TP 14011E

FEASIBILITY STUDY FOR THE STRUCTURAL TESTING OF A LARGE ICE-STRENGTHENED PROPELLER

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Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

Project team

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Un sommaire français se trouve avant la table des matières.

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16. Abstract

A feasibility study to conduct a large-scale experiment to investigate the elastic and ultimate strength and behaviour of the full-scale propellers of the Canadian icebreaker *Louis S. St. Laurent* was carried out by the Institute for Marine Dynamics and Memorial University of Newfoundland. The purpose of the project is to conduct large-scale laboratory measurements and collect data to complement full-scale measurements of ice loads inserted on the propeller blades during ship trials in 1999. The data will also be used for validation of the Finite Element model of the propeller developed by Fleet Technology Limited under separate contract from the Transportation Development Centre.

This study considers the logistics of propeller transportation, its handling in the laboratory space, design of the test frame, instrumentation and data acquisition system, project schedule and budget.

The large-scale experiment will be conducted at the structural laboratory of the Memorial University of Newfoundland in St. John's, Newfoundland. An initial design/analysis of the test frame, capable of an estimated load of 3 MN and able to accommodate propellers of approximately 15 ft. diameter, and weighting 16 t, has been conducted. The final frame design will be structurally analyzed to assure safety and viability of the experiment. The experimental setup will allow for measurement of load applied to the propeller blade, blade deflections and strain in several locations. The budget required for the project's experimental phase has been estimated at CAD$211,417 and the experiments can be completed in six months or could be split up into two phases.

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16. Résumé

L'Institut de dynamique marine (IDM), à St. John's, Terre-Neuve, a étudié, en collaboration avec la Memorial University of Newfoundland (MUN), la faisabilité d'une expérience en vraie grandeur visant à mesurer la résistance élastique, la résistance à la rupture et le comportement des pales des hélices qui équipent le brise-glace canadien *Louis S. St. Laurent*. Le projet a pour but l'acquisition à grande échelle de mesures prises en laboratoire et la collecte de données qui compléteront les mesures en vraie grandeur des sollicitations de l'hélice par les glaces, prises lors d'essais en mer menés en 1999. Les données recueillies serviront à valider le modèle à éléments finis de l'hélice, mis au point par Fleet Technology Limited aux termes d'un contrat distinct du Centre de développement des transports.

L'étude s'intéresse à la logistique du transport de l'hélice et de sa manutention dans les locaux du laboratoire, à la conception du bâti d'essai, au système d'instrumentation et d'acquisition de données, à la durée du projet et au budget nécessaire.

L'expérience à grande échelle se déroulera dans le laboratoire de structures de la Memorial University of Newfoundland, à St. John's, Terre-Neuve. Les chercheurs ont terminé une première étude conceptuelle du bâti d'essai, prévu pour supporter une charge estimative de 3 MN et recevoir des hélices d'un diamètre d'environ 15 pi, pesant 16 tonnes. Le bâti construit sera soumis à une analyse structurale, pour vérifier la sécurité et la faisabilité de l'expérience. Le montage expérimental permettra de mesurer en plusieurs points les sollicitations, la flexion et la déformation des pales de l'hélice. Le budget pour la phase expérimentale du projet a été estimé à 211 417 $CAN. De plus, selon la disponibilité des fonds, le projet pourrait être achevé en 6 mois ou, encore, il pourrait s'étendre sur deux phases.

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SUMMARY

The Institute for Marine Dynamics (IMD) in St. John's, Newfoundland, in collaboration with the Memorial University of Newfoundland (MUN) was awarded a contract to conduct a feasibility study to conduct a full-scale experiment to investigate the elastic and ultimate strength and behaviour of the full-scale propellers of the Canadian icebreaker *Louis S. St. Laurent*. The purpose of the project is to conduct a large-scale (full-scale) experiment in a laboratory environment and collect data to complement full-scale measurements of ice loads on the propeller blade during ship trials in 1999. As well, the experimental work will validate the Finite Element model of the propeller developed by Fleet Technology Limited under separate contract from the Transportation Development Centre.

Phase 1 of the project, the feasibility study, considers the logistics of propeller transportation, handling in the laboratory space, design of the test frame, instrumentation and data acquisition system, project schedule and budget.

The large-scale experiment will be conducted at the structural laboratory of the Memorial University of Newfoundland in St. John's, Newfoundland. An initial design/analysis of the test frame, capable of an estimated load of 3 MN and able to accommodate propellers of approximately 15 ft. diameter, and 16 t, has been conducted. As part of the actual testing, the detailed design and construction of the test frame will take place. The final frame will be structurally analyzed to assure the safety and feasibility of the experiment. The experimental setup will allow for measurement of load applied to the propeller blade, blade deflections and strain. It is anticipated that the experiment will be conducted on three undamaged propeller blades. For safety reasons and to minimize exposure of the non-project personnel to the test environment, the experiment will be carried out after normal working hours and/or at times when students do not occupy the lab. The required budget for the experimental phase of the project has been estimated at CAD$211,417, including a CAD$76,000 in-kind contribution from IMD and MUN. The budget includes costs for test frame construction, purchase of transducers, assembly of data acquisition system, testing, data analysis and reporting. The experiment can be completed within six months or could be split up into two phases, depending on availability of funds.

SOMMAIRE

Un contrat a été passé avec l'Institut de dynamique marine (IDM), à St. John's, Terre-Neuve, pour la détermination, en collaboration avec la Memorial University of Newfoundland (MUN), de la faisabilité d'une expérience en vraie grandeur visant à mesurer la résistance élastique, la résistance à la rupture et le comportement des pales des hélices qui équipent le brise-glace canadien *Louis S. St. Laurent*. Le projet prévoit la conduite d'une expérience à grande échelle (en vraie grandeur) en laboratoire; il s'agit donc de collecter des données qui compléteront les mesures en vraie grandeur des sollicitations de l'hélice par les glaces, prises lors d'essais en mer menés en 1999. Aussi, les résultats de cette recherche permettront de valider le modèle à éléments finis de l'hélice, mis au point par la société Fleet Technology Limited selon les termes d'un contrat distinct du Centre de développement des transports.

La phase 1 de l'étude de faisabilité s'intéresse à la logistique du transport de l'hélice et de sa manutention dans les locaux du laboratoire, à la conception du bâti d'essai, au système d'instrumentation et d'acquisition de données, à la durée du projet et au budget nécessaire.

L'expérience à grande échelle se déroulera dans le laboratoire de structures de la Memorial University of Newfoundland, à St. John's, Terre-Neuve. Les chercheurs ont terminé une première étude conceptuelle du bâti d'essai, prévu pour supporter une charge estimative de 3 MN et recevoir des hélices d'un diamètre d'environ 15 pi, pesant 16 tonnes. Dans le cadre des essais proprement dits, on entreprendra l'étude détaillée et la construction du bâti. Celui-ci sera soumis à une analyse structurale, pour vérifier la sécurité et la faisabilité de l'expérience. Le montage expérimental permettra de mesurer les sollicitations, la flexion et la déformation des pales de l'hélice. Trois pales non endommagées devraient normalement être utilisées pour les essais. Par mesure de sécurité et pour éviter le plus possible que des personnes extérieures au projet soient exposées à des risques, il a été décidé de faire les essais en dehors des heures normales et/ou pendant qu'aucun étudiant ne se trouve dans le laboratoire. Le budget pour la phase expérimentale du projet a été estimé à 211 417 $CAN et comprend une contribution non monétaire de 76 000 $CAN par l'IDM et par la MUN. Il couvre les coûts du bâti d'essai, l'achat des transducteurs, l'assemblage du système d'acquisition de données, les essais, l'analyse des données et la production des rapports. Selon la disponibilité des fonds, le projet pourrait être achevé en 6 mois ou, encore, il pourrait s'étendre sur deux phases.

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1 BACKGROUND

Measurements of the blade deflections of a Stone Marine monoblock propeller under icebreaking loads were carried out onboard the *Louis S. St. Laurent* in 1999. Based on the as-new measured stiffness of the blades, the corresponding ice loads have been computed for deflections within the elastic range of the material. When the trials were carried out, however, at least three of the four blades had already experienced some plasticity, two of them to a significant degree. In addition, during the trials some additional plasticity was observed in the blades.

Because the loads seen by these blades during icebreaking in multi-year ice were high enough to cause plasticity, it is difficult to quantify the ice loads from the measured deflections without a better understanding of the post-yield behaviour of this material. It is understood that a small-scale sample of the material from one of the failed blades is being tested to examine its post-yield behaviour.

As it is understood that at least one damaged propeller of this same type is still available in storage at the Canadian Coast Guard's Dartmouth base, the opportunity exists to make post-yield load and deflection measurements on at least three intact (unbroken) blades, each of which has experienced a different degree of plasticity. By characterizing the existing deformation before further loading and by performing systematic load versus deflection measurements all the way through yield to failure, the effect of plasticity on the blade stiffness and ultimate load carrying capability can be characterized.

The information that can be obtained from such measurements would complement those made on small-scale samples of the material by helping to show how the large-scale strength of the material can differ (in general it should be lower due to casting flaws) from the small-scale strength. In addition, such measurements can help to quantify the influence of effects, such as work hardening, on the stiffness and load carrying ability of bronze material in the post-yield regime.

1.1 Current Project Objectives

This report describes the first phase, a feasibility study, of the project to conduct a large-scale laboratory experiment to investigate the elastic and ultimate strength and behaviour of the full-scale ice-strengthened propeller. The study included the following:

<u>Feasibility analysis</u>. The propellers are quite massive (see Figure 1). This task examined the dimensions, weight and handling of the propeller. The key issues

were the cost and safety issues of shipping, and the ability to fit the propeller and test frame into the structures lab at Memorial University of Newfoundland (MUN) (see Figure 2).

Design of test equipment. The test frame must be capable of supporting the test load with considerations for safety. Test loads of approximately 2-3 MN (450,000 – 670,000 lb.) are expected. MUN currently has a 550,000 lb. actuator. An actuator capable of 4+MN together with a load-cell and connection would be preferable and will be investigated. (Preliminary investigation has indicated that a 5.3 MN actuator can be acquired at reasonable cost.) Structural analysis of the frame and actuator system was used to verify the design.

Test plan and budgeting. The test schedule, costs, sensors, data acquisition and reductions were determined. A detailed cost proposal will be produced for Phase 2 (construction and assembly of the test frame, implementation of the tests).

Figure 1. Two propellers from the *Louis S. St. Laurent* (stacked)

Figure 2. MUN Structures Lab showing a 600,000 lb. actuator in a frame being prepared for a test. The lab has a 3 ft. thick reinforced concrete floor slab with anchor points at 2 ft. centres (with access from below).

1.2 Experimental Project Objectives

The principal objectives are as follows:

1. Measure the shapes of the load/deflection curves for each of several blades that have already experienced different degrees of plasticity in service and compare these with the small-scale test results for new material of the same type. This will permit a more realistic estimation of the ice loads associated with deflections in the plastic regime.

2. Quantify the effect of different initial plastic deformation on subsequent stiffness in both the elastic and inelastic regimes, as well as on the yield and ultimate strengths. This will help to bind the ice loads estimated from deflections of previously yielded blades.

3. Characterize the variability of the blade stiffness and the Ultimate Tensile Strength in the post-yield regime due to large-scale effects, particularly casting variability and the degree of deformation resulting from in-service episodic plasticity.

4. Quantify, with large-scale laboratory measurements, the loads actually required to cause the blades of an “experienced” ice-going propeller of this type to fail. This should provide a conservative lower bound for the ice loads that could be carried by ice-going propellers of modern design and materials at a similar scale. Since many (at least a dozen) propellers of this same design and material have experienced blade failures on this same vessel, and the operating history is well known, this will firmly establish the frequency of occurrence of blade loads exceeding this level.

1.3 Uniqueness

As far as can be determined, measurements of the actual loads required to cause the blades of a full-scale icebreaker propeller that has seen active ice service to fail have never been made. Estimates of the loads to cause the blades to fail have always been made based on small-scale strength tests on new material and the blade geometry. This is an opportunity to quantify how realistic such estimates are.

1.4 Required Resources

The laboratory investigation will require two principal resources:

1. The use of a damaged monoblock propeller, ideally one from the *Louis S. St. Laurent* with at least three intact blades that have experienced differing degrees of in-service yielding. This would reveal the importance of scale and the extent of previous plastic deformation upon section strength for this material.

2. Access to a laboratory facility capable of applying loads of several hundred tons to the propeller specimen, sufficient to cause the unfailed blades to fail completely. Only a few facilities are known to be able to readily generate the required loads for such a test and this is being investigated further to determine the best venue for such tests.

2 LARGE-SCALE TESTS

The purpose of this report is to outline the findings of a preliminary study into the methods and viability of conducting large structural tests to meet the project objectives as outlined in Section 1.2. Of primary concern was the feasibility of performing the proposed tests, both financially and physically.

2.1 Feasibility

The physical feasibility of performing these tests is constrained primarily by the dimensions of the propeller. The weight and size of the propeller cause concern for the following reasons:

1. Transportation of the propeller from Halifax to the S. J. Carew Building of MUN in St. John's. It has been assumed that CCG would transport the propeller from Halifax to the Southside Dock in St. John's. Transport from dockside to the university can be performed by a local trucking company.

2. Test setup. The Structures Laboratory of MUN has ample room to perform the required tests; however, the dimensions of the propeller limit mobility within the lab. The design of the test frame would be such as to limit any unnecessary movement of the propeller. Once installed in the frame upon delivery, the propeller should not need to be moved again until completion of the tests.

3. Performance of the tests. The availability of heavy structural steel can facilitate the construction of a test frame that can safely handle the expected loads of these tests. The required load can be supplied by a single linear actuator operating at 10,000 psi.

Financially, the major expenses of the project will be associated with the fabrication of the test frame.

2.2 Design of Test Setup

Please refer to the drawings in Appendix A. The test frame consists of four major parts. The base platform, a moment-resisting-member or "shaft" on which the propeller is mounted, H-frame subsections for mounting the actuator, and a top cross member that also resists the applied bending moment. Combined, the base, H-frames and top cross member create a self-contained frame that eliminates the need to transmit the high loads of the test to the floor or exterior structure. The structural members of the frame are I beams designated W310 x 375. The size and thickness of other steel members will be determined through detailed design and analysis.

It is intended to make the connections between these components bolted connections if design permits. This would allow easier installation of the propeller and facilitate the setup for testing the third blade. As shown in the drawings, the frame is not symmetrical about its centre. This is so that the actuator can be placed directly over the radius of the blade that is to be tested. To facilitate testing on a different radius on each blade, it would be more feasible in terms of time and energy to move the actuator to an appropriate position than to try to move the propeller. The bolted connections would allow the frame to be removed so the propeller could be turned and the frame reinstalled at the appropriate position for testing of the third blade.

To deform the blades of the propeller in a fashion that would represent the deformation of the blades in operation, the load will be applied initially parallel to the axis of the propeller shaft. Once the blade begins to deform, the combination of bending and twisting motions will create a load path that will no longer be parallel to the propeller shaft. If the connection were too rigid, lateral loads and eccentricities would develop in the actuator and load cell, causing severe error in load readings if not damage to the actuator or load cell. Universal joints, the type and design of which are to be determined, would prevent any harmful eccentricities developing in the actuator or load cell.

The stiffness of the test setup must be given special consideration. The test setup has to be fairly stiff to minimize any energy absorbed during the elastic loading. For a frame with insufficient stiffness, the absorbed energy will be released at the post-peak (plastic) stage. As a result, full control of load and measurements may not be attained. The current loading frame is designed appropriately with sufficient stiffness. Consequently, the energy absorbed during the elastic loading will be minimal. The measurements and the load will be accurately controlled in the post-peak (plastic) region.

A detailed preliminary analysis of the test frame concept can be found in Appendix B. For an applied load of 2 MN, the maximum stress in the structure is 116 MPa and the maximum deflection is 2.3 mm.

2.3 Test Plan

2.3.1 Test Implementation

Testing will be done after regular working hours, with a minimal number of personnel present. Given the magnitude of the loads to be used in these tests, safety is of utmost concern. Precautions will be taken to ensure the safety of those operating the equipment and supervising. Enclosures, either of the test itself or of an area occupied by operators, will be constructed to prevent injury.

Once setup and calibration are complete, tests will begin by applying a load at a specified blade radius. The load will be recorded along with strain and deflection at various points.

