3D Studio Max, Navisworks, etc.).

Attaching scans in AutoCAD:
Click the INSERT ribbon and choose to ATTACH a point cloud. Select your RCP file and scan data will import to AutoCAD. Click on the point cloud to reveal additional options. Notice the Point Cloud Manager option. Here you will see the list of RCS scan positions which make up your RCP project from Autodesk ReCap. Turn positions on, off or navigate to scan positions freely by double clicking the scan position in the list.

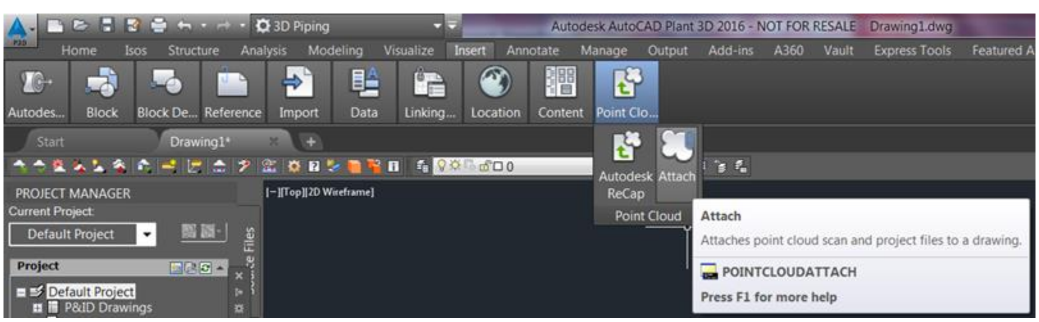

FIGURE 4

What’s New in 3D Data Capture?

Hardware:
Although terrestrial scanners are becoming commonplace in industrial facilities the addition of new capture technology is beginning to complement and in some cases replace this technology. Users now have options based on job at hand.

Handheld Scanning:
Handheld scanners enable users to maneuver and scan in tight and hard-to-reach areas in plant facilities, waste water treatment facilities, vessel and tank interiors, equipment rooms, and many other confined spaces. The FARO Scanner Freestyle^{3D} is one such device that provides a fast and easy to use scanning solution with verifiable accuracy of the 3D color scan data. Moreover, the handheld 3D scanner maximizes productivity offering fast data acquisition, real-time visualization, and the largest scan volume on the market (86sqft). With this the scan time in the field is reduced enormously during the point cloud acquisition as well as with the processing of scan results.

FIGURE 5

UAV (Drones)
Laser scanning utilizing high-end unmanned airborne vehicles provides the possibility to acquire data in dangerous and/or hard-to-reach areas, while offering an excellent cost-to-benefit-ratio for numerous applications.

FIGURE 6

Software:
What’s trending in the software world of Reality Capture?

Registration:
The reality capture industry is shifting more and more towards targetless registration as this saves time in the field and cost in equipment purchases. Traditionally registration required that each scan be aligned to the other with 3 points or using targets. In this new trend, improved algorithms are able to identify and align overlapping data to automatically register scans. This is something that has been possible in certain scanner registration software packages like FARO SCENE and is now available using ReCap 360 Ultimate. For more information and a brief video use this link: Recap Registration

Recap 360 also has many new tools to extract value from the cloud quickly and easily including:

- Ortho Dimension Tools -
- Smart Measure Tools – see video above
- Markup and Tagging -
- Search and Sync -

Autodesk ReCap Point Cloud Engine Improvements:
In 2015 the Recap point cloud engine enabled the use of individual scan positions instead of one unified cloud. This enabled users to turn scan positions on and off in CAD using the Point Cloud Manager and minimize the number of points on screen in order to isolate areas of interest, improve view quality and minimize error in point selection. In 2016 the engine has improved in two main areas: AutoCAD no longer slows down on cropping of point cloud regions and 3rd party pattern recognition tools are able to use 100% of the scan data for fitting algorithms; even when areas have been cropped/isolated from the user’s point of view.

Extracting Value from Point Clouds

Point clouds are in and of themselves not intelligent. Aside from coordinate and color data there is no other information attached to these large volumes of points. Designers are simply replacing their traditional measurement devices with a more powerful tool which allows them to bring the field into the office. Making use of scan data and creating value can be broken into two main sections; as-built modeling and analysis.

As-built Modeling:

As-built modeling is the process of extracting geometric shapes from real world conditions. Why would users re-create a model of existing conditions? Isn’t having the point cloud enough? In some cases, yes, the point cloud can be used for analysis of field conditions (discussed in the next section) but there are many cases where modeling a point cloud is useful in plant design.

Asset Management:

Asset management means knowing what equipment you have in your facility and having documentation of those systems and components. Having a point cloud to create models of the piping systems, structural components, tanks, equipment, power components and all other systems can be an invaluable tool in ensuring that all assets are accounted for.

FIGURE 7

Fabrication:

Using measurements from the cloud or models and drawings created from the cloud of the existing conditions engineers can assess and design new components, systems, and structures for the facility. Having the field available in point cloud format during the fabrication design process for those additional measurements that might require a second trip to the field to acquire saves both time and money.

