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# Design, Develop and Validate Nitrile Hose in Mandrel less Construction

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***Abstract: This A hose is a flexible hollow tube designed to carry fluids from one location to another. Hoses are also sometimes called pipes (the word pipe usually refers to a rigid tube, whereas a hose is usually a flexible one), or more generally tubing. The shape of a hose is usually cylindrical (having a circular cross section). Hose design is based on a combination of application and performance. Common factors are size, pressure rating, weight, length, straight hose or coil hose, and chemical compatibility. Applications mostly use nylon, polyurethane, polyethylene, PVC, or synthetic or natural rubbers, based on the environment and pressure rating needed. In recent years, hoses can also be manufactured from special grades of polyethylene (LDPE and especially LLDPE). Other hose materials include PTFE (Teflon), stainless steel, and other metals. Dredge rubber hoses have a long story, which features high strength and flexibility. A flexible dredging hose widely used in dredgers for silt/gravels conveyance. It is abrasion and wear-resistant to ensure long service life. Types of flexible dredge hose: floating rubber hose, discharge hose, suction hose, armoured hose and ceramic hose.***

***Keywords**: Discharge hose, fluid, flexible, suction hose, armoured hose, and ceramic hose*

## I. INTRODUCTION

A hose is flexible, reinforced tube designed to transfer high pressure fluids from one location to a different. The hose construction typically has inner plastic or rubber tube compatible with the fluid being transferred, metal or fibre reinforcement to stand with pressure and outer plastic or rubber cover protects the reinforcement from external environment.

Nitril Series Easy Couple hose is a multipurpose vinyl nitrile hose that is good for several uses. It is designed for purpose of using with Barb-Tite, push-to-connect reusable hose fittings which make it very easy to work with onsite locations. This hose is good choice for transfer of oil and fuel and the black version is MSHA (2G-13C) approved.

### *A. Hydraulic hose construction basics*

The Modern hydraulic hose generally consists of at least three parts: an inner tube that carries the fluid, a reinforcement layer, and a protective outer layer. The inner tube should have some flexibility and needs to be compatible with the type of fluid it will carry along. Usually used compounds include synthetic rubber, thermoplastics, and PTFE, sometimes is called as Teflon. The reinforcement layer contains of one or more sheaths of braided wire, spiral-wound wire, or textile yarn. The outer layer is frequently weather-, oil-, or abrasion-resistant, depending upon the type of environment the hose is especially designed for. A not surprisingly, hydraulic hoses typically have a finite life. Correct sizing and use of the accurate type of hose will certainly extend the life of a hose assembly, nonetheless there are many different factors that affect a hose's lifespan. The SAE identifies some of the worst offenses as – flexing / twisting the hose to less than the specified minimum bend radius twisting, pulling, the kinking, crushing, or abrading the hose operating the hydraulic system above the maximum or below the minimum temperature. A Exposing a hose to rapid or transient rises (surges) in a pressure above the maximum operating pressure, and intermixing hose, fittings, or assembly equipment not suggested as compatible by the manufacturer or not following the manufacturer's directions for fabricating hose assemblies.

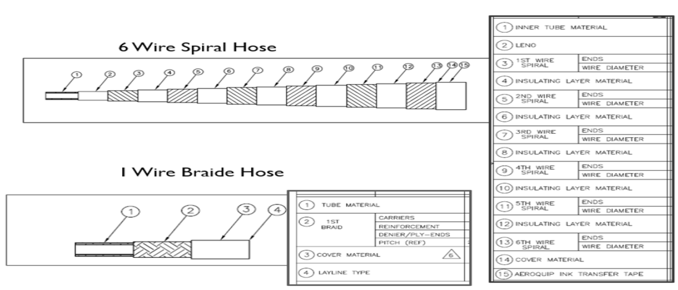

Figure 1: Spiral & Braided Hose construction.