2.3.2 Data Acquisition

Measuring the displacement of the propeller blade requires measurement in possibly three dimensions. This would make using linear measuring devices very difficult if not impossible. Also, the scale of the tests and the loads involved would likely cause a lot of damage to equipment, which would be costly to replace. These obstacles could be overcome by using non-contact measuring methods. Such methods would include photogrammetry or laser tracking. Laser tracking is limited by the scanning speed of the equipment. For a surface the size of the propeller blade considered here, the time would be in the order of tens of seconds. Photogrammetry provides a means of non-contact measuring with very high accuracy and quick measuring capability.

The strain developed in the blade upon loading will be measured by strain gauges fastened along the chords and radii of the propeller blades. A maximum of 256 gauges can be recorded simultaneously, giving a distribution of the strain in the blades. In addition to measuring displacement, photogrammetry could also be used to measure strain, which would give a better strain distribution over the surface of the blades. Included in Appendix C is more information on photogrammetry.

The load applied during testing can be measured in different ways. The most common means of monitoring the load as part of the data collection and control of the experiment is by using a load cell. Load cells of appropriate magnitude are available and calibrated at full scale to 1.2 million lb. or 5.3 million N. The problem with a load cell capable of handling loads of such magnitude is its size, weight and cost. An alternative to using a load cell would be to place a pressure transducer in the hydraulic line just as the oil enters the actuator. This setup would require calibration to compensate for frictional losses but could prove to be more accurate than using a load cell. However, there are considerations for safety that have to be made when operating at a pressure of 10,000 psi.

2.4 Safety Concerns for Propeller Test

Loading any part or member to failure always causes concern for safety. In the case of these proposed propeller tests, the strength of the propeller blade and the magnitude of the load required to plastically deform it makes safety of utmost importance.

The element of the unknown increases the need to exercise extreme caution. It is not known how the blades will fail under extreme loading. Calculations based on geometry and material properties can give only an indication of a possible failure mode. It is a part of these tests to determine what effect flaws in manufacturing will have on the final strength of the blades. These same flaws could cause the blades to fail catastrophically, and given the magnitude of the loads there is significant risk to personnel and equipment.

To complete the proposed tests in a safe manner the following requirements must be met:

1. Minimize the number of people accessing the lab area.
2. Contain any breakage of the propeller blade or of the test setup within the test frame or immediate area.
3. Keep personnel and equipment as remote as possible.

Since the lab in which the tests are to be done is part of an academic unit, there is too high a risk in performing the tests during regular working hours, as students performing undergraduate lab exercises may be present. High pressures, extreme loads and the possibility of broken loose debris require containment of possible debris. An enclosure around the test setup is one possibility but this may interfere with the data collection by photogrammetry. The data collection requires clear viewing by multiple cameras that could be blocked by a protective structure. Alternatively, the protective structure could be built around a control area housing the control equipment and personnel.

2.5 Test Schedule

Ideally, the final fabrication and test setup would be done during exam periods and between semesters when students do not occupy the labs.

Since these tests will be done in a working undergraduate laboratory, the scheduling will be greatly influenced by the safety considerations of such tests. If there is significant risk in performing the tests, work will have to be done after hours so as not to endanger any students working in the laboratory.

3 BUDGET

Table 1: Project Cost Estimate

DESCRIPTION	HRS.	RATE (CAD$/HR.)		TOTAL COST (CAD$)
LABOUR:				
Initial Setup				
Safety Planning and Setup				
Supervising Engineer	20	100.00		$ 2,000.00
Industrial Development Engineer	40	50.00		$ 2,000.00
Student Engineer	40	25.00		$ 1,000.00
Finite Element Analysis of Frame	80	100.00		$ 8,000.00
Test Frame Setup				
Supervising Engineer	15	100.00		$ 1,500.00
Industrial Development Engineer	40	50.00		$ 2,000.00
Lab. Technician	42	45.00		$ 1,890.00
Student Engineer	40	25.00		$ 1,000.00
TOTAL:				**$ 19,390.00**
Test Setup			**Per Test**	**3 Tests**
Supervising Engineer	10	100.00	$ 1,000.00	$ 3,000.00
Hydraulics Setup				
Lab. Technician	8	45.00	$ 360.00	$ 1,080.00
Data Acquisition Setup				
Lab. Technician	100	45.00	$ 4,500.00	$ 13,500.00
Industrial Development Engineer	20	50.00	$ 1,000.00	$ 3,000.00
Student Engineer	40	25.00	$ 1,000.00	$ 3,000.00
TOTAL:				**$ 23,580.00**
Testing (after hours)				
Technician	5	68.00	$ 340.00	$ 1,020.00
Industrial Development Engineer	5	75.00	$ 375.00	$ 1,125.00
Supervising Engineer	4	100.00	$ 400.00	$ 1,200.00
Student Engineer	5	37.50	$ 187.50	$ 562.50
TOTAL:				**$ 3,907.50**
Preliminary Data Analysis and Reporting				
Industrial Development Engineer	120	50.00		$ 6,000.00
Student Engineer	120	25.00		$ 3,000.00
Supervising Engineer	60	100.00		$ 6,000.00
Printing Services				$ 250.00
TOTAL:				**$ 15,250.00**
Post Test Cleanup				
Propeller Disposal				$ 2,000.00
Lab. Technician	42	45.00		$ 1,890.00
Industrial Development Engineer	20	50.00		$ 1,000.00
TOTAL:				**$ 4,890.00**
MATERIALS:				
	#	CAD$/PIECE		
Steel and Cables for Lifting Frame				$900.00
Strain Gauges	200	15.00	$ 3,000.00	$ 9,000.00
SUBCONTRACTS				
Test Frame Fabrication - Tech. Services				$ 30,000.00
Lifting Frame Fabrication				$1,500.00
Propeller Transport - Local Trucking Co.				$ 2,000.00
Deflection Measurement (estimate)				$ 25,000.00
SUB TOTAL:				**$ 135,417.50**
IN-KIND CONTRIBUTIONS				
	HRS.	RATE (CAD$/HR.)		
IMD - Supervising Engineer	200	140.00		$ 28,000.00
MUN - Supervising Engineer	200	100.00		$ 20,000.00
MUN - Test Frame Materials				$ 5,000.00
MUN - Rental of Laboratory				$ 20,000.00
MUN - Rental of Actuators and Load Cells				$ 3,000.00
TOTAL:				**$ 76,000.00**
GRAND TOTAL				**$ 211,417.50**

4 CONCLUSIONS

The large-scale experiment to measure elastic and ultimate strength and the behaviour of the full-scale propeller blades of the Canadian icebreaker *Louis S. St. Laurent* are feasible. The feasibility study considered logistical problems due to size and mass of the propeller, technical problems related to measurement of required parameters and safety aspects of the experiment.

The experiment will be conducted at the structural laboratory of the Memorial University of Newfoundland in St. John's, Newfoundland. A custom designed test frame will be constructed for the experiment. The frame will be self-contained, so that the applied loads will not be transmitted to the structure of the laboratory and, once placed, the propeller will not be moved within the frame structure for various test setups.

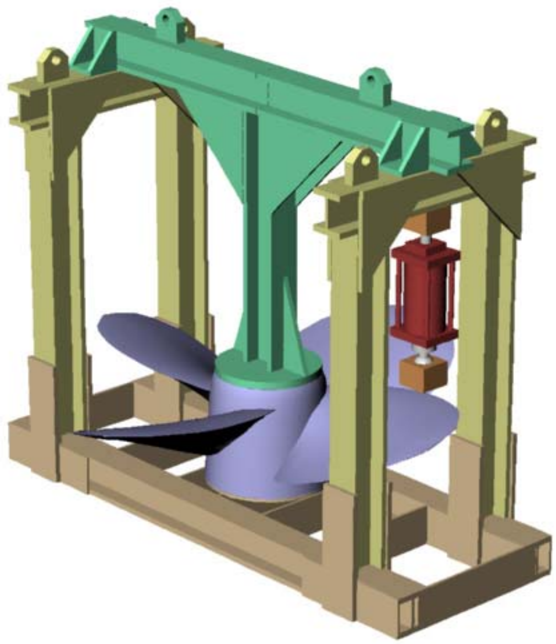
The experiments will be carried out on three blades of a propeller that has been removed from service. The measurement will consist of incrementally applied loads (estimated maximum value over 600,000 lb), three-dimensional propeller blade deflection and strains at 256 locations. Due to the size and mass of the propeller and the considerable applied loads, safety during the experiment is a concern. The experiment will be conduced after normal working hours and possibly at times when students are not present in the lab.

The estimated budget is CAD$211,500 and includes CAD$76,000 in-kind support from the Institute for Marine Dynamic and Memorial University of Newfoundland.

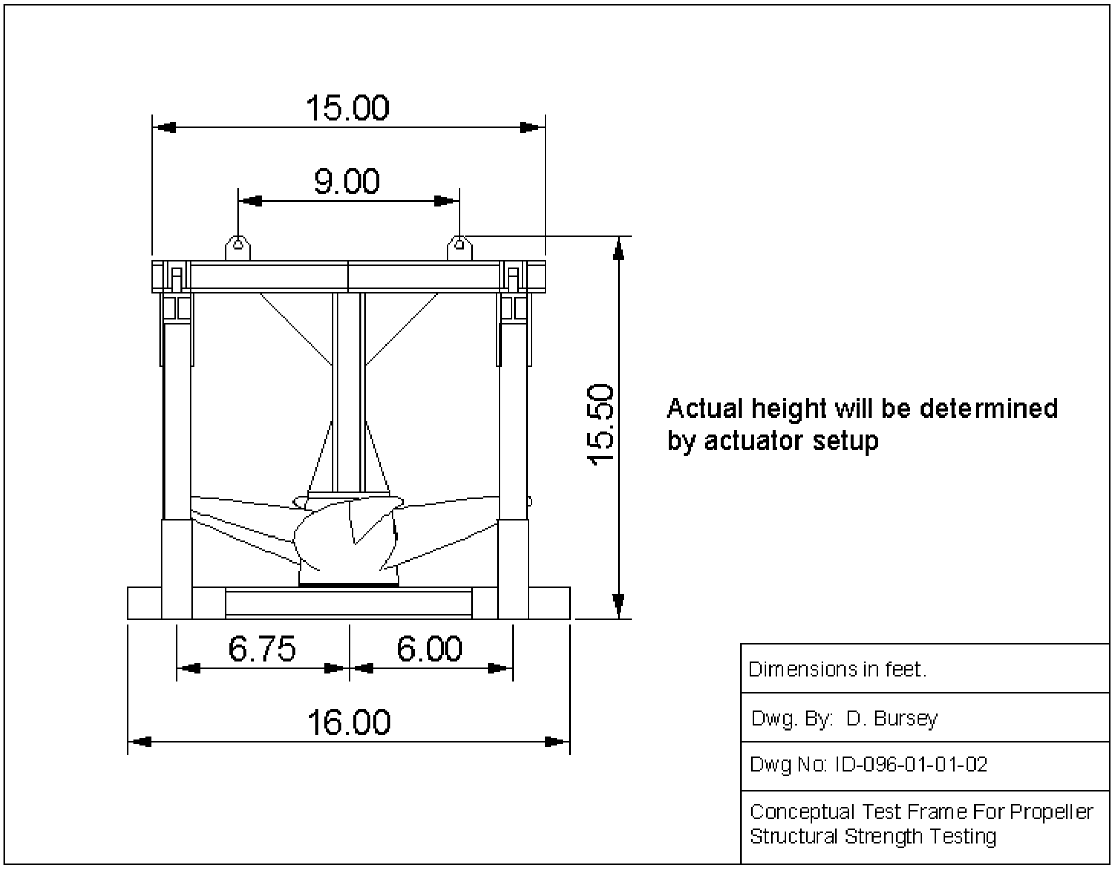
The project will require approximately six to eight months to be completed, and it could be conducted in two phases depending on the availability of funds.

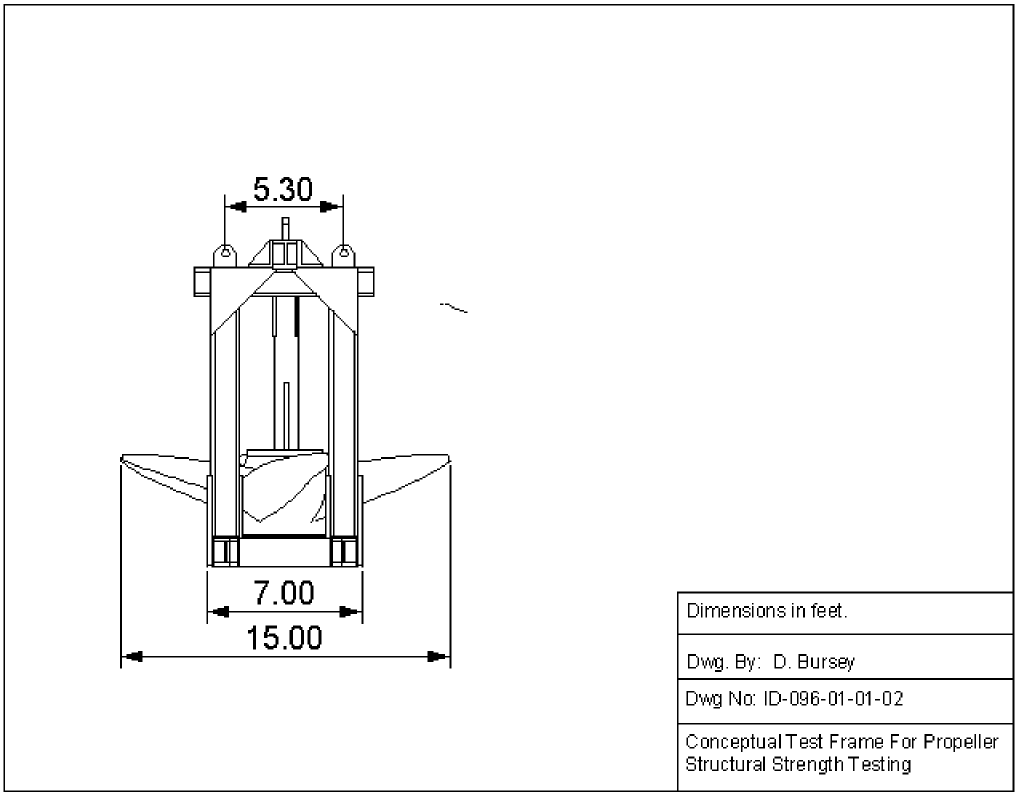
Appendix A

Figures



DWG: ID-096-01-01
Conceptual Test Frame for Propeller Structural


15.00
9.00
15.50
Actual height will be determined
by actuator setup
6.75
6.00
16.00
Dimensions in feet.
Dwg. By: D. Bursey
Dwg No: ID-096-01-01-02
Conceptual Test Frame For Propeller
Structural Strength Testing


5.30
7.00
15.00
Dimensions in feet.
Dwg. By: D. Bursey
Dwg No: ID-096-01-01-02
Conceptual Test Frame For Propeller Structural Strength Testing

Appendix B

Test Frame Analysis

General Description

This appendix contains the analysis of the proposed test frame. The analysis has been performed with a frame analysis program called 3D-BEAM, which is part of the Nauticus Suite of programs produced by det Norske Veritas (DNV). The objectives of the analysis are:

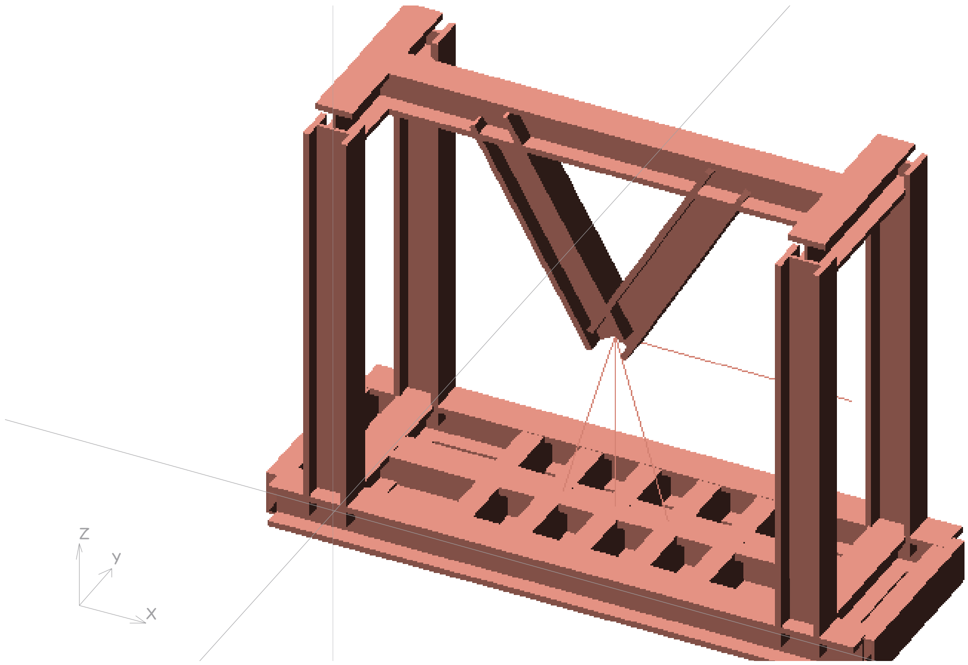
- To determine the stress and deformation in the different beams of the test frame.
- To ensure the overall stability of the frame.

