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How to solve the Actuated Valve (AV) Assembly Torque Requirement Puzzle?

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An article on the What, Why, How and the potential benefits to size & select Fit for the Application Actuated Valve Assemblies (Picture 1), called also Automated On/Off Valves, Emergency Shutdown Valves (ESDV), Blowdown Valves, Automated Block Valves, or other named valves within the process industry…

WHAT ARE AV ASSEMBLIES?

ISO 12490, the latest standard in this domain, uses the term "Actuated Valve Assemblies", therefore we have adopted this term, mainly because we have so many names for the same device. They are called Automated On/Off valves, or Emergency Shutdown Valves (ESDV), or Blowdown valves. Some call them Automated Block Valves (ABV). A pity we have so many names for the same kind of device…

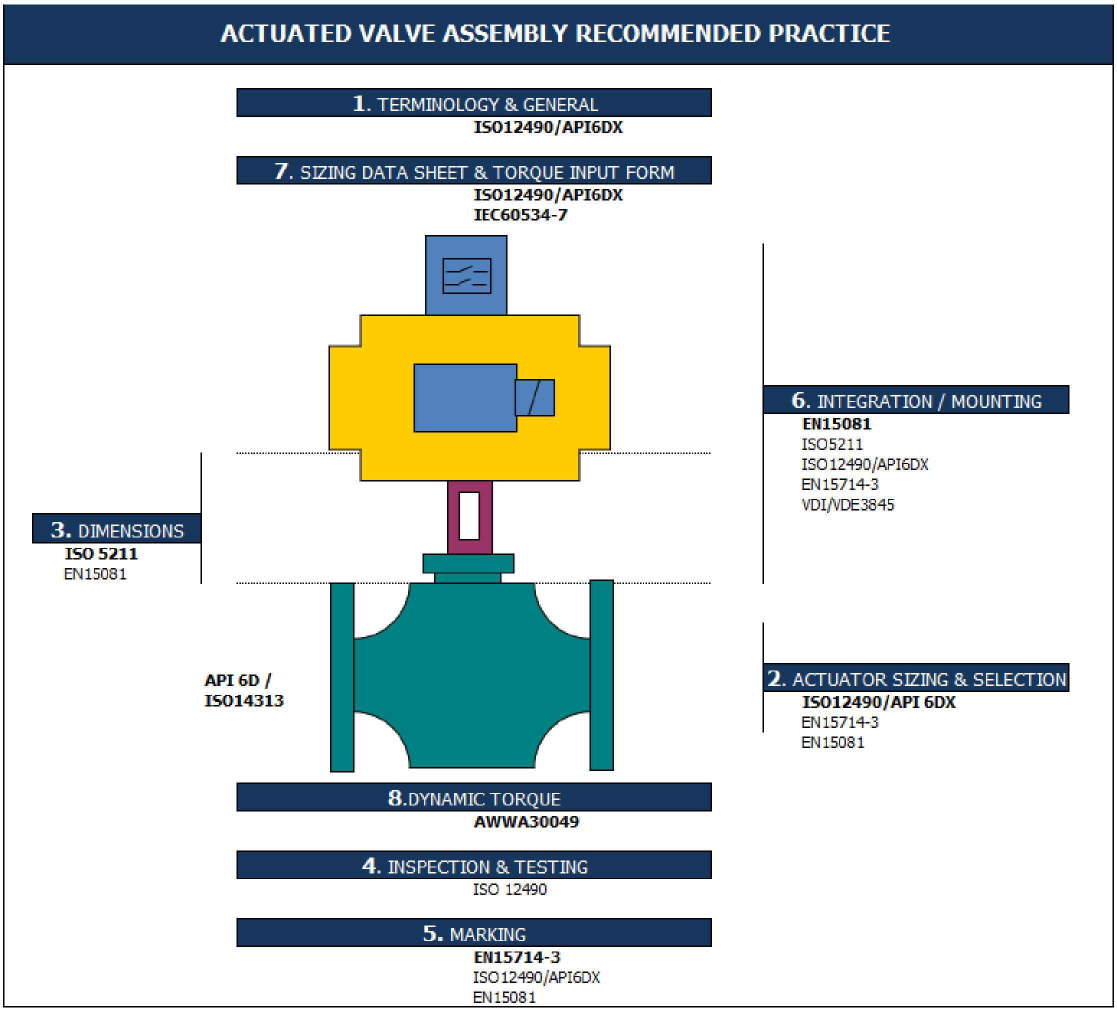
Picture 1: AV Assembly puzzle

In contrast with Control Valves, AV assemblies have been treated poorly, to say the least. They lack coherent international standardization often causing more confusion and misunderstanding. They are often handled as commodities while control valves, for as long as we can recall are handled as engineered products. And they are often handled by different organization, typically not communication between each other. If purchased by the piping organization the focus is on the valve aspects, not on the actuation aspects. As we sometimes say: "They buy metal, while we need torque!"

