HYDRAULIC SYSTEMS FOR MOVABLE BRIDGES

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EXHIBITION ON MOVABLE BRIDGE DESIGN & TECHNOLOGY

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MOVABLE BRIDGES ARE SUCH MASSIVE STRUCTURES THAT THE VERY NATURE OF THEM REQUIRES SMOOTH ACCURATE CONTROL. THIS AND SEVERAL OTHER REQUIREMENTS FOR THEIR OPERATION AND SAFETY ARE EASILY ACCOMPLISHED WITH HYDRAULICS. CIVIL ENGINEERING PROJECTS REQUIRING A HIGH DEGREE OF RELIABILITY HAVE BEEN UTILIZING HYDRAULIC SYSTEMS FOR DECADES.

THE BASIC CRITERIA FOR MOVABLE BRIDGES MOST DIRECTLY ATTAINABLE WITH HYDRAULICS ARE THE FOLLOWING OBJECTIVES:

1) ABILITY TO HANDLE VARYING LOADS (WIND/ICE),

2) SMOOTH ACCELERATION AND DECELERATION,

3) POSITIVE LOCKING IN ANY POSITION,

4) DRIVING ENDLOCKS.

SEVERAL OTHER INHERENT ADVANTAGES TO A HYDRAULIC SYSTEM CAN ALSO BE REALIZED. FOR EXAMPLE, THE COMPONENTS HAVE A GOOD POWER TO WEIGHT RATIO THAT MAKES THEM SMALLER, LIGHTER, AND EASIER TO SERVICE. FURTHERMORE, MANY OF THE COMPONENTS ARE USUALLY STANDARD "OFF THE SHELF" ITEMS.

THERE ARE TWO BASIC METHODS OF POWERING A BRIDGE WITH HYDRAULICS:

1) HYDRAULIC CYLINDERS,

2) HYDRAULIC MOTORS.

EACH METHOD HAS ITS UNIQUE FEATURES AND BOTH METHODS CAN BE ACCOMPLISHED WITH THE SAME DEGREE OF ACCURACY AND RELIABILITY. THE DESIGN ASPECTS WHICH MIGHT DICTATE A PARTICULAR METHOD DEPEND ON THE FUNCTION OF THE BRIDGE AND ITS ENVIRONMENT.

THE REHABILITATION OF OLDER MECHANICAL BRIDGES TO MODERN HYDRAULIC OPERATION IS A VERY COST EFFECTIVE WAY TO OBTAIN ADDITIONAL YEARS OF SERVICE. THESE CAN BE EITHER TEMPORARY OR PERMANENT REHABILITATIONS. DUE TO THE RELATIVELY SMALL COMPONENT SIZE, THE HYDRAULIC SYSTEM CAN BE INSTALLED ADJACENT TO THE OLD MECHANICAL SYSTEM WITHOUT DISTURBING THE NORMAL BRIDGE OPERATION. THIS COULD PERMIT SOME MECHANICAL REPAIRS WHILE THE HYDRAULIC SYSTEM OPERATES THE BRIDGE.

HYDRAULIC MOTORS

WHEN HYDRAULIC MOTORS ARE BEING CONSIDERED, THERE ARE THREE GENERAL CLASSIFICATIONS. EACH CLASSIFICATION REPRESENTS A SPEED RANGE THAT IS MOST EFFICIENT FOR A PARTICULAR MOTOR DESIGN:

1) HIGH SPEED/LOW TORQUE = 500 - 3000 RPM
2) LOW SPEED/HIGH TORQUE = 10 - 500 RPM
3) LOW SPEED/HIGH TORQUE - 0 - 50 RPM

THE AMOUNT OF GEARING REQUIRED FOR OPERATION OF A BRIDGE IS DEPENDENT ON THE TYPE OF MOTOR SELECTED. IN ADDITION TO NEW BRIDGE DESIGNS, HYDRAULIC MOTORS CAN BE USED TO OPERATE VARIOUS AMOUNTS OF EXISTING GEARING FOR REHABILITATION OF OLDER MECHANICAL BRIDGE SYSTEMS.