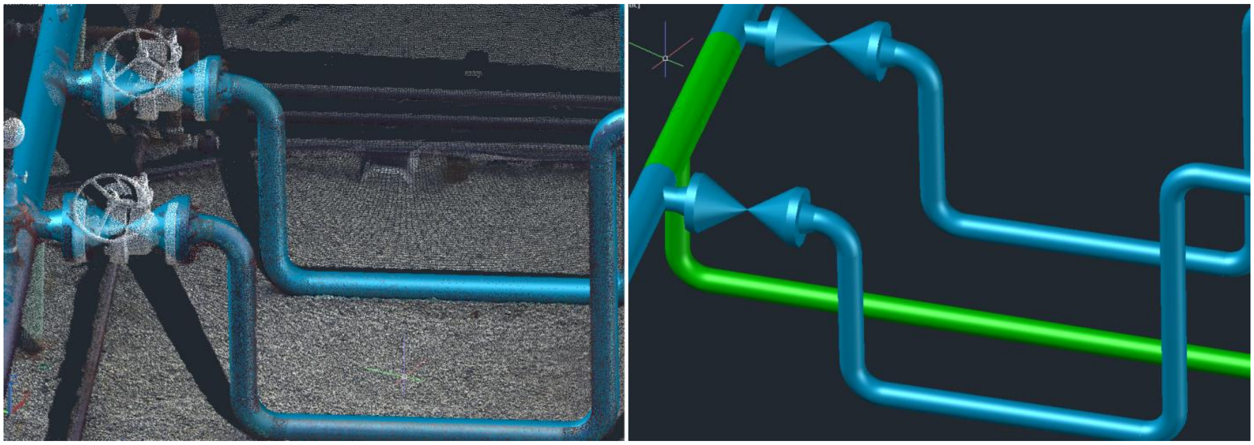

FIGURE 8

Clash Detection:
As-built modeling is also created for the purposes of clash detection. Clash detection allows for the identification, inspection and reporting of interferences in a 3D project model or point cloud data set. This may be completed at various stages in the life of a project and can be for the purposes of coordination or verification.

Analysis:
Analysis is a valuable tool of the reality computing workflow and one of the main reasons to adopt the use of point clouds in plant design. After fabrication and installation analysis is done to verify that the final products and/or their placement meet with the proposed design and to document the final conditions in the field and how they differ from original plans or designs.

Clash Detection:
Performing a clash detection analysis between a fabricated component and the cloud in order to identify possible issues with existing equipment can save time and money. Reality computing enables you to analyze whether the model of your fabricated equipment will fit in with what is already there in the field. You can also identify any logistical challenges like clearances for lifting equipment during installation prior to the arrival of the component in the field

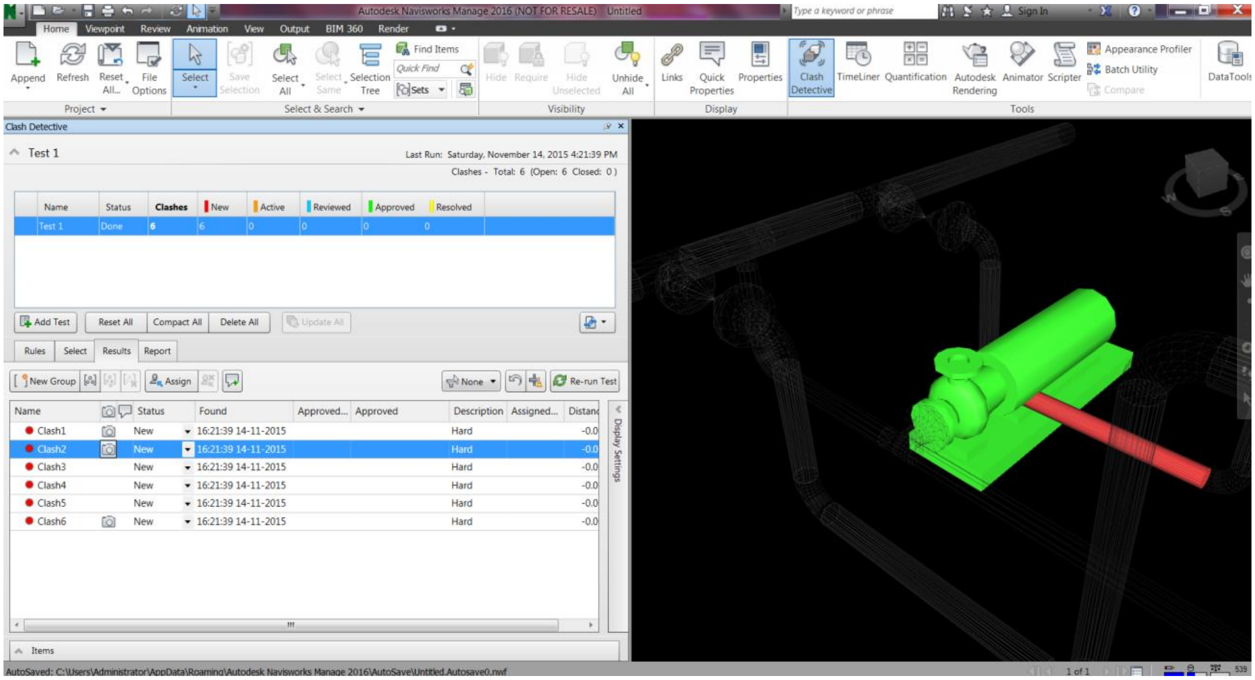

FIGURE 9

Quality Control & Verification:

Another reason to perform analysis is for quality control purposes. Did the equipment end up in the correct location? Is it in the proposed orientation? Was it installed properly? Does the equipment meet standards or does it need to be replaced? Is the structure plumb? Where is liquid draining in case of a spill? These are all questions that can be answered after a scan of the installed components or existing equipment or surfaces are compared to the proposed design or a perfect shape.

