Cycle Time Reduction of D-301 Blender

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Jan 8, 2018

Abstract

The D-301 blender is the one that blends NC-701 with different products to produce various required compositions. NC-701 is unloaded from a truck to the blender manually and the blending process is initiated. This however has limited the availability of blender to a point where the blender can be used only if the truck is available, thus increasing the cycle time for an output from D-301. This paper proposes the introduction of a buffer storage tank D-12516 along with piping, valves, pumps and other instrumentation to reduce the cycle time of the D-301 blender.

1 Keywords

Cycle time, process optimization, instrumentation, controller, NC-701, unit based control

2   Introduction

It is proposed that the material (NC-701) from the truck be unloaded to a buffer storage tank D-12516. D-12516 will serve as a holding tank when the trucks are available to unload. The material can be transferred from D-12516 to D-301 as and when required. Material unloading from the truck will be effected by pump MP-516T. This pump could either transfer the material to D-12516 or to D-301 directly. The material stored in D-12516 can be transferred to D-301 using MP-516A pump.

The following are the two benefits that are expected out of this proposal:

- The cycle time of D-301 will be greatly reduced

- The truck waiting times can be drastically reduced resulting in lower cost

- The product stored in D-12516 can be stored and maintained at a temperature, most suited for blending

3 Overall Scheme

Below is the overall scheme for the project. The tag numbers for the various equipment shown in overall scheme are indicative. Tags and IO type to be finalized based on Process and Control narrative finalization.
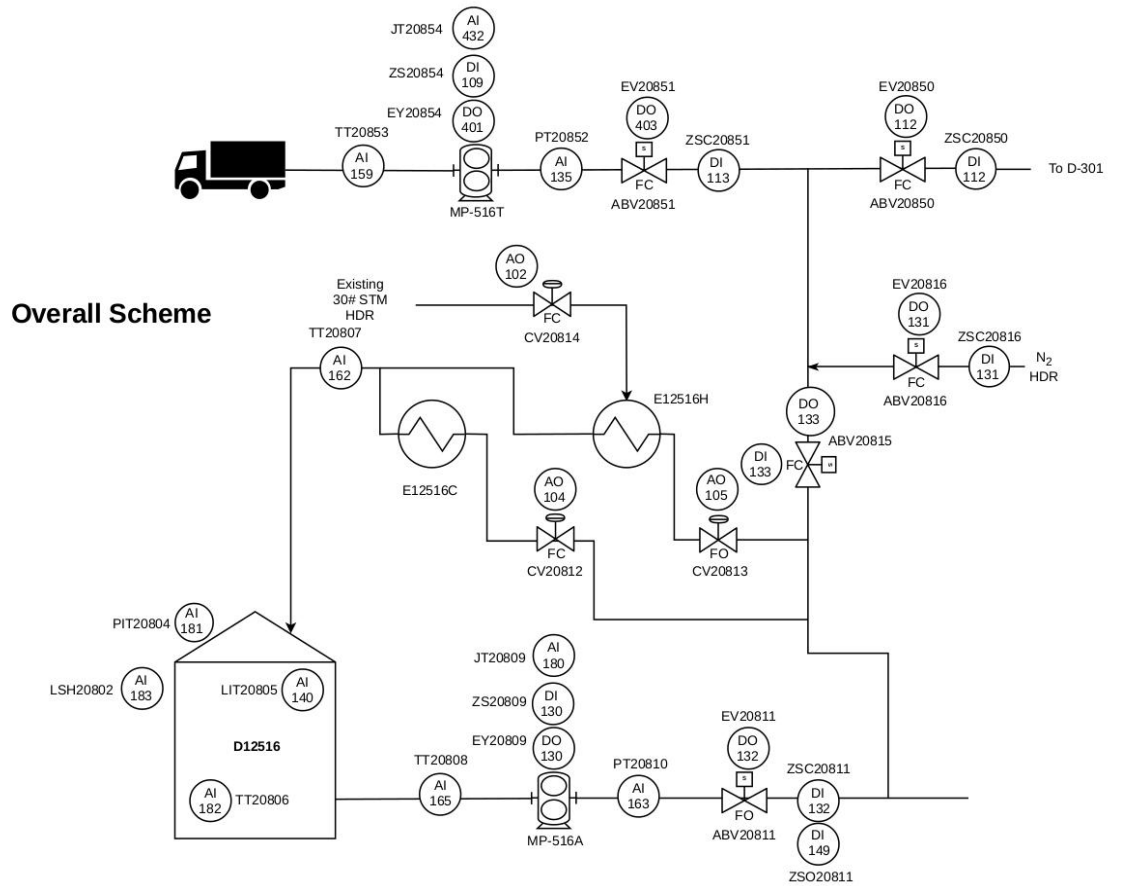

Figure 1: Schematic showing truck unloading, D-12516 tank and path to D-301

4 Process Narrative

The addition of a buffer storage tank calls for a operating procedure to unload from the truck, recycle the product (and regulate temperature, if required) and transfer to D-301 when required. It should also specify when a direct transfer from tank truck can be initiated toward the blender D-301. The following section details the process narrative using state based (or unit based control).

4.1 State based control

The following is the abstract from the white paper presented by David A.Huffman on benefits of State Based Control.

> State Based Control is a plant automation control design based on the principle that all process facilities operate in recognized, definable Process States that represent a variety of normal and abnormal conditions of the process. State Based Control, implemented with the latest developments in object-based technologies, delivers direct benefits to its adopters in a variety of Operational Excellence categories. It results in productivity increases, higher asset utilization of both people and process, automated responses and recovery for abnormal conditions and provides an environment for knowledge capture directly into the control design.