HYDRAULIC CYLINDERS

THE USE OF HYDRAULIC CYLINDERS TO OPERATE MOVABLE BRIDGES HAS BEEN THE MOST POPULAR METHOD TO DATE. WHETHER THE BRIDGE IS A BASCULE, LIFT, OR SWING TYPE, CYLINDERS CAN EASILY BE FITTED TO BOTH NEW AND EXISTING DESIGNS. ALTHOUGH ANY NUMBER OF CYLINDERS IS POSSIBLE, USUALLY TWO PER SPAN ARE USED.

HYDRAULIC CYLINDERS COME IN TWO TYPES OF CONSTRUCTION--TIE ROD AND WELDED. BOTH TYPES HAVE A NUMBER OF DIFFERENT MOUNTING STYLES. THE TWO MOST COMMON STYLES FOR BRIDGES ARE THE INTERMEDIATE TRUNNION AND SPHERICAL BEARING CLEVIS BOTH ENDS. THE TIE ROD TYPE HYDRAULIC CYLINDERS ARE FREQUENTLY USED AND ARE INEXPENSIVE. THE NATIONAL FLUID POWER ASSOCIATION (NFPA) ESTABLISHED A STANDARD FOR TIE ROD TYPE HYDRAULIC CYLINDERS MAKING THEM DIMENSIONALLY INTERCHANGEABLE. THIS PROVIDES GOOD AVAILABILITY AND EASE OF REPLACEMENT FOR MAINTENANCE OF THE BRIDGE. TIE RODS SHOULD BE INSPECTED FOR CORROSION DAMAGE MUCH THE SAME AS ANY STRUCTURAL MEMBER OF THE BRIDGE.

WELDED TYPE HYDRAULIC CYLINDERS PROVIDE EXCELLENT LONGEVITY FOR BRIDGE APPLICATIONS. THEY CAN BE SUPPLIED WITH HEADS AND CAPS WHICH ARE BOLTED ON. THIS ALLOWS FOR MAINTENANCE TO BE CARRIED ON "IN PLACE" EVEN AFTER YEARS OF SERVICE. A WELDED CYLINDER WITH A 316 STAINLESS STEEL CHROME PLATED PISTON ROD IS THE BEST TYPE FOR CIVIL ENGINEERING PROJECTS.

COUNTERBALANCE VALVES

THE ABILITY OF A HYDRAULIC SYSTEM TO HANDLE VARYING LOADS MAKES IT AN EXCELLENT CHOICE FOR MOVABLE BRIDGES. WIND AND ICE LOADS CAN UNBALANCE A SPAN AND CAUSE A RUN-AWAY CONDITION. IN A HYDRAULIC SYSTEM, A COUNTERBALANCE VALVE KEEPS THIS CONDITION IN CHECK. EVEN IF THE BRIDGE HAS NO COUNTERWEIGHT, A COUNTERBALANCE VALVE WILL SMOOTHLY CONTROL THE LOWERING OF THE SPAN.

A COUNTERBALANCE VALVE PERFORMS AN ADDITIONAL FUNCTION OF HOLDING THE BRIDGE FIRMLY IN ANY POSITION. THE VALVE ACTS AS A CHECK VALVE LOCKING FLUID IN THE CYLINDERS UNTIL PILOTED OPEN BY PRESSURE FROM THE OPPOSITE DIRECTION. SHOULD A WIND GUST OCCUR GREATER THAN THE INTENDED HOLDING FORCE OF THE CYLINDERS, AN INTEGRAL RELIEF VALVE WILL RELIEVE THE EXCESSIVE LOAD SAFELY.

PROPORTIONAL VALVES

SMOOTH ACCELERATION AND DECELERATION ARE CRITICAL TO THE SAFE OPERATION OF THE BRIDGE. THIS IS EASILY ACCOMPLISHED BY GRADUALLY INCREASING OR DECREASING THE AMOUNT OF FLOW TO THE CYLINDERS. IN ALMOST ALL CASES, THIS IS BEST PERFORMED WITH PROPORTIONAL VALVES. THE USE OF SERVO VALVES FOR THIS TASK IS NOT RECOMMENDED. SERVO VALVES CAN BE MADE TO PERFORM PROPERLY; BUT THEY ARE GENERALLY CONSIDERED OVERKILL FOR BRIDGES DUE TO THEIR HIGH SENSITIVITY, THEIR INCREASED COST, ADDITIONAL FILTRATION REQUIREMENTS, AND THE INABILITY TO FIELD SERVICE THEM.