Frame analysis is capable of assessing the overall loads and response (primary stresses and response) of a structure, including the overall stresses and deflections. However, this type of analysis does not model local details, such as connections and stress concentrations (secondary stresses).

The structural elements of the proposed frame were modelled using a three-dimensional beam element with six degrees of freedom at every node – three displacements and three rotations. The analysis takes account of the axial stress, bending stress, stress due to torsion and the associated shear stresses.

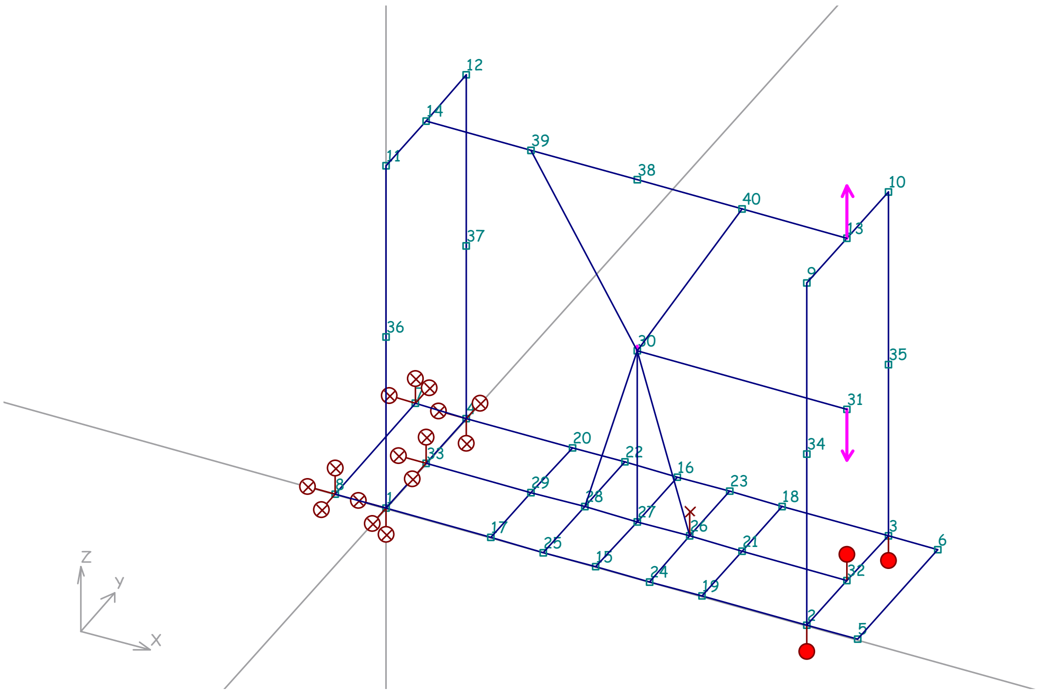
The boundary conditions are an important aspect of the design and analysis. The frame will experience two points of large loads, being at the actuator support (node 13) and in the region of the base of the propeller (node 26). The frame will tend to distort most in the loaded half of the frame. The base of the frame directly under the actuator will tend to pull off the floor, while directly under the propeller hub it will be pushed into the floor. The nodes on the base, under the loaded end, are modelled using stiff springs with appropriate stiffness values. These springs are used to simulate a set of 3 tie rods (50 mm diameter and 1 m long), which will be used to anchor the end of the frame.

The results of the analysis indicated that the principal stresses, in each member of the proposed frame, do not exceed a value of approximately 116 MPa at maximum load. The yield stress of the steel used in manufacturing the set-up is 300 MPa. Consequently, the factor of safety will be approximately equal to 2.5. The maximum deflection at the actuator support, at ultimate load of 2 MN, is equal to 2.3 mm. The frame is very stiff.

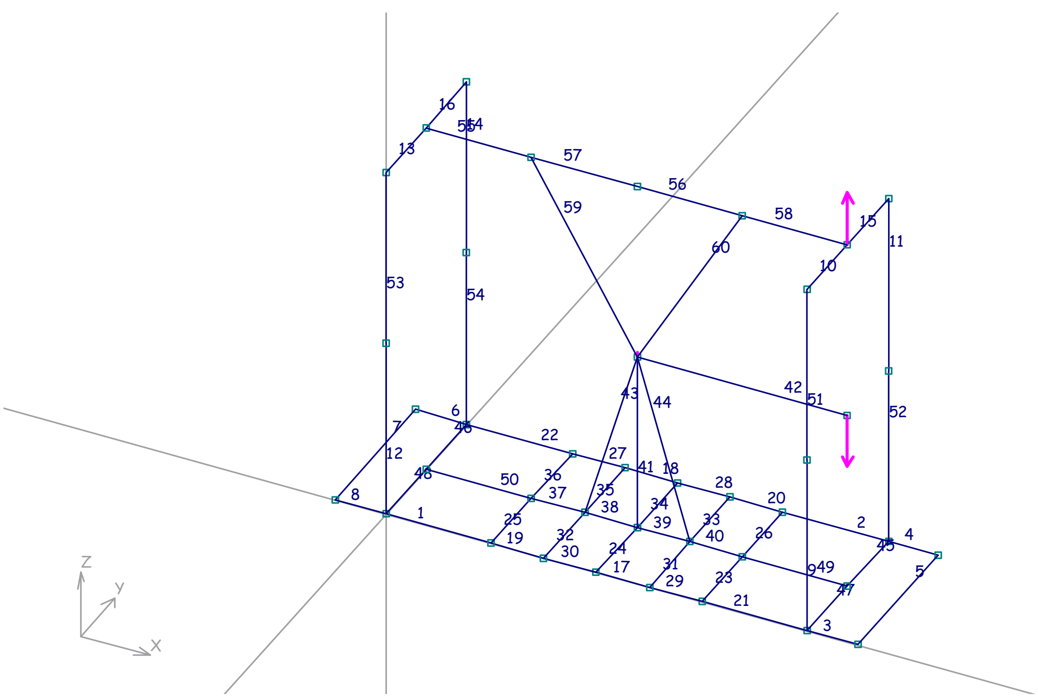


Rendered drawing of test frame.

Node Numbers, and boundary conditions



Beam Numbers and applied loads



Beam information, sorted by BeamNo in ascending order

Beam	Beam Name	Start Node	End Node	Length [mm]	Profile	Angle [°]	Rigid Start [mm]	Rigid End [mm]	Hinged at Start	Hinged at End	Non Linearities
1		1	17	1042.5	2	0.0	0	0			
2		3	18	1042.5	2	0.0	0	0			
3		2	5	500	2	0.0	0	0			
4		3	6	500	2	0.0	0	0			
5		6	5	1600	3	0.0	0	0			
6		4	7	500	2	0.0	0	0			
7		7	8	1600	3	0.0	0	0			
8		8	1	500	2	0.0	0	0			
9		2	34	1825	2	0.0	0	0			
10		9	13	800	2	0.0	0	0			
11		10	35	1825	2	0.0	0	0			
12		1	36	1825	2	0.0	0	0			
13		11	14	800	2	0.0	0	0			
14		12	37	1825	2	0.0	0	0			
15		13	10	800	2	0.0	0	0			
16		14	12	800	2	0.0	0	0			
17		15	24	521.25	2	0.0	0	0			
18		16	22	521.25	2	0.0	0	0			
19		17	25	521.25	2	0.0	0	0			
20		18	23	521.25	2	0.0	0	0			
21		19	2	1042.5	2	0.0	0	0			
22		20	4	1042.5	2	0.0	0	0			
23		19	21	800	3	0.0	0	0			
24		15	27	800	3	0.0	0	0			
25		17	29	800	3	0.0	0	0			
26		21	18	800	3	0.0	0	0			
27		22	20	521.25	2	0.0	0	0			
28		23	16	521.25	2	0.0	0	0			
29		24	19	521.25	2	0.0	0	0			
30		25	15	521.25	2	0.0	0	0			
31		24	26	800	3	0.0	0	0			
32		25	28	800	3	0.0	0	0			
33		26	23	800	3	0.0	0	0			
34		27	16	800	3	0.0	0	0			
35		28	22	800	3	0.0	0	0			
36		29	20	800	3	0.0	0	0			
37		29	28	521.25	4	0.0	0	0			
38		28	27	521.25	4	0.0	0	0			
39		27	26	521.25	4	0.0	0	0			
40		26	21	521.25	4	0.0	0	0			
41		27	30	1825	5	0.0	0	0			
42		31	30	2085	5	0.0	0	0			
43		30	28	1898	5	0.0	0	0			
44		30	26	1898	5	0.0	0	0			
45		3	32	800	2	0.0	0	0			
46		4	33	800	2	0.0	0	0			
47		32	2	800	2	0.0	0	0			
48		33	1	800	2	0.0	0	0			
49		32	21	1042.5	4	0.0	0	0			
50		29	33	1042.5	4	0.0	0	0			

Beam information, sorted by BeamNo in ascending order

Beam	Beam Name	Start Node	End Node	Length [mm]	Profile	Angle [°]	Rigid Start [mm]	Rigid End [mm]	Hinged at Start	Hinged at End	Non Linearities
51		34	9	1825	2	0.0	0	0			
52		35	3	1825	2	0.0	0	0			
53		36	11	1825	2	0.0	0	0			
54		37	4	1825	2	0.0	0	0			
55		14	39	1042.5	2	0.0	0	0			
56		38	40	1042.5	2	0.0	0	0			
57		39	38	1042.5	2	0.0	0	0			
58		40	13	1042.5	2	0.0	0	0			
59		39	30	2101.8	2	0.0	0	0			
60		40	30	2101.8	2	0.0	0	0			

Profiles

Profile	Profile Name	Type	Material	Ignore S. C.	Profile parameters
2	main	I-section	1 Steel	X	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
3	cross	Box section	1 Steel	X	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
4	base	I-section	1 Steel	X	Bt=328 mm Tt=75 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
5	blade	General section	1 Steel	X	Ax=10000 mm2 Ay=10000 mm2 Az=10000 mm2 Ix=1e+012 mm4 Iy=1e+012 mm4 Iz=1e+012 mm4 Wx=10000000 mm3 Wy=100000000 mm3 Wz=100000000 mm3 ey=0 mm ez=0 mm fy=1.0 fz=1.0

Profile properties

Profile	Axial			Local x-z plane				Local x-y plane				Shear Centre	
	Ax [mm2]	Wx [mm3]	Ix [mm4]	Az [mm2]	Wy_t [mm3]	Wy_b [mm3]	Iy [mm4]	Ay [mm2]	Wz_t [mm3]	Wz_b [mm3]	Iz [mm4]	e_y [mm]	e_z [mm]
2	45600	946614	5.2064e+007	10981	5556728	5556728	1.0836e+009	23479	1977965	1977965	3.2439e+008	0	0
3	21600	2592000	3.1104e+008	12033	2055158	2055158	3.9048e+008	6763	1372800	1372800	1.3728e+008	0	0
4	52160	1178384	8.8379e+007	11392	7001417	6000451	1.3248e+009	27850	2336579	2336579	3.832e+008	0	5.756
5	10000	10000000	1e+012	10000	100000000	100000000	1e+012	10000	100000000	100000000	1e+012	0	0

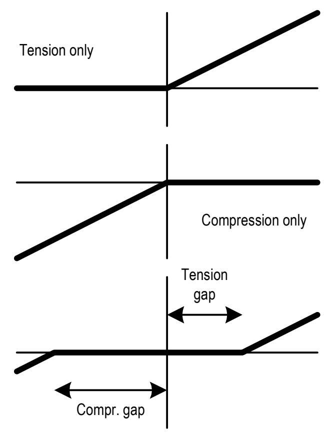
Materials

Material	Material Name	E [N/mm2]	Density [kg/m3]	Poisson	Thermal Coefficient [mm/mm/°C]	Yield Stress [N/mm2]
1	Steel	210000	7800.0	0.30	1.26e-005	235

Abbreviations

Beam information:

Beam:	Beam identification number
Beam Name:	User's beam identification
Start/End Node:	Node numbers for the start and end nodes respectively
Length:	Total length of beam, including possible rigid ends
Profile:	Profile identification number
Angle:	Angle between the profile's z-axis and the plane through the beam and the global Z-axis. Positive for clockwise rotation when seen in positive local x-direction.
Rigid Start/End:	Length of possible rigid part of the beam at the start and end ends respectively
Hinged at Start/End:	Possibly defined hinge at the start and end nodes respectively, where hinges are defined as:
dX, dY, dZ:	Hinged with respect to translation in the global X-, Y-, and Z-direction respectively
rX, rY, rZ:	Hinged with respect to rotation about the global X-, Y-, and Z-axis respectively
Non Linearities:	Possibly specified non-linear properties for the beam. For definition see figure below.



Profiles:

Profile:	Profile identification number
Profile Name:	User's profile identification
Type:	Profile type
Material:	Material identification
Ignore S.C.:	If ticked "X", then the program ignores the possible shear centre offset for the profile.
Profile parameters:	Input parameters defining the profile.

Profile properties:

Profile:	Profile identification number
Ax:	Axial area (total profile area)
Wx:	Torsion section modulus
Ix:	Torsional moment of inertia
Az:	Shear area in local z-direction ($I_y t_p / S_y$)
Wy_t:	Section modulus about local y-axis at top of profile
Wy_b:	Section modulus about local y-axis at bottom of profile
Iy:	Moment of inertia about local y-axis
Ay:	Shear area in local y-direction ($I_z t_p / S_z$)
Wz_t:	Section modulus about local z-axis at top of profile
Wz_b:	Section modulus about local z-axis at bottom of profile
Iz:	Moment of inertia about local z-axis
	Note: $Wz_t = Wz_b = Wz_{min}$ for all profile types except I - types
e_y:	Shear centre distance from vertical neutral axis
e_z:	Shear centre distance from horizontal neutral axis
f_y:	Shear factor in local y-direction
f_z:	Shear factor in local z-direction
	Note: The shear factor is used for shear stiffness of beam, but not for calculation of shear stress

Where:

S_y, S_z:	1^{st} area moment about y- and z- axis respectively
t_p:	value for profile thickness depending on profile type

Materials:

Material:	Material identification
Material Name:	User's material identification
E:	Young's Modulus
Density:	Density
Poisson:	Poisson's ratio for transverse contraction
Thermal Coefficient:	Coefficient of thermal expansion
Yield Stress:	Specified yield stress (information only)

Node information, sorted by NodeNo in ascending order

Node No	Name	X [mm]	Y [mm]	Z [mm]	Boundary Conditions					
					X transl	Y transl	Z transl	X rot	Y rot	Z rot
1		0	0	0	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
2		4170	0	0	Free	Free	Spring, 4.19e+005 N/mm	Free	Free	Free
3		4170	1600	0	Free	Free	Spring, 4.19e+005 N/mm	Free	Free	Free
4		0	1600	0	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
5		4670	0	0						
6		4670	1600	0						
7		-500	1600	0	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
8		-500	0	0	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
9		4170	0	3650						
10		4170	1600	3650						
11		0	0	3650						
12		0	1600	3650						
13		4170	800	3650						
14		0	800	3650						
15		2085	0	0						
16		2085	1600	0						
17		1042.5	0	0						
18		3127.5	1600	0						
19		3127.5	0	0						
20		1042.5	1600	0						
21		3127.5	800	0						
22		1563.8	1600	0						
23		2606.3	1600	0						
24		2606.3	0	0						

Node information, sorted by NodeNo in ascending order

Node No	Name	X [mm]	Y [mm]	Z [mm]	Boundary Conditions					
					X transl	Y transl	Z transl	X rot	Y rot	Z rot
25		1563.8	0	0						
26		2606.3	800	0	Free	Free	Fixed	Free	Free	Free
27		2085	800	0						
28		1563.8	800	0						
29		1042.5	800	0						
30		2085	800	1825						
31		4170	800	1825						
32		4170	800	0	Free	Free	Spring, 4.19e+005 N/mm	Free	Free	Free
33		0	800	0	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
34		4170	0	1825						
35		4170	1600	1825						
36		0	0	1825						
37		0	1600	1825						
38		2085	800	3650						
39		1042.5	800	3650						
40		3127.5	800	3650						