To address those pitfalls we, a combination of End Users and Tool developers came up with the two key elements to complete the AV Assembly puzzle:

- A WIB AV Assembly Recommended Practice (RP), compiling the essential ingredients to "brew" a Fit For The Application" AV assembly
- A CONVAL AV Assembly module prototype fully compliant with the WIB AV Assembly Recommended practice to facilitate and improve the AV Assembly sizing & selection process.

We call them the jigsaw puzzle closing pieces to properly engineer Fit For The Application AV assemblies! The WIB Recommended Practice is following the same structure as the IEC 60534 international standard to realize Fit For the Application Control Valves (CV). This IEC60534 CV standardization contains eight standards. The WIB Recommended Practice



Picture 2: Actuated Valve Assembly recommended practice

(RP) contains following matching sections (**Picture 2**).

- 1. Terms & Definitions
- 2. Sizing
- 3. Dimensions
- 4. Inspection & Testing
- 5. Marking
- 6. Integration
- 7. Data sheet & Valve Torque Input form
- 8. Dynamic

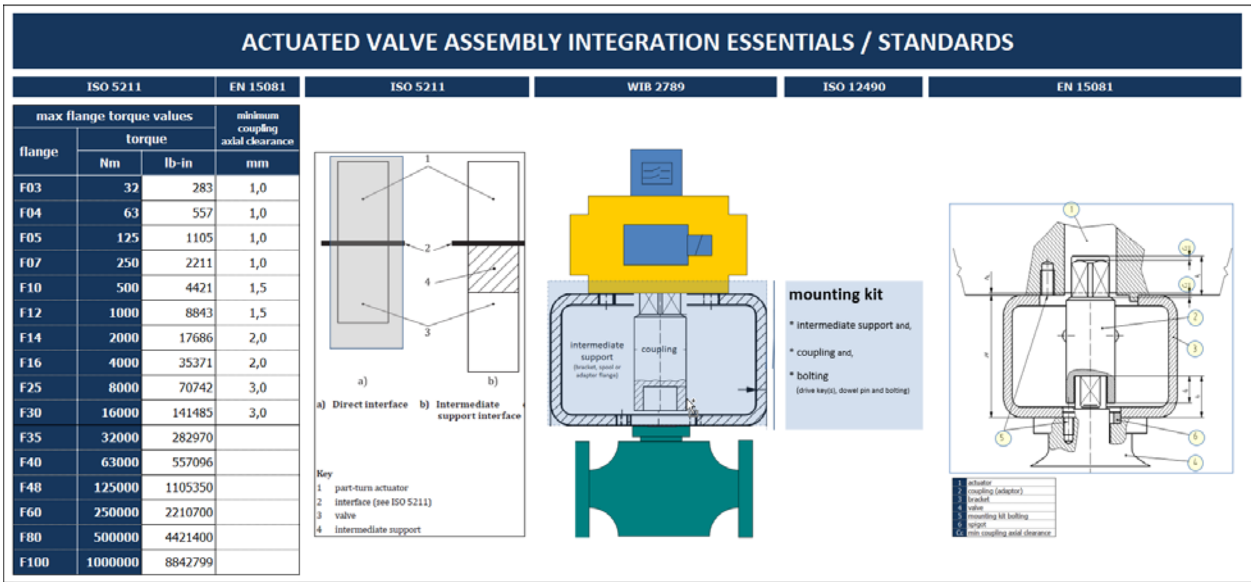
The RP, currently focusing on pneumatic part-turn actuators, will be released at the upcoming Valve World Dusseldorf event. The author will present this RP and the CONVAL prototype in a 20 minutes talk at the conference. The prototype will be demonstrated at the F.I.R.S.T. GmbH booth, Hall 4 /B10.