The proposal intends leverage the State Based Control scheme for this implementation. The various steps involved in control and operation of the plant are listed below:

1. Maintenance Wait

2. Process Wait

3. Recycle

4. Transfer

5. Unload

6. Direct Transfer

7. Line Clear

4.2 Steps

4.2.1 Maintenance Wait

In this step, the instruments and the control system are in maintenance.

All the process valves will assume their safe state. The outputs from the control system will be in Fail-safe state. All (or most) of the instruments are in de-energized state. Most of (or all non-critical) the alarms are disabled in this step.

4.2.2 Process Wait

This is the step in which all the instruments, valves and the control system remain energized. The plant is preparing for start up.

The maintenance/operation team should ensure that all (or almost all) instruments and valves are in healthy condition. Most of the alarms are enabled in this step. Maintenance/operation would look of instrument out of service alarms. If any of the devices are in "out-of-service" state, they should be fixed and put in service for a effect a start up.

4.2.3 Recycle

During the recycle step, the temperature of the product can be controlled, if required. NC-701 is ideal for blending when its temperature is around 45 degree Celsius. NC-701 is a highly viscous liquid which needs to be agitated periodically to maintain consistency of the product.

During the winter months, the product temperature drops because of ambient temperature. In order to compensate and supplement heat to the product, NC-701 can be passed through a heat exchanger in order to raise its temperature. The NC-701 would pass through the tube side of the exchanger. The shell side would pass a 30 barg steam from the plants' existing steam header. The flow rate of NC-701 through the heat exchanger E-12516H can be effected by throttling the control valve CV-20813. If the product temperature drops, the steam control valve CV-20814 should approach 100% open position while the CV-20813 should approach around 50% of opening. The best ratio of opening the steam line vs opening the NC-701 line should be ascertained during operation / trail run for utmost efficiency

During the summer months, the product temperature could go way beyond the desired set-point and might require cooling before being blended. For this case, we can close CV-20813 and also the steam valve CV-20814 and let the NC-701 to recycle through CV-20812. The tube side of the exchanger E-12516C would pass NC-701. The shell side would pass the cooling tower water to effect cooling of NC-701. The flow rate of NC-701 is adjusted using the control valve CV-20812 to effect the desired cooling. Note that, the cooling tower water does not have any controls on it which is unlike the steam control line which is used in the heating circuit.

4.2.4 Transfer

During this step, the material from D-12516 will be transferred to D-301 blender.

The pump MP-516A will be used to effect this transfer via the ON-OFF valves EV-20811, ABV-20815 and ABV-20850. During the transfer step, it should also be ensured that the control valves CV-20812 and CV-20813 remain completely closed to avoid any re-circulation. The nitrogen purge line should also remain isolated (or closed) using EV-20816. Before a transfer is initiated, sufficient level in D-12516 must be ensured. This will prevent the dry running of MP-516A which might in turn damage the seal of the pump. D-12516 should be at least at 60% level (arbitrary value) to initiate a transfer.

4.2.5 Unload

During the unload step, NC-701 is unloaded from the truck to D-12516.

The pump MP-516T is utilized to pump the material from the truck to the tank. Since unloading requires manual connection of the unload hose to the tank truck, a signal to indicate ready-to-unload is provided by the operator. This signal will serve as a permissive to starting MP-516T pump. The material will flow via the pump MP-516T, ABV-20815 and CV-20813. Note that CV-20813 valve leads into the E-12516H heat exchanger. During unload, the steam supply to the E-12516H is shut off. The control valve CV-20813 is a fail-open valve. It should be ensured that EV-20811 and EV-20816 remain closed during the unload step.

4.2.6 Direct Transfer

During the Direct transfer step, the material from the truck is directly transferred to the D-301 blender. This is the present set up. Hence this functionality is being retained.

In order to effect a direct transfer, a signal from D-301 blender control system is required to inform that the material can be accepted by the D-301 blender. After receipt of this signal, the operator shall connect the hose to the tank truck and start the MP-516T pump for the direct transfer to happen. The NC-701 will flow through EV-20851 and EV-20850 to reach D-301. It should be ensured to close EV-20816 and ABV-20815 during the direct transfer step to avoid material flowing into the D-12516 circuit or into the N_2 line.

4.2.7 Line Clear

The purpose of line clear step is to ensure that NC-701 does not clog the line leading to the blender D-301.

The N_2 is purged by opening EV-20816 and EV-20850 valves. N_2 enters the D-301 carrying with it any residual NC-701 and leaves D-301 through a N_2 vent. Line clear operation should be carried out for a minimum of 30 minutes (arbitrary value) to ensure complete purging of the line leading to D-301. During this step, it should be ensured to close the EV-20851 and ABV-20815 to prevent N_2 from flowing elsewhere than desired.