Abbreviations

Node No: Node identification number
Name: User's node identification
X, Y, Z: Node coordinates in the global coordinate system
X transl, Y transl, Z transl: Boundary conditions w.r.t. translation along the global axes
X rot, Y rot, Zrot: Boundary conditions w.r.t. rotation about the global axes

Where:
Free: The node is free
Fixed: The node is fixed
FD: The node has a prescribed displacement or rotation
Spring: The node is supported by a spring

Beams' length and profile information, sorted by BeamNo in ascending order

Beam	Length [mm]	Profile No	Angle [°]	Profile Type	Profile Name	Profile parameters
1	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
2	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
3	500	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
4	500	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
5	1600	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
6	500	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
7	1600	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
8	500	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
9	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
10	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
11	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
12	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
13	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
14	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
15	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
16	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
17	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
18	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
19	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
20	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
21	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
22	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
23	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
24	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
25	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
26	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
27	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
28	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
29	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
30	521.25	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
31	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
32	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0

Beams' length and profile information, sorted by BeamNo in ascending order

Beam	Length [mm]	Profile No	Angle [°]	Profile Type	Profile Name	Profile parameters
33	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
34	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
35	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
36	800	3	0.0	Box section	cross	B=200 mm Tt=20 mm H=380 mm T=20 mm Tb=20 mm fy=1.0 fz=1.0
37	521.25	4	0.0	I-section	base	Bt=328 mm Tt=75 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
38	521.25	4	0.0	I-section	base	Bt=328 mm Tt=75 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
39	521.25	4	0.0	I-section	base	Bt=328 mm Tt=75 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
40	521.25	4	0.0	I-section	base	Bt=328 mm Tt=75 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
41	1825	5	0.0	General section	blade	Ax=10000 mm2 Ay=10000 mm2 Az=10000 mm2 Ix=1e+012 mm4 Iy=1e+012 mm4 Iz=1e+012 mm4 Wx=10000000 mm3 Wy=100000000 mm3 Wz=100000000 mm3 ey=0 mm ez=0 mm fy=1.0 fz=1.0
42	2085	5	0.0	General section	blade	Ax=10000 mm2 Ay=10000 mm2 Az=10000 mm2 Ix=1e+012 mm4 Iy=1e+012 mm4 Iz=1e+012 mm4 Wx=10000000 mm3 Wy=100000000 mm3 Wz=100000000 mm3 ey=0 mm ez=0 mm fy=1.0 fz=1.0
43	1898	5	0.0	General section	blade	Ax=10000 mm2 Ay=10000 mm2 Az=10000 mm2 Ix=1e+012 mm4 Iy=1e+012 mm4 Iz=1e+012 mm4 Wx=10000000 mm3 Wy=100000000 mm3 Wz=100000000 mm3 ey=0 mm ez=0 mm fy=1.0 fz=1.0
44	1898	5	0.0	General section	blade	Ax=10000 mm2 Ay=10000 mm2 Az=10000 mm2 Ix=1e+012 mm4 Iy=1e+012 mm4 Iz=1e+012 mm4 Wx=10000000 mm3 Wy=100000000 mm3 Wz=100000000 mm3 ey=0 mm ez=0 mm fy=1.0 fz=1.0
45	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
46	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
47	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
48	800	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
49	1042.5	4	0.0	I-section	base	Bt=328 mm Tt=75 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
50	1042.5	4	0.0	I-section	base	Bt=328 mm Tt=75 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
51	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
52	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
53	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
54	1825	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
55	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
56	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
57	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
58	1042.5	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
59	2101.8	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0
60	2101.8	2	0.0	I-section	main	Bt=328 mm Tt=55 mm Hw=280 mm Tw=34 mm Bb=328 mm Tb=55 mm fy=1.0 fz=1.0

Abbreviations

Beam:	Beam identification number
Length:	Total length of beam, including possible rigid ends
Profile No:	Profile identification number
Angle:	Angle between the profile's z-axis and the plane through the beam and the global Z-axis. Positive for clockwise rotation when seen i positive local x-direction.
Profile Type:	Profile type
Profile Name:	User's profile identification
Profile parameters:	Input parameters defining the profile.

Beam Loads in local coordinate system, sorted by BeamNo in ascending order

Beam No	Distributed Loads						Temperature Loads		
	Px1 [N/mm]	[N/mm]	Pz1 [N/mm]	Px2 [N/mm]	Py2 [N/mm]	Pz2 [N/mm]	Gy [°C/mm]	Gz [°C/mm]	Temperature [°C]
1	0	0	-3.486	0	0	-3.486			
2	0	0	-3.486	0	0	-3.486			
3	0	0	-3.5	0	0	-3.5			
4	0	0	-3.486	0	0	-3.486			
5	0	0	-2	0	0	-2			
6	0	0	-3.486	0	0	-3.486			
7	0	0	-2	0	0	-2			
8	0	0	-3.486	0	0	-3.486			
9	-3.486	0	0	-3.486	0	0			
10	0	0	-3.486	0	0	-3.486			
11	3.486	0	0	3.486	0	0			
12	-3.486	0	0	-3.486	0	0			
13	0	0	-3.486	0	0	-3.486			
14	3.486	0	0	3.486	0	0			
15	0	0	-3.486	0	0	-3.486			
16	0	0	-3.486	0	0	-3.486			
17	0	0	-2	0	0	-2			
18	0	0	-3.486	0	0	-3.486			
19	0	0	-3.486	0	0	-3.486			
20	0	0	-3.486	0	0	-3.486			
21	0	0	-3.486	0	0	-3.486			
22	0	0	-3.486	0	0	-3.486			
23	0	0	-2	0	0	-2			
24	0	0	-2	0	0	-2			
25	0	0	-2	0	0	-2			
26	0	0	-2	0	0	-2			
27	0	0	-3.486	0	0	-3.486			
28	0	0	-3.486	0	0	-3.486			
29	0	0	-3.486	0	0	-3.486			
30	0	0	-3.486	0	0	-3.486			
31	0	0	-2	0	0	-2			
32	0	0	-2	0	0	-2			
33	0	0	-2	0	0	-2			
34	0	0	-2	0	0	-2			
35	0	0	-2	0	0	-2			
36	0	0	-2	0	0	-2			
37	0	0	-3.5	0	0	-3.5			
38	0	0	-3.5	0	0	-3.5			
39	0	0	-3.5	0	0	-3.5			
40	0	0	-3.5	0	0	-3.5			
45	0	0	-3.5	0	0	-3.5			
46	0	0	-3.5	0	0	-3.5			
47	0	0	-3.5	0	0	-3.5			
48	0	0	-3.5	0	0	-3.5			
49	0	0	-3.5	0	0	-3.5			
50	0	0	-3.5	0	0	-3.5			
51	-3.486	0	0	-3.486	0	0			
52	3.486	0	0	3.486	0	0			

Beam Loads in local coordinate system, sorted by BeamNo in ascending order

Beam No	Distributed Loads						Temperature Loads		
	Px1 [N/mm]	Py1 [N/mm]	Pz1 [N/mm]	Px2 [N/mm]	Py2 [N/mm]	Pz2 [N/mm]	Gy [°C/mm]	Gz [°C/mm]	Temperature [°C]
53	-3.486	0	0	-3.486	0	0			
54	3.486	0	0	3.486	0	0			

Abbreviations

Beam No:	Beam identification number
Px1, Px2:	Load intensity in local x-direction at the start and end ends of the beam respectively
Py1, Py2:	Load intensity in local y-direction at the start and end ends of the beam respectively
Pz1, Pz2:	Load intensity in local z-direction at the start and end ends of the beam respectively
Gy, Gz:	Temperature gradients in local y- and z-directions
Temperature:	Mean temperature. NB! Any non-zero value is regarded as a temperature load

Node Loads in global coordinate system, sorted by NodeNo in ascending order

Node No	Px [N]	Py [N]	Pz [N]	Mx [Nmm]	My [Nmm]	Mz [Nmm]
13	0	0	2000000	0	0	0
30	0	0	150000	0	0	0
31	0	0	-2000000	0	0	0

Abbreviations

Node No:	Node identification number
Px, Py, Pz:	Node load in global X-, Y-, and Z- direction
Mx, My, Mz:	Node moment about global X-, Y-, and Z- axis (positive for right-handed screw)

Forces, Moments and Deflections, signed values, sorted by BeamNo in ascending order

Beam No.	N_x [N]	Q_y [N]	Q_z [N]	M_x [Nmm]	M_y [Nmm]	M_z [Nmm]	δ [mm]	δ_x [mm]	δ_y [mm]	δ_z [mm]
1	10724	677	-113944	1319779	-67414449	-476105	0.20049	0.0011675	-0.00032607	0.20049
2	28032	1574	-195978	-495147	121794498	-1046448	0.78392	0.0084061	-0.0011691	0.78388
3	1	3887	3348	2788810	1227948	1901965	0.85333	0.0084112	0.0007129	0.85329
4	-1	-3887	3345	-2785051	1245302	-1900465	0.85284	0.008406	-0.00065832	0.85279
5	-3887	-1	-1602	-8378	-3426932	43231	0.85333	0.0084112	0.0007129	0.85329
6	0	0	872	0	72625	0	0.00012532	0	0	-0.00012532
7	0	0	1600	0	426667	0	0.0010747	0	0	-0.0010747
8	0	0	-872	0	72625	0	0.00012532	0	0	-0.00012532
9	783178	-16565	37090	-204218	121260343	23961079	1.2321	0.54993	0.58706	0.9333
10	16565	37090	-792329	-14119535	578554295	-29468085	3.0466	1.983	0.0027645	2.3129
11	789486	16541	-37112	204834	-53610291	-54148912	2.1651	1.8751	0.0041464	1.0824
12	-67241	1766	27121	-144058	96213074	2101528	0.63988	0.6392	-0.026806	-0.012209
13	-1766	27121	54517	-2776840	-38152484	-21552362	2.0431	2.0404	0.0010984	-0.10514
14	-60945	-1797	-27106	145499	-46694017	4398528	1.9613	1.9612	0.00094822	-0.02323
15	16541	-37112	792275	14119894	578555576	-29485110	3.0466	1.983	0.0027645	2.3129
16	-1797	-27106	-54583	2774807	-38152419	-21539465	2.0431	2.0404	0.0010984	-0.10514
17	21588	2765	-2288	-1026034	-49109643	823109	0.16717	0.0040102	4.2097e-005	0.16712
18	17300	2975	31128	2517574	7924630	-776761	0.21222	0.0018899	7.0089e-005	0.21222
19	13313	2348	-26650	-944104	49389393	-733602	0.21519	0.0017291	-0.00027256	0.21519
20	24778	2344	-60842	2079475	-93226726	-627930	0.27927	0.0053544	-0.00015433	0.27922
21	28030	1560	-195766	499242	121694007	-1037494	0.78469	0.0084111	0.001209	0.78465
22	10714	658	-113650	-1324261	-67086503	-469473	0.19961	0.0011664	0.00026525	0.1996
23	-773	-3240	131508	18614648	-101991360	1375196	0.28095	0.0053596	0.00011783	0.2809
24	-207	-4265	30294	41500135	-22099016	1808450	0.16578	0.0028351	-4.7526e-006	0.16576
25	1672	-2589	-90712	13506002	69665365	1104278	0.45199	-0.0072014	-3.1236e-005	0.45193
26	-770	3254	-131502	-18631226	-101986768	1380594	0.27927	0.0053544	-0.00015433	0.27922
27	13290	2339	-26360	938334	49285205	-727367	0.21386	0.001709	0.00020089	0.21385
28	21569	2770	-2664	1025305	-49315305	827588	0.16517	0.0040056	-0.00010915	0.16512
29	24790	2333	-60624	-2076060	-93010237	-627876	0.28095	0.0053596	0.00011783	0.2809
30	17323	2973	30866	-2522461	8005727	-780139	0.2137	0.0018922	-0.00015215	0.21369
31	-432	-3202	56519	44821544	-45625093	1355286	0.16717	0.0040102	4.2097e-005	0.16712
32	624	-4010	-59115	41383667	45073938	1705163	0.37587	-0.011048	-4.2071e-005	0.37571
33	-425	3209	-56360	-44826631	-45502374	1357627	0.16517	0.0040056	-0.00010915	0.16512
34	-206	4268	-30159	-41487800	-21994647	1810329	0.16385	0.0028316	-7.7577e-005	0.16383
35	636	4010	59088	-41360574	45051314	1706612	0.37587	-0.011048	-4.2071e-005	0.37571
36	1681	2576	90708	-13480848	69663514	1099284	0.45199	-0.0072014	-3.1236e-005	0.45193
37	-80830	21	-629197	-5664	689723223	-10781	0.48193	-0.0086438	-3.7168e-005	0.48185
38	3717	14	-699973	-16	184397281	-3700	0.37587	-0.011048	-4.2071e-005	0.37571
39	97005	-2	-1037861	-5	-273259762	-711	0.085436	-0.010871	-4.1311e-005	0.084742
40	24635	-13	-593687	-932	-694612584	-5869	0.117	-0.0054928	-2.4752e-005	-0.11687
41	-393316	18	-101821	4869	726467705	104359	2.2911	2.2766	0.0016904	-0.25707
42	0	0	2000000	0	4170000000	0	8.6364	2.2766	0.0017152	-8.3309
43	21936	-19	-102534	7499	1147063870	67963	2.2911	2.2766	0.0016904	-0.25707
44	-967179	18	207646	-37821	-1445618325	117789	2.2911	2.2766	0.0016904	-0.25707
45	-14228	-9080	-248995	791279	-202012062	-4111928	0.78392	0.0084061	-0.0011691	0.78388
46	0	0	-1400	0	186667	0	0.0003321	0	0	-0.0003321
47	-14238	9061	248934	-794284	-202008403	-4105391	0.78469	0.0084111	0.001209	0.78465
48	0	0	-1400	0	186667	0	0.0003321	0	0	-0.0003321
49	18141	10	-337526	3660	-348382910	-6537	0.36947	-0.003356	1.9553e-005	0.36946
50	-75666	-12	-445953	-3813	335242951	-7992	0.45199	-0.0072014	-3.1236e-005	0.45193
51	789540	-16565	37090	-204218	53570404	54193014	2.1659	1.8756	0.0013806	1.0832

Forces, Moments and Deflections, signed values, sorted by BeamNo in ascending order

Beam No.	N_x [N]	Q_y [N]	Q_z [N]	M_x [Nmm]	M_y [Nmm]	M_z [Nmm]	δ [mm]	δ_x [mm]	δ_y [mm]	δ_z [mm]
52	783124	16541	-37112	204834	-121340475	-23961430	1.23	0.54941	-0.58428	0.93252
53	-60879	1766	27121	-144058	46718117	-4345579	1.9623	1.9622	0.0012459	-0.023205
54	-67307	-1797	-27106	145499	-96162842	-2160753	0.63959	0.63886	0.027827	-0.012221
55	54227	-31	103522	65	-113473814	19143	2.0774	2.0463	0.0018289	-0.35816
56	-253684	4	140571	-348	-261527038	14677	2.0636	2.0187	0.0023312	-0.42838
57	-253684	4	140571	-348	-114981313	19247	2.0774	2.0463	0.0018289	-0.35816
58	-74203	24	-415396	-1281	-404811374	-17025	3.0466	1.983	0.0027645	2.3129
59	120557	35	285741	114	455522377	73397	2.5551	2.5536	0.0020256	-0.088956
60	571781	-20	-119920	1047	-395327723	-40307	2.7619	2.7241	0.0022152	-0.4549

Abbreviations

N_x: Axial force (Positive gives tension)
Q_y: Shear force in local y-direction (Positive rotates an isolated piece clockwise)
Q_z: Shear force in local z-direction (Positive rotates an isolated piece counter-clockwise)
M_x: Torsional moment (Positive produces a right-handed screw)
M_y: Bending moment about local y-axis (Positive gives tension at local positive Z-axis side of profile)
M_z: Bending moment about local z-axis (Positive gives tension at local positive Y-axis side of profile)
δ: Maximum total deflection of beam ($\sqrt{(\delta_x^2 + \delta_y^2 + \delta_z^2}$)
δ_x , δ_y , δ_z : Maximum deflection of beam in global X-, Y-, and Z- directions

