

Energy Efficient Hydraulics and  
Pneumatics Conference

# Cartridge Valve and Manifold Technologies

A Components Approach to Improved  
Energy Efficiency

## How Can Components Lead to Greater Energy Efficiency?

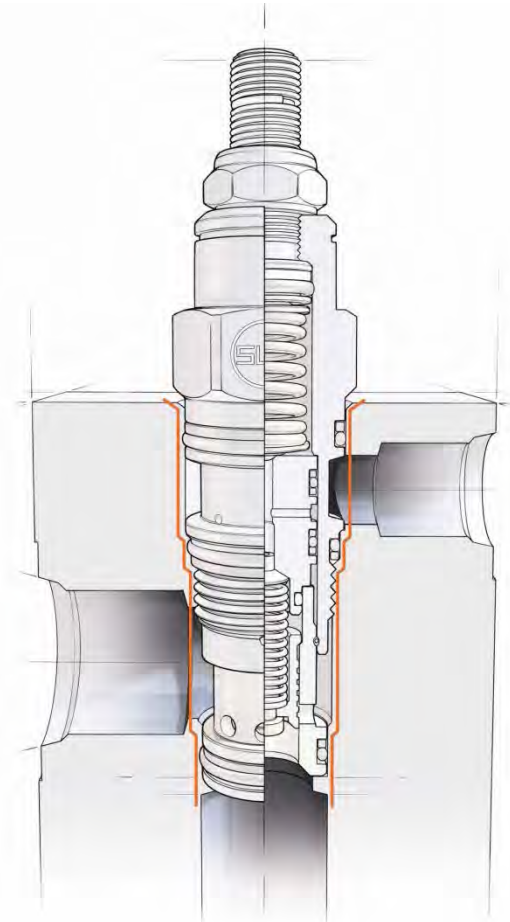
- Higher Capacity
- Energy Saving Functions
- Optimized Manifold Assemblies

# Higher Capacity

- Lower pressure drop for a given flow rate in the same size, or equivalently sized, valve

## Higher Capacity: Sun Cavity

- Unique to Sun Hydraulics
- Differs from Industry Common Cavities
  - Centrally located threads
  - Allowance for nose support
  - Defined port usage



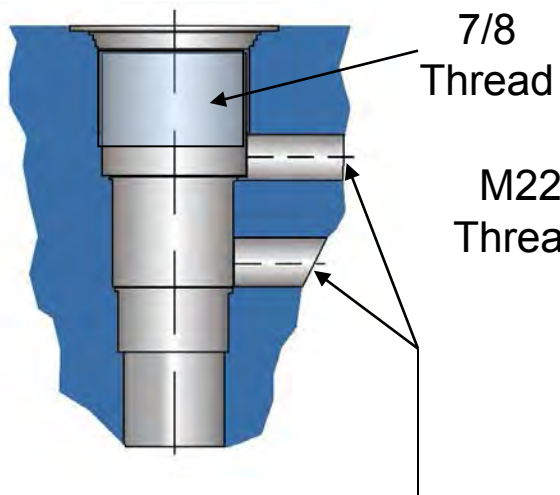
## How Does the Sun Cavity Improve Efficiency?

- Larger Working Port Diameters
  - Compared to equivalently sized industry common cavities
  - Lower cavity interconnection velocities
    - Lower pressure drop  $\approx$  Improved efficiency

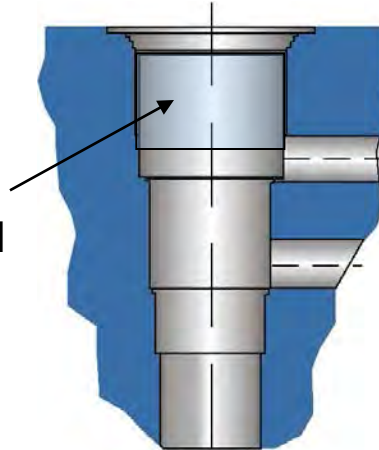
# Screw-in Cartridge Cavity Comparison

## Working Port Capacity Differences

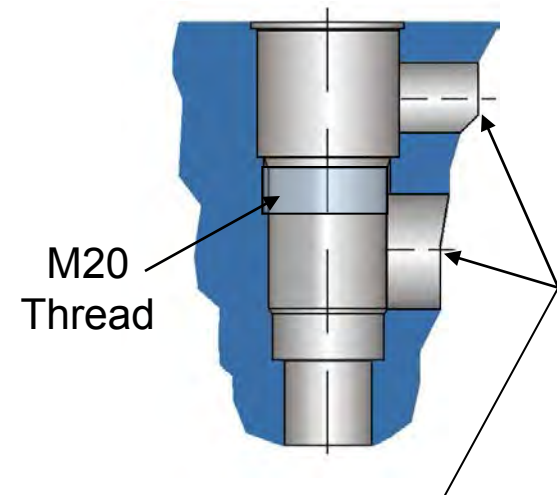
**SAE-10 Cavity**



**ISO-7789 Cavity**



**SUN T-11A Cavity**

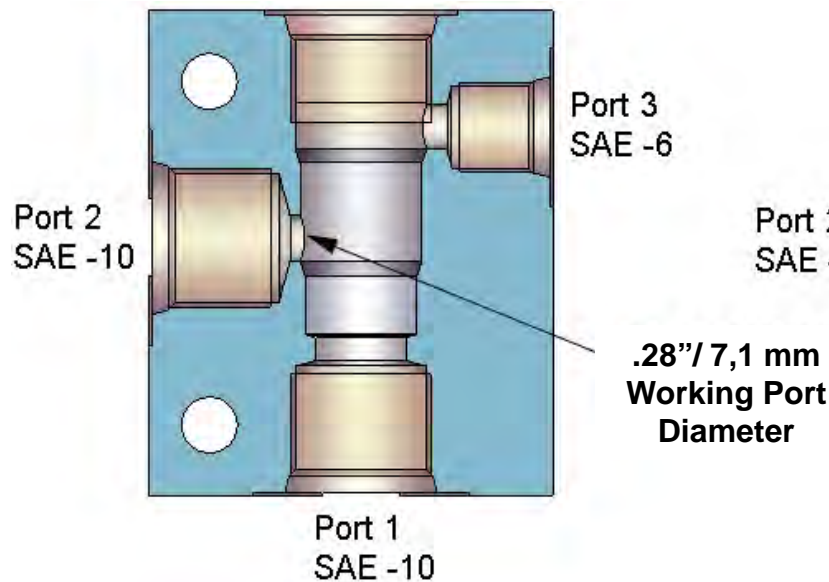


SAE and ISO versions are driven by the threaded port, limiting the size of working port connections