5 Step Transition

During start-up, the process would start in Maintenance wait step. The transition (or changeover) from one step to another (like from maintenance wait to process wait step) may be initiated either manually or may happen automatically based on process conditions.
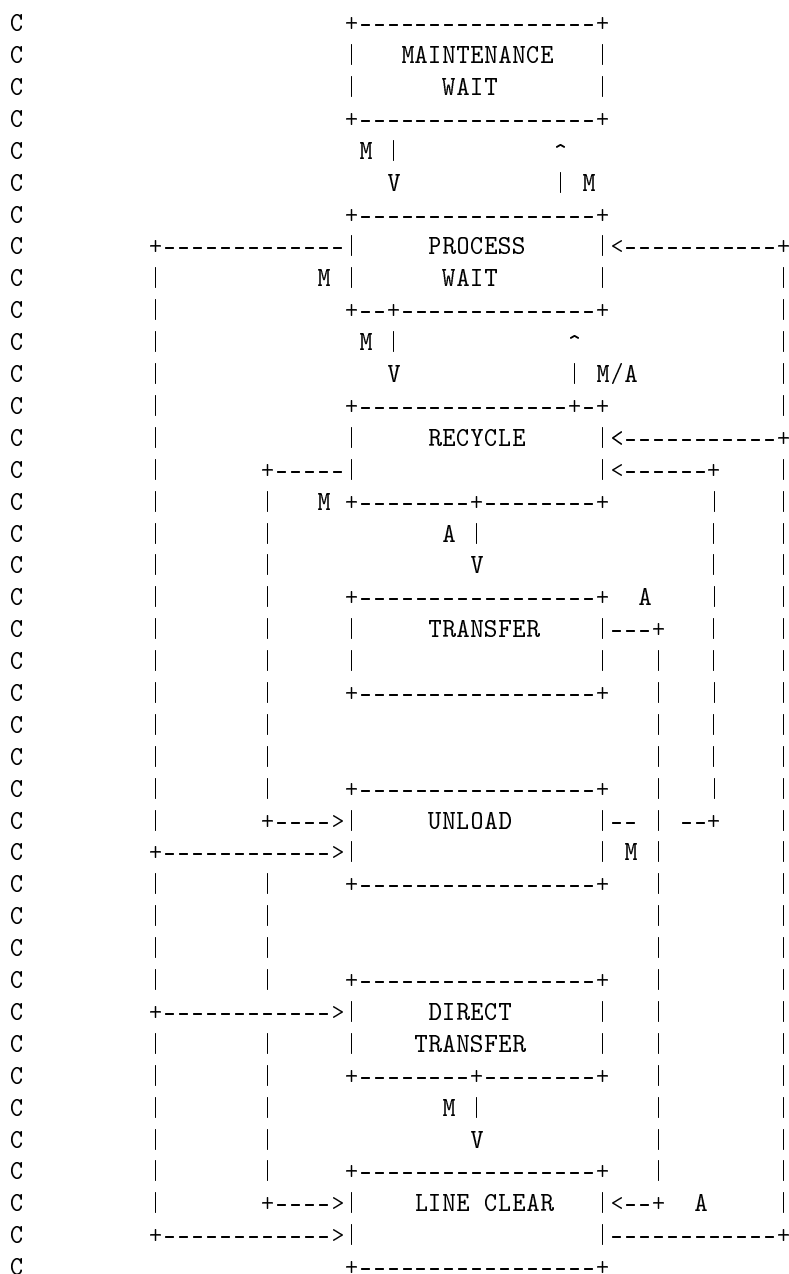
```
C                               +-----------------+
C                               |   MAINTENANCE   |
C                               |      WAIT       |
C                               +-----------------+
C                                 M |            ^
C                                   V            | M
C                               +-----------------+
C             +-------------|      PROCESS    |<-----------+
C             |          M |      WAIT       |            |
C             |            +--+-------------+            |
C             |             M |            ^            |
C             |               V            | M/A        |
C             |            +---------------+-+            |
C             |            |     RECYCLE     |<-----------+
C             |     +-----|                 |<------+    |
C             |     |    M +--------+--------+       |    |
C             |     |           A |                 |    |
C             |     |             V                 |    |
C             |     |    +-----------------+  A      |    |
C             |     |    |    TRANSFER     |---+     |    |
C             |     |    |                 |   |     |    |
C             |     |    +-----------------+   |     |    |
C             |     |                          |     |    |
C             |     |                          |     |    |
C             |     |    +-----------------+   |     |    |
C             |   +---->|     UNLOAD       |-- | --+   |
C             +------------->|                 | M |     |
C             |     |    +-----------------+   |       |
C             |     |                          |       |
C             |     |                          |       |
C             |     |    +-----------------+   |       |
C             +------------>|     DIRECT       |   |       |
C             |     |    |    TRANSFER     |   |       |
C             |     |    +--------+--------+   |       |
C             |     |          M |             |       |
C             |     |            V             |       |
C             |     |    +-----------------+   |       |
C             |   +---->|    LINE CLEAR    |<--+  A    |
C             +------------->|                 |-----------+
C                           +-----------------+
M denotes a manual transition initiated by the operator
A denotes an automatic transition based on process condition
```

6 Control Narrative

The control narrative will pictorially represent the process conditions that are required in each of the steps. There are no valve line up and vessel line up requirements for Maintenance Wait and Process Wait steps as there are no actions/functions. As a general convention, the equipment shown in green colour are open/running. Similarly, equipment's in red colour are either closed/stopped.