WHY THOSE AV ASSEMBLY INITIATIVES? WHAT ARE CURRENTLY THE ROOT CAUSES?

What are the potential root causes with AV Assemblies? Let's quickly review the various phases of an AV Assembly lifecycle and what potentially can and has been causing AV Assembly failures, but not limited to:

Sizing and Selection phase

- There is NOT ENOUGH TORQUE to move the AV valve in a given position! For example the ESDV valve may NOT close to its safe position, or the Blowdown valve may NOT open to its safe position. Or the valve stops somewhere in between. Challenging Safety Hazards. Or the ESDV valve will NOT open during startup; Not a safety concern but a reliability and $$ concern!
- There is TOO MUCH TORQUE and will damage one or more components from the drive train. A challenge that also the piping folks are very concerned about. It can be a safety and / or reliability issue.
- To manage this torque dilemma, one needs to know the valve torque requirements, more precisely the valve torque at the moment of a demand (we call it valve torque on demand); one needs to address the effects of the maximum and the



flange	max flange torque values – torque Nm	max flange torque values – torque lb-in	minimum coupling axial clearance mm
F03	32	283	1,0
F04	63	557	1,0
F05	125	1105	1,0
F07	250	2211	1,0
F10	500	4421	1,5
F12	1000	8843	1,5
F14	2000	17686	2,0
F16	4000	35371	2,0
F25	8000	70742	3,0
F30	16000	141485	3,0
F35	32000	282970	
F40	63000	557096	
F48	125000	1105350	
F60	250000	2210700	
F80	500000	4421400	
F100	1000000	8842799	

Picture 3: Tool to facilitate the sizing & selection process

minimum air supply pressure, i.e. the valve has also to move also at the minimum air pressure, while avoiding that the drive train be damaged at the maximum air pressure!

- Obtaining those valve torque values has been and still is a real challenge. Quite often valve manufacturers are on the breaks to provide that essential data. Thanks to the ISO12490 it became a mandatory requirement!
- To make sure we have enough torque, end users in the petrochemical and chemical industry applied safety factors to size the actuator, quite often causing oversized actuators. Oversized actuators that require additional torque to handle the unbalance effects, the center of gravity effects to name a few. To overcome the potential damage of drive train components, exotic drive train materials have been considered. All this is driving up the cost of those assemblies and often causing issuing with the mounting kit. For those not familiar a mounting kit, as defined in ISO12490 consist of an intermediate support like a bracket, a coupling and the corresponding fasteners to mount everything together.
- To make the torque dilemma complete we currently lack standardization on torque terms & definitions, a challenge causing more confusion than you may like or expect and often an excuse of the valve manufacture to not provide quality valve torque data.
- The RP document is sprinkled with a comprehensive set of terms and definitions (**Table 1**) to eliminate those confusions and excuses. Having quality torque data is a MUST to perform a proper AV assembly sizing & selection. Without those you are just gambling and taking high risks!