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### *B. Selecting the Correct Hose*

Here are the seven suggested steps the system designer should follow during the hose and coupling selection process. To help identify the proper hose for an application, we can use the acronym STAMPED – that is Size, Temperature, Application, Materials, Pressure, Ends, and Delivery. Here are more details for consideration in each area:

Size - To select the correct hose size for replacement, it is imperative to measure the inside and outside hose diameters accurately using a precision-engineered calliper, as well as also the length of the hose. Hose OD is primarily important when hose-support clamps are used or even when the hoses are routed through bulkheads. Check the separate hose specification tables for ODs in suppliers' catalogues. When replacement a hose assembly, always cut the new hose of the same length as the one being removed from system. The moving components of the equipment might pinch or even sever too long a hose. If the replacement hose is too short, pressure might cause the hose to contract and to be stretched, leading to reduced service life of hose. Changes in the hose length when pressurized range between +2% to 4% while hydraulic mechanisms are also in process. Permit for possible shortening of the hose during operation by making the hose lengths slightly longer than the actual distance between the two connections or systems.

Temperature – Mostly all hoses are rated with a maximum working temperature ranging from 200° to 300° F based upon the fluid temperature. Revelation to continuous high temperatures can lead to hoses losing their flexibility. Failure to use hydraulic oil with the correct viscosity to hold up under high temperatures may accelerate this problem.

Please always follow the hose manufacturer's recommendations. Surpassing these temperature recommendations can reduce hose life by as much as 80%. Depending upon materials used, acceptable temperatures shall range from -65° F (Hytrel and winterized rubber compounds) to 400° F (PTFE). Outer temperatures become a factor when hoses are exposed to a turbo manifold or some other heat source. When hoses are typically exposed to high external and internal temperatures concurrently, there will be a considerable reduction in hose service life. Insulating sleeves may help protect hose from hot equipment parts and other high temperature sources that are potentially hazardous. In these situations, an additional barrier is typically required to shield hydraulic fluid from a potential source of ignition.

Application - May the designated hose meet bend radius requirements? This refers to the minimum bend radius (usually in inches) that is a hydraulic hose must meet. Exceeding this bend radius (using a radius smaller than recommended) is mostly to injure the hose reinforcement and reduce hose life. Routes high-pressure hydraulic lines are parallel to machine contours whenever possible. This practice may help save money by reducing line lengths and also minimizing the number of hard-angle, flow-restricting bends. These routing also can protect lines from external damage and promote easier servicing.

Materials - It is required to consult a compatibility chart to check that the tube compound is compatible with the fluid used in the system. Raised temperature, fluid contamination, and concentration will affect the chemical compatibility of the tube and fluid as well. Most of the hydraulic hoses are very compatible with petroleum-based oils. Note that new readily biodegradable or green fluids may present a issue for some hoses.

Pressure capabilities –Hose working pressure must always be selected so that it is greater than or equal to the maximum system pressure, including pressure spikes. Pressure spikes must greater than the published working pressure will greatly shorten hose life.

Hose ends - The coupling-to-hose mechanical interface should be compatible with the hose chosen. The suitable mating thread end must be chosen so that connection of the mating components will result in leak-free sealing.

### *C. Objective & Project Plan*

The objective of this project is to design & validate nitrile (-06 size) on Air Mandrel as opposed Nylon Mandrel currently being used.

*1)* Measure Milestones:
*2)* To Identify & Validate the Inner Tube Compound
*3)* To Finalize Hose Dimensions
*4)* To Identify risks and mitigation plan
*5)* To Build the Hose
*6)* To Perform the Test and validate the results with Nylon Mandrel.
*7)* To Initiate the PCR (Process Change Request) & PPAP process.
*8)* To Send the customer Notification

TABLE I
Project Plan

| Phase | Design, Develop & Validate nitrile hose in Mandrel less construction |
|---|---|
| Phase 1 | Project Kick of |
| | Project Charter (Project Scope) |
| | Project plan (Volume, Cost out) |
| Phase 2 | Identify & Validate Inner Tube material for Air Mandrel |
| | Evaluate various hose tube materials for Air mandrel |
| | Select & validate the suitable inner tube material. |
| Phase 3 | Design & develop the hose |
| | Tolerance stack-up analysis for ID & OD |
| | Define & finalize ID & OD Dimensions. |
| Phase 4 | Experimental Hose builds |
| | Release advance print |
| | Raise PO for Proto Build |
| | Develop Proto Build at forest city |
| Phase 5 | Validation of hose by performing product testing. |
| | Identify test and execute as per test plans |
| | Purchase Order Hose, Fitting's for Testing |
| | Get Hose, Fitting's for testing |
| | Complete Hose Assembly testing |
| | Complete Compound related testing |
| | Compare test results against the analytical predictions. |
| | Capability study |
| Phase 6 | PPAP Approval & Notifications |
| | Initiate PPAP |
| | Initiate Customer change Notification |
| | Release production drawing |
| | Issue PCR |
| | Complete PPAP for CL |
| | Send Customer Notification & Production release |
| | Lessons learned captured thorough discussion with all project team |