6.1 Recycle

Recycle step has the possibility of either heating or cooling the material. When the yellow colored valves are in open position heating shall take place. Cooling of material shall happen when the blue coloured valves are open.
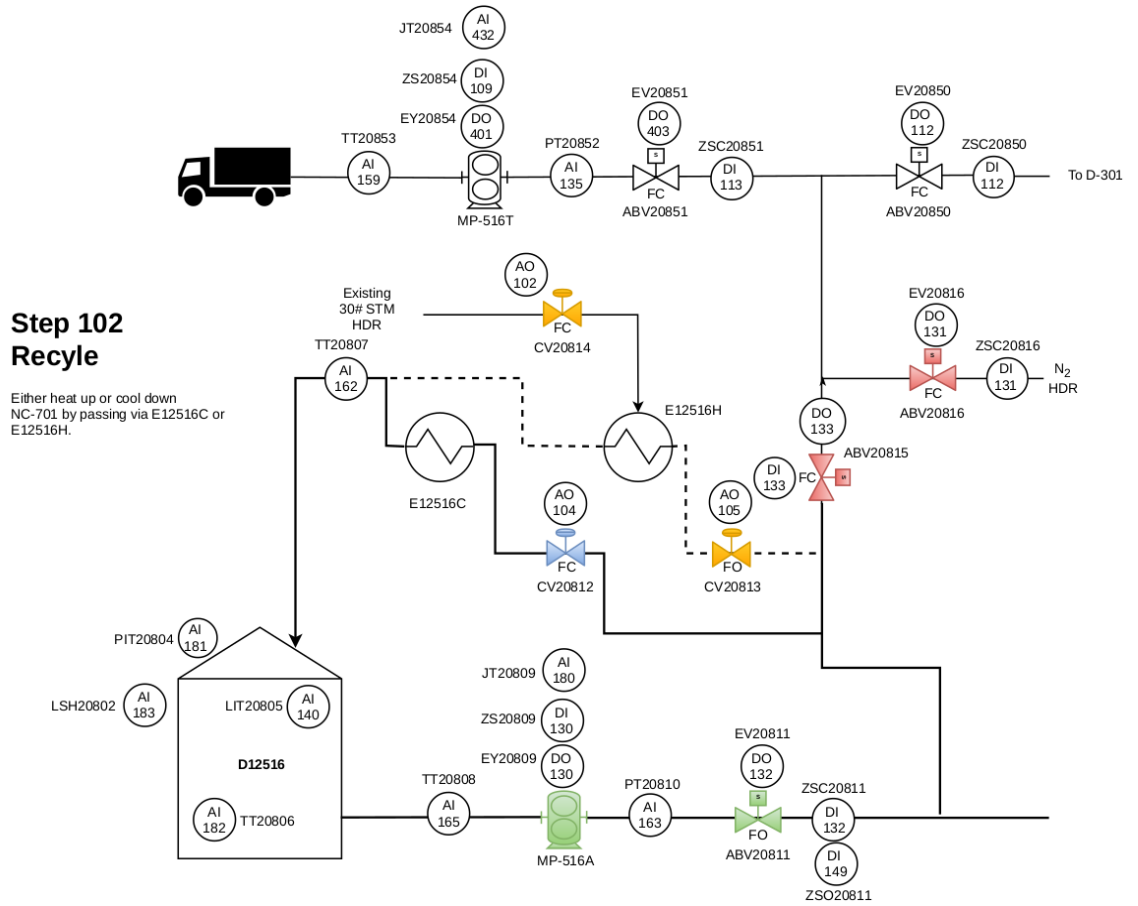
Figure 2: Recycle step

6.2 Transfer

During transfer step, in addition to the lining up of the transfer valves, the