Integration phase (Picture 3)

ISO5211 is the foundation international standard to properly integrate the AV actuator on top of an AV valve. Fundamental is the "flange" classification: a given flange with specific dimensions defines the maximum torque that can be transferred from the actuator to the valve; for example a flange called F30, has specific dimensions per the standard and can handle a torque of 16000 N-m (or 141485 lb-in). This guides the valve manufacturer, the actuator manufacturer and the mounting kit manufacturer to properly size their drive train parts accordingly.

- Too often we see assemblies not matching those ISO5211 requirements. End Users have numerous examples of mounting kit deficiencies. Too often those brackets (there are other types of intermediate supports such as an adapter flange or a spool), couplings and fasteners were designed and manufactured improperly and causing reliability issues. In a recent startup a major petrochemical project had most problems with AV assemblies with improper mounting kits.
- Of course not applying the ISO 5211 guidelines can potential cause the mounting kit to fail at maximum air supply pressure.

Handling phase

- Sloppiness and / or unawareness are often root causes of AV assemblies malfunctions. For example leaving those assemblies on project laydown areas

TORQUE DATA DEFINITIONS					
symbol	definition	travel ° open		uom	clarification
Torque values					torque data at the given travel position
MAST	**M**aximum **A**llowable **S**tem **T**orque			Nm / lb-ft	The maximum torque to dimension the drive train elements to ensure the weakest link in the drive train can handle this maximum torque
Valve torques					
BTO	**Break** to Open	0		Nm / lb-ft	To break the valve open, also called Unseating Torque
RTO	**Run** to Open	min		Nm / lb-ft	Minimum torque running in opening direction
ETO	**End** to Open	90		Nm / lb-ft	To fully open the valve
BTC	**Break** to Close	90		Nm / lb-ft	To break from opening
RTC	**Run** to Close	min		Nm / lb-ft	Minimum torque running in closing direction
ETC	**End** to Close	0		Nm / lb-ft	To fully close the valve, also called Seating or Reseating Torque
Actuator torques					
ATS	Air to **Start**	0	90	Nm / lb-ft	Air torque at which the actuator spring starts to compress
ATR	Air to **Run**	min		Nm / lb-ft	Air torque at which the actuator spring is compressing
ATE	Air to **End**	90	0	Nm / lb-ft	Air torque at which the actuator spring is fully compressed
STS	Spring to **Start**	90	0	Nm / lb-ft	Spring torque at which the actuator spring starts to relax
STR	Spring to **Run**	min		Nm / lb-ft	spring torque at which the actuator spring is relaxing
STE	Spring to **End**	0	90	Nm / lb-ft	spring torque at which the actuator spring is fully relaxed
Torque Factors					torque data for a given AV assembly
SF	Torque **Safety Factor**	-		-	Actuated Valve Assembly Torque Safety Factor is a dimensionless factor, expressed as a ratio, listed in the AV Assembly sizing data sheet to specify the safety margin between the valve torque value, including the ODCF, and the corresponding actuator torque value.
ODCF	**On Demand** Valve Torque **Correction Factor**	-		-	A correction factor to multiply a net torque value, like the BTO, to correct the net torque for specific combined process characteristics
Travel angle					
ba	**breakaway angle** or percent of stroke	0		-	The breakaway angle or percent of stroke is the point at which the seat breaks/makes sealing contact with the obturator. The breakaway angle or percent of stroke can be significant to actuator sizing when in excess of 5°

Table 1: Torque data definitions

or even in project warehouses within corrosive environments (close to the sea for example) without proper handling and protection can cause corrosion or rust on various assembly components. A recent startup reported a broken actuator spring due to poor protection handling in warehouse and laydown areas. Lots of problems can be avoided by applying proper handling during shipment, during storage and during installation before the plant is started.