5	circumference	slice volume	total volume	deadwood slice volume	reduced slice volume	reduced total volume
5	392.444072	18379.71815	18379.71815	8.82702492	18370.89113	18370.89113
5	392.444072	36759.31442	55139.03257	8.73207552	36750.58234	55121.47347
6	392.4425258	36759.5161	91898.54867	4.521402483	36754.9947	91876.46817
1	392.446108	36763.80074	128662.3494	4.521402483	36759.27934	128635.7475
7	392.4905844	36763.68867	165426.0381	4.521402483	36759.16727	165394.9148
4	392.4514074	36770.4242	202196.4623	4.521402483	36765.90279	202160.8176
8	392.5681799	36786.99101	238983.4533	4.521402483	36782.4696	238943.2872
3	392.6290161	36785.28937	275768.7427	4.521402483	36780.76797	275724.0551
8	392.5561507	36772.29541	312541.0381	4.521402483	36767.774	312491.8291
1	392.503155	36772.84845	349313.8865	4.521402483	36768.32705	349260.1562
3	392.5684008	36776.25463	386090.1411	4.521402483	36771.73323	386031.8894
1	392.5477894	36768.80307	422858.9442	4.521402483	36764.28167	422796.1711
7	392.4999788	36770.00769	459628.9519	4.521402483	36765.48629	459561.6574
1	392.565038	36774.42117	496403.3731	4.521402483	36769.89977	496331.5571
6	392.5498065	37597.99644	534001.3695	4.623919683	37593.37252	533924.9297

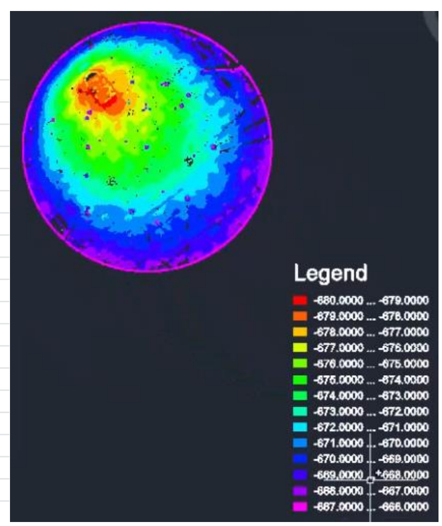

FIGURE 10

As-Built Piping and Tie-Ins

This section describes how to create typical plant deliverables as listed in the "Create" portion of Reality Computing.

Matching Generic Shapes With Intelligent Parts

The creation of as-built models or tie-in points from point clouds requires shape extraction tools which pull geometry from patterns found in groups of point cloud points. Without pattern recognition algorithms in place, the modeling process is completely inefficient and inconsistent results are more likely. In addition, a piping designer needs more than primitive solids/surfaces to get to final deliverables such as intelligent models and accurate shop drawings (isometric, orthographic). For this reason, 3rd party software aids in connecting extraction algorithms to industry standard catalogs.