valves in the recirculation line of the pump (CV-20813 or CV-20812) shall be kept open to allow for minimum re-circulation. The purpose of re-circulation is to prevent the pump from deadheading in case if the blender D-301 circuit trips and closes blender inlet valves
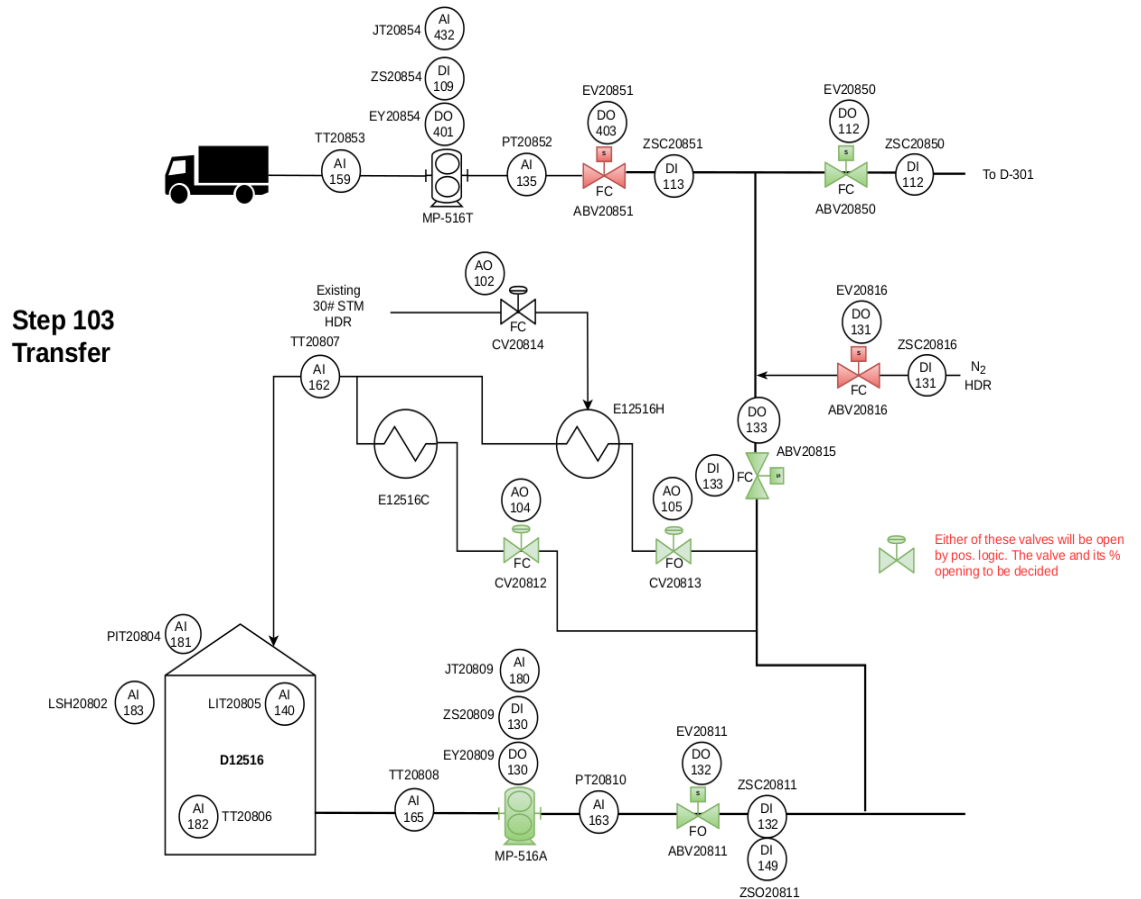
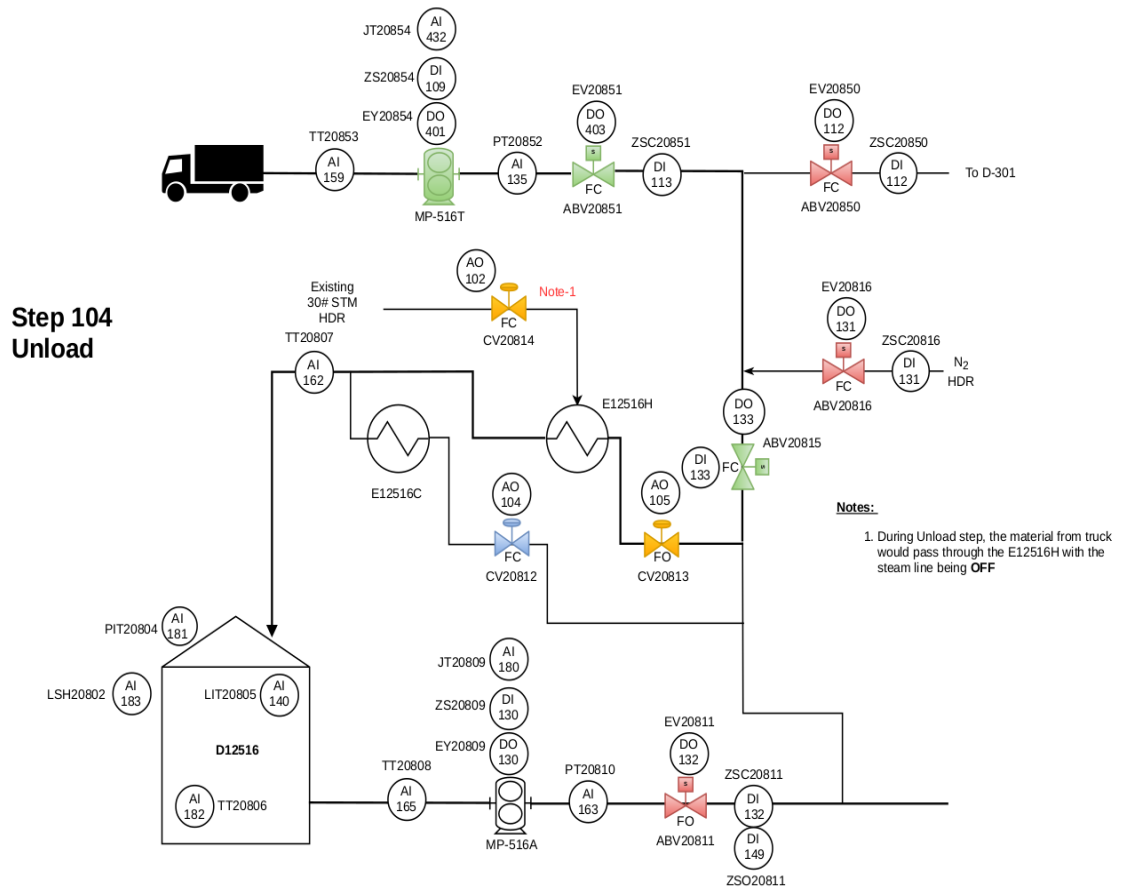Figure 3: Transfer from D-12516 to D-301