Beam Stresses, values, sorted by SigMy in descending order

Beam No.	σ_{Nx} [N/mm2]	τ_{Qy} [N/mm2]	τ_{Qz} [N/mm2]	τ_{Mx} [N/mm2]	σ_{My} [N/mm2]	σ_{Mz} [N/mm2]	σ_{Ny} [N/mm2]	σ_{Nz} [N/mm2]
40	0	0	52	0	116	0	116	0
37	2	0	55	0	115	0	116	2
15	0	2	72	15	104	15	104	15
10	0	2	72	15	104	15	104	15
59	3	0	26	0	82	0	85	3
58	2	0	38	0	73	0	74	2
60	13	0	11	0	71	0	84	13
49	0	0	30	0	58	0	58	0
50	1	0	39	0	56	0	57	1
23	0	0	11	7	50	1	50	1
26	0	0	11	7	50	1	50	1
56	6	0	13	0	47	0	53	6
39	2	0	91	0	46	0	47	2
42	0	0	200	0	42	0	42	0
45	0	0	23	1	36	2	37	2
47	0	0	23	1	36	2	37	2
25	0	0	8	5	34	1	34	1
36	0	0	8	5	34	1	34	1
38	0	0	61	0	31	0	31	0
31	0	0	5	17	22	1	22	1
33	0	0	5	17	22	1	22	1
32	0	1	5	16	22	1	22	1
35	0	1	5	16	22	1	22	1
2	1	0	18	1	22	1	23	1
21	1	0	18	1	22	1	23	1
52	17	1	3	0	22	12	39	20
9	17	1	3	0	22	12	39	29
57	6	0	13	0	21	0	26	6
55	1	0	9	0	20	0	22	1
12	1	0	2	0	17	1	19	2
54	1	0	2	0	17	1	19	3
20	1	0	6	2	17	0	17	1
29	1	0	6	2	17	0	17	1
44	97	0	21	0	14	0	111	97
1	0	0	10	1	12	0	12	0
22	0	0	10	1	12	0	12	0
43	2	0	10	0	11	0	14	2
24	0	1	3	16	11	1	11	1
34	0	1	3	16	11	1	11	1
11	17	1	3	0	10	27	27	10
51	17	1	3	0	10	27	27	45
19	0	0	2	1	9	0	9	1
28	0	0	0	1	9	0	9	1
27	0	0	2	1	9	0	9	1
17	0	0	0	1	9	0	9	1
53	1	0	2	0	8	2	10	3
14	1	0	2	0	8	2	10	1
41	39	0	10	0	7	0	47	39
13	0	1	5	3	7	11	7	11
16	0	1	5	3	7	11	7	11
5	0	0	0	0	2	0	2	0

Beam Stresses, values, sorted by SigMy in descending order

Beam No.	σ_{Nx} [N/mm2]	τ_{Qy} [N/mm2]	τ_{Qz} [N/mm2]	τ_{Mx} [N/mm2]	σ_{My} [N/mm2]	σ_{Mz} [N/mm2]	σ_{Ny} [N/mm2]	σ_{Nz} [N/mm2]
30	0	0	3	3	1	0	2	1
18	0	0	3	3	1	0	2	1
4	0	0	0	3	0	1	0	1
3	0	0	0	3	0	1	0	1
7	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0

Abbreviations

Principal stresses:

σ_{Nx}: Axial stress (N_x/A_x)

τ_{Mx}: Torsional stress (M_x/W_x)

τ_{Qy}: Shear stress in local y-direction (Q_y/A_y)

τ_{Qz}: Shear stress in local z-direction (Q_z/A_z)

σ_{My}: Bending stress about local y-axis (M_y/W_y)

σ_{Mz}: Bending stress about local z-axis (M_z/W_z)

Stress combinations:

σ_{Ny}: Normal stress in local xz-plane, max of ($\sigma_{Nx} \pm \sigma_{My}$)

σ_{Nz}: Normal stress in local xy-plane, max of ($\sigma_{Nx} \pm \sigma_{Mz}$)

Where:

A_x: Axial area (total profile area)

A_y: Shear area in local y-direction ($I_z t_p / S_z$)

A_z: Shear area in local z-direction ($I_y t_p / S_y$)

W_x: Torsion section modulus

W_y: Minimum section modulus about local y-axis

W_z: Minimum section modulus about local z-axis

N_x: Axial force

Q_y: Shear force in local y-direction

Q_z: Shear force in local z-direction

M_x: Torsional moment

M_y: Bending moment about local y-axis

M_z: Bending moment about local z-axis

S_y, S_z: 1st area moment about y- and z- axis respectively

t_p: profile thickness value depending on profile type

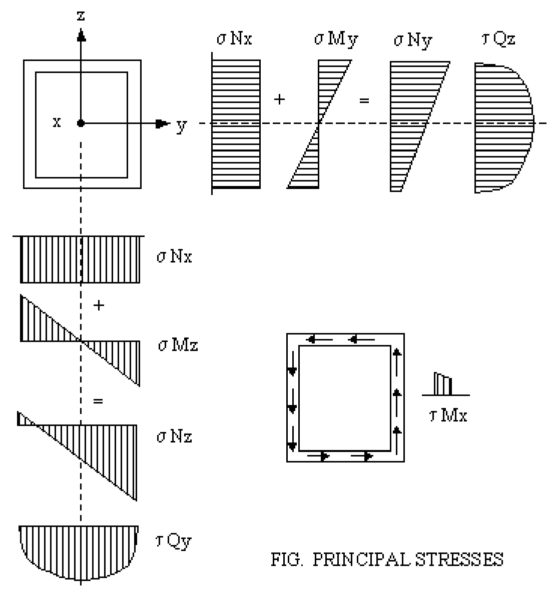
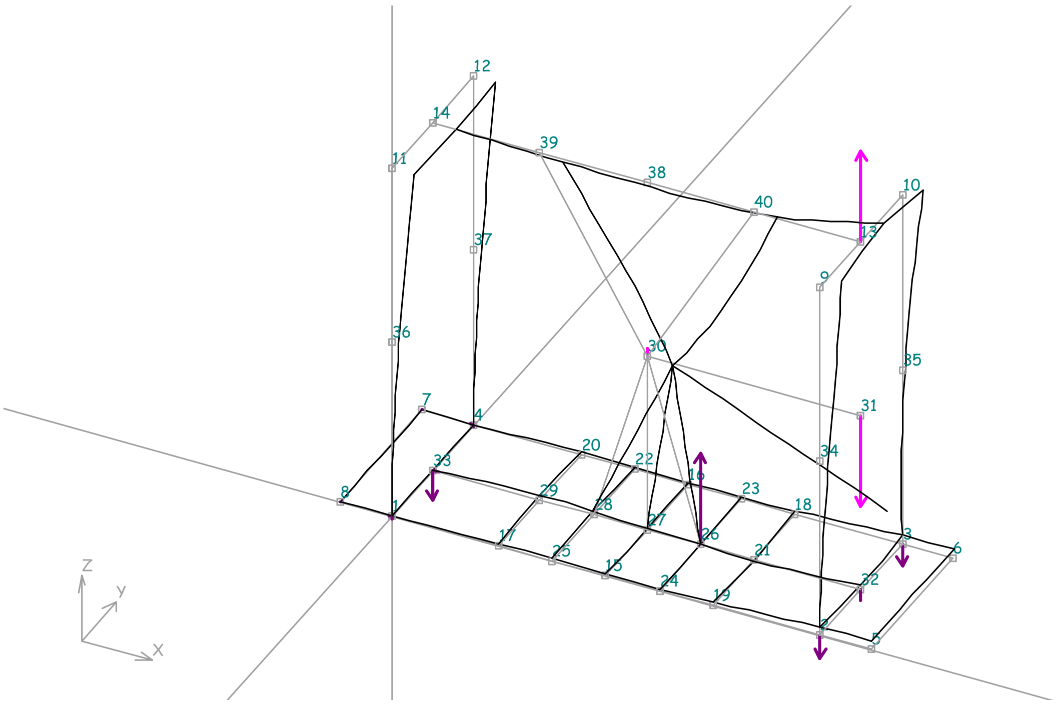


FIG. PRINCIPAL STRESSES

Model with nodes and deflected shape, applied loads and reactions



Node Deflections, Reaction Forces and Moments, signed values, sorted by NodeNo in ascending order

Node No.	δ_x [mm]	δ_y [mm]	δ_z [mm]	r_x [rad]	r_y [rad]	r_z [rad]	P_x [N]	P_y [N]	P_z [N]	M_x [Nmm]	M_y [Nmm]	M_z [Nmm]
1	0	0	0	0	0	0	-37845	2443	-40797	-3234641	-28725999	373469
2	0.0084111	0.001209	0.78465	-0.0003633	-0.0001409	5.66e-006	0	0	-328768	0	0	0
3	0.0084061	-0.0011691	0.78388	0.0003622	-0.0001415	-5.625e-006	0	0	-328445	0	0	0
4	0	0	0	0	0	0	-37821	-2455	-40438	3298347	-29003714	-362087
5	0.0084112	0.0007129	0.85329	-3.167e-005	-0.0001397	-1.167e-006	0	0	0	0	0	0
6	0.008406	-0.00065832	0.85279	3.103e-005	-0.0001402	1.191e-006	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	2472	-426667	-72625	0
8	0	0	0	0	0	0	0	0	2472	426667	-72625	0
9	1.8756	0.0013806	1.0832	0.0009206	0.0007184	-0.0001716	0	0	0	0	0	0
10	1.8751	0.0041464	1.0824	-0.0009217	0.0007185	0.0001722	0	0	0	0	0	0
11	1.9622	0.0012459	-0.023205	-6.012e-005	0.0007494	-0.000125	0	0	0	0	0	0
12	1.9612	0.00094822	-0.02323	5.995e-005	0.000749	0.0001263	0	0	0	0	0	0
13	1.983	0.0027645	2.3129	0	-0.001968	0	0	0	0	0	0	0
14	2.0404	0.0010984	-0.10514	0	0.0002211	0	0	0	0	0	0	0
15	0.0028351	-4.7526e-006	0.16576	-0.0001025	5.533e-005	2.859e-006	0	0	0	0	0	0
16	0.0028316	-7.7577e-005	0.16383	0.0001001	5.572e-005	-2.846e-006	0	0	0	0	0	0
17	0.0011675	-0.00032607	0.20049	0.0003272	-4.253e-005	1.888e-006	0	0	0	0	0	0
18	0.0053544	-0.00015433	0.27922	0.0004849	-0.0002343	-2.167e-006	0	0	0	0	0	0
19	0.0053596	0.00011783	0.2809	-0.000487	-0.0002338	2.227e-006	0	0	0	0	0	0
20	0.0011664	0.00026525	0.1996	-0.0003283	-4.173e-005	-1.935e-006	0	0	0	0	0	0
21	-0.0050825	-1.8527e-005	-0.089927	-1.04e-006	0.000359	0	0	0	0	0	0	0
22	0.0018899	7.0089e-005	0.21222	-0.000212	5.579e-005	-2.836e-006	0	0	0	0	0	0

Node Deflections, Reaction Forces and Moments, signed values, sorted by NodeNo in ascending order

Node No.	δ_x [mm]	δ_y [mm]	δ_z [mm]	r_x [rad]	r_y [rad]	r_z [rad]	P_x [N]	P_y [N]	P_z [N]	M_x [Nmm]	M_y [Nmm]	M_z [Nmm]
23	0.0040056	-0.00010915	0.16512	0.0002272	-5.638e-005	-2.037e-006	0	0	0	0	0	0
24	0.0040102	4.2097e-005	0.16712	-0.0002297	-5.622e-005	2.075e-006	0	0	0	0	0	0
25	0.0018922	-0.00015215	0.21369	0.0002102	5.505e-005	2.818e-006	0	0	0	0	0	0
26	-0.0062548	-3.4115e-005	0	0	0.001371	0	0	0	1323336	0	-0	0
27	-0.010871	-4.1311e-005	0.084742	0	0.001377	0	0	0	0	0	-0	0
28	-0.011048	-4.2071e-005	0.37571	0	0.001373	0	0	0	0	0	-0	0
29	-0.0072014	-3.1236e-005	0.45193	0	0.0003876	0	0	0	0	0	0	0
30	2.2766	0.0016904	-0.25707	0	0.001382	0	0	0	0	0	-0	0
*31 **	*2.2766*	*0.0017152*	*-8.3309*	*0*	*0.001403*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
32	-0.003356	1.9553e-005	0.36946	0	-0.000292	0	0	0	-154803	0	0	0
33	0	0	0	0	0	0	75666	12	-439505	3813	127761515	7992
34	0.54993	0.58706	0.9333	-0.0001263	0.0005602	-8.297e-005	0	0	0	0	0	0
35	0.54941	-0.58428	0.93252	0.0001246	0.0005601	8.327e-005	0	0	0	0	0	0
36	0.6392	-0.026806	-0.012209	1.312e-005	0.0005732	-6.252e-005	0	0	0	0	0	0
37	0.63886	0.027827	-0.012221	-1.396e-005	0.0005729	6.315e-005	0	0	0	0	0	0
38	2.0187	0.0023312	-0.42838	0	-0.0002426	0	0	0	0	0	0	0
39	2.0463	0.0018289	-0.35816	0	-5.154e-005	0	0	0	0	0	0	0
40	1.9911	0.0025994	0.050578	0	-0.001105	0	0	0	0	0	0	0

** this deflection is for prop tip and is not structurally relevant*

Abbreviations

δ_x, δ_y, δ_z: Translation in global X-, Y-, and Z- direction
r_x, r_y, r_z: Rotation about global X-, Y-, and Z- axis (positive for right-handed screw)
P_x, P_y, P_z: Reaction force in global X-, Y-, and Z- direction
M_x, M_y, M_z: Reaction moment about global X-, Y-, and Z- axis (positive for right-handed screw)

Appendix C

Equipment Information

Optical Metrology Centre (Research) > Photogrammetry

"Photogrammetry is a non-contact multiple point measuring tool which is capab measurement of all points simultaneously but often requires some expertise to ı

This tutorial gives an overview of photogrammetry (multiple point optical triangulation). what the technique does and typical applications. Further detail is then given about ho fast and how accurate. That is followed by a list of benefits and limitations and typical ı further information. For assistance on purchasing or using photogrammetric systems c

What does it do?
Measures the 3-D location of points or features

- at one instant using between one and many cameras at the same time, or
- over a period of time using one camera

It provides high accuracy results

- between 1 part in 5000 to 1 part in 1,000,000 of the largest dimension of the ot

The method can be applied to objects ranging from mm to kilometres in size
Statistical self checking is available and estimates of precision can be produced as pa

What does photogrammetry get used for?

- Mapping
- Shipbuilding
- Architectural models of buildings or facades,
- Archaeology surveys
- Medical uses e.g. human body scans for back problem or gait analysis
- Missile or plane tracking
- Antenna measurement
- Verification of the design of manufactured structures.
- Virtual reality
- Entertainment

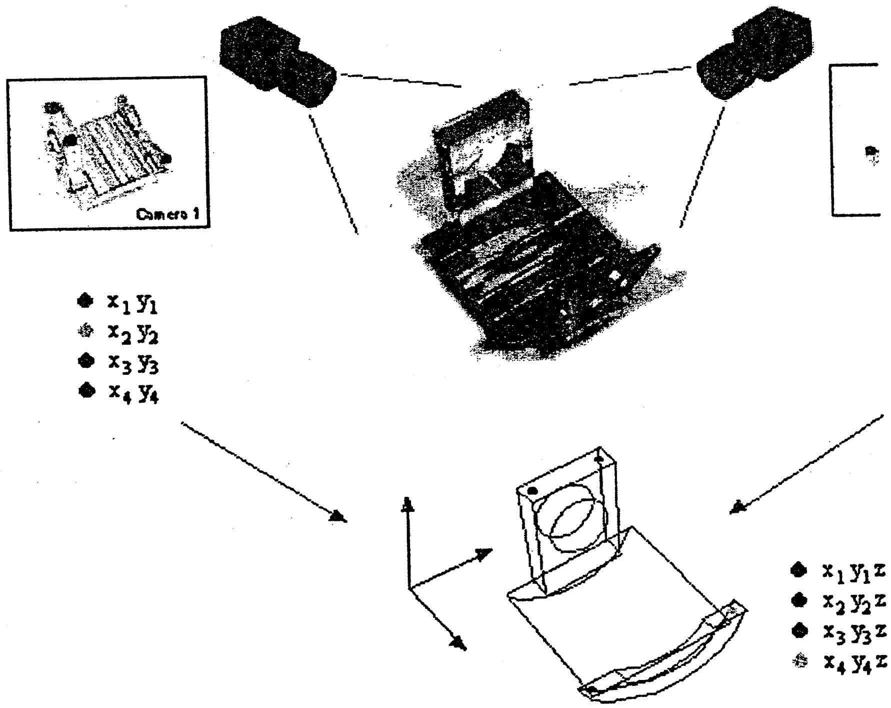
What type of information can it provide?