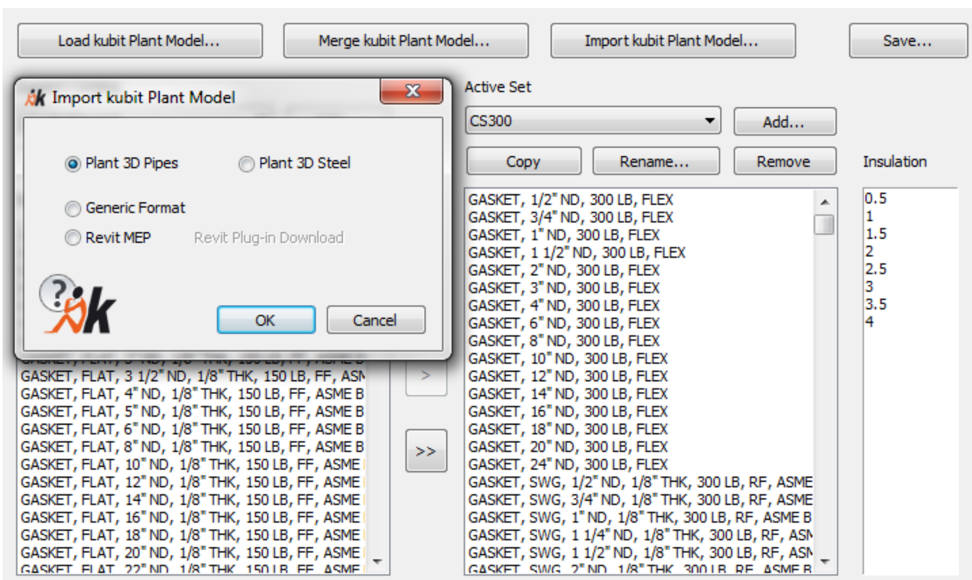

FIGURE 11: EXAMPLE OF A CATALOG FOR SHAPE EXTRACTION PATTERNS

As-built Modeling

Once a catalog is in place as a guide for what is allowed into the model, the user can begin the intelligent modeling process. For example, a user extracts a cylinder shape with a shape extraction tool. The diameter of 8.39 inches is reported. This is ok if the user's job is to simply extract non intelligent geometry. The algorithm performs a best possible fit based on the points given. More intelligent software may reference this 8.39 inch cylinder back to the user's CS150 catalog and recommend an 8 inch nominal diameter pipe in place of the irregular shaped cylinder. Now the user has a catalog object instead of a useless solid.

Additional algorithms must be in place to help in the detection and placement of elbows, tees and inline fittings throughout the as-built modeling process.

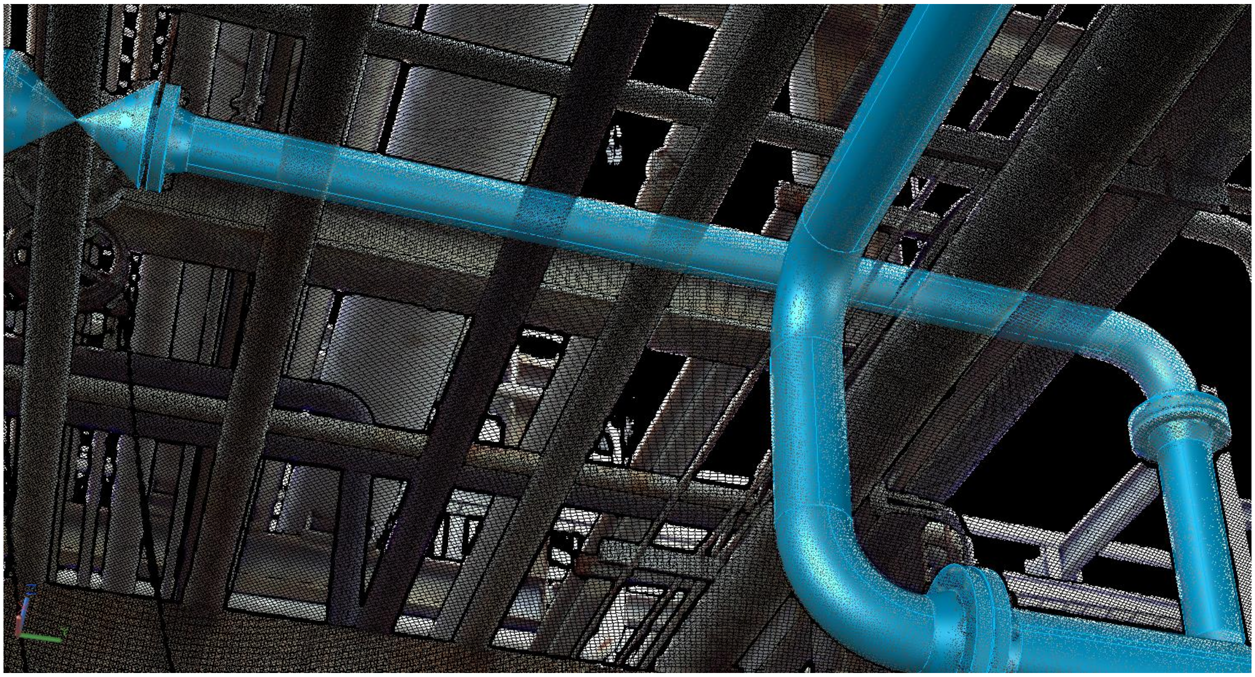

FIGURE 12: PIPING COMPONENTS MODELED OVER CLOUD DATA

Matching Design Constraints

The process for modeling objects from point clouds now seems fairly simple. With the right shape extraction tools and the correct reference catalogs the as-built model begins to form. Now comes the process of bringing the model into a traditional design deliverable. It is important to remember that the reference catalog is placing “perfect” catalog shapes over the imperfect real world conditions. As a result, gaps and misalignments occur when force fitting perfect objects into the point cloud. Design software such as AutoCAD Plant 3D and Autodesk Revit does not accept these misalignments and are not built to handle traditional brownfield environments. Such products expect connected objects, coaxial/coplanar axis’, 90°/45° angles, etc. Inserting a misaligned pipe run into Plant 3D would result in multiple, disconnected runs as well as the dreaded water drop symbols (indicating a missed connection). Before the runs are finalized they must meet the rules of the end software. This is the process of applying design constraints.

A proper application of constraints aims 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 final design software. An exaggerated model below shows the theoretical adjustment from as-built objects to a globally constrained pipe run.