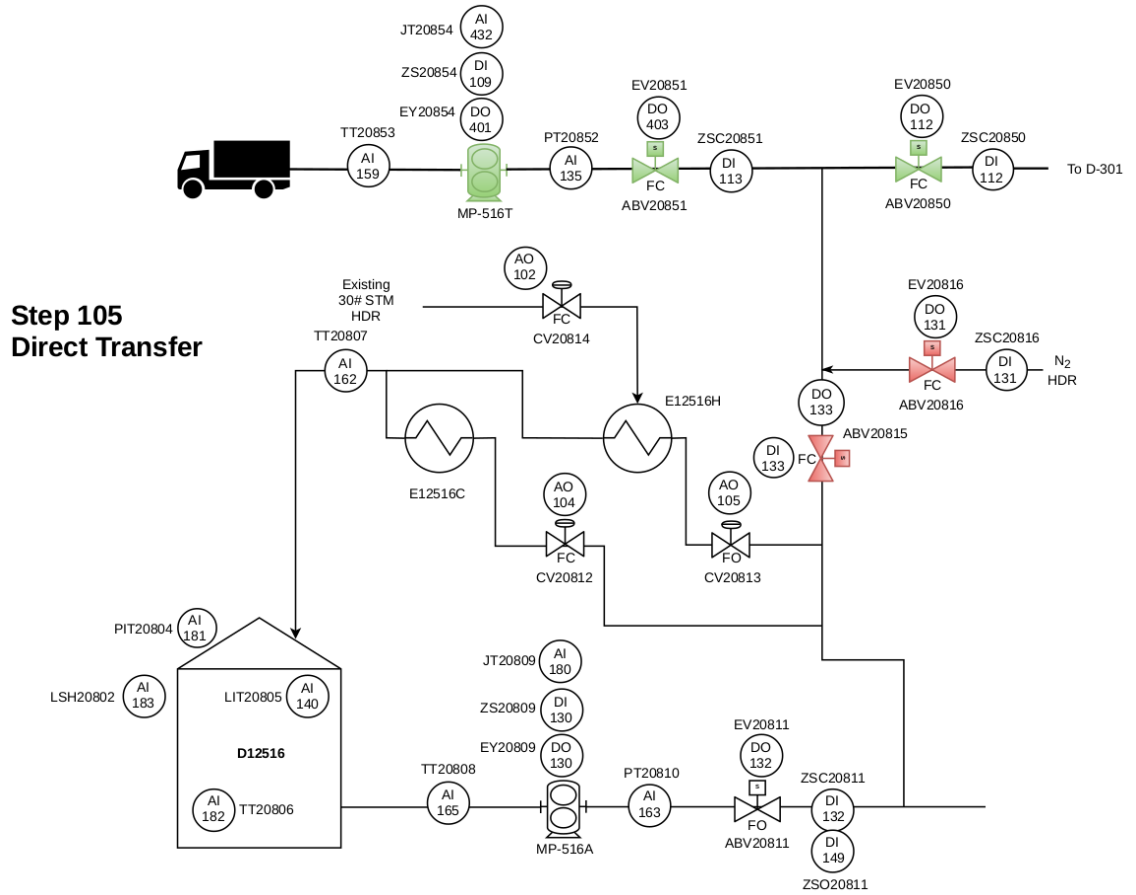## 6.3   Unload

Figure 4: Unload from truck to D-12516

6.4 Direct Transfer

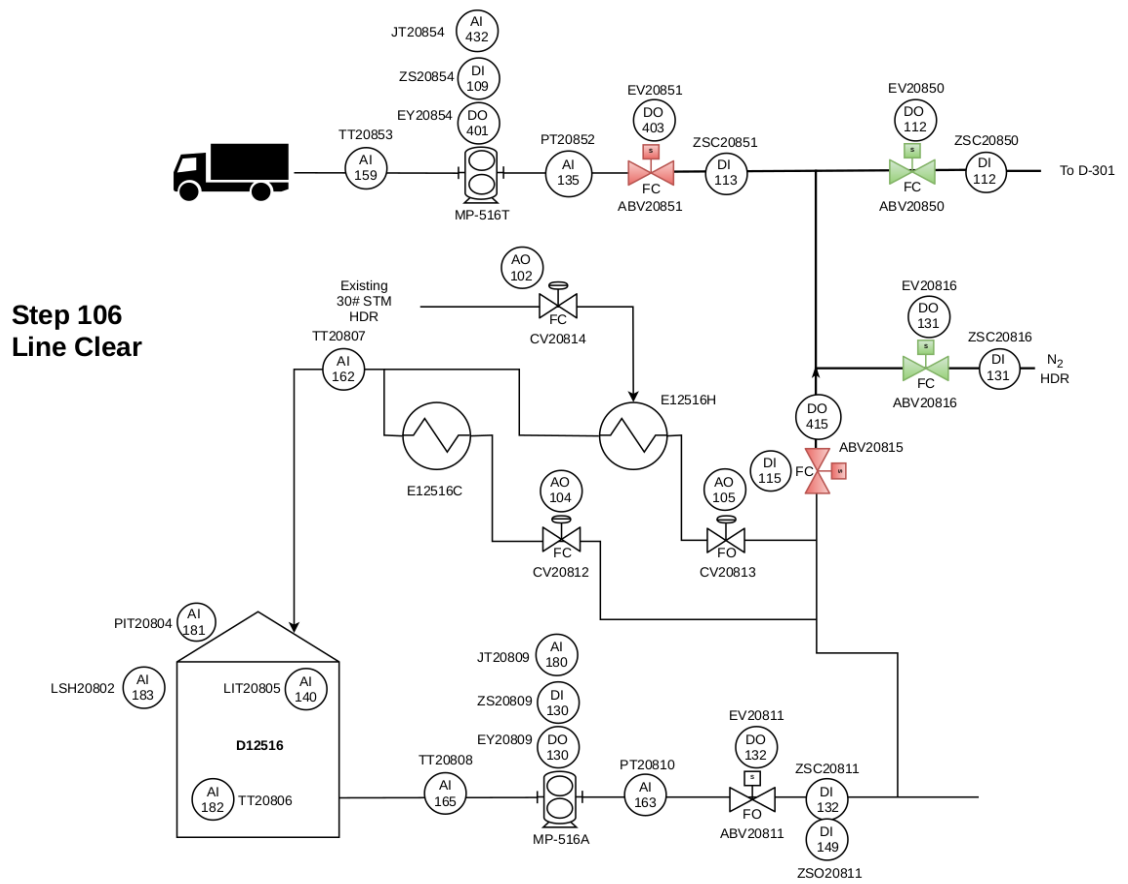Figure 5: Unload from truck and Direct transfer to D-301

6.5 Line Clear

Figure 6: Line clear

7 P & ID

« Insert P & ID here »

8   IO list

Tag Name	IO #	I/O Type	Description with Engg.units	Equip. Name	Min. Value	Max. Value
PIT20804	181	AI	N2 Pad Pressure [inH2O]	D12516	0	25
TT20806	182	AI	Temperature [degC]	D12516	0	200
TT20807	162	AI	Recycle line temperature [degC]	D12516	0	200
JT20809	180	AI	Power meter [hp]	MP-516A	0	25
TT20808	165	AI	Suction temperature [degC]	MP-516A	0	200
PIT20810	163	AI	Discharge pressure [psig]	MP-516A	0	200
TT20853	159	AI	Suction temperature [degC]	MP-516T	0	200
PIT20852	135	AI	Discharge pressure [psig]	MP-516T	0	200
JT20854	432	AI	power meter [hp]	MP-516T	0	25
EY20854	401	DO	Pump should run F.Off	MP-516T	Off	On
EY20809	130	DO	Pump should run F.Off	MP-516A	Off	On
EV20850	112	DO	TT to D-301 BV	D12516	Close	Open
EV20851	403	DO	Discharge BV F.C.	D12516	Close	Open
EV20816	131	DO	Outlet N2 clear BV F.C	D12516	Close	Open
EV20815	133	DO	Outlet BV F.C	D12516	Close	Open
EV20811	132	DO	Discharge BV F.O.	D12516	Open	Close
ZS20854	109	DI	Pump is on	MP-516T	Off	On
ZS20809	130	DI	Pump is on	MP-516A	Off	On
ZSC20850	112	DI	TT to D-301 BV ZSC	D12516	close	Open
ZSC20851	113	DI	discharge BV ZSC	D12516	close	Open
ZSC20816	131	DI	Outlet N2 clear BV ZSC	D12516	close	Open
ZSC20815	133	DI	Outlet BV ZSC	D12516	close	Open
ZSC20811	132	DI	Discharge BV ZSC	D12516	Closed	Open
ZSO20811	149	DI	discharge BV ZSO	D12516	Open	Closed
CV20812	104	AO	E-12516C Cooler CV F.C	D12516	0	110
CV20813	105	AO	E-12516C Heater CV F.O.	D12516	0	110
CV20814	102	AO	E-12516C Steam CV F.C	D12516	0	110
EV40215	428	DO	NC-701 BV	D301	Close	Open
ZSC40215	429	DI	NC-701 BV ZSC	D301		
LIT20805	140	AI	dP Level [%]	D12516	0	100
LSH20802	183	AI	Level Switch	D12516	high	not high