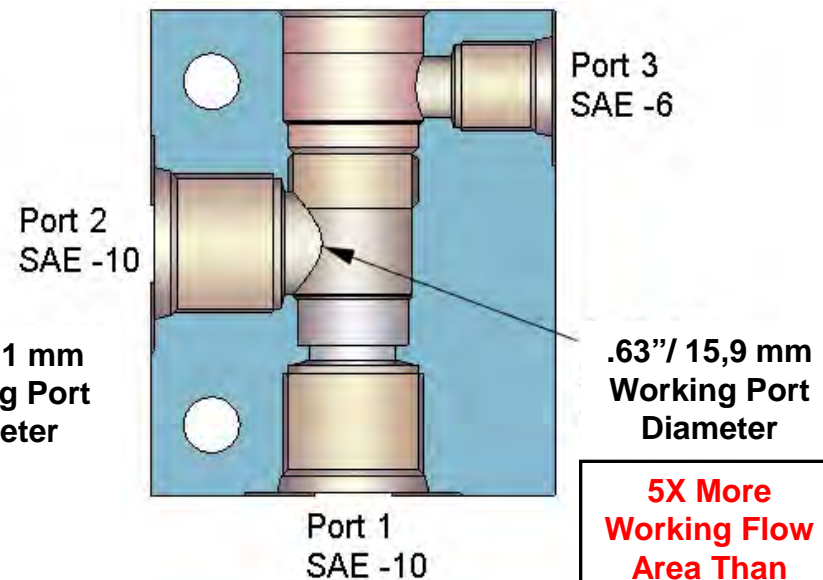
SUN cavity is specifically designed to optimize port capacity, allowing larger port connections

# Higher Capacity in Single Element Blocks

**Industry 'Common' 3-Port Body**



**Sun 3-Port Body**

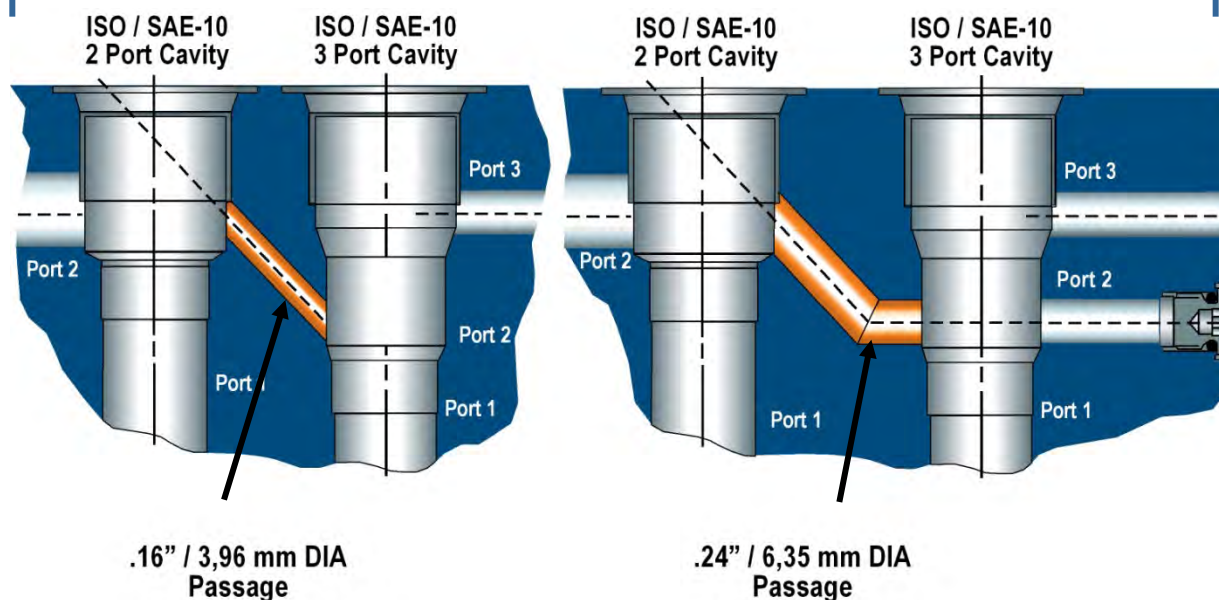


**5X More  
Working Flow  
Area Than  
Industry  
Common  
Body**

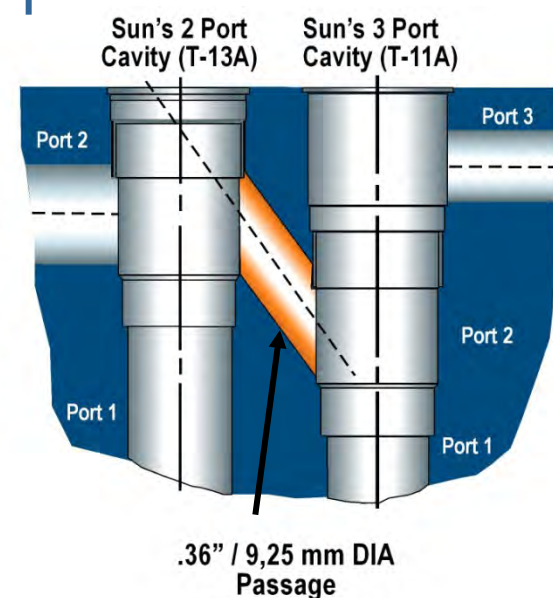


# Lower Cavity Interconnection Velocities

## ISO-7789 and SAE 10



## Sun Series 1



Flow Rate	.16" (3,96 mm) DIA	.24" (6,35 mm) DIA	.36" (9, 25 mm) DIA
5 gpm (20 L/min.)	80 ft/sec (24.4 m/sec)	35 ft/sec (10.7 m/sec)	16 ft/sec (4.9 m/sec)
10 gpm (40 L/min.)	160 ft/sec (48.8 m/sec)	70 ft/sec (21.4 m/sec)	32 ft/sec (9.8 m/sec)
15 gpm (60 L/min.)	240 ft/sec (73.2 m/sec)	105 ft/sec (32 m/sec)	47 ft/sec (14.3 m/sec)



## Sun Cavity Recap

### Features

- Larger working port diameters
- Equivalent sizes to industry common cavities

### Benefits

- Lower interconnection velocities result in less energy loss
- Greater capacity than equivalently sized industry common cavities

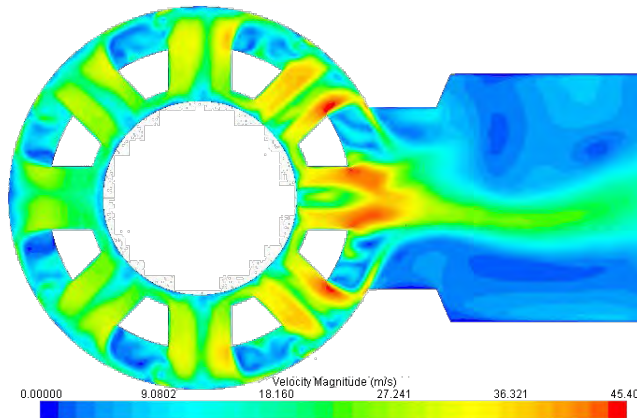
## Higher Capacity: Series 4+

- High Capacity Versions of Existing Valves
  - Check and non-modulating logic valves
  - 50-80% more capacity
- Alternative to DIN 25/32 Valves
  - Similar capacity
  - Smaller footprint