Testing and inspection phase

It is essential to properly test and inspect those AV Assemblies. We properly test our control valves, i.e. Factory Acceptance Tests (FAT) are scheduled, manned and executed by specialists, but often AV Assemblies are left behind, not addressed. No surprise to phase delays during commissioning & startup because AV Assemblies inspections have not been addressed properly or none at all. A current project is hampered and causing startup delays because of Less Than Adequate (LTA) integration, handling and inspection activities.

Installation phase

Improper mounting of a perfect functioning AV Assembly at the Factory Acceptance Test will invalidate its proper functioning. Installation requirements should be clearly addressed and inspected.

Operate & Maintain phase

Actuators and Valves come with Operate & Maintain (O&M) manuals. Actuator and valve manufacturers specify regular or preventive maintenance guidelines in their O&M manuals. Following root causes are observed:

- The mounting kit design may not allow to perform such maintenance activities on a running valve stem.
- Using an AV assembly on a Long Stand Still (LSS) application, i.e. an ESDV assembly will remain OPEN for a longer period than the required period to maintain the actuator, maintenance cannot be performed as per the A&M manual and causing a problem due to lack of maintenance.

Picture 4: WIB Membership List

HOW WE TACKLED THOSE ROOT CAUSES? PART I – AN END-USER RECOMMENDED PRACTICE

Potential root causes with AV Assemblies occur during the various phases mainly due to lacking international standardization, not being handled as Engineered Products, and/or because they are handled by uncoordinated disciplines. WIB, an End-user driven organization with members globally (**Picture 4**), developed an AV Assembly Recommended Practice to tackle those root causes.

Lacking international standardization

About 67% of the IEC60534 control valve (CV) standards deal with sizing and with fluid dynamics. CV sizing means deriving the flow capacity called C_v (or K_v). CV fluid dynamic deals with noise, with cavitation, with velocities.

We expect a similar percentage to deal with AV Assembly sizing, integration and fluid dynamics.

- Integration is unique for AV, because we need to integrate the AV actuator with the AV valve using an AV mounting kit., most probably from three different sources.
- AV sizing means obtaining and applying the valve torque on demand to derive at the appropriate actuator, operating at the minimum specified air supply pressure, while within the limits of the Maximum Allowable Stem Torque (MAST) at maximum air supply pressure, more precisely within the limits of the mounting kit and drive train components.
- AV fluid dynamics deal with dynamic torque aspects, an area rather unknown with the chemical and petrochemical industry.

To consistently and correctly obtain the proper valve torque data (coefficients, factors and torque values) from the valve manufacturers the proposed AV Assembly Recommended Practice created a torque input form compiling:

- Dynamic torque coefficients
- Cv flow coefficients (to derive at dp, only for dynamic torque modelling)
- Breakaway angles,
- MAST values
- BTO, RTO, ETO, BTC, RTC and ETC torque values

And last but not least the torque on demand correction factor (ODCF) (**Table 2**)