Based on the proposed control narrative, the following IO count would be required to realize the project.

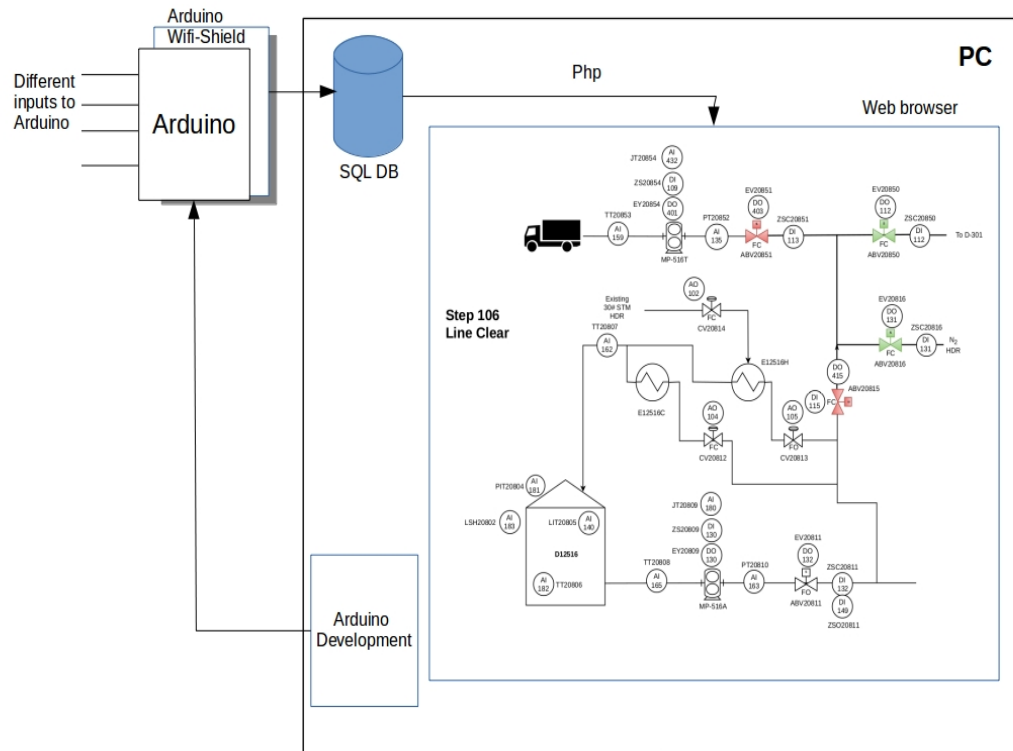| S.No.	IO Type	IO Qty
1	AI	11
2	AO	3
3	DI	9
4	DO	8

9 Implementation Strategy

Figure 7: Implementation architecture showing Arduino, SQL dB & Web-browser interface

9.1 Hardware

Based on the above architecture, Arduino Mega 2560 shall be used as the micro-controller for interfacing all the field IO. The AO shall be converted or treated as Digital output as there are no analog output pins on such microcontroller family. The temperature control loop can be simulated for the purpose of demonstration.

The Mega2560 can be interfaced to an Ethernet Shield, by stacking the Ethernet Shield over the arduino board. This enables to aruduino to communicate to the PC over WiFi. This communication will be used to receive process values from the controller to the PC for logging and display purposes. A WiFi router will be used establish the local network consisting of arduino (with WiFi shiled) and PC.

The PC is a general purpose laptop that will be used for programming the arduino. The PC will also serve as an HMI to display the process values and log the process values which will be used for trending.

9.2 Software

The aruduino will be configured as a webserver and the PC will act as a client. The following sofware will be used for this implementation:

- Arduino programmer check

- WAMP / LAMP stack

  - Windows / Linux
  - Apache web server
  - mySQL (database server)
  - PHP or Python
  - HTML/CSS/JavaScript

9.2.1 Arduino programmer check

This is used to develop debug and download the code to the controller. The control files are created with .ino extension

9.2.2 WAMP/LAMP stack

1. Windows/Linux The operating system for the PC could either be Windows / Linux. This will be the host for the other software such as the webserver, database server and Python/PHP.

2. Apache Webserver « *Insert Apache configuration here* »

3. mySQL « *Insert mySQL configuration here* »

4. PHP/Python « *Insert PHP/Python code here* »

   PHP code identified for use is listed below. The following code is a place-holder and needs to be further customized to have a complete working code.