## How Were the Efficiency Gains Achieved?

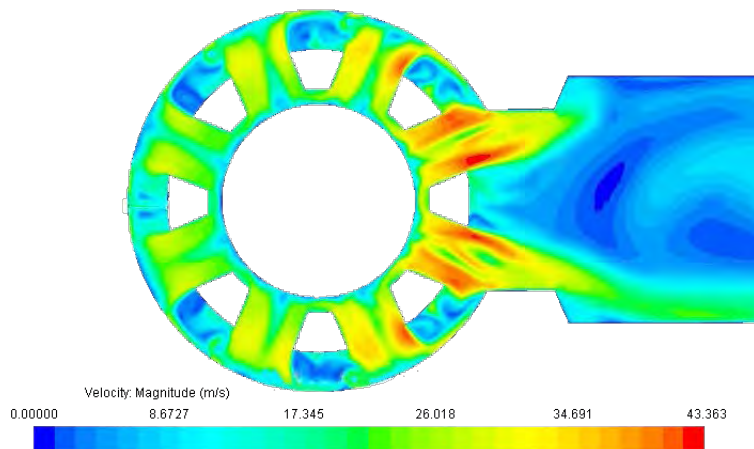
- Computational Fluid Dynamics Modeling
  - Computer simulation of valve performance
  - Identified flow restrictions
  - Quantified potential improvements
- Hydraulic Testing for Verification

## CFD Findings – Orientation Sensitivity



Original  
orientation

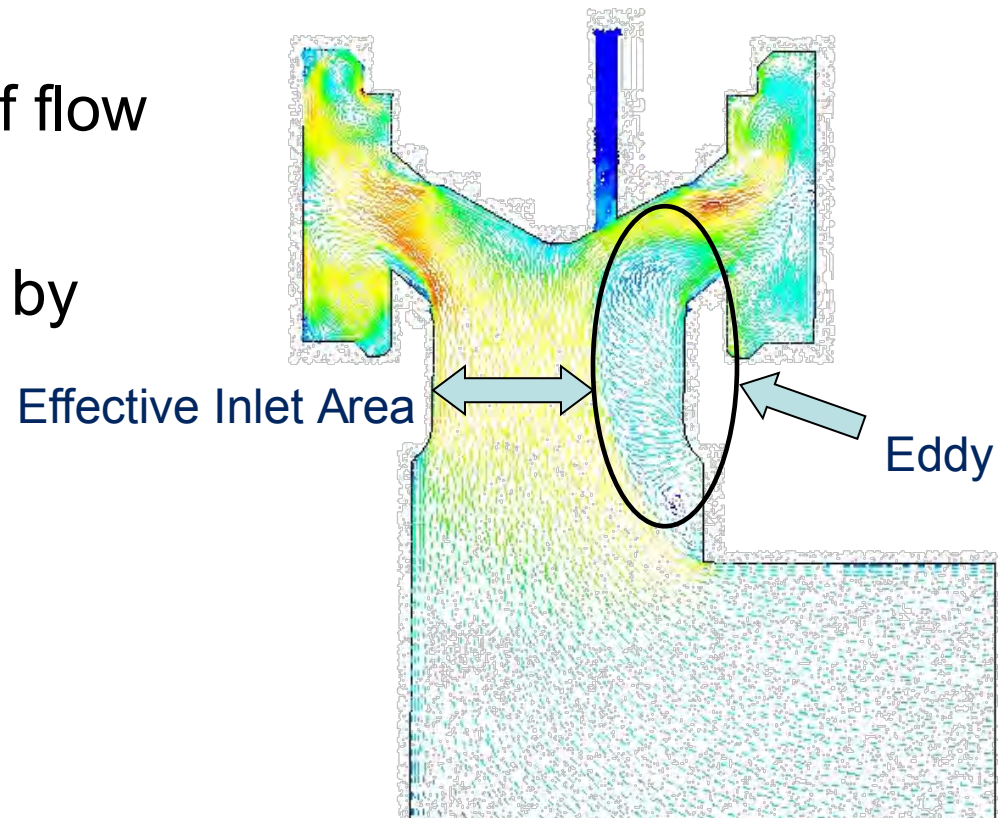
- Inconsistent performance
  - Alters pressure drop
- Affected by flow rate
  - Greater sensitivity at higher flows
- Cavity can be restrictive
  - Increases at high flows (200+ gpm)
  - Must be considered for optimization



Rotated  
22.5 degrees

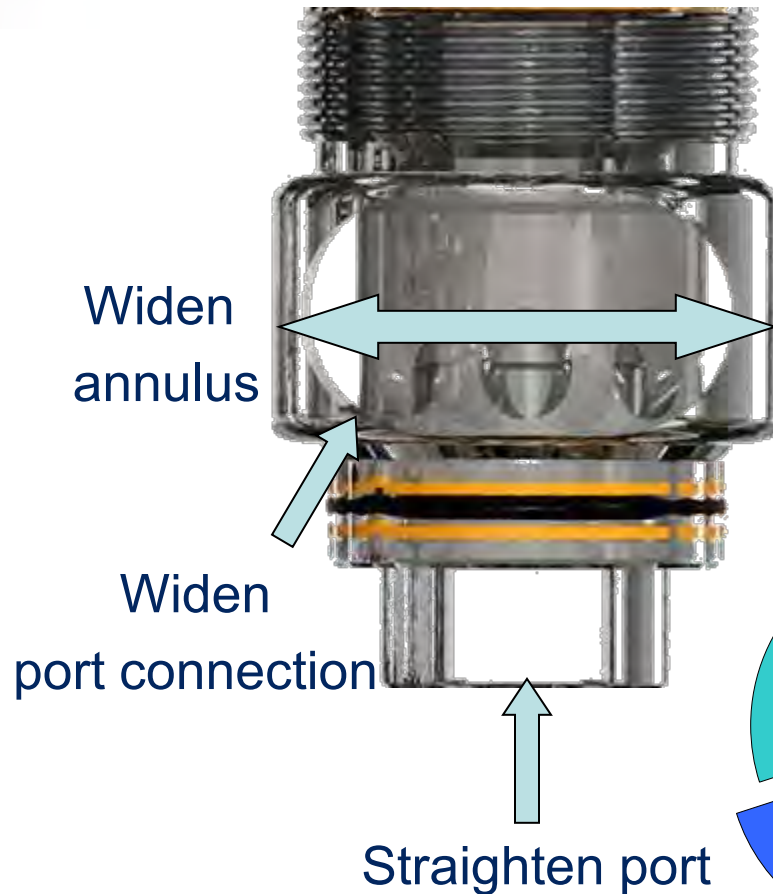
## CFD Findings – Hydraulic Eddy

- Hydraulic restriction of flow
- Inlet geometry critical
- Performance affected by upstream and downstream constraints