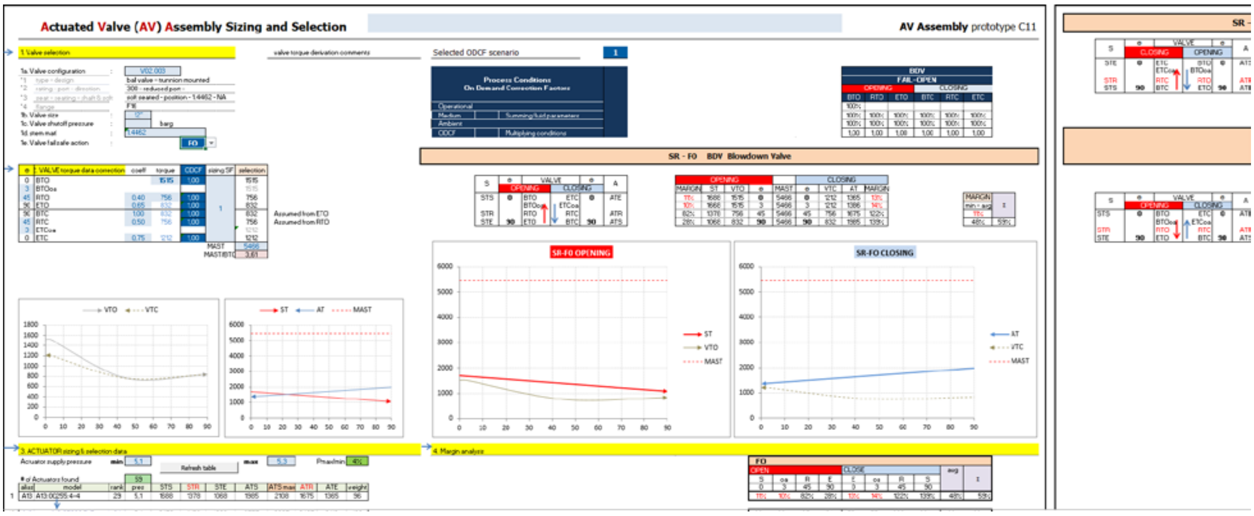
To obtain the ODCF, the end user must specify Operational, Fluid and Ambient Conditions as seen on the left. The valve manufacturer shall provide the data as well as the method to deal with combined process conditions. This forms the closing piece of the valve torque requirement puzzle!

Not handled as Engineered Products and handled by uncoordinated disciplines

As stated, most often AV Assemblies are handled as commodities by uncoordinated disciplines. In order to handle them in the same way as control valves, the following essential aspects must be considered and documented in this recommended practice:

Handling AV Assemblies as engineered products have been implemented by few End Users. Key elements are described by one of them [*]:

- Awareness and understanding of AV Assemblies using root cause analysis
- Getting management support and buy-in from your organization
- Implementing a business process getting all parties involved
- Developing For The Application prescriptive directives of valve styles in relation to application characteristics, valve materials, actuator coating, drive



Picture 5: **Print screen of part of the prototype GUIs**

train and torque aspects

Using a sizing data sheet and a tool to facilitate the sizing & selection process (**Table 3**): The current RP sizing data sheet.

It yielded them

- A precise focus, i.e. an optimal design that corresponds to the application, with a clear focus on reliability.
- Addressing SIS AV Assemblies reliability and safety issues
- Lower cost of ownership
- A transparent and auditable business process

Critical Success Factors (CSF) were:

- Technological:
- A tool developed to facilitate sizing & selection in accordance with Fit For The Application Guidelines
- Organizational:
- working as teams using a common tool

HOW WE TACKLED THOSE ROOT CAUSES? PART II – AN RP COMPLIANT CONVAL PROTOTYPE

We learned from those End-users who introduced the handling of AV Assemblies as Engineered Products that a tool to facilitate sizing & selection in accordance with Fit For The Application Guidelines was a Critical Success Factor. Since CONVAL is a commercial instrument & process design sizing & selection tool, already used for control valve sizing & selection, especially for troubleshooting challenging sizing & selection applications, we worked with the CONVAL developer to develop an RP compliant AV Assembly module covering following functionality:

- A framework / structure to store quality valve torque data, emulating the RP Valve Torque Input Form (VTIF)
- A complete emulation to simulate On Demand Correction Factors (ODCF) for different combined process conditions (operational, fluid and ambient conditions

ON DEMAND TORQUE CORRECTION FACTOR — **Table 6**

Characteristic	Application Data		setting	uom	CF	For which torque values applies the ODCF?					
	CF %	value				BTO	RTO	ETO	BTC	RTC	ETC
long stand still time	150%	15	12	month	150%						
Fluid Characteristics											
state / phase											
non-lubricating fluid	140%	Present			140%						
sticking service	120%	Present			120%						
non-clean service		None			115%						
clean service		None			110%						
		None			100%						
temp minimum	130%	-160	-150	ºC	130%						
temp maximum			500	ºC	100%						
fluid correction factor	190%		Sum of fluid parameters								
ODCF	**285%**		**Multiply**								