- CAD models
- Surfaces
- Deformation

- Movement
- Reverse engineering data
- Tracking of objects

How does photogrammetry work?
The main steps are:

- take images
- find the locations of features (targets, edges, corners, etc.)
- correspond features between
- compute the 3-D location of corresponding points using triangulation



To achieve this it is necessary to have the following information:

- where the cameras are
- which direction the cameras are pointing
- the camera's characteristics
- measurements in the object space to give scale
- a datum definition

This information may be collected as:

- part of the measurement process, or
- as a series of steps e.g. camera calibration, physical setting up

In general there are two stages

- *Start up:* where the datum and information about the cameras is computed
- *Measurement:* where images of the object are collected, analysed, and results

How fast does it work?
For multiple camera scheme:

- image capture can take place in as little as 1/10,000 of a second
- measurement can be repeated every 1/25 of a second
- processing of images may take place on-line or off-line hence the latency of the but unlikely to be any less than 1/25 of a second

For a single camera scheme:

- images may be collected over a period of a few minutes to a few hours
- processing of images and computation of results may take a few seconds to a
- for either mode of operation the speed will be dependent on the type of sensor number of targets or features being measured

How accurate?
Accuracy in photogrammetric systems related to:

- the number of pixels in the sensor and the size of the object e.g. a bigger sens accurate results for the same size object
- the type of feature being detected (in order of increasing accuracy)

  Natural features such as corners, edges, etc.
  Projected features (lines, grids, random patterns, dot arrays)
  Black on white or white on black features
  Retro-reflective targets

What are the benefits of photogrammetric systems?

- Simultaneous measurement of many points at one point
- Storage of results for post processing or analysis
- Can capture fast events
- Potentially highly accurate
- Statistical feedback on reliability of the measurement process
- Scaleability to measurement problem
- Incorporation of additional information such as measured distances
- Well developed and mature technique

What are the limitations of photogrammetric systems?
The primary limitations are:

- *Geometry:* clear lines of sight are required to each camera, when more than on usually occupy a large volume compared with the object being measured
- *Set up:* before measurement can take place the system must be initialised and cameras calibrated prior to setting up
- *Complexity:* these systems have many degrees of freedom and a high level of to get the best results
- *Cost:* few off-the-shelf systems so expense is often high
- *Image collection:* bright lights or specular effects can cause problems, some ob controlled illumination especially if edges or features are used

How much do photogrammetric systems cost?
Photogrammetry can be performed for a few hundred pounds with camcorders, standa cameras, digital cameras, or even with film cameras and a image scanner. It will be ne some software to produce 3-D measurements and accuracy will be low.
At the other end of the extreme accurate measurement comes with a price tag of the c

thousands of pounds.

Where do I get further information?
Books

- Close Range Photogrammetry and Machine Vision, 1996. Edited by K.B. Atkin: Whittles Publishing, Roseleigh House, Latheronwheel, Caithness, Scotland, KV ISBN 1-870325-46-X
- Manual of Photogrammetry, 1980. Edited by C.C. Slama (Fourth Edition). Ame Photogrammetry, Falls Church, Virginia, 1056 pages.

Journals

- Photogrammetric Record. Editor K.B. Atkinson. The Photogrammetric Record, Geomatic Engineering, University College London, Gower Street, London, WC 868X
- Photogrammetry and Remote Sensing. Editor D.A. Tait. Published by Elsivier S Molenwerf 1, PO Box 211, 1000 AE Amsterdam. The Netherlands. ISSN 0924-
- Photogrammetric Engineering and Remote Sensing. American Society for Phot Remote Sensing, 5410 Grosvenor Lane, Suite 210, Bethesda, Maryland 20814

Conferences

- ISPRS Commission V proceedings (1908 - 1996). International Archives of Phc Remote Sensing, RICS Books, Surveyor Court, Westwood Way, Coventry, CV
- Optical 3-D Measurement techniques (1 - 4), Edited by A. Gruen, and H. Kahm Wichmann Verlag, Huthig GmbH, Heidelberg.
- Videometrics (1-5) Edited by S.F. El-Hakim. Published by SPIE. Po Box 10, Be Washington 98227-0010, USA

14 June 2001

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There is also a Dutch version of this page

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- Three-dimensional metrology
- Volume computations
- Three-dimensional machine vision
- Image processing

Mapping

- Topographic mapping
- Digital terrain modeling

Training

- Specialists for photogrammetric and geodetic applications
- Operators using Geodelta software

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- GIS applications

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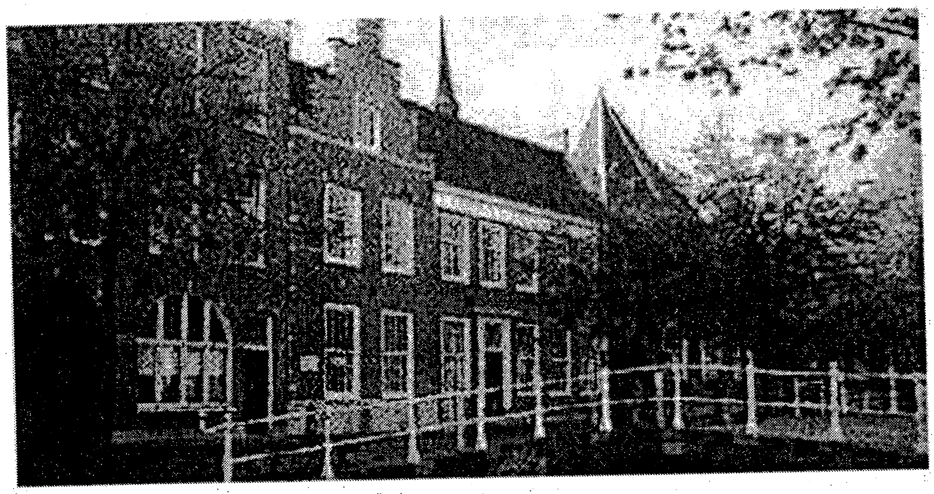

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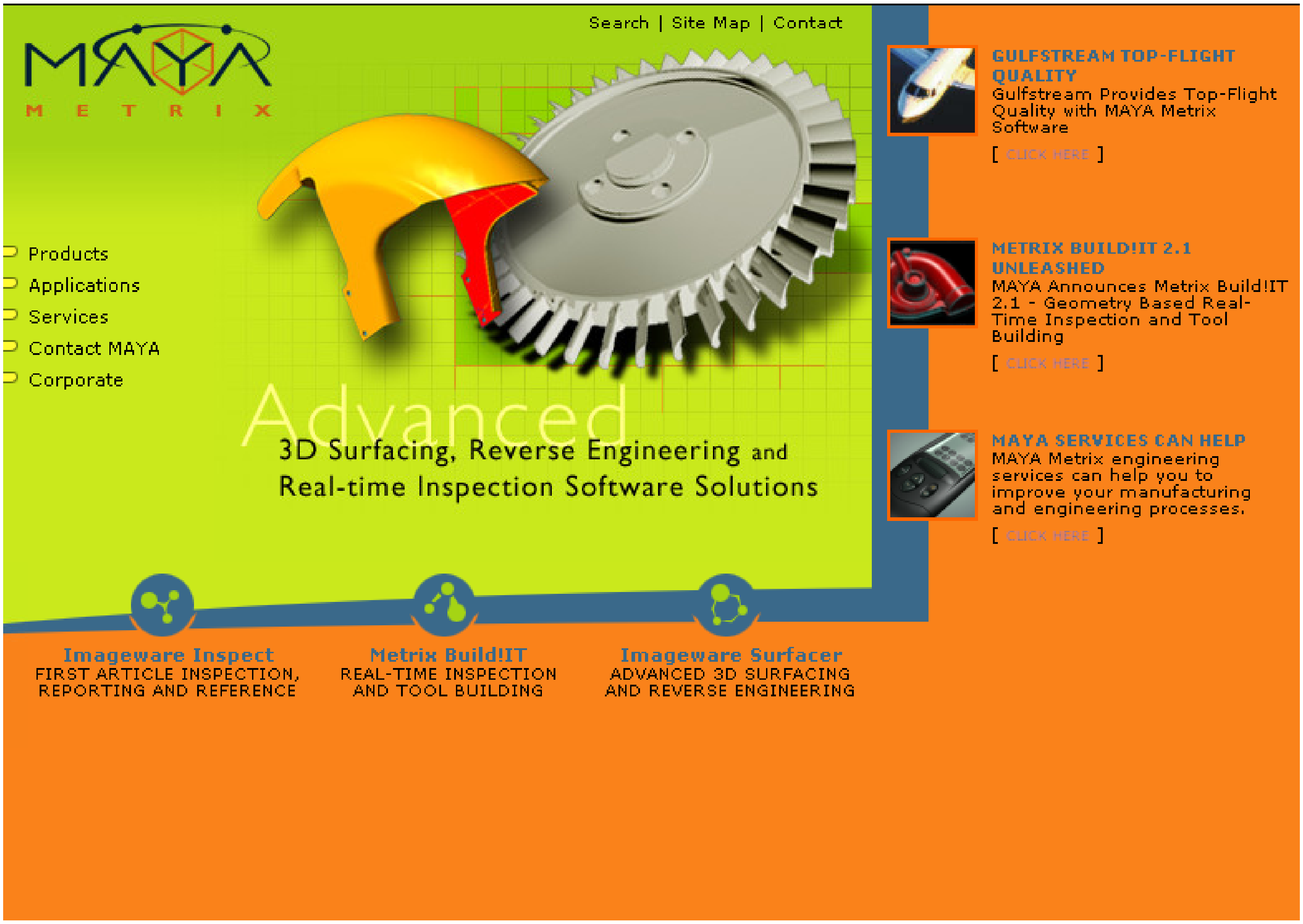
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eMail: **support@mayametrix.com**

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FTP Security Notice

Only MAYA customers and authorized users are given permission to access MAYA's anonymous ftp server. However, note that MAYA's ftp site is accessible on the internet. We have taken precautions to make the ftp site secure and we do not allow users to view directory contents or get files from the incoming directories. However, we cannot guarantee security so we do not recommend you place very sensitive files on our ftp server. You can also encrypt files with passwords using WinZip. Of course, you will need to tell us the password !

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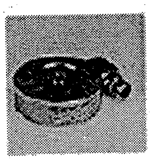
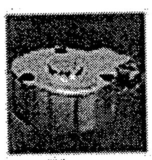
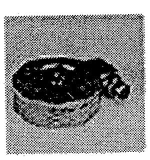
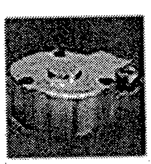
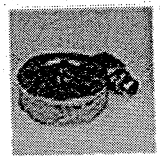
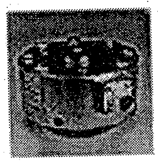
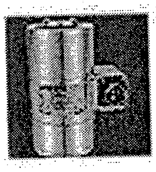
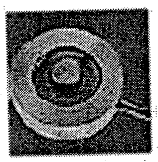
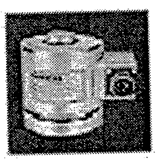
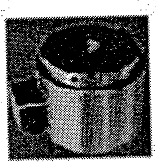
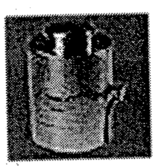
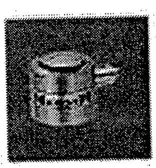
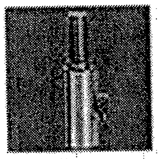
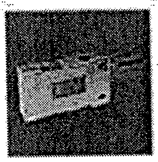
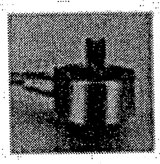
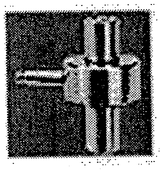
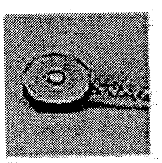
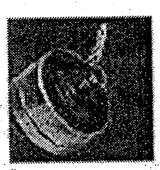
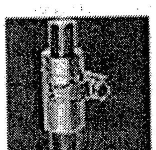
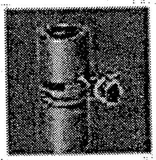
	**41**	Pancake Style; 5 to 500,000 lbs. Amplified Output Option; Tension/Compression. Model 41 data sheet.pdf (77.3k)
	**43**	Pancake Style; 5 to 500,000 lbs.; Amplified Output Option; Compression Only. Model 43 data sheet.pdf (77.3k)
	**42**	0.05% Linearity; Pancake Style; Welded Stainless Steel; Amplified Output Option. Model 42 data sheet.pdf (65.2k)
	**73**	Pancake Style; Compression Only; Amplified Output Option; 50 to 200,000 lbs. Model 73 & 75 data sheet.pdf (73.1k)

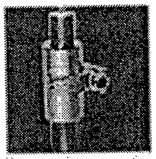
	75	Pancake Style; Tension/Compression; Amplified Output Option; 50 to 200,000 lbs. Model 73 & 75 data sheet.pdf (73.1k)
	45 & 47	Pancake Style; Tension/Compression; Industry Interchangeable. Model 45 & 47 data sheet.pdf (82k)
	UG	0.03% Linearity; Welded Stainless Steel; Ranges to 200,000 lbs.
	53	Low Cost; 0.25% Non-Linearity; 5 to 50,000 lbs. Model 53 data sheet.pdf (66.5k)
	WG	0.02% Linearity; Welded Stainless Steel; Ranges to 500,000 lbs.
	TG	For High Side Load Applications; Tension/Compression; Ranges to 500,000 lbs.
	MIL	Family of Ranges Up to 3,000,000 lbs.
	LFH-81	Miniature; Ranges to 100,000 lbs.; 2" Maximum Diameter.

	RI	1 to 100 Tons; High Overload Capacity; Rod End.
	SP	**0.03% Non-Linearity; Compact Size; Ranges to 100 lbs.**
	31	Welded Stainless Steel; Tension/Compression; 50 grams to 10,000 lbs. Model 31 & 34 data sheet.pdf (82.8k)
	34	Welded Stainless Steel; Tension/Compression; 50 grams to 1,000 lbs. Model 31 & 34 data sheet.pdf (82.8k)
	13	Compression Type; Ranges from 0-50 grams with 3/8" Diameter. Model 13 data sheet.pdf (14.3k)
	11	Tension/Compression Type; Ranges from 0-50 grams with 1/2" Diameter. Model 11 data sheet.pdf (53.3k)
	LFH-71	Compression Type; Ranges from 250 lbs. with 1/2" Diameter.
	RM	Welded Stainless Steel; Ranges from 0-100 to 200,000 lbs. Model RM & RF.pdf (86.4k)



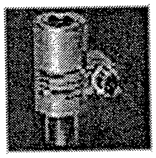
RF

Welded Stainless Steel; Ranges from 0-100 to 200,000 lbs. Model RM & RF.pdf (86.4k)



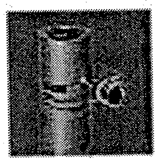
RGM

Side Loading Protected; Ranges to 0-50,000 lbs; 0-5VDC or 4-20mA Option. Model RGM & RGH & RGF.pdf (87.7k)



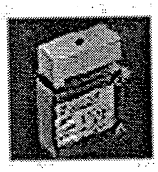
RGH

Side Loading Protected; Ranges to 0-50,000 lbs; 0-5VDC or 4-20mA Option. Model RGM & RGH & RGF.pdf (87.7k)



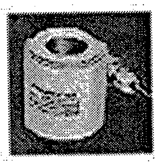
RGF

Side Loading Protected; Ranges to 0-50,000 lbs; 0-5VDC or 4-20mA Option. Model RGM & RGH & RGF.pdf (87.7k)



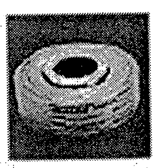
81 & 82

0.03% Non-Linearity; 5 to 20,000 lbs; Compact Size.



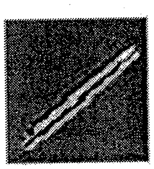
TH

Compression; 1 1/2" Diameter; Ranges from 0-15,000 lbs.



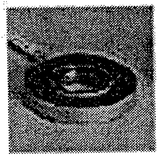
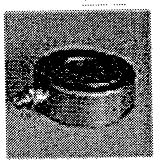
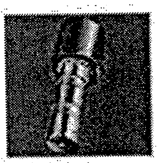
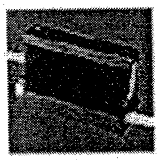
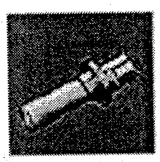
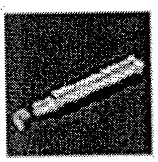
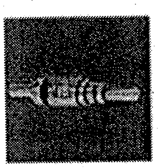
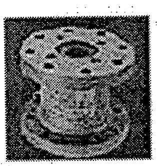
D

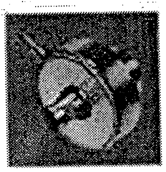
150 grams - 30,000 lbs; Flexible Design; 0.05% Non-Linearity.