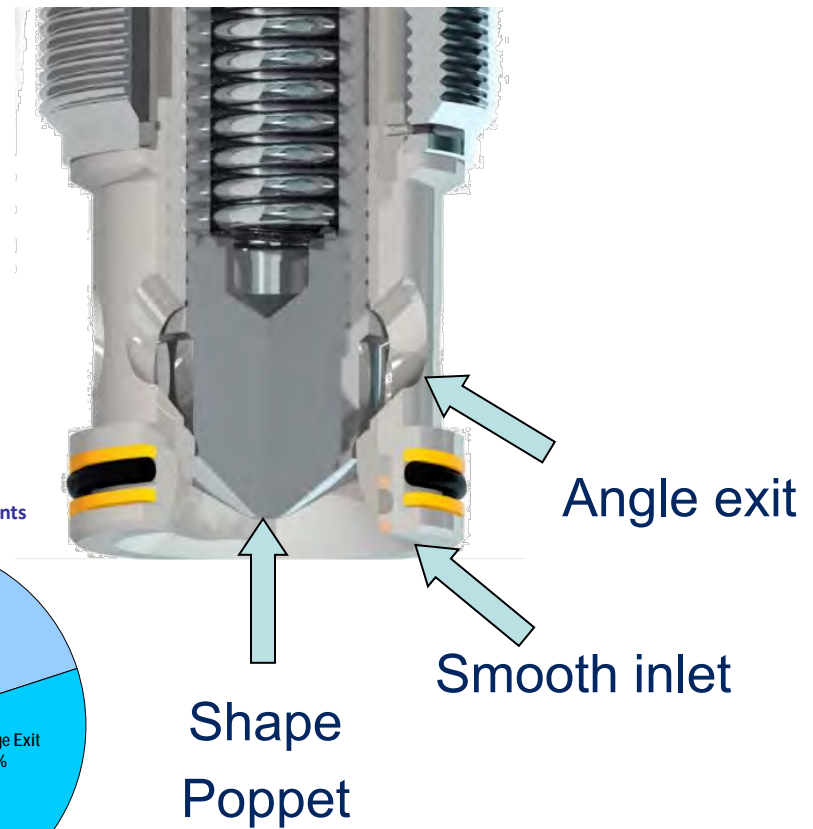


## Results – Critical Geometry

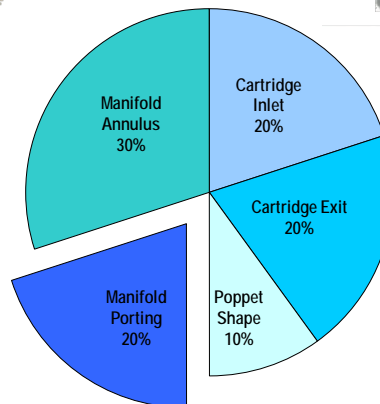
### Optimized Cavity



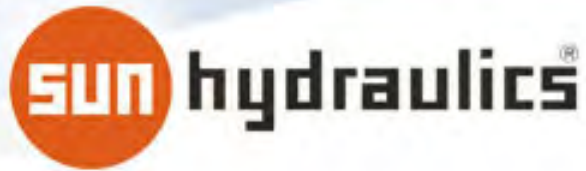
### Optimized Cartridge



#### Performance Improvements

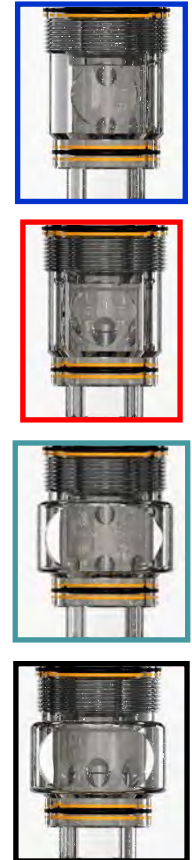
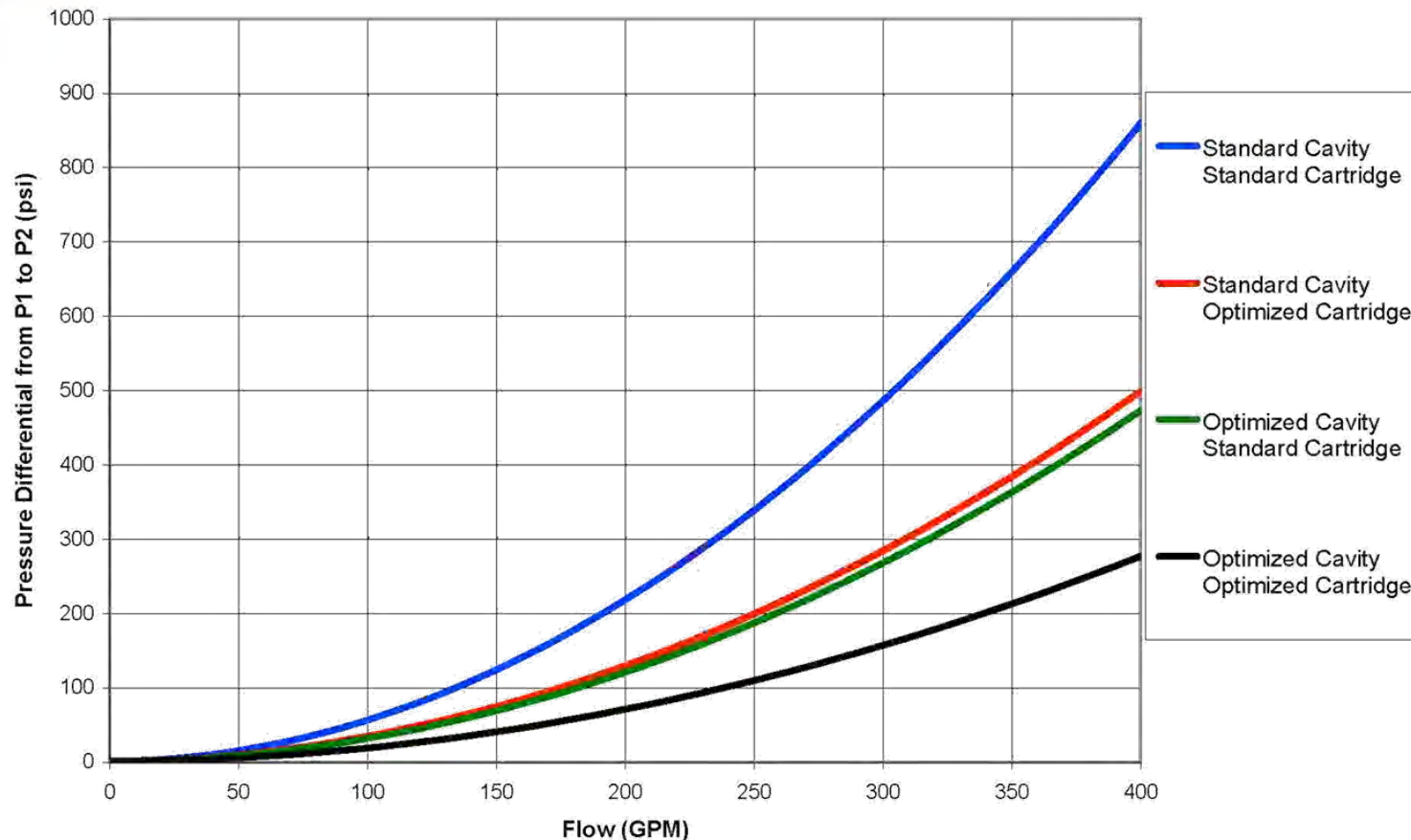