PROPORTIONAL VALVES HAVE PROVED TO BE RUGGED AND RELIABLE FOR MOVABLE BRIDGE HYDRAULIC SYSTEMS. THE BASIS FOR THEIR OPERATION IS A PROPORTIONAL FORCE COIL. THESE FORCE CONTROLLED SOLENOIDS PROVIDE AN ADJUSTABLE FORCE OUTPUT PROPORTIONAL TO THE AMOUNT OF DC CURRENT BEING FED INTO THEM. TYPICAL POWER REAUIREMENTS ARE 0 - 9 VOLTS DC/800 MILLIAMPS.

THE ADJUSTABLE FORCE DELIVERED FROM THE SOLENOID IS THEN USED TO VARY THE TRAVEL OF THE MAIN VALVE SPOOL. LARGE "V" SHAPED NOTCHES IN THE MAIN SPOOL PROVIDE EXCELLENT METERING OF THE HYDRAULIC FLUID BOTH TO AND FROM THE CYLINDERS. INFINITELY VARIABLE CYLINDER SPEEDS CAN BE ATTAINED BY THROTTLING FLUID THROUGH THE NOTCHES OF THE SPOOL.

ELECTRONIC AMPLIFIER CARDS ARE USED TO CONTROL THE CURRENT TO THE PROPORTIONAL SOLENOID. STANDARD CARDS HAVE AN ADJUSTABLE RAMP CIRCUIT ON THEM. THIS RAMP FEATURE PROVIDES AN ADJUSTABLE ACCELERATION TIME REGARDLESS OF THE ABRUPTNESS OF A COMMAND. WHEN USED WITH THE "NEARLY OPEN/NEARLY CLOSED" LIMIT SWITCHES, THE BRIDGE WILL AUTOMATICALLY DECELERATE. THIS SETS THE STAGE FOR THE USE OF A PROGRAMMABLE CONTROLLER OR SIMPLE "RAISE/LOWER" PUSHBUTTONS AT THE CONTROL DESK.

HYDRAULIC PUMPS

HYDRAULIC PUMPS COME IN ALL TYPES AND SIZES. THE VARIABLE VOLUME-BENT AXIS-PISTON TYPE PUMP IS THE MOST ENERGY EFFICIENT. OTHER FACTORS, INCLUDING STRONG SUCTION CAPABILITY AND GREATER DIRT TOLERANCE, MAKE THEM A GOOD CHOICE FOR MOVABLE BRIDGE PROJECTS. PUMPS WHICH REQUIRE A BOOST OR SUPERCHARGE ONLY ADD COMPLEXITY TO THE DESIGN.

HYDRAULIC DESIGNERS ARE ALWAYS KICKING AROUND THE TERMS "OPEN LOOP AND "CLOSED LOOP." ALL HYDRAULIC SYSTEMS ARE BASICALLY "CLOSED" SINCE THEIR FLUID IS RECIRCULATED BACK TO THE RESERVOIR. WHAT IS MEANT BY "CLOSED LOOP" IS A TYPE OF PUMP THAT IS CAPABLE OF PUMPING IN TWO DIRECTIONS (OR "OVERCENTER"). THIS ELIMINATES THE NEED FOR A DIRECTIONAL CONTROL VALVE. THE PUMP IS SWIVELED IN THE PROPER DIRECTION AND THE DISPLACEMENT GOVERNS THE SPEED OF OPERATION. "CLOSED LOOP" PUMPS ARE GENERALLY NOT RECOMMENDED FOR USE IN BRIDGE SYSTEMS.

"OPEN LOOP" PUMPS PULL THEIR SUCTION DIRECTLY FROM THE RESERVOIR AND CAN ONLY PUMP IN ONE DIRECTION. THIS TYPE OF PUMP IS BEST FOR POWERING CYLINDERS. IT SIMPLIFIES THE CIRCUITRY TO HANDLE THE DIFFERENTIAL CYLINDER VOLUMES REQUIRED TO CYCLE A CYLINDER IN BOTH DIRECTIONS. IN THIS SYSTEM, THE PROPORTIONAL DIRECTIONAL VALVE CONTROLS SPEED AND DIRECTION OF THE CYLINDER. THE VARIABLE VOLUME "OPEN LOOP" PUMP BECOMES A SLAVE TO THE PROPORTIONAL VALVE BY ONLY DELIVERING THE FLOW REQUIRED THROUGH THE METERING NOTCHES OF THE VALVE SPOOL.