MBL & MBH

t25 grams to 10 lbs.; Miniature; 0.1% Non-Linearity.

	**DLN**	Compression Only; High Frequency & stiffness; Thin, Piezoelectric; 1000 lbs.
	**DLS**	Compression Only; High Frequency & stiffness; Thin, Piezoelectric; 10,000 lbs.
	**LP**	Welded Stainless Steel; Amplified Output Options; Ranges from 0-2,000 lbs. with 1/2" Diameter. Load pin data sheet.pdf (85.9k)
	**MT**	Miniature; Splash Proof; High Natural Frequency.
	**DZ**	High Range; Insensitive to Contact Point Location.
	**WU**	Low Range; Universal Design; Rugged.
	**QSFK-9**	Shaft Type; Reaction Torque Sensors; Ranges up to 24,000 in-lbs.
	**QFFH-9**	Flange Type; 3,000 to 24,000 in-lbs.; Reaction Torque Sensors.



QWFK-8M & QWLC-8M

Miniature Reaction Torque Sensors; Low Ranges from 0-50 in.-oz.; Shaft or Flange/Shaft Connections.

---

239 East 6th Avenue,
Vancouver, BC V5T 1J7
Phone (604) 872-7894
Fax (604) 872-0281
email salesv@Hoskin.ca

4210 Morris Drive,
Burlington, ON L7L 5L6
Phone (905) 333-5510
Fax (905) 333-4976
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8425 Devonshire,
Montreal, PQ H4P 2L1
Phone (514) 735-5267
Fax (514) 735-3454
email salesm@Hoskin.ca

A-Tech Instruments Ltd.

TEL:(416) 754-7008
FAX:(416) 754-2351

P.O. Box 252
Scarborough, ON
M1E 4R5

27840

11-Apr-02

Memorial University of Nfld
Dept of Eng., Rm EN 3059
St. John's, Nfld.
A1C 5S7
1709 737 8958
1709 737 4042

ATTENTION: D. Bursey

RE: QUOTE OT1301080

Dear Dave

Thank you for your interest in our products. As promised, we are now enclosing our preliminary quotation for the products that you had requested.

We hope that this information is helpful and look forward to the opportunity of doing business. Should you have any further questions, please do not hesitate to contact the writer at (416) 754-7008.

Yours Truly,

Alastair. Lindsay. / . Mitul. Desai

includes calibration to 300,000 lbs

Item	Qty.	Delivery	Product Description	Unit Price
1	1	10-12 wks	F203-MJP-1200K, Compression Load Cell;1200,000 lbs; 2mV/V o/p;10vdc exc. Nom. Rqd;0.15%non-lin;8 " dia.,7.5" height;PT02E-10-6P connector(AG002)	$8,117.00
2	1	1-2 days	AG002-ZA502-030-03(16048A), 30 ft. Cable 6 pin KPT to open leads; KPT06F-10-6S, A+exc. D-exc. B+sig C-sig; to ends with ferrules, Red+exc. Blk-exc. Grn+sig Wht-sig; KIT14580;; 4 cond. overall shield	$68.57
3	1	1-2 days	DSCA38-05, DIN Rail Mount Strain Gauge Conditioner; +/-20mV i/p; +/-10Vdc o/p, +10V exc.; 19-29Vdc@60mA pwr req'd; 3Khz BW; 22.5mm (0.89")W DIN; removable screw term. I/O	$355.00
4	1	1-2 days best avail. on market	3170, Strain Gauge Conditioner; 1 to 8mV/V i/p; 3x +/-5Vdc o/p@2, 200 & 2KHz,exc. 5/10Vdc; 115Vac pwr req'd;0.05Acc; -18 to +55deg.C; Desktop/ Panel mount; c/w solder conn.	$1,300.00
5	1	1-2 days	CO-SG-S(13142), Single Channel Strain Gauge Conditioner Configuration; I/P: strain gage; O/P: analog;;;	$56.00
6	1	12-16 wks	F347-1200K, Fatigue Rated Universal Load Cell;1,200,000 lbs.;2mV/V o/p; 10Vdc exc.;;;bendix PT02E-10-6P connector(AG002)	$20,781.00

Note: Prices are in Canadian Funds and are F.O.B. our Scarborough facility. G.S.T. and P.S.T. are Extra. Our Terms are Net 30 days OAC. Interest of 2% per month applies on all over due accounts. This quote is valid for 15 days. Delivery given above is subject to change without notice.
Mailing address: A-Tech Instruments Ltd. P.O. Box 252 Scarborough, Ontario, Canada. M1E 4R5

A-Tech Instruments Ltd.
P.O. Box 447 Pointe Claire, PQ H9R 4N9

MTL. Tel. (514) 695-5147
Fax (514) 630-6136
TOR. Tel. (416) 754-7008
Fax (416) 754-2351
e-mail: sales@a-tech.ca
www.a-tech.ca

FAX TRANSMISSION

Date: 18-Apr-02
Page: 1/5

To/A: **Dave Bursey**
Memorial University

From/ Expéditeur: Alastair Lindsay
A-Tech Instruments Ltd., Montréal

Fax: 709-737-4042

Telephone: (514) 695-5147
Fax: (514) 630-6136

Subject: 1,200 kip L/C

Ref.:

Dear Dave,

Here are the dimensions for the two load cell models quoted.

We are in the process of finding out the details for calibrating the unit to full scale. My contact at the NRC Mass Standards Group in Ottawa told me that we will have to use the NIST facility in the U.S. which has deadweights up to one million pounds and hydraulics for above that.

SensorData is already in touch with them so we hope to be able to have pricing information for you shortly.

The following drawings are for the standard models which are not rated for your capacity. A final engineering drawing will be prepared at the time of an order.

The F203 series will have a diameter of about 8" and an overall height of about 7.5"

The F347 would have a diameter of 16" and a height of 6".

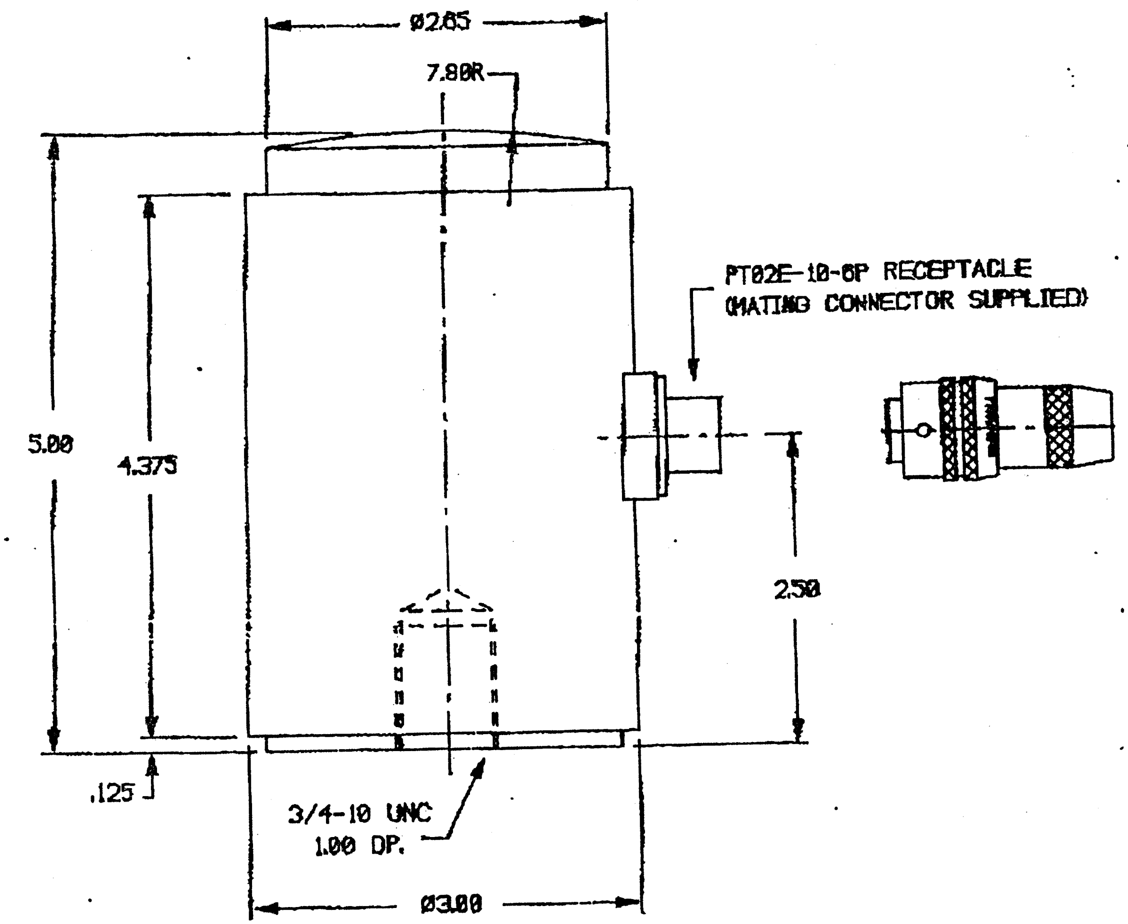
For compression only measurements we recommend the F203 since the accuracy is still very good for a much better price. A fatigue design is only required for cyclic applications involving both tension and compression loads. The difference in price (due to material and machining costs) between the two models is the result of the type of structure used. The F203 is a column type load cell while the F347 uses a shear beam structure which provides a better linearity.

I trust that this information is useful for you at this time. Please let me know if you have any questions.

Regards,

Alastair Lindsay

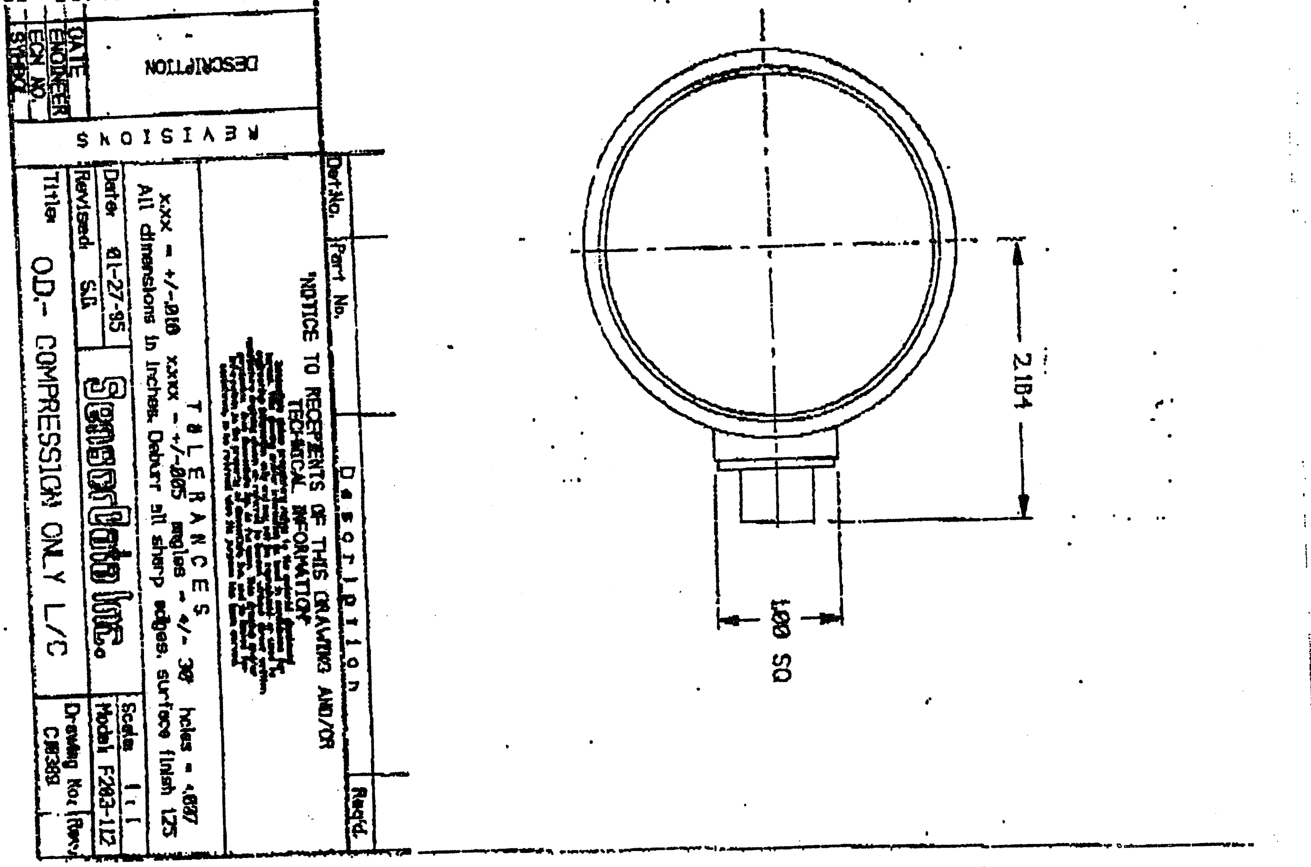
F203-MJP-1,200K
Ø8"
H 7.5"



CAPACITY : 50, 100, 200, 300 K Lb.

n.lin.	hyst.	repeat.	output	zero balance	bridge resist.	max. exc. voltage	overload	cross-talk	temp. range comp.	temp. range usable	temp. effect on zero	temp. effect on output	accuracy
0.15% ORC	0.15% ORC	0.05% ORC	2.00 mv/v	1.00% ORC	350 OHM	20 VOLTS	150% ORC	N/A ORC	70/170 °F	-65/200 °F	0.002% ORC/°F	0.002% ORC/°F	0.35 ORC

ATTN: MITUL



DESCRIPTION
DATE
ENGINEER
ECN NO.
SYMBOL
REVISIONS
Def.No.
Part No.
Description
Req'd.
NOTICE TO RECIPIENTS OF THIS DRAWING AND/OR TECHNICAL INFORMATION
TOLERANCES
xxx = +/-.010 xxxx = +/-.005 angles = +/- 30' holes = +.007
All dimensions in inches. Deburr all sharp edges. surface finish 125
Date: 01-27-95
Revised: SJ
Title: OD. COMPRESSION ONLY L/C
Scale 1:1
Model F203-1/2
Drawing No:
Rev.
2.184
1.00 SQ

Product Techfile
MODEL F341 Series

Fatigue Rated Load Cell
Model F341 Series

Typical Applications:

The **Model F341 Series Fatigue Rated Load Cells** are designed for materials testing machines and applications where full fatigue design is mandatory. These field proven low profile sensors are fatigue rated for full tension and compression loading, and provide the characteristics of high performance, very low deflection at full scale loading, and superior resistance to extraneous bending moments and side loading. These sensors are also available in dual bridge configuration. The **Model F341 Family Series** of Low Profile load cells range in capacity from **200 pounds force to 500,000 pounds force.**

Features:

- Low Profile
- Field Proven Design
- Fully Fatigue Rated
- Low Deflection
- High Accuracy Performance
- Extraneous Load Resistance
- Traceable to NIST

Special Applications:

SensorData Technologies, Inc. welcomes the opportunity to serve your special testing requirements. We will be pleased to discuss the details of your unique test situation and assist in the proper selection of a standard transducer. Our design staff can also provide you with a special sensor design specifically suited to your application. Often requested accommodations, such as; mounting alterations, wiring code changes and special capacities, are all handled with minimal amounts of delay. All special inquiries are welcome and encouraged by the factory.

SensorData Technologies, Inc.

Force Sensors

Reaction Torque Sensors

Rotating Torque Sensors

Multiple Axis Sensors

MODEL F341 Series

Toronto Tel: (416) 734-7006
Fax: (416) 734-2351
Montreal Tél: (514) 695-5147
Fax: (514) 630-6136
Email: sales@a-tech.ca
Web: www.a-tech.ca

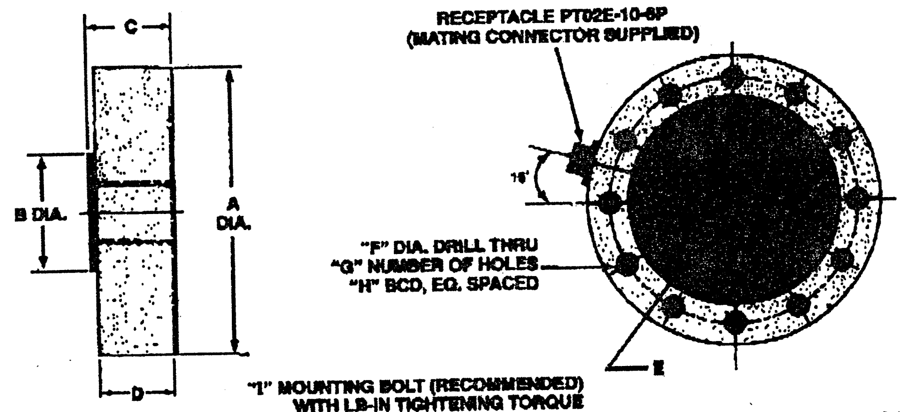
A-Tech Instruments Ltd.