# Results – Hydraulic Validation

Pressure Differential vs. Flow



**67%** improvement over standard valve ≈ Savings of 28 hp

## Series 4+ Recap

### Features

- Streamlined cartridge
- Enlarged cavity annulus
- Enlarged port connections
- Shares form and function with existing Sun valves

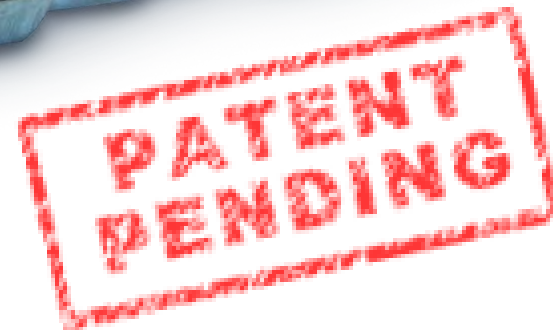
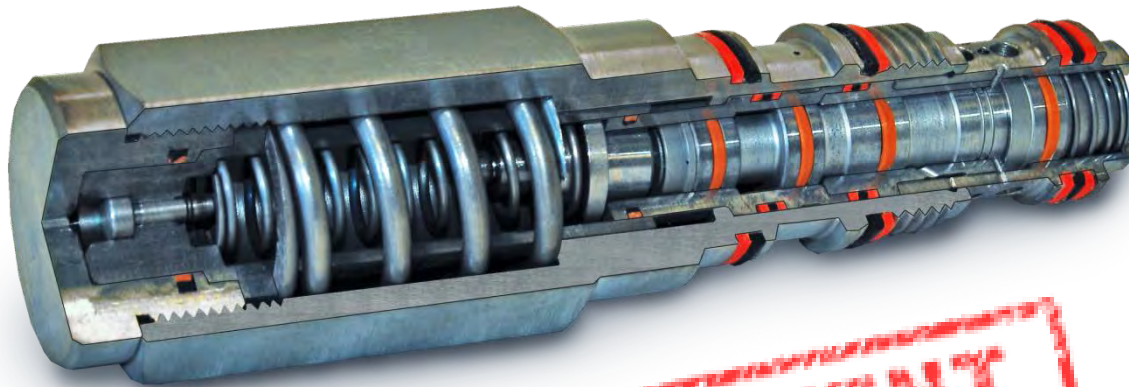
### Benefits

- 25-40% lower pressure drop with either cartridge or cavity
- 50-80% lower pressure drop with cartridge and cavity
- Can replace existing applications without circuit redesign

# Energy Saving Functions

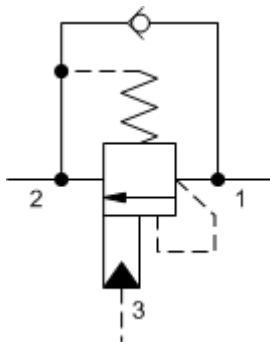
- Interchangeable, industry accepted functions performed in new ways that provide significant energy savings

# Energy Saving Functions: LoadMatch™ Counterbalance Valves

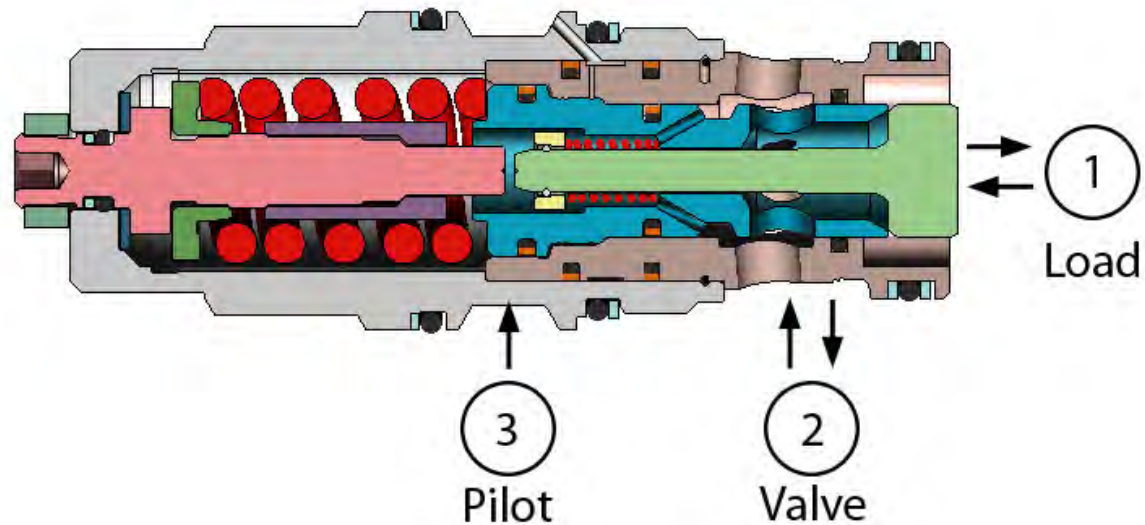


## What is a Counterbalance Valve?

- Direct Acting Relief Valve
- Pilot Assist
  - Reduces effective relief setting
- Integrated Reverse Free Flow Check



Functional Symbol



## What Does a Counterbalance Valve Do?

- Load Control
  - Prevents unintended motion
  - Requires positive signal to open
  - Modulates opening for smooth control
- Provides Relief Protection



## Counterbalance Valves Consume Energy

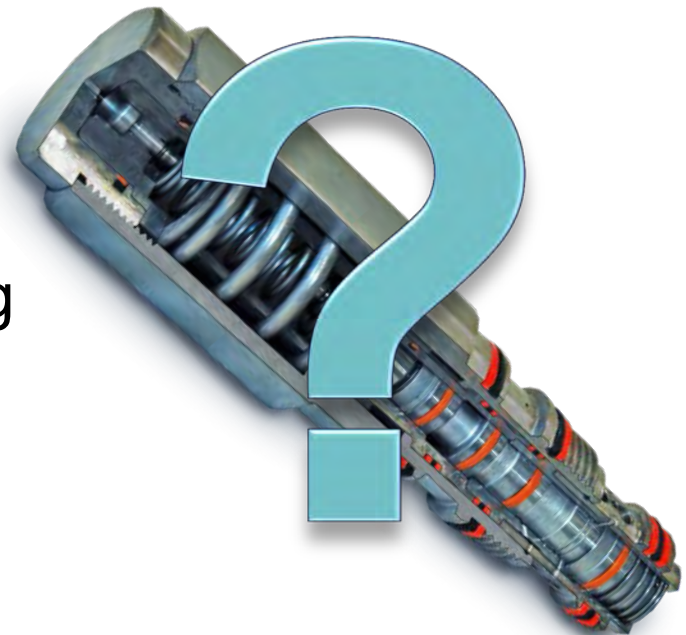
- Create a Variable Resistance to Flow
  - Energy sacrificed for control/stability
- Pilot Assist Reduces Resistance to Flow

$$\text{Pilot Pressure To Open} = \frac{\text{Valve Setting} - \text{Load Pressure}}{\text{Pilot Ratio}}$$