ANOTHER MAJOR BENEFIT OF HYDRAULICS FOR MOVABLE BRIDGES IS THE "HORSEPOWER LIMITER" CONTROL FOR HYDRAULIC PUMPS. THIS CONTROL ENHANCES THE SYSTEMS ABILITY TO HANDLE HEAVY WIND OR ICE LOADS ON THE BRIDGE. HIGHER LOADS REQUIRE HIGHER PRESSURES

FROM THE PUMP. WHEN THE PRESSURE GOES UP, THE HORSEPOWER LIMITER REDUCES THE PUMPS OUTPUT FLOW AS REQUIRED TO MAINTAIN A CERTAIN HORSEPOWER. THIS INSURES THAT THE ELECTRIC MOTOR CANNOT BE STALLED IN THE MIDDLE OF THE CYCLE. THE SPAN SIMPLY TRAVELS AS FAST AS IT SAFELY CAN FOR ANY GIVEN LOAD.

HYDRAULIC FLUIDS

AT THIS POINT, IT IS PROBABLY BEST TO SAY A LITTLE ABOUT HYDRAULIC FLUIDS. WE CALL THEM PETROEUM "FLUIDS" RATHER THAN "OILS" TO EMPHASIZE THAT IT IS A SPECIAL FORMULATION WITH THE ADDITIVES TO MAKE IT SUITABLE AS A HYDRAULIC FLUID. PRIMARILY, THESE ADDITIVES INHIBIT OR PREVENT RUST, OXIDATION, FOAM, AND WEAR. THERE ARE THREE COMMON GRADES OF "ANTI-WEAR" HYDRAULIC FLUIDS.

ISO GRADE	GENERAL VISCOSITY	NORMAL OPERATING TEMP.
AW32	LIGHT	10°-150°F
AW46	MEDIUM	30°-160°F
AW68	HEAVY	40°-170°F

MOST BRIDGE SYSTEMS DO NOT CYCLE ENOUGH TO HEAT THE FLUID ABOVE ABOUT 110°F. OBVIOUSLY, THE HEAVIEST FLUID PROVIDES THE BEST LUBRICATING ABILITY; BUT IT MAY REQUIRE A TANK HEATER FOR COLD WEATHER OPERATION.

FILTRATION

THE PROPER FILTRATION OF THE FLUID IS ESSENTIAL TO THE SURVIVAL OF A HYDRAULIC SYSTEM. A TEN (10) MICRON FILTER IS GENERALLY CONSIDERED ADEQUATE FOR FLUID USED IN PISTON PUMPS. THE RELATIVE SIZE OF A PARTICLE THIS SMALL IS HARD TO COMPREHEND SINCE FORTY (40)MICRONS IS THE LOWER LIMIT OF HUMAN VISIBILITY. A TEN (10) MICRON PARTICLE IS ABOUT THE SIZE OF A RED BLOOD CELL!

THE STANDARD, BY WHICH ALL HYDRAULIC FILTER ELEMENTS ARE RATED, IS THE "BETA RATIO" SYSTEM. THIS SYSTEM CLASSIFIES FILTER ELEMENTS BY THEIR EFFICIENCY AT REMOVING A CERTAIN PARTICLE SIZE. A SIMPLE TEST IS PERFORMED BY INTRODUCING

PARTICLES OF KNOWN QUANTITY AND SIZE UP STREAM OF THE ELEMENT AND RECORDING THE NUMBER THAT PASS THROUGH DOWNSTREAM. BY DIVIDING THE UPSTREAM PARTICLES BY THE NUMBER DOWNSTREAM, A BETA RATIO CAN BE DETERMINED. TEN (10) MICRON FILTERS WITH A BETA RATIO OF 50 ARE GOOD COST EFFECTIVE FILTRATION.

$$BETA_X = \frac{UPSTREAM}{DOWNSTREAM} = \frac{100}{2} = 50$$

BETA RATIO NUMBER

BETA RATIO VS. EFFICIENCY

BETA	% EFFICIENT
1	0
2	50
4	75
5	80
10	90
20	95
25	96
50	98
70	98.5714
75	98.6667
85	98.9474
99	98.9899
100	99.0000
1000	99.9
10,000	99.99

ANOTHER CONSIDERATION FOR PROPER FILTRATION SHOULD BE TO DETERMINE WHERE THE PARTICLES COULD POSSIBLY BE GENERATED. A LOOK AT THE CYLINDER CIRCUIT WE'VE BEEN TALKING ABOUT INDICATES THREE POSSIBLE POINTS OF ORIGIN.