## II. PROJECT SCOPE IDENTIFICATION

Nitrile Series Easy Couple hose is a versatile vinyl nitrile hose that is good for many uses. It's designed for use with Barb-Tite (Aeroquip Socket less, – Push On) push-to-connect reusable hose fittings which make it very easy to work with on site. This is general purpose hose & widely used in air & Diesel fuel applications. Looking at its wide range of application & annual usage volume, one of the requirements is came from marketing about cost reduction of this hose. Existing hose is made up with mandrel construction.  Below is the information about construction, performance, application, usage & potential saving of existing 06 size Hose.

| Part Number | Hose I.D. | | | Hose O.D. | | | Working Pressure | | Min. Burst Pressure | | Min. Bend Radius | | Hose Weight | | Avail. Lengths |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | in | fraction | mm | in | fraction | bar | psi | bar | psi | mm | in | Kg/m | lbs/100ft | feet |
| H20104BK<br>H20104BK-250R<br>H20104BK-500R | 6,4 | 0.25 | 1/4 | 12,7 | 0.50 | 1/2 | 20,7 | 300 | 82,7 | 1,200 | 76,2 | 3.00 | 3,6 | 8 | 50<br>250<br>500 |
| H20106BK<br>H20106BK-250R<br>H20106BK-500R | 9,5 | 0.38 | 3/8 | 16,7 | 0.65 | 21/32 | 20,7 | 300 | 82,7 | 1,200 | 76,2 | 3.00 | 5,9 | 13 | 50<br>250<br>500 |
| H20108BK<br>H20108BK-250R<br>H20108BK-500R | 12,7 | 0.50 | 1/2 | 19,1 | 0.75 | 3/4 | 20,7 | 300 | 82,7 | 1,200 | 127,0 | 5.00 | 6,8 | 15 | 50<br>250<br>500 |
| H20110BK<br>H20110BK-250R | 15,9 | 0.63 | 5/8 | 23,8 | 0.93 | 15/16 | 20,7 | 300 | 82,7 | 1,200 | 152,4 | 6.00 | 9,1 | 20 | 50<br>250 |
| H20112BK<br>H20112BK-250R | 19,1 | 0.75 | 3/4 | 26,2 | 1.03 | 1-1/32 | 20,7 | 300 | 82,7 | 1,200 | 177,8 | 7.00 | 11,8 | 26 | 50<br>250 |

**Inner Tube:** Nitrile
**Reinforcement:**
1 Fiber Braid
**Cover:** Neoprene (Black),
Vinyl Nitrile (Colored Hoses)
**Temp. Range:**
-40°C to +100°C
(-40°F to +212°F )

**Typical Application:**
General purpose hose. Air and diesel fuel applications.
**MSHA Approved**
**(Black only)**

**Note:**
For colors change BK to: Gray (GY), Red (RD), Green (GN) & Yellow (YW), Blue (BU)

| Hose Fitting Reference | Page |
|---|---|
| *Field Attachable* | |
| 100 'B' Barb-Tite® Series | K-5-7 |

Figure 2: Existing Reference 20106 Nitrile Hose information.

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Initiated a program to introduce a 201 hose that is make on an air mandrel as opposed to the nylon platform currently being used. The primary CTQ identified by the team was tube material that maintains its' concentricity independent of mandrel type employed during processing. This identified property was determined to be related to the "green" or unvulcanised strength of the tube compound. A request was made to assist in the selection of a current FC production compound as a potential replacement formulation for the 201 incumbent 640-99.

## III.IDENTIFY & VALIDATE INNER TUBE MATERIAL FOR AIR MANDREL

An important step in hose design is the identification of inner tube material. For identification of tube material, we have searched for existing hoses which are made up with mandrel less construction, & we got following options.