- High Pilot Ratios Increase Efficiency
- High Pilot Ratios Decrease Stability

## What is a LoadMatch™ Counterbalance Valve?

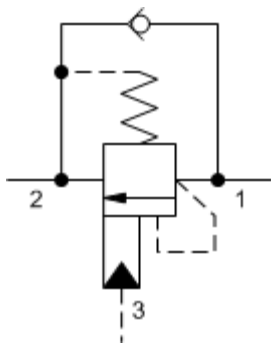
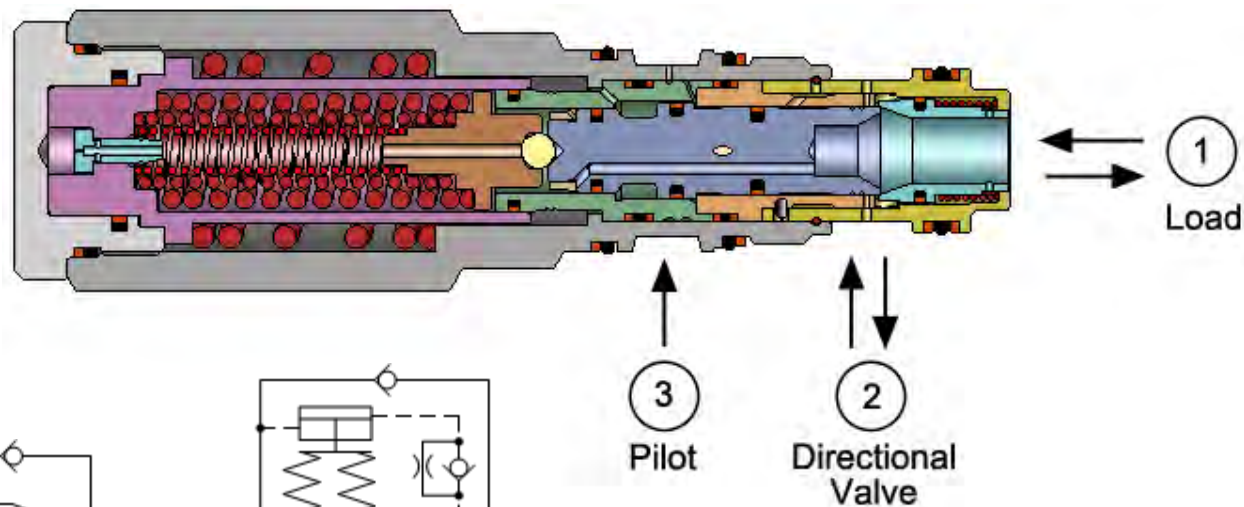
- Counterbalance Valve + New Control
  - Improved modulation
  - Non-adjustable
  - Fixed relief setting
  - Dynamic load holding setting



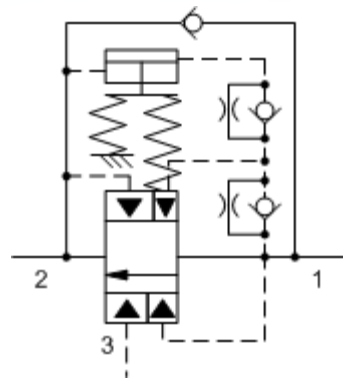
## What Does a LoadMatch™ Valve Do?

- Counterbalance function
  - Full flow relief protection
  - Excellent modulating characteristics
  - Stable load control
- Low Pilot Pressure Requirements
- Pilot Pressure Independent of Load

## LoadMatch™ Cartridge Model MBEP



Simplified Symbol



Detailed Functional Symbol

# LoadMatch™ Advantages

## Dynamic Load Holding Setting

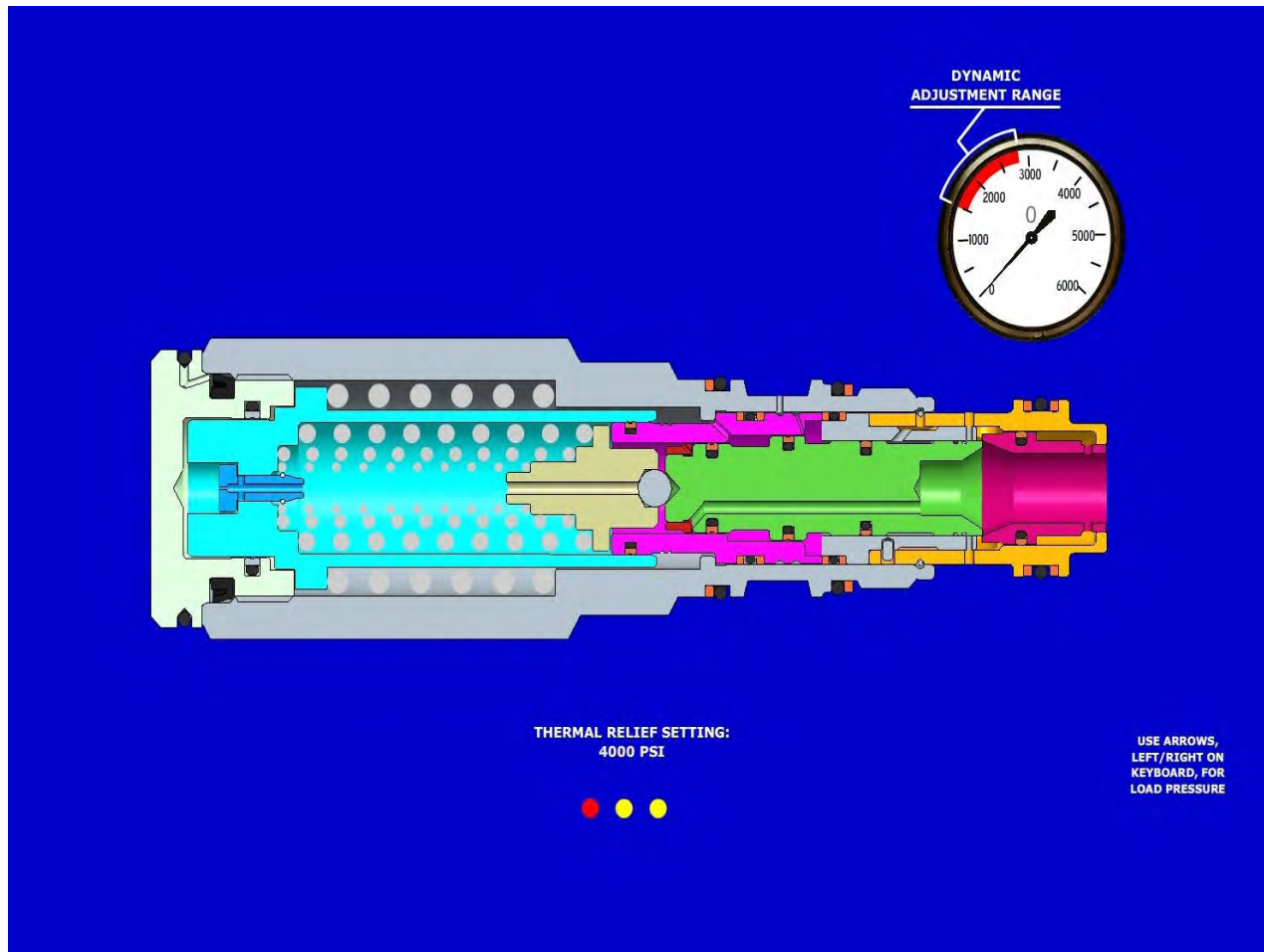
### Design Features

- Self sets to hold load
- Set point is higher than load pressure by a fixed differential
- Low, consistent pilot pressure