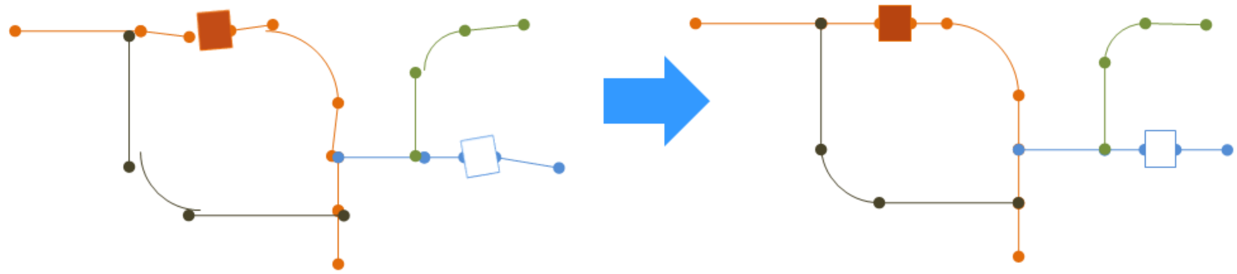

FIGURE 13: APPLYING DESIGN CONSTRAINTS

The constrained model is now ready for conversion into its final design software. Firms like FARO Technologies, Inc. provide conversion tools which automate the intelligent Plant 3D object creation from detected pipe runs. Once converted these design software packages allow for asset management reports, isometrics/bill of material reports and more.

Tie-in Point Extraction:

Sometimes modeling a pipe run 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.

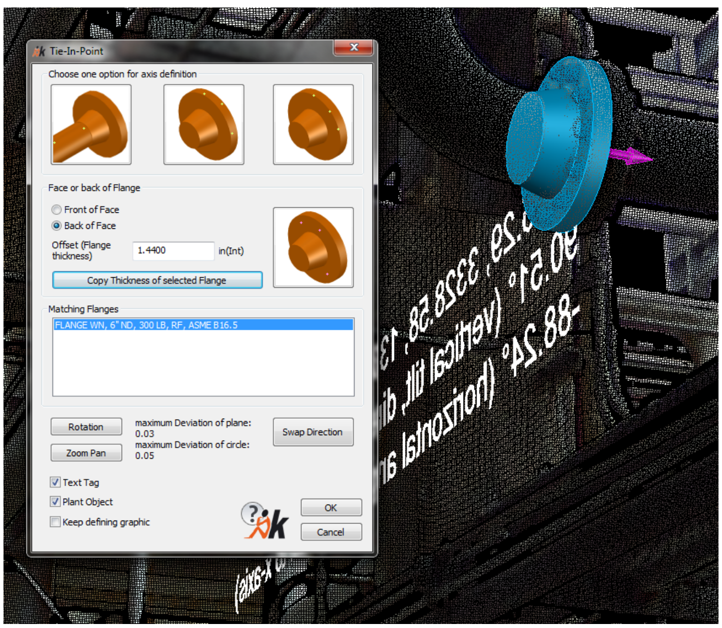

FIGURE 14: TIE-IN POINT EXTRACTION SHOWING MULTIPLE INSERTION OPTIONS

As shown in the previous figure, a more advanced, catalog driven tie-in point routine could enable users to extract the needed location, tilt, roll angle and more simply by choosing a selection of points on or near to the flange.

Point Clouds for Structural design

Similar to piping the point cloud, structural modeling from point clouds uses intelligent pattern recognition algorithms for recognizing steel members by matching detected shapes to catalogs. Although similar, structural extraction poses many more challenges. A pipe carries a consistent cylindrical shape so algorithms need little more than 15-20% of a pipe to determine size. Structural beams carry a variety of shapes and faces.

Scanning Structural:
A surveyor can scan pipe more carelessly than structural steel. If the desired deliverable is to determine the size/type and location of steel members, the capture device should pick up as many faces of the structure as possible. Take the figure below as an example. From one side the shape resembles a typical channel beam, but if scanned from an additional position, the data reveals that the shape is in fact a wide flange. Software cannot make this determination alone and can only suggest possible options. To avoid problems during the modeling process, it is recommended that the surveyor and designer have strong communication on what data is needed in order to complete modeling routines more efficiently.