TABLE II
Material identification

| Part Number | Size | Description | Tube Stock |
|---|---|---|---|
| EC03804 | 04 | AIR BRAKE | F26053 |
| EC03806 | 06 | AIR BRAKE | F26053 |
| EC03808 | 08 | AIR BRAKE | F26053 |
| H11605 | 05 | Mandrel-Less Boston Performer II | F23210 |
| H11606 | 06 | Mandrel-Less Boston Performer II | F23210 |
| H11606BU | 06 | Mandrel-Less Boston Performer II | F23210 |
| H11608 | 08 | Mandrel-Less Boston Performer II | F23210 |
| H177604 | 04 | Mandrel-less Boston Perfection | F23052 |
| H177606 | 06 | Mandrel-less Boston Perfection | F23052 |

We did detailed study of each hose tube compound, its properties, performance & application, with reference to this study we got below results about the properties, Green tensile strength of the rubber material is important parameter, The green strength of an elastomer is its resistance to deformation and fracture before vulcanization. As per our study & results in table, we found that F23052 tube compound is having 132.60 psi tensile strength which is less than existing 640-99 compound (133.48 psi). FC26053 compound is having 490.07 psi tensile strength which is very higher than existing 640-99 compound (133.48 psi) & costlier also. Looking at our requirements FC23210 is found more suitable option because it is having 171.00 psi tensile strength which is within our limits. After identification of FC23210 material, we have done material testing of this compound

TEST PROCEDURES AND RESULTS:
Test procedures and results shown on the following pages of this report.

MATERIAL LAB REQUEST

REFERENCE: ML3816

PROCEDURES: CHECK ALL THAT APPLY AND PROVIDE APPROPRIATE PARAMETERS BELOW. ADD ADDITIONAL PROCEDURES AS NECESSARY

| | DESCRIPTION: | SPECIFICATION | PARAMETERS |
|---|---|---|---|
| ☒ | Cure Press | ASTM D 3182 F23210 and 640-99 | Time: 30' Temperature: 320°F |
| ☒ | Durometer Hardness (Shore A) | ASTM D 2240-95 | |
| ☒ | Large dumbells 20"/min | ASTM D 412-92 | |
| ☒ | Air Age | ASTM D 573-88 | Time: 70hrs Temperature: 100°C |
| ☒ | Effects of liquids | ASTM D 471-95 + VS | Time: 70hrs Temperature: 127°C Fluid: IRM903 |
| ☒ | Effects of liquids | ASTM D 471-95 + VS | Time: 70hrs Temperature: 21°C Fluid: Diesel Fuel |
| ☒ | Effects of liquids | ASTM D 471-95 + VS | Time: 48hrs Temperature: 21°C Fluid: Fuel B |

Figure 2: Original Properties

| Compound | Tensile (psi) | % Elong | 100% Mod (psi) | Shore A |
|---|---|---|---|---|
| 640-99 | 1853.39 | 263.55 | 858.88 | 77 |
| F23210 | 1454.31 | 343.47 | 604.70 | 76 |

Figure 3: Percent Change Air Aging Properties 70hrs @ 100°C
(Tensile change max 20%; Elong change max 50%)

| Compound | Tensile (psi) | % Elong | Shore A |
|---|---|---|---|
| 640-99 | 12.66 | 35.26 | -15.58 |
| F23210 | 18.79 | 28.91 | -11.84 |

Figure 4: Percent Change IRM 903 Oil Aging Properties 70hrs @ 127°C (Max 100% VC)

| Compound | Tensile (psi) | % Elong | Shore A | VC (%) |
|---|---|---|---|---|
| 640-99 | 26.29 | 46.06 | 16.88 | 21.23 |
| F23210 | 39.07 | 34.86 | 27.63 | 38.25 |

Figure 5; Diesel Fuel Aging Properties 70hrs @ 21°C (Max 60% VC)

| Compound | Tensile (psi) | % Elong | Shore A | VC (%) |
|---|---|---|---|---|
| 640-99 | 10.12 | 9.99 | 16.88 | 15.57 |
| F23210 | 30.46 | 20.49 | 27.63 | 32.13 |

Figure 6: Fuel B Aging Properties 48hrs @ 21°C (Max 40% VC)

| Compound | Tensile (psi) | % Elong | Shore A | VC (%) |
|---|---|---|---|---|
| 640-99 | 27.13 | 24.41 | 24.68 | 31.58 |
| F23210 | 44.04 | 33.14 | 42.11 | 38.19 |

Figure 3: Material Properties

Testing was performed according to the ASTM standards described in the "Test Procedures and Results" section above. The only deviation is the unvulcanised rubber tensile strength assessment.