	ORIGIN	REASON	FILTER
1)	PUMP	WEAR	PRESSURE FILTER
2)	CYLINDERS	WEAR & ATMOSPHERIC	RETURN FILTER
3)	RESERVOIR	ATMOSPHERIC	BREATHER W/DESSICANT

FILTERING THE OIL AT THE PUMPS SUCTION WITH STRAINERS IS UNNECESSARY. THIS PRACTICE IS LOSING ACCEPTANCE THROUGHOUT THE HYDRAULIC INDUSTRY. THE HIGH VACUUM CONDITION AT THE SUCTION OF THE PUMP AS A RESULT OF USING A STRAINER CAN RESULT IN EARLY PUMP FAILURE.

INSTALLATION

IN ORDER TO GUARANTEE PROPER FILTRATION, A GREAT DEAL OF CARE SHOULD BE TAKEN IN THE INITIAL FABRICATION AND INSTALLATION OF ANY HYDRAULIC SYSTEM. THE RESERVOIR SHOULD BE CLEANED OF ALL SLAG, PROPERLY BLASTED, AND COATED FOR RUST PREVENTION. ONCE THE RESERVOIR IS CLEAN, THE INITIAL FILLING OF OIL SHOULD BE THROUGH A TEN (10) MICRON FILTER.

FLUSHING THE LINES PRIOR TO START UP IS ANOTHER KEY FACTOR IN SYSTEM CLEANLINESS. IN ORDER TO PROPERLY DISLODGE ANY PARTICLES IN THE LINES, A FLUSHING VELOCITY OF AT LEAST THE INTENDED SYSTEM FLOW IS REQUIRED. A QUESTION HEARD REPEATEDLY: "WHAT FLUID SHOULD I USE TO FLUSH WITH AND HOW?" THERE ARE MANY ANSWERS TO THE QUESTION; HOWEVER, A SIMPLE COST EFFECTIVE WAY TO FLUSH IS TO USE THE FLUID AND PUMPS INTENDED FOR FINAL SYSTEM USE. THE USE OF COMPRESSED AIR AND SOLVENTS ONLY RUNS THE RISK OF FURTHER CONTAMINATION OF THE HYDRAULIC FLUID.

THINK ABOUT IT! IF THE RESERVOIR IS CLEAN, THE FILTERS ARE 98% EFFICIENT, AND THE OIL HAS BEEN FILTERED INTO THE RESERVOIR. WHAT BETTER FLUSHING UNIT COULD BE MORE READILY AVAILABLE? SIMPLY LOOP THE LINES TOGETHER SO THAT THE OIL RETURNS DIRECTLY TO THE TANK THROUGH THE RETURN FILTER. CONSTANTLY MONITOR THE FILTER INDICATORS AND OIL LEVELS WHILE RUNNING THE PUMPS.

PIPING

THE TYPES OF PLUMBING TO BE USED SHOULD BE SPECIFIED AT THE DESIGN LEVEL. MANY POTENTIAL PROBLEMS CAN BE ELIMINATED BY THE USE OF PROPER PLUMBING TECHNIQUES. HYDRAULIC SYSTEMS OF THIS NATURE SHOULD ONLY BE INSTALLED BY A QUALIFIED COMPANY WITH PRIOR EXPERIENCE.

BLACK IRON PIPE IS NOT RECOMMENDED FOR USE ON BRIDGE SYSTEMS. IT HAS TOO MANY RUST, SCALE, AND FITTING PROBLEMS ASSOCIATED WITH IT. STAINLESS STEEL TYPE 316 PIPE OR TUBING, PROPERLY CLAMPED EVERY 5 TO 7 FEET, WILL PROVIDE MANY YEARS OF TROUBLEFREE SERVICE.