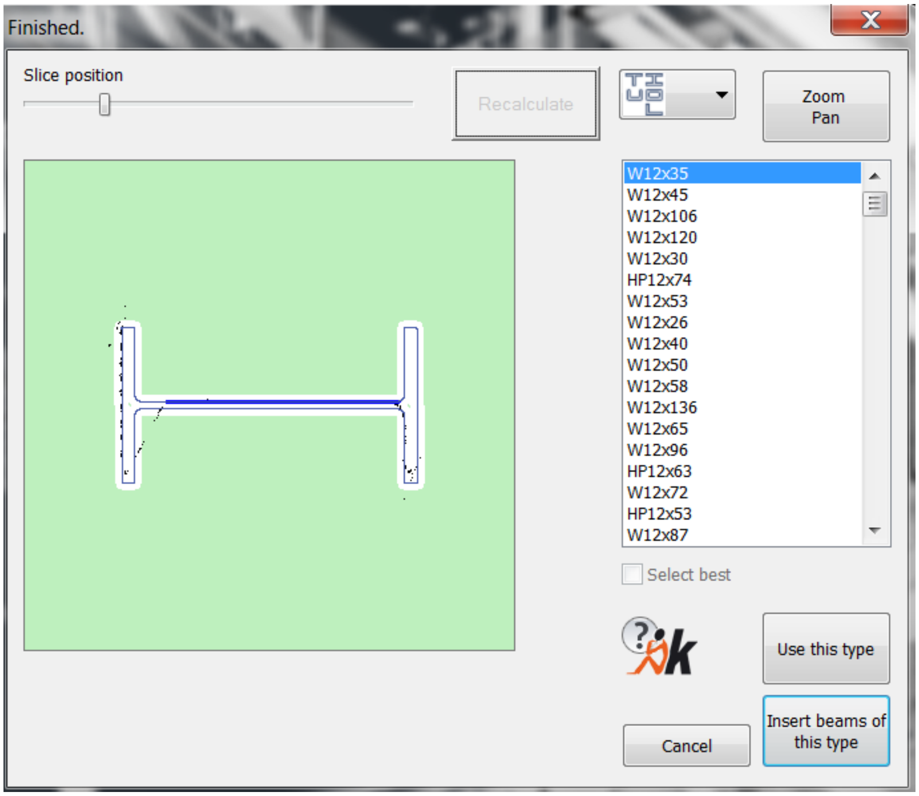

FIGURE 18: SOFTWARE NEEDS TO BE ABLE TO MATCH PARTIAL PATTERNS

Matching Design Constraints:
As discussed in piping design, structural members must also undergo the process of applying constraints if the user intends to bring detection objects into intelligent design packages (Advanced Steel, Autodesk Revit, Plant 3D, etc.). Centerline grids must align properly to avoid misconnections in final design software.

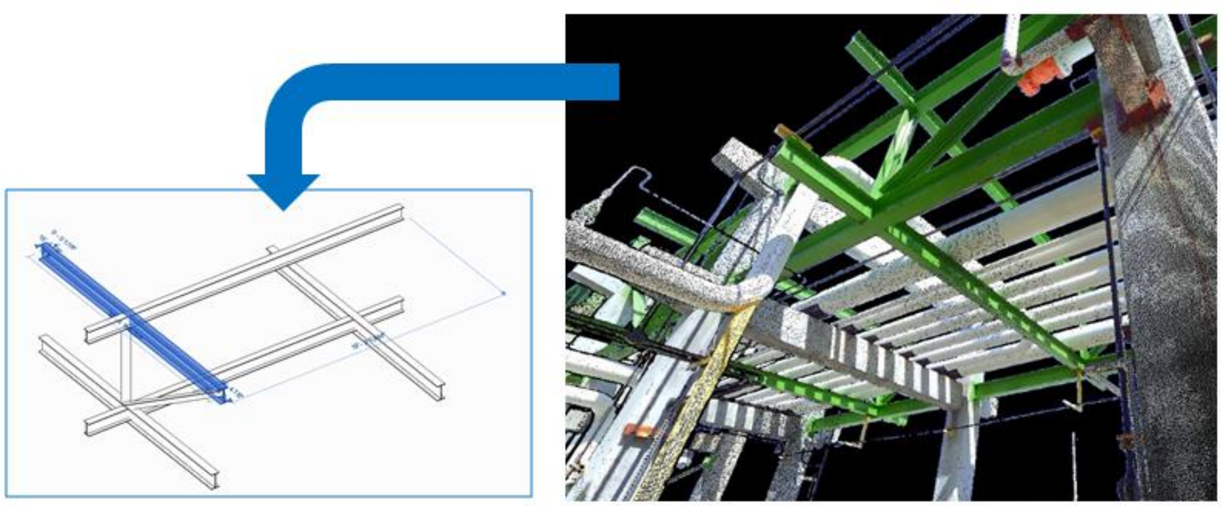

FIGURE 19: BEAMS MUST ALIGN TO GRID

Analyzing the As-built

As stated above, modeling the as-built is not always a necessity. In fact, using the scan data as a reference to the real world or as a assessment of existing conditions is often times more than enough for the project at hand. Analyzing laser scan data for industrial facilities is broken into 3 sections below: Quality control through construction, equipment analysis and clash detection.

Quality Control through Construction

One very powerful use of point clouds is running assessments of construction quality throughout the phases of the renovation or new-build process. Especially in structural design, structural framing and concrete fabrication, designers have already created a proposed model for construction. Although no construction site will perfectly adhere to the proposed model, the use of scan data is now allowing engineers to verify that construction remain within tolerance to the model via deformation analysis. Figure X below illustrates a Revit Structure model and point cloud which has gone through a deformation analysis on the modeled faces of structural framing and concrete slab. In this view the user is able to see possible flaws in concrete slab layout. The same steps can be performed for framing and vertical beam structure. The real world conditions vs. proposed model is visualized as designers can measure the distance the point cloud sways from perfection.