The results in figure describe the "green", unvulcanised rubber tensile strength measurement which has been incriminated as a primary factor affecting hose tube dimensional stability. The results suggest that the current production compound used at the Forest City plant that has the strongest "green" strength is F26210 (171.00 psi) which has a 21.94% higher tensile strength then the 201 incumbent 640-99 tube. Other non-standard recipes that can be implemented into Forest City are 31440 and 640-33 (26.50% and 31.15% higher tensile strength respectively) based on the generated data. The project team took this data and found success in constructing -6 and -8 builds with some minor "tweaking" to obtain the desired dimensions.

The second section of this test request was generated to ensure that changes to 201 continue to meet the ES4189 specification. The requirements include air, IRM903, diesel and fuel B exposure testing. The results in figure 2 detail the original properties of the F23210 and 640-99 compounds. A comparison of the two formulations characterizes the F23210 as having a 21% lower tensile strength, 23% higher percent elongation and a 30% lower modulus as opposed to the incumbent 640-99.

Figure shows the results generated after air aging at 100°C for 70 hours. The data suggest that F23210 has slightly higher change in tensile strength (6%) and 7% less change in percent elongation versus 640-99. Both compounds pass the ES4189 specification of 20% maximum tensile change and 50% maximum elongation change.

The results from IRM 903 oil exposure are detailed in figure 4 where F23210 passed the ES4189 standard of allowing a maximum of 100% volume swell after 70 hours at 127°C with a 38.25% result. Similar to the above-mentioned air aging results, F23210 lost more tensile strength (11%) and had higher percent elongation retention (12%) when compared to 640-99.

While diesel fuel (figure 5) proved to have up to a 20% higher negative effect (tensile strength) on F23210 versus 640-99, it still easily passed the ES4189 limit of 60% volume swell with a 32.13% measured value.

The final fluid exposure was a 48 hour at 21°C material soak in ASTM reference fuel B which is a blend of 70% isooctane and 30% toluene. The data in figure 6 imply that F23210 is adversely affected by fuel B up to 18% (shore A) more than the incumbent elastomeric formulation. Additionally, F23210 narrowly passed the ES4189 volume swell requirement of 40%.

In conclusion, while the F23210 recipe does vary from the incumbent 201 recipe (640-99), it does pass the ES4189 fluid compatibility requirements. Additionally, F23210 has proven successful in the -6 and -8 201 builds from July 2014 from a processing and concentricity aspect. These results together suggest that F23210 is a good candidate for the 201 mandrel less hose project.

| Compound | Tensile (psi) |
|---|---|
| F23052 | 132.60 |
| 640-44 | 145.42 |
| *640-99 | 133.48 |
| F23210 | 171.00 |
| **F26053 | 490.07 |
| 3799-4 | 119.72 |
| 3799-1 | 137.82 |
| 3799-3 | 129.95 |
| 3799-2 | 123.12 |
| 31440 | 181.64 |
| 640-33 | 193.87 |

Figure 4: Green Tensile Strength

## IV. LITERATURE STUDY

As per the Hose Handbook 2003, the three basic methods of making hose are: (1) non-mandrel, (2) flexible mandrel, and (3) rigid mandrel. In methods (2) and (3), the mandrels are typically used for support and as dimensional control devices for the hose tube during the processing. Then after the hose building and, if required, the vulcanization is complete, the mandrels are removed, inspected and recycled. Non-mandrel Type -The non-mandrel method of manufacture is usually used for lower working pressure (less than 500 psi), smaller diameter (2" and under), textile reinforced products may not require stringent dimensional tolerances. Normally hose products in this category would include garden, washing machine inlet, and multipurpose air and water styles etc. Fundamentally, the non-mandrel technique involves extruding the tube, applying the reinforcing, and extruding the cover in an unsupported mode (It's without a mandrel).