STAINLESS PIPE SHOULD BE EITHER SOCKET OR BUTT WELDED. THE SAE 4 BOLT FLANGES AND 37° FLARE WITH "O" RING WORK BEST FOR WELDED PIPE END CONNECTIONS. THE USE OF PIPE THREADS OR SCREWED UNIONS WILL ONLY RESULT IN LEAK SPOTS LATER ON.

FITTINGS FOR SEAMLESS HYDRAULIC TUBING SHOULD BE EITHER 37° FLARE OR AN "O" RING SEAL TYPE. WHEN ASSEMBLED PROPERLY, THESE PROVIDE A GOOD LEAKFREE SEAL. THE USE OF A POWER FLARING TOOL INSURES AN ACCURATE FLARE.

THE BEST SOLUTION TO THE PIPE THREAD LEAK PROBLEM IS NOT TO USE THEM! STRAIGHT THREAD FITTINGS ARE HIGHLY RECOMMENDED SINCE THEY RELY ON AN "O" RING FOR THEIR SEAL. SAE STRAIGHT THREAD FITTINGS CAN BE SPECIFIED FOR THE PORT CONNECTION OF ALMOST ALL HYDRAULIC COMPONENTS.

THE SAE HOSE SPECIFICATION FOR HYDRAULIC HOSES HAS DETAILED INFORMATION ABOUT HOSE SIZE, RATINGS, AND BEND RADIUS. AGAIN, THE BEST CONNECTION IS A 37° FLARE OR AN "O" RING SEAL. GOOD INSURANCE OF A HOSE ASSEMBLY'S INTEGRITY IS TO HAVE THEM TESTED TO 1 1/2 TIMES WORKING PRESSURE PRIOR TO INSTALLATION.

SUMMARY

MAINTENANCE TO THE SYSTEM IS A TOPIC DESERVING A SEPARATE DISCUSSION. THERE ARE, HOWEVER, SEVERAL IDEAS THAT CAN BE "DESIGNED IN" TO ASSIST IN PERIODIC MAINTENANCE:

1) PUMPS AND MOTORS SHOULD BE ACCESSIBLE FOR WORK,
2) VIBRATION MOUNTS AND HOSES TO ISOLATE PUMP VIBRATION,

3) THE USE OF ANSI STANDARD BOLT PATTERN SUBPLATE MOUNTED VALVES,
4) DRILLED MANIFOLDS TO MINIMIZE PIPING AND FITTINGS,
5) FILTERS WHICH ARE EASY TO CHANGE WITH GOOD CLOGGING INDICATORS,
6) SPECIFY STRAIGHT THREAD "O" RING PORTS AND FITTINGS,
7) LARGE ACCESS COVERS FOR RESERVOIRS.

HYDRAULIC SYSTEMS ARE NOT EXTREMELY DIFFICULT TO DESIGN; HOWEVER, CERTAIN CARE SHOULD BE EXERCISED IN THE SELECTION OF COMPONENTS. NOT ALL COUNTERBALANCE AND PROPORTIONAL VALVES ARE THE SAME. THEIR REACTION WITH OTHER COMPONENTS OF THE SYSTEM NEEDS TO BE ANALYZED. A PRUDENT PRACTICE WOULD BE TO WORK WITH COMPONENTS FROM A SINGLE MANUFACTURER WHO IS WILLING TO TAKE RESPONSIBILITY FOR HIS PRODUCT'S PERFORMANCE IN THE SYSTEM.

IN CONCLUSION, HYDRAULICS HAS BEEN USED SINCE THE TIMES OF THE ROMAN EMPIRE. IRONICALLY, THIS IS APPROXIMATELY THE SAME TIME PERIOD IN WHICH EARLY BRIDGE DESIGNS WERE CONCEIVED. BOTH TECHNOLOGIES HAVE EVOLVED INTO A USEFUL TOOL FOR MODERN MAN. HYDRAULIC SYSTEMS HAVE PROVED TO BE AN EFFICIENT AND COST EFFECTIVE MEANS OF POWERING A BRIDGE. IT IS NOW TIME TO PUT THIS PRACTICAL KNOWLEDGE OF HYDRAULICS TO USE ON THE BRIDGES WHICH WILL CARRY US INTO THE TWENTY-FIRST CENTURY.