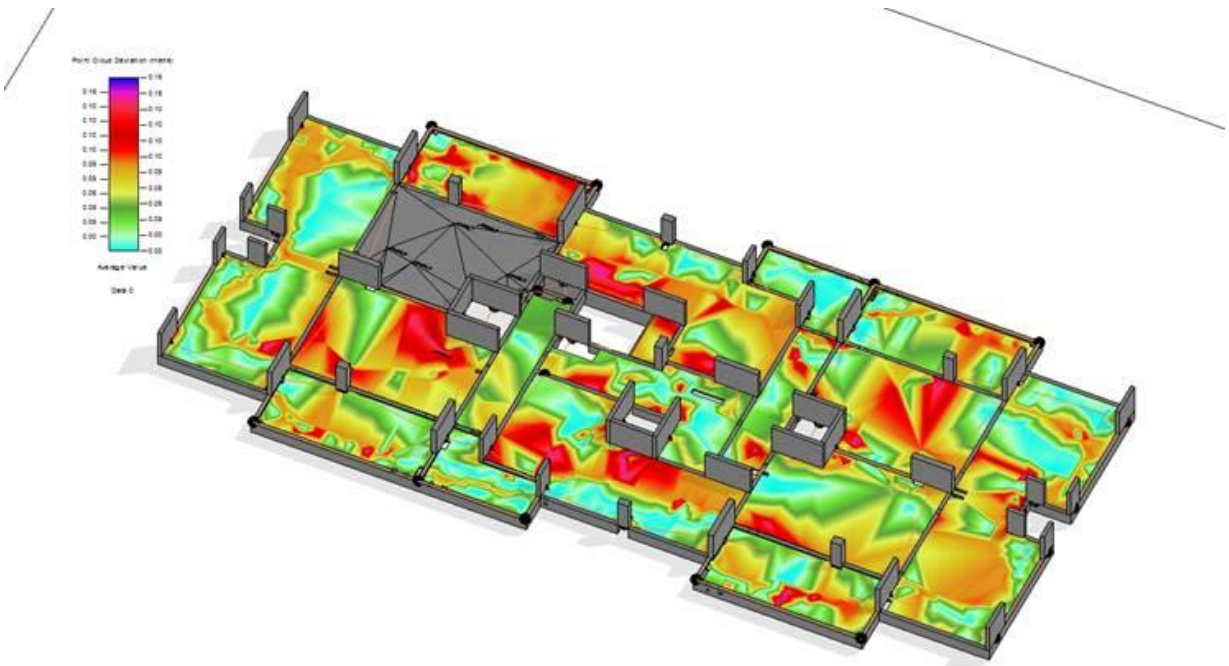

FIGURE 15: ASSESSING CONCRETE SLAB DEFORMATION BETWEEN POINT CLOUD AND PROPOSED MODEL IN REVIT

Here designers are able to make adjustments before continuing to the next phase of building. This helps avoid costly mistakes and future problems with structural integrity. Thanks to Autodesk’s available API, products like FARO Technologies’ PointSense for Revit and AutoCAD add additional value to Revit point cloud users for this purpose. There are a number of 3rd party tools available to assist in analyzing conditions from point clouds but this tool is working directly within Autodesk design environments.

Equipment and Tank Analysis

Industrial equipment and tanks are another unique and powerful application for laser scan data. In this section, the use of point clouds for tank analysis can be broken into two sections; shell deformation and volumetric calculation.

Shell Deformation:

Over time equipment can age due to heavy use, extreme temperatures, natural weathering or be subject to harsh chemicals. Using point clouds allows engineers to determine irregularities in the tank shell. This is most often performed by comparing a perfectly cylindrical tank to the as-built scan data. The figures below show screenshots from PointSense Plant software in AutoCAD. A user must first extract a perfect cylindrical shape from the tank or begin with a 3D solid from a known industry standard diameter. In a second step the point cloud is “unwrapped” on to a flat plane (Imagine unrolling a poster on to a flat desk). The algorithm first asks the user to define a grid across the entire façade of the unwrapped tank. This user defined grid size will determine the level of detail the tool will use for inspection. The smaller the grid squares, the more intense the inspection but also the more demanding on the software. Within each grid square is a series of points from the scan. The tool is able to report back the average distance between the points in each square to the perfect model (options for minimum and maximum distances within each grid are also possible).

A variety of reporting options are available from the completed analysis. A simple heat map helps users quickly visualize how much the tank is bulging or caving within each region. For more precise results a deformation table is exported to Excel or database of choice. This table shows users where the point cloud crosses beyond the generated cylinder and where it is located within the cylinder. A perfectly round and symmetrical point cloud would generate values close to or equal to zero.

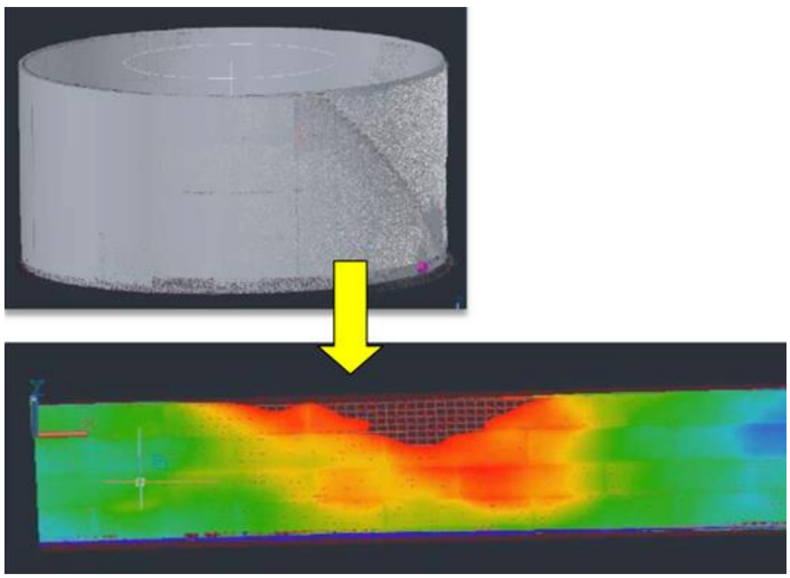

FIGURE 16

Volume Calculation

Tanks hold truly liquid assets for companies. It is critical that owners have precise knowledge of the volume of these assets at varying levels. Using the deformation grid method mentioned above, engineers are able to place the X grid lines at desired intervals to determine accurate tank volumes.