Most often low-pressure air is used inside the tube for a minimal support, keeping the tube from flattening during the reinforcing process. In some cases, particularly 1" to 2" ID, the tube might be extruded with air injection along with an internal lubricant to avoid adherence to itself. The non-mandrel tube extrusion process may be done continuously, if appropriate handling equipment is accessible, thus providing outstanding length patterns for the finished products. In a recent year with developments in die design and cooling, dimensional control of non-mandrel rubber tube is approaching that of flexible mandrel style. Most smooth bore thermoplastic hoses usually are extruded non-mandrel. The higher rigidity of most thermoplastics removes the need for mandrel support. In addition, with the advanced cooling and dimensional sizing equipment, thermoplastic tube dimensions may be maintained quite accurately.

Flexible Mandrel Type - When a moderate tube processing support is needed and more accurate dimensional tolerances are a required, flexible mandrels may be utilized. These mandrels are either rubber or thermoplastic extrusions, sometimes may with a wire core to minimize distortion. This style process can be used for mid-range working pressures (up to 5000 psi) with ID's of 1/8" to 1-1/2". Of the three flexible mandrel types, solid rubber offers negligible support, while rubber with the wire core and thermoplastic versions provide decent dimensional control. In all these cases, the flexible mandrel is usually removed from the hose with either the hydrostatic pressure or mechanical push/pull after processing. The mandrel is later then inspected for dimensional and the cosmetic imperfections, re-joined into the continuous length, and recycled into a hose making process. Though the flexible mandrel is continuous, limitations of expulsion from the finished hose hardly allow hose lengths above 1000 ft. Either textile or wire reinforcements can be used. Examples of this style product are the power steering, hydraulic, a wire braided and air conditioning hoses.

Rigid Mandrel Type - In larger a hose sizes, where flexible mandrels become quite cumbersome to handle and working pressures are high, or stringent dimensional control is mostly required, the rigid mandrel process is the most preferred technique. This method is used for any rubber hose greater than 2" ID and for 1/8" to 2" ID constructions that have higher working pressures, particularly wire spiral reinforced products. The rigid mandrels are usually aluminium or steel. For a specialty application where cleanliness is a necessity, stainless steel mandrels can be used

## V. DESIGN & DEVELOPMENT

After finalizing the tube compound, next step is to define ID & OD dimensions. We have performed Tolerance stack up analysis for this. We have taken existing mandrel hose OD & Cap ID dimensions to find out min & maximum gap requirement.
With reference to that we got below results.

### A. Hose OD & Hose cap ID

Root Sum Square Tolerance Stack-up analysis was done to identify the gap requirement between hose OD & Hose cap ID.

- Root Sum Square Method

$$t_{RSS} = \sqrt{\sum_{i=1}^{n} t_i^2}$$

$t_{RSS}$ = Total expected (Equal Bilateral) variation using MRSS method
n = Number of contributing dimension
$t_i$ = Equal Bilateral tolerance for the individual contributing dimension

Figure 5: Root sum square method Equation

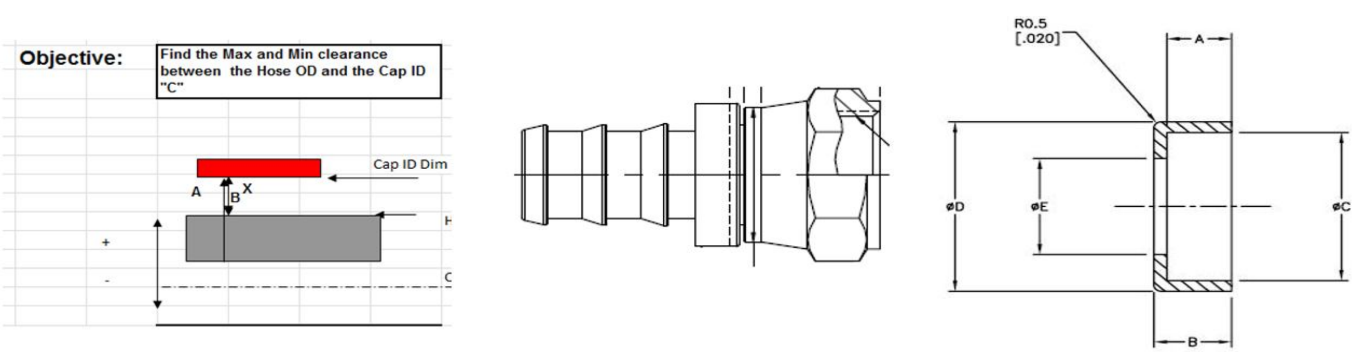


Figure 6: Hose OD & Cap ID Tolerance Stack up

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TABLE III
Tolerance stack up