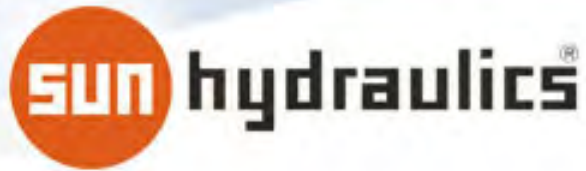
### Benefits

- Safe Load Holding
- Good control and stability
- Predictable Metering
- Energy Savings

# LoadMatch™ Function



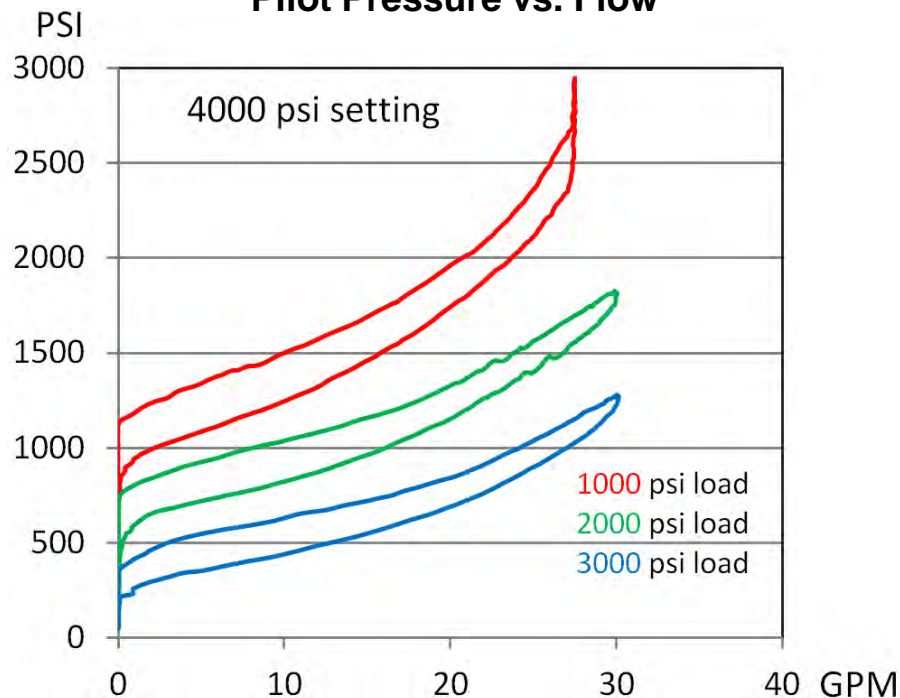




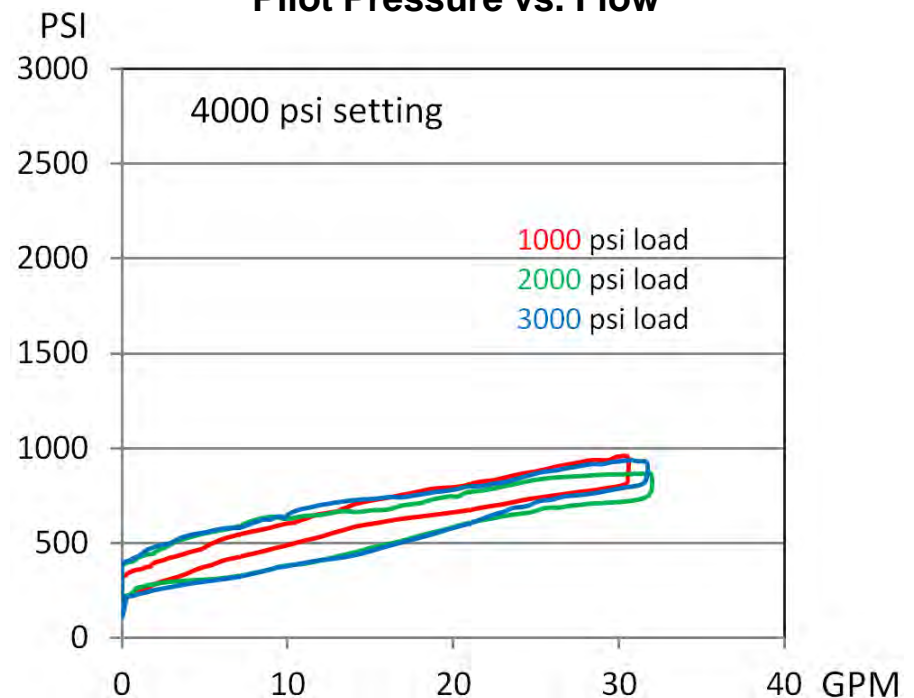
# Performance Comparisons

Pilot Pressure Requirements  
4000 psi Valve setting

**Standard Counterbalance**  
**Pilot Pressure vs. Flow**



**LoadMatch™**  
**Pilot Pressure vs. Flow**



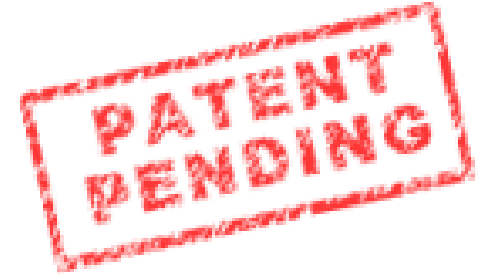
**65%** lower pilot pressure over standard valves at 1000 psi load pressure

## Where Does LoadMatch™ Apply?

- Off Road Tele-handlers/Forklifts
- Winches
- Cranes
- Battery Operated Equipment



## LoadMatch™ Recap



### Features

- Dynamic Load Holding Setting
- Lower pilot pressures
- Consistent pilot pressures
- Includes pressure relief
- Shares cavity with other Sun counterbalance valves

### Benefits

- Enhanced performance over standard counterbalance
- Reduces energy consumption
- Extends run-time of battery powered machinery
- Can replace existing Sun counterbalance applications