Table 2: **torque on demand correction factor (ODCF)**

	AV Assembly sizing data sheet - Metric units of measure (uom)						
	category	label	symbol	data value	data uom	data provider	
1		Tag		V02.003		Purchaser	1
2		Service		Feel to boiler 1		Purchaser	2
3	IDENTIFICATION	P&ID		PID 456		Purchaser	3
4		Line Number		Line-100-ABV		Purchaser	4
5		PO Number / Purchase requisition		PO 789		Purchaser	5
6		Remarks		nothing special		Purchaser	6
7		Ambient temperature min / max		-10 - 50	DegC	End User	7
8	AMBIENT CONDITIONS	Environmental conditions		outdoor		End User	8
9		Environmental conditions		corrosive		End User	9
10		Fail direction		fail-closed		End User	10
11		Travel time to fully open / close		10 / 5	s	End User	11
12	APPLICATION	Response time to fully open / close		20 / 8	s	End User	12
13		Torque Sizing Safety Factor		1,1	-	End User	13
14		Min/max air supply		4 / 10	bar(g)	End User	14
15		Medium		hydrocarbon + tar		End User	15
16		State / phase				End User	16
17		Mass flowrate		100000	kg/h	End User	17
18		Volume flowrate		125	m3/h	End User	18
19		Density		900	kg/m3	End User	19
20		Long stand still time		5	yr	End User	20
21	PROCESS			sticking service		End User	21
22		Fluid characteristics		clean service		End User	22
23						End User	23
24		Fluid operating temperature		250	DegC	End User	24
25		Max DP shutoff		20	bar	End User	25
26		Design pressure		30	bar(g)	End User	26
27							27
28		Valve type / Model		ball valve		End User	28
29		Valve design		trunnion mounted		End User	29
30		Port		reduced port		End User	30
31		Shutoff flow direction		uni-directional		End User	31
32		Seat designation (material)		soft seated		End User	32
33		If applicable, soft seated material				End User	33
34		Sealing				End User	34
35		Pressure class rating		300		End User	35
36		Tightness class				End User	36
37		Valve size		12	"	End User	37
38		Line pressure	dp	20	bar	End User	38
39		Stem orientation		vertical		End User	39
40		Break to Open torque	BTO	1515	Nm	valve manufacturer	40
41	VALVE	BTO breakaway angle	BTO_{ba}	3	θ	valve manufacturer	41
42		Run to Open torque	RTO	756	Nm	valve manufacturer	42
43		End to Open torque	ETO	832	Nm	valve manufacturer	43
44		Break to Close torque	BTC	832	Nm	valve manufacturer	44
45		Run to Close torque	RTC	756	Nm	valve manufacturer	45
46		ETC breakaway angle	ETC_{ba}	3	θ	valve manufacturer	46
47		End to Close torque	ETC	1212	Nm	valve manufacturer	47
48		On Demand torque Correction Factor	ODCF	1,68	-	valve manufacturer	48
49		Max allowable torque drive train (MAST)	$MAST_d$	5466	Nm	valve manufacturer	49
50		Max allowable flange torque (ISO5211)		F16 4000 Nm		valve manufacturer	50
51		Stem / top works dimensions provided Y/N?		Yes		valve manufacturer	51
52							52
53							53
54		Material				mounting kit manufacturer	54
55		Height aspect		hot temperature		mounting kit manufacturer	55
56	MOUNTING KIT	Max allowable coupling torque	$MAST_c$	5466	Nm	mounting kit manufacturer	56
57		Intermediate support mechanical integrity checked & documented			No	AV Assembly Contractor	57
58							58
59		Supply pressure min / max		5.1 / 5.3	bar(g)	End User	59
60		Actuator drive medium		pneumatic		End User	60
61		Actuator drive medium quality (ISO 57)		clean		End User	61
62		Actuator style		scotch yoke		assembly contractor	62
63		Model		Brand B001		assembly contractor	63
64		Size		100	inch2	assembly contractor	64
65		Spring set number				assembly contractor	65
66	ACTUATOR	Spring to Start torque	STS	2052	Nm	actuator manufacturer	66
67		Spring to Run torque	STR	1201	Nm	actuator manufacturer	67
68		Spring to End torque	STE	2614	Nm	actuator manufacturer	68
69		Air to Start torque	ATS	4813	Nm	actuator manufacturer	69
70		Air to Run torque	ATR	1420	Nm	actuator manufacturer	70
71		Air to End torque	ATE	1818	Nm	actuator manufacturer	71
72		Air to Start torque @ max press	ATS_{max}	5010	Nm	actuator manufacturer	72
73		Max operating pressure	MOP	10	bar(g)	actuator manufacturer	73
74							74