| | | | | |
|---|---|---|---|---|
| Dimension Totals | 9.75 | 8.3375 | 1.0325 | |
| Nominal Dim.= (Pos - Neg. Dim)= | | 1.4125 | | |
| | | | | |
| Result | Nominal | Tolerance | Maximum | Minimum |
| Worst Case Method | 1.4125 | 1.0325 | 2.445 | 0.38 |
| Statistical Stack ( RSS) | 1.4125 | 0.65858 | 2.07108 | 0.75392 |
| Adjusted Statistical: 1.5*RSS | 1.4125 | 0.98787 | 2.40037 | 0.42463 |

Concentricity of hose ID to OD = 1.02 / 2 = 0.51
Min 0.7539 mm clearance required for Cap and new Hose OD

### *B. Hose ID & Nipple OD*

Root Sum Square Tolerance Stack-up Anaylasis was done to identify the gap requirement between hose ID & Nipple OD.
Some interference observed between Nipple OD & Hose ID which was acceptable considering exapansion of rubber tube material.

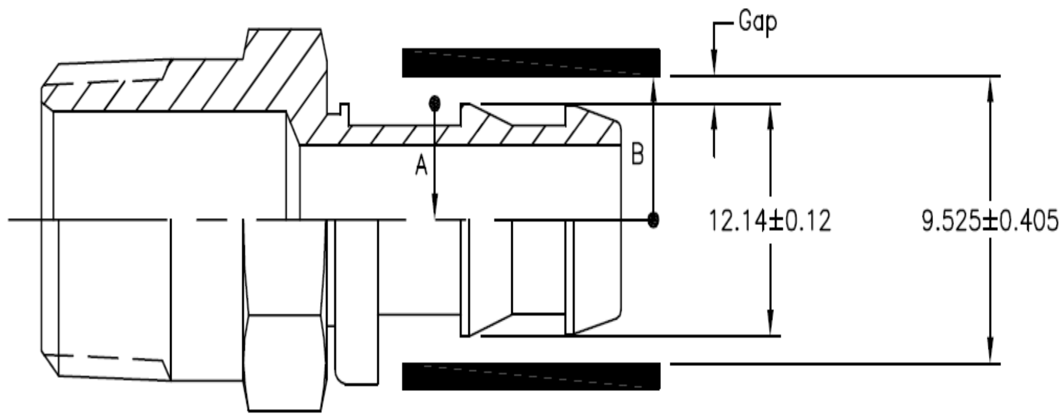


Figure 7: Tolerance stack-up Hose ID & Nipple OD

TABLE IV
Tolerance stack up hose id nipple Od

| | | | | |
|---|---|---|---|---|
| Dimension Totals | 4.7625 | 6.07 | 0.8975 | |
| Nominal Dim. = (Pos - Neg. Dim)= | | -1.3075 | | |
| | | | | |
| Result | Nominal | Tolerance | Maximum | Minimum |
| Worst Case Method | -1.3075 | 0.8975 | -0.41 | -2.205 |
| Statistical Stack ( RSS) | -1.3075 | 0.56598 | -0.74152 | -1.87348 |
| Adjusted Statistical: 1.5*RSS | -1.3075 | 0.84897 | -0.45853 | -2.15647 |

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### *C. Hose ID & OD selection*

With the help of Tolerance Stack-up Analysis, Hose handbook & Benchmarking approach, we came up with below ID & OD dimensions for new hose.

TABLE V
Dimension selection

| Dash Size | -6 | |
|---|---|---|
| 201 | Min | Max |
| I.D | 9.12 | 9.93 |
| O.D | 15.88 | 17.47 |

## VI. EXPERIMENTAL HOSE BUILD

After finalizing the dimensions, the mandrel less hose build process begins. Below figure shows the steps of sample preparation.