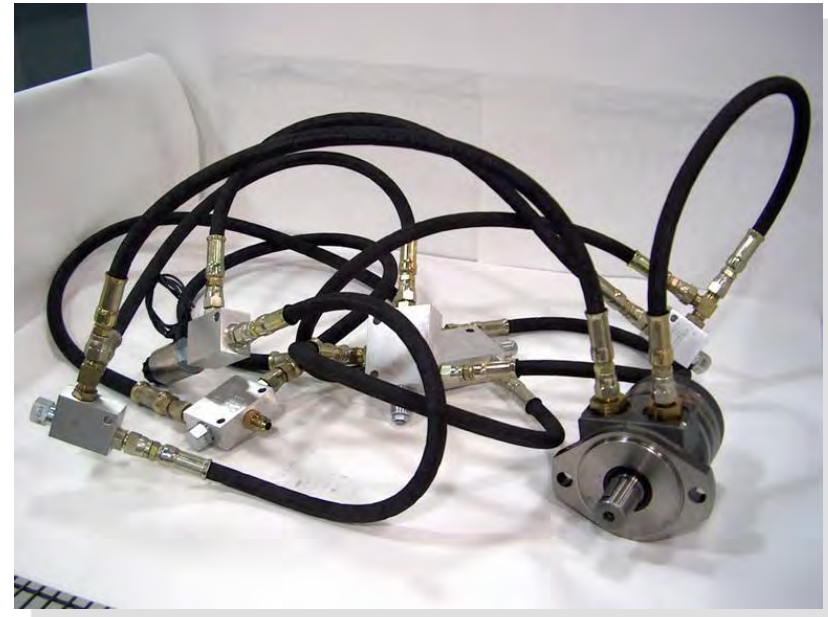
# Optimized Manifold Assemblies

- A hydraulic circuit integrated into a single block to minimize pressure losses between valves

# Line Mounted Valves Reduce Circuit Efficiency

- Sources of Pressure Loss
  - Fittings
  - Long and undersized hoses or tubing

**Motor Control Circuit –  
components line mounted**



# How Can Manifold Assemblies Improve Efficiency?

- Minimize Pressure Losses
  - Fewer fittings
  - Larger diameter connections
  - No long hoses or tubing

**Motor Control Circuit –  
components manifold mounted**





## Optimized Manifold Assemblies: 5-Axis Machining

- 3-Axis
  - **X**, **Y**, and **Z** axes
- 5-Axis
  - **X**, **Y**, and **Z** axes
  - Plus **A** (rotate) and **B** (tilt)
  - Enables use of compound angles



## 5-Axis vs. 3-Axis Efficiency Advantages

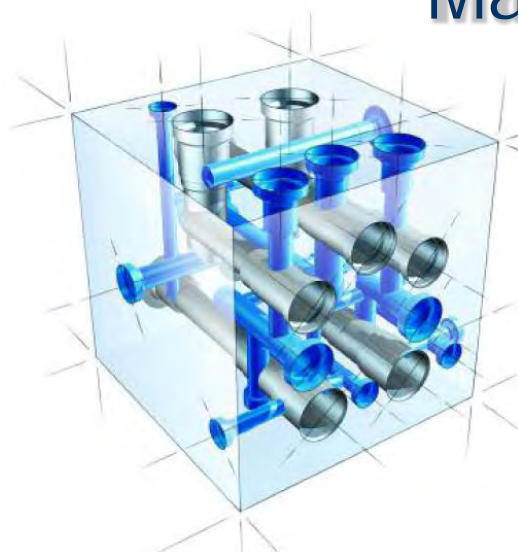
- Improved Flow Paths
  - Optimized cavity connections
  - Fewer drillings to connect cavities
  - Less restrictive drilling connections
    - Angles greater than  $90^{\circ}$



## Additional 5-Axis Advantages

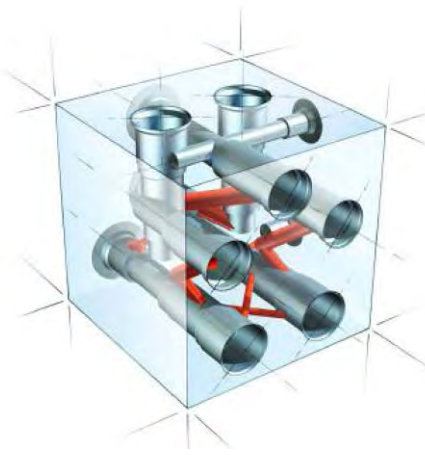
- **Reduced Package Size**
  - Easier packaging
  - Weight savings for mobile applications
- **Fewer Construction Holes**
  - Potential leak points

## Manifold Design Comparison



### 3-Axis Straight Hole Drilling

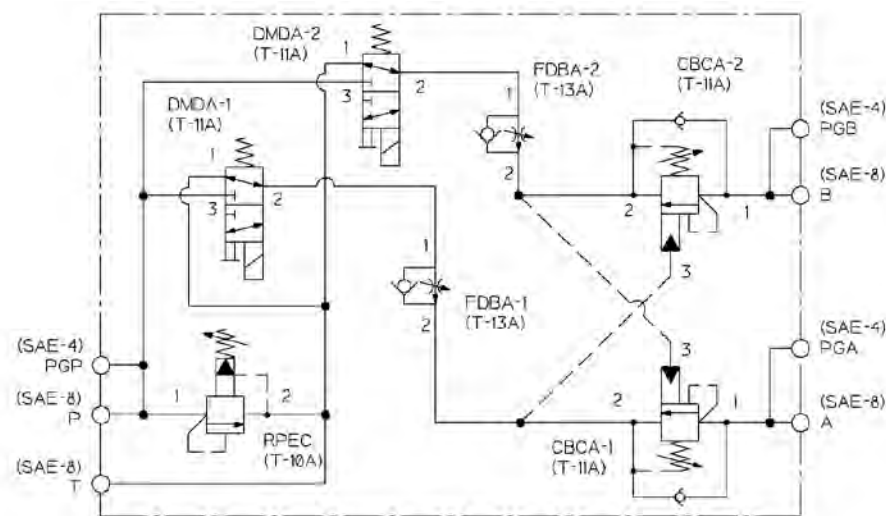
Size: **125** cubic inches  
**5 x 5 x 5** inches  
 No. of Plugs: **17**



### 5-Axis Compound Angle Drilling

Size: **64** cubic inches  
**4 x 4 x 4** inches  
 No. of Plugs: **0**

Schematic for both designs



## Designing 5-Axis Manifolds for Energy Savings

- 5-Axis Designs Typically Reduce Block Size
  - Package size may increase when designing for optimum efficiency
- For Flow Path Efficiency
  - Minimize acute drilling connections
  - Maximize connection diameters
  - Optimize placement of components

## 5-Axis Recap

### Features

- Compound angle drillings
- Connection angles greater than 90°
- Reduced block size
- Fewer construction holes

### Benefits

- Improved flow paths
- Optimized cavity hits
- Lower pressure drop between installed components
- Less mass for mobile applications
- Fewer leak points



## Considerations About Energy Savings

- Your Savings May Vary
  - Energy efficient components do not guarantee an efficient circuit
  - Simple substitution may not produce savings
  - Savings difficult to predict
  - Consider complete circuit with efficiency in mind

## Bringing It All Together

- Higher Capacities
  - Reduce component pressure losses
- Energy Saving Functions
  - Use less power for critical functions
- Optimized Manifold Assemblies
  - Minimizes circuit losses

## Bringing It All Together

- Choose Components with Efficiency in Mind
  - Sun Cavities allow large connections
  - Series 4+ valves operate at low pressure drop
  - LoadMatch™ valves reduce energy requirements
  - 5-Axis manifolds leverage efficient circuit design and packaging
- Combine to Optimize System Efficiency

# Questions?