- dbconfig.php

```php
<?php
define('DB_USER', "testuser");       // Your database user name
define('DB_PASSWORD', "test123");    // Your database password (mention your db pas
define('DB_DATABASE', "TESTDB");     // Your database name
define('DB_SERVER', "localhost");    // db server (Mostly will be 'local' host)

?>
```

- dbconnect.php

```php
<?php

class DB_CONNECT {

    // Constructor
    function __construct() {
// Trying to connect to the database
$this->connect();
    }

    // Destructor
    function __destruct() {
// Closing the connection to database
$this->close();
    }

   // Function to connect to the database
    function connect() {

//importing dbconfig.php file which contains database credentials
$filepath = realpath (dirname(__FILE__));

require_once($filepath."/dbconfig.php");

// Connecting to mysql (phpmyadmin) database
$con = mysql_connect(DB_SERVER, DB_USER, DB_PASSWORD) or die(mysql_error());

// Selecing database
$db = mysql_select_db(DB_DATABASE) or die(mysql_error()) or die(mysql_error());

// returing connection cursor
return $con;
    }

// Function to close the database
    function close() {
// Closing data base connection
mysql_close();
    }
```

```php
    }

    ?>
```

- insert.php

```php
<?php

header("Access-Control-Allow-Origin: *");
header("Content-Type: application/json; charset=UTF-8");

//Creating Array for JSON response
$response = array();

// Check if we got the field from the user
if (isset($_GET['temp']) && isset($_GET['hum'])) {

    $temp = $_GET['temp'];
    $hum = $_GET['hum'];

    // Include data base connect class
    $filepath = realpath (dirname(__FILE__));
require_once($filepath."/db_connect.php");


    // Connecting to database
    $db = new DB_CONNECT();

    // Fire SQL query to insert data in weather
    $result = mysql_query("INSERT INTO weather(temp,hum) VALUES('$temp','$hum')")

    // Check for succesfull execution of query
    if ($result) {
// successfully inserted
$response["success"] = 1;
$response["message"] = "Weather successfully created.";

// Show JSON response
echo json_encode($response);
    } else {
// Failed to insert data in database
$response["success"] = 0;
$response["message"] = "Something has been wrong";

// Show JSON response
echo json_encode($response);
    }
} else {
    // If required parameter is missing
    $response["success"] = 0;
```

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```php
        $response["message"] = "Parameter(s) are missing. Please check the request";

        // Show JSON response
        echo json_encode($response);
   }
   ?>
```

- readall.php

```php
<?php

header("Access-Control-Allow-Origin: *");
header("Content-Type: application/json; charset=UTF-8");


//Creating Array for JSON response
$response = array();

// Include data base connect class
$filepath = realpath (dirname(__FILE__));
require_once($filepath."/db_connect.php");

 // Connecting to database
$db = new DB_CONNECT();

 // Fire SQL query to get all data from weather
$result = mysql_query("SELECT *FROM weather") or die(mysql_error());

// Check for succesfull execution of query and no results found
if (mysql_num_rows($result) > 0) {

// Storing the returned array in response
    $response["weather"] = array();

// While loop to store all the returned response in variable
    while ($row = mysql_fetch_array($result)) {
// temperoary user array
$weather = array();
$weather["id"] = $row["id"];
$weather["temp"] = $row["temp"];
$weather["hum"] = $row["hum"];

// Push all the items
array_push($response["weather"], $weather);
    }
    // On success
    $response["success"] = 1;

    // Show JSON response
    echo json_encode($response);
}
```

```
    else
    {
        // If no data is found
    $response["success"] = 0;
        $response["message"] = "No data on weather found";

        // Show JSON response
        echo json_encode($response);
    }
    ?>
```

5. HTML/CSS/JavaScript « *Insert HTML/CSS/JavaScript code here* »

6. **TODO**

   ☐ include org-babel execute function for HTML

   ☐ create stylesheet and move CSS information

   ☐ create object for valve - two part valve - left side shows DO - right side shows feedback

7. HTML code

```
<!DOCTYPE html>
<html>
  <head>
    <link rel="stylesheet" type="text/css" href="css/index.css">
</head>
<body>
  <img src="img/D301.png">
<p id="tt853"> </p>
<p id="pt852"> </p>
<p id="tt807"></p>
<p id="pit804"></p>
<p id="lit805"></p>
<p id="tt806"></p>
<p id="tt808"></p>
<p id="pt810"></p>
<script type="text/javascript">
    document.getElementById('tt853').innerHTML = "35 degC";
    document.getElementById('pt852').innerHTML =  "100 psig";
    document.getElementById('tt807').innerHTML = "23 degC";
    document.getElementById('pit804').innerHTML = "6 psig";
    document.getElementById('lit805').innerHTML = "12 %";
    document.getElementById('tt806').innerHTML = "15 degC";
    document.getElementById('tt808').innerHTML = "17 degC";
    document.getElementById('pt810').innerHTML = "20 psig";
</script>

</body>
</html>
```

8. CSS code

```
#tt853    {
position: absolute;
left: 350px;
top: 110px;
color: blue;
font-weight: bold;
}
#pt852    {
position: absolute;
left: 525px;
top: 110px;
color: blue;
font-weight: bold;
}
#tt807    {
position: absolute;
left: 340px;
top: 290px;
color: blue;
font-weight: bold;
}
#pit804    {
position: absolute;
left: 170px;
top: 510px;
color: blue;
font-weight: bold;
}
#lit805    {
position: absolute;
left: 260px;
top: 595px;
color: blue;
font-weight: bold;
}
#tt806    {
position: absolute;
left: 189px;
top: 685px;
color: blue;
font-weight: bold;
}
#tt808    {
position: absolute;
left: 410px;
top: 670px;
color: blue;
```

```
font-weight: bold;
}
#pt810    {
position: absolute;
left: 610px;
top: 670px;
color: blue;
font-weight: bold;
}
```

10 Bill of Material

« *Insert BOM here* »

11   Conclusion

The proposed solution in this paper shall meet its objective of reducing the cycle time of D-301 blender by removing the dependency of the truck for NC-701 material. It will also ensure that the quality of the blending product is improved by regulating the product temperature.

12   References

1. Benefits of State Based Control