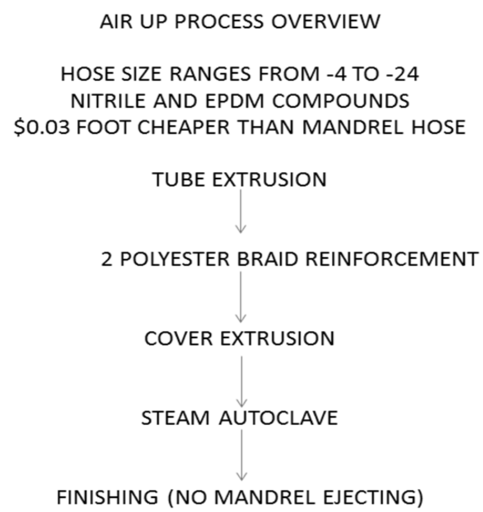

Figure 8: Hose build process

## VII. DESIGN & DEVELOPMENT

Below test were finalized to perform in concept testing to establish the initial diameter range.

*1)* Assembly
*2)* Examination of Product
*3)* Proof Pressure
*4)* Elongation and Contraction
*5)* Leakage
*6)* Burst Pressure
*7)* Cold Flexibility Test
*8)* Ozone Resistance
*9)* Adhesion Test
*10)* Oil Resistance
*11)* Tensile Test
*12)* Dry Heat Resistance
*13)* Fuel Resistance Test
*14)* Diesel Fuel Resistance Test
*15)* High Temperature Burst

We decided to build 6 samples for testing to get more reliable result.

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TABLE VI
PRODUCT TEST & VALIDATION

| Test Type | Test Purpose | Failure Criteria |
|---|---|---|
| Examination of product | To determine the hose and end fittings are in conformance with applicable Eaton drawings with respect to material, size and workmanship | The samples shall conform to the requirements of applicable Eaton drawings with respect to material, size and workmanship. |
| Proof | This test is used to determine the integrity of the hose fitting interface. | There shall be no evidence of permanent deformation, damage or leakage from the hose assembly during or at the completion of this test. |
| Elongation & contraction | This test is used to determine whether the proper braid-angle has been used for the end application. Deformation is calculated in Pressurizes and de-pressurized condition on Specified length | Elongation or contraction in excess of the limits specified in the applicable engineering document referencing this test shall be cause for rejection. |
| Leakage | This test is used to determine the leak-proof integrity of the hose-fitting combination at 70% of the hose minimum burst pressure. | Any evidence of leakage from hose or fittings, hose burst, fitting blow-off or other malfunction shall constitute failure. |
| Burst | This test is used to determine the ultimate pressure potential of an assembly. Burst pressure and type of failure also indicate the quality of the assembly process | The hose shall not burst, the fittings shall not blow off or loosen, and there shall be no leakage from the hose or fittings or other evidence of malfunction below the specified burst pressures. The type of failure shall be recorded. |
| Cold Flexibility test | This test is used to establish the suitability of the hose, and tube-stock compound, in cold-weather applications. | Evidence of cover cracks or leakage during proof testing shall be cause for rejection. |
| Ozone Resistance | This test is used to determine the comparative ability of rubber compounds to withstand the effects of normal weathering, or exposure in an atmosphere containing controlled amounts of ozone | After 70 hours of exposure, the samples shall not show evidence of cracking or deterioration while viewed under 7x magnification and still in the stressed condition. |
| Adhesion Test | This test is used to determine the adhesion strength between different layers of hose. | An average adhesion value lower than the values specified in the applicable engineering documents shall be cause for rejection. |
| Oil Resistance | This test is used to determine the relative fluid resistance qualities of the tube and cover compounds. | Volume change shall not exceed the amount specified in the applicable engineering document. |
| Tensile test | This test is used to determine the integrity of hose fittings interface, when subjected to tensile force. | he hose assembly, complete with fittings, shall withstand a minimum pull of values specified in the applicable engineering documents without separation from the end fittings or rupture of the hose structure.<br>Test assemblies shall not pull apart or pull out of the end fittings at less than the values specified in the applicable engineering documents. |

## VIII. OBSERVATION

Cold temp flexing test was done on one sample only and met the required criteria. All the hose samples made out of F23210 Inner tube compound met the High Temp. Burst, Ozone & Cold Temp Flexing test.

## IX. CONCLUSION

201 hose made by F23210 Inner tube compound has passed the entire performance requirements as specified in ES 4189. Based on the test results for F23210 material testing (Refer R-0119A) and test results conducted, we recommend building 201 in Mandrel less construction with the suggested inner tube material.

## REFERENCES

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