Table 3: **AV Assembly sizing data sheet**

- A framework / structure to store actuator data as available from actuator catalogs, both Rack & Pinion and Scotch Yoke actuators
- An algorithm to derive and order for a given application by preference those actuators matching the given valve torque data (BTO, RTO, ETO, BTC, RTC, ETC, breakaway angles, MAST and ODCF).
- Graphically visualizing using valve and actuator

curves which actuator fits best and those which do not fit the application
- Generating the AV Assembly datasheet
- Simulating the sizing impact and effects of
- A Fail Close (FC) application vs a Fail Open (FO) application,
- Varying maximum and minimum actuator air supply pressures
- Varying assembly Safety Factors
- Varying On Demand Correction Factors
- Varying MAST values, to name the essential ones simulated.

A picture says more than 1000 words. Therefore a print screen of part of the prototype GUIs (**Picture 5**). But nothing better than a demonstration.

WHAT ARE THE REAL BENEFITS FOR END-USERS, EPCS, INTEGRATORS AND MANUFACTURERS?

Applying those missing AV Assembly puzzles, following overall benefits can be realized:
- A Fit For The Application Assembly, thereby significantly reducing the probability of an assembly failure, directly impacting plant safety and reliability!
- A time and money saver, thereby directly impacting the Long Term Cost of Ownership!
- A quality troubleshooting tool, thereby reducing the time and effort to address AV Assembly challenges!
- A clear signal to the manufacturers, thereby initiating steps to resolve the impasse how AV Assemblies should be handled!

Direct benefits realized by the WIB AV Assembly Recommended Practice are:
- That Torque Terms and Definitions became definitely settled!
- That the process to obtain quality valve torque data became definitely settled!

Direct benefits realized ty by the CONVAL AV Assembly module prototype are:
- A tool fully compliant with the End Users Recommended Practice!
- A true AV Assembly domain educational tool providing:
- Probably the quickest way to select the appropriate cost-effective Fit For The Application actuator out of the huge variety of offered devices!
- A strong troubleshooting tool to quickly resolve improper AV actuator selections!
- A powerful visualization of AV Assembly "unknowns" and their effects, especially handy and valuable for those not directly familiar with those domain pitfalls.
- Almost a logical extension to the CONVAL Control Valve module, a commercial module that has set the standard to better understand the dynamics within a control valve for at least the last couple of decades
- Today in CONVAL, especially in the field of valves, there are established concepts such as KPIs for reliability & controllability, a traffic light system to quickly detect problems, the possibility of bulk processing in projects (CAT) and much more. Such concepts together with the AV Recommended Practice will be available in the future to optimize the sizing & selection of AV assemblies and lead to safe and reliable solutions.

Demonstrations of the AV Assembly prototype can be seen during the full Valve World Conference at the booth of

VALVE WORLD EXPO: HALL 4, BOOTH B10

[*] These concepts have been published as a Valve World paper Maastricht 2006 "Sizing and Selection of Automated On/Off Valves, a hurdle race!" An end-user perspective

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