Many tanks contain deadwood (equipment running inside of the tank such as pipes/structure) which can exaggerate the calculation. These items take up volume but do not count toward the overall liquid space. Programs that support tank volume analysis must also account for deadwood. Within the PointSense Plant software a user should first create a simple solid from this objects prior to running a volume analysis. These solids can then be subtracted from the overall volume calculation. Visualizing volume reports is realized using typical Excel spreadsheets and accompanying graphs generated from the exported numerical values.

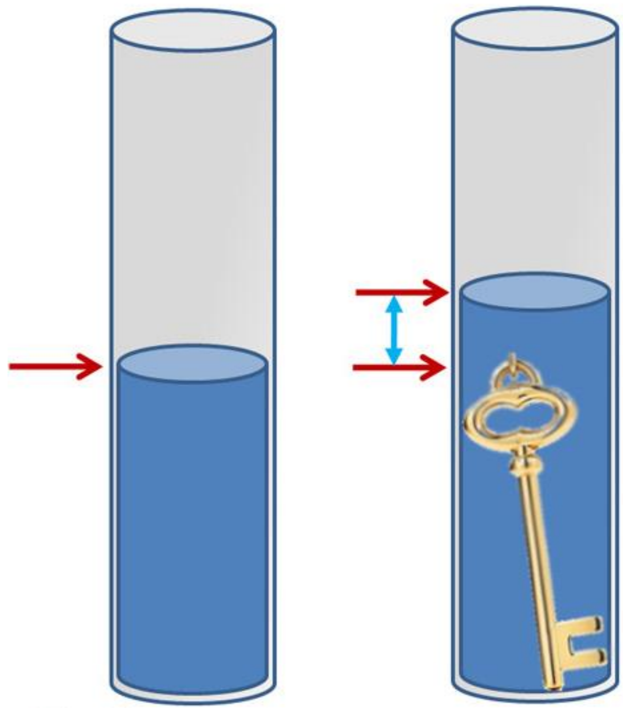

FIGURE 17: DEMONSTRATING VOLUME DIFFERENCES WITH AND WITHOUT DEADWOOD

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.

Navisworks Manage

Please read the recommended instructions below for clashing between model point cloud with Manage.

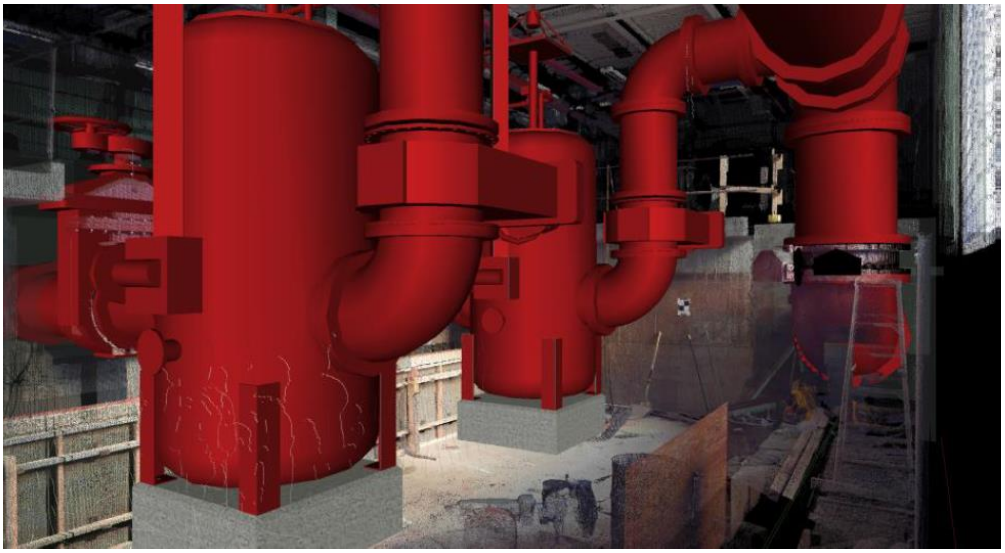

FIGURE 20: NAVISWORKS CAN FIND CLASHES BETWEEN CLOUDS AND SOLIDS

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 2016
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
9. Set an appropriate tolerance for the clash searching between points and solids
10. Set the clash type to CLEARANCE and Run the clash detective
11. 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.

As an alternative to automated clash detection, which may yield more results than desired (and is only available in the Manage version of Navisworks), users may also perform a simple visual inspection. Navisworks allows users to navigate to the inner diameter of pipe runs. By simply walking through the pipe run model, users may look for point cloud data which appears inside of the solid pipe. This can indicate a clash between existing conditions and proposed model.