SENSORS/TRANSMITTERS
SIGNAL CONDITIONERS
INDICATORS
DATA COLLECTION TERMINALS
DATA ACQUISITION
HARDWARE/SOFTWARE

Fatigue Rated Load Cell
Model F341 Series

Mechanical Interface

The **Model F341 Fatigue Load Cell Series** are designed for material testing machines, hydraulic actuators, and production line machine control applications.The field proven shear beam design of these low profile sensors provide the characteristics of high accuracy performance, very low deflection at full scale loading,and superior resistance to extraneous bending moments and side loading.They are fatigue rated for full tension and compression loading, and are also available in dual bridge configuration. Please note, the unique shear design requires the use of a machined mounting base for optimum performance.The mounting base must be flat and parallel within +/-0.0005 inch, and loading is accomplished by mounting to the active center loading thread. Factory installed (optional) tension plates are available for those installations where a machine finish in the mounting area is not practical.



Dimensions and Specifications are subject to change without notice. Please request certified drawings prior to the design of mounting fixtures.

Series Models

Model	F312-110	F341-110	F342-110	F344-110	F346	F347
Capacity (LBS.)	200, 500, 1K, 2K, 3K	5K, 10K, 20K	50K	100K	250K	500K

Series Diagram Measurements

Model	A	B	C	D	E	F	G	H	I
F312-110	4.125	1.270	1.250	1.125	5/8-18 UNF-3B	0.281	8	3.500	1/4-28 (180)
F341-110	6.060	2.420	1.625	1.500	1 1/4-12 UNF-3B	0.406	12	5.125	3/8-24 (600)
F342-110	8.000	3.140	1.875	1.750	1 3/4-12 UNF-3B	0.530	16	6.500	1/2-20 (1,560)
F344-110	11.000	4.920	3.500	3.375	2 3/4-8 UNF-3B	0.656	16	9.000	5/8-18 (3,000)
F346	12.000	5.340	4.000	3.940	3 -12 UNF-3B	0.656	16	10.000	5/8-18 (3,000)
F347	14.000	6.340	4.000	3.940	3 1/2-12 UNF-3B	0.781	16	12.000	3/4-16 (4,980)

Performance Specifications

									temp range		temp effect		
n.lin.	hyst.	repeat.	mv/v output	zero balance	resist.	exc. volt.	overload	# of bridges	comp	usable	on zero	on output	accuracy
0.05% ORC	0.05% ORC	0.02% ORC	2.00 Nom.	1% ORC	700 OHM	20 RMS VOLTS	150% ORC	1 or 2	70 to170 °F	-65 to 200 °F	.002% ORO/°F	.002% ORO/°F	0.09% ORC

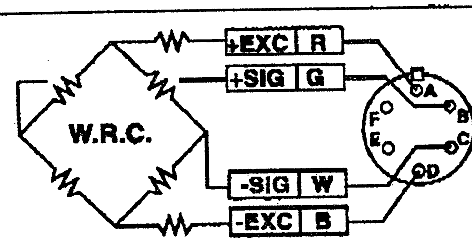
Physical Characteristics

MATERIAL : SAE 4340 Alloy Steel

CAPACITIES : See Chart

SEALING : Mechanical sealing methods utilized for splashproof conditions.

Wiring Diagram



SensorData Technologies, Inc. • 43626 Utica Rd. Sterling Heights, Michigan 48314, U.S.A. • Phone: (810) 739-4254 • Fax: (810) 739-5689

MEASUREMENT SPECIALISTS, INC.
"The Load Cell Source"

690 Discovery Dr. N. W.
Huntsville, AL 35806

Phone: (800) 899-9988
Fax: (800) 264-9991

3 pages

Memorial University
Tel 709-737-8958
Fax 709-737-4042
Atn: David Bursey

QUOTATION NO.MULS030502WH
DATE: March 8, 2002

WE ARE PLEASED TO SUBMIT THE FOLLOWING FOR YOUR CONSIDERATION:

QUANTITY	DESCRIPTION	UNIT PRICE	EXTENSION
1	P/N XXXXXXX Dual Male threaded load cell 1,200,000 Lb capacity, Universal, stainless steel. (similar to our drawing # 1200105 that follows)	$3,299.00/each	
1	P/N XXXXXXX Dual Female threaded load cell 1,200,000 Lb capacity, universal, stainless steel. (similar to our drawing # 1200338 that follows)	$5,999.00/each	March 21. C$ 9407.40

***P/N XXXXXXX is To Be Determined.
Thread will be 4" you will need to provide mounting hardware for us to perform calibration.

***The above pricing does not include calibration fees. Once I know which style that you prefer I will quote you on that. I apologize for not including this pricing in the quote but I wanted to get this preliminary pricing over to you as soon as possible.

DELIVERY:	F.O.B. Huntsville, AL	TERMS: Net 30 days WAC

IMPORTANT:
Prices good for acceptance and shipment in 30 days only, Unless such time is extended in writing. Quantities shown above are not guaranteed.

RESPECTFULLY SUBMITTED,

Laurieellen Stimpson
Sales Representative

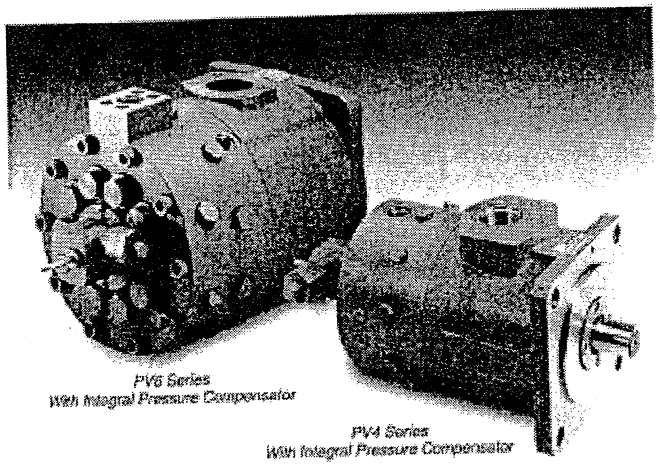
Models Available to Maintain Pressure To 8500 psi (590 bar)

High pressure pumps adjust their output flow to maintain a preset maximum pressure.

The mechanical variable delivery design provides superior efficiency with little heat build-up, even when compensating for long periods.

The integral compensator overrides a maximum volume control to smoothly and quietly regulate delivery. Fast response to load conditions assures full power in the circuit up to a pressure very close to the compensator setting.

Electro-hydraulic volume control can be achieved using a Dynex *Remote Proportional Actuator* (RPA). The bracket-mounted actuator strokes the pump volume control stem.



PV6 Series
With Integral Pressure Compensator

PV4 Series
With Integral Pressure Compensator

Installation and Operation Data

Refer to page 20 for general instructions for mechanical variable delivery pumps.

OPERATING RECOMMENDATIONS

Mechanical Volume Control

These compensated models deliver *full flow* with the volume control stem extended out of the pump.

Setting the Compensator

The desired pressure is set by turning the adjustment, .625 inch (15,88 mm) hex, clockwise for increased pressure; one-quarter turn equals approximately 1000 psi (70 bar).

The adjustment range is 1000 psi (70 bar) to the maximum intermittent pressure rating. Torque required to adjust the compensator is approximately 20 lb·in at 8000 psi (2,3 N·m at 560 bar).

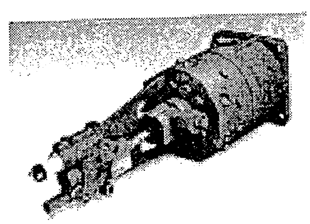
Electro-Hydraulic Pump Control

PV4000 and PV6000 Series pumps can use a bracket-mounted RPA to stroke the pump volume control stem.

The following kits include a bracket and hardware. The RPA must be ordered separately.

PV4000 Non-Compensated Models: Kit KP4026-9047;
PV4000 Compensated Models: Kit KP4020-9047;
PV6000 Compensated Models: Kit KP6046-9047

Pressure compensated PV4 Series pumps can also be ordered as a complete integral unit with an RPA and bracket. See page 23.



PV4000 Series Pressure Compensated Pump With Electro-Hydraulic Control

RPA SPECIFICATIONS

Pumps using an RPA for electro-hydraulic volume control require a separate pilot supply.

For complete RPA specifications, refer to Bulletin EES.RPA.

Supply Pressure

Minimum, 200 psi (15 bar);
Maximum, 3000 psi (210 bar).

Required Flow

50 in³ (820 cm³) per minute at 200 psi (15 bar).

Maximum Return Pressure

10% of supply pressure.

Minimum Filtration Levels

10 μ nominal.

Electrical Requirements

Rated Voltage, ± 12 V (D.C.);
Full Stroke Voltage, ± 9 V (D.C.);
Rated Input Current, ± 490 mA;
Resistance, 24.5 Ω;
Wattage, 5.9 W;
Inductance at 1.0 kHz ± 60 mHz

Pump Type

Mechanical variable delivery with integral pressure compensation override. These pumps are not bi-directional and rotation must be specified (viewed from shaft end).

Electro-hydraulic models utilize a Dynex RPA which strokes the pump volume stem control.

Mounting

S.A.E. D 4-bolt pattern with 0.25 inch (6,4 mm) pilot engagement;
1.25 inch (31,8 mm) diameter shaft.

Weight (Mass)

Manual Control Models:
140 lb (63,5 kg);
Electro-hydraulic Control Models:
156 lb (70,8 kg)

Installation Notes

Note the radial position of the inlet/drain port. This port is 38° from the vertical centerline for PV4020 models and 36° from the centerline for PV4026 and PV4033 models.

Inlet/Drain Port

The inlet/drain port has a dual function, allowing fluid to travel in both directions. Acting as an inlet, the port increases volumetric efficiency during the piston suction stroke. More fluid is available to improve filling of the piston chamber.

Acting as a drain, the port diverts unused fluid at low pressure from the piston chamber, providing improved internal circulation which dissipates heat. Even when operating for extended periods of time at full compensation, the pump temperature will remain stable. To allow proper draining, pressure at this port should not exceed 50 psi (3,4 bar).

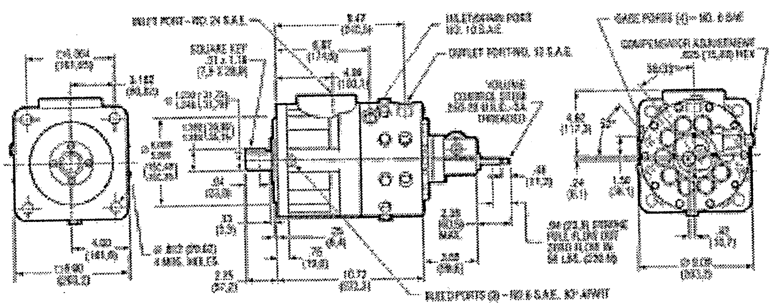
Assembly of RPA/Bracket

For ease of shipping, electro-hydraulic models are shipped as two sub-assemblies. The RPA/bracket sub-assembly must be mounted to the rear of the pump using the tie rods and nuts provided with the pump. Recommended torque is 40 lb-ft (54 N·m).

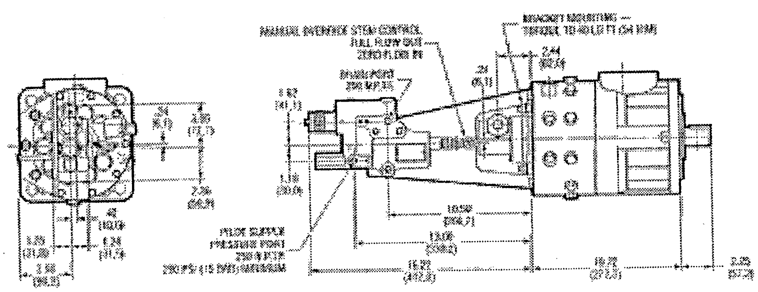
SPECIFICATIONS

Pump Model Numbers[2] Manual Stem Control	Pump Model Numbers[2] Electro-Hydraulic Control	Flow at 1800 rpm[1] U.S. gpm	Flow at 1800 rpm[1] L/min	Rated Pressure psi	Rated Pressure bar	Maximum Intermittent Pressure psi	Maximum Intermittent Pressure bar	Rated and Maximum Speed (rpm)
PV4020-3046	PV4020-3187	12.0	45,4	8500	590	8500	590	1800
PV4026-3126	PV4026-3188	18.1	68,5	4000	280	6000[3]	420[3]	1800
PV4033-3127	PV4033-3189	22.2	84,0	4000	280	6000[3]	420[3]	1800

① Output flow based on typical performance at rated pressure with pressurized inlet where required.
② Models shown are for clockwise rotation and deliver full flow with the volume stem actuator in the "out" (fully extended) position. For counter clockwise rotation and other control options, contact the Dynex sales department.
③ For higher intermittent pressures contact the Dynex sales department for a review of your application requirements.

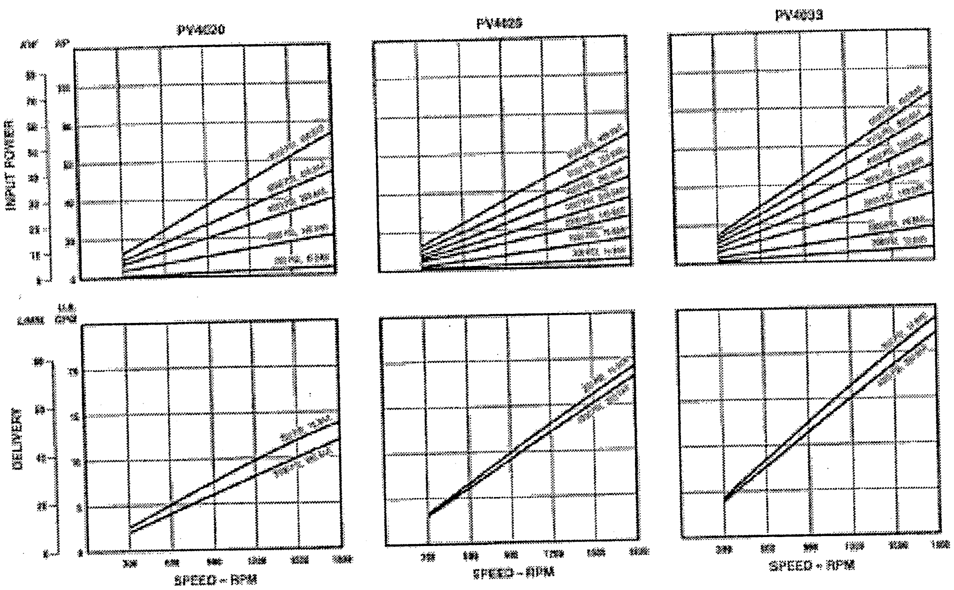


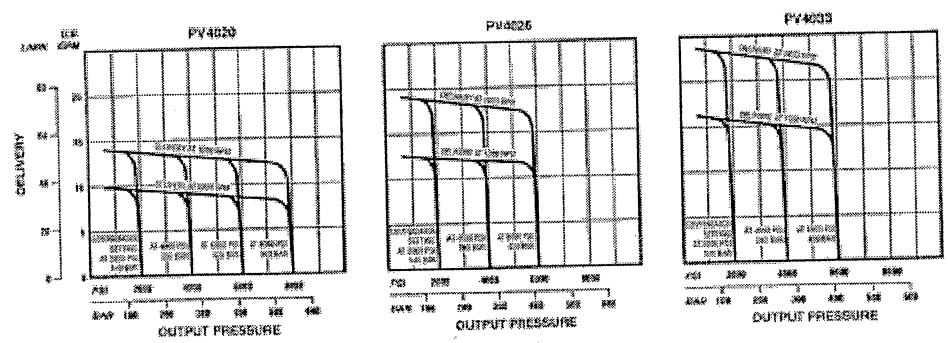
Manual Volume Control Pressure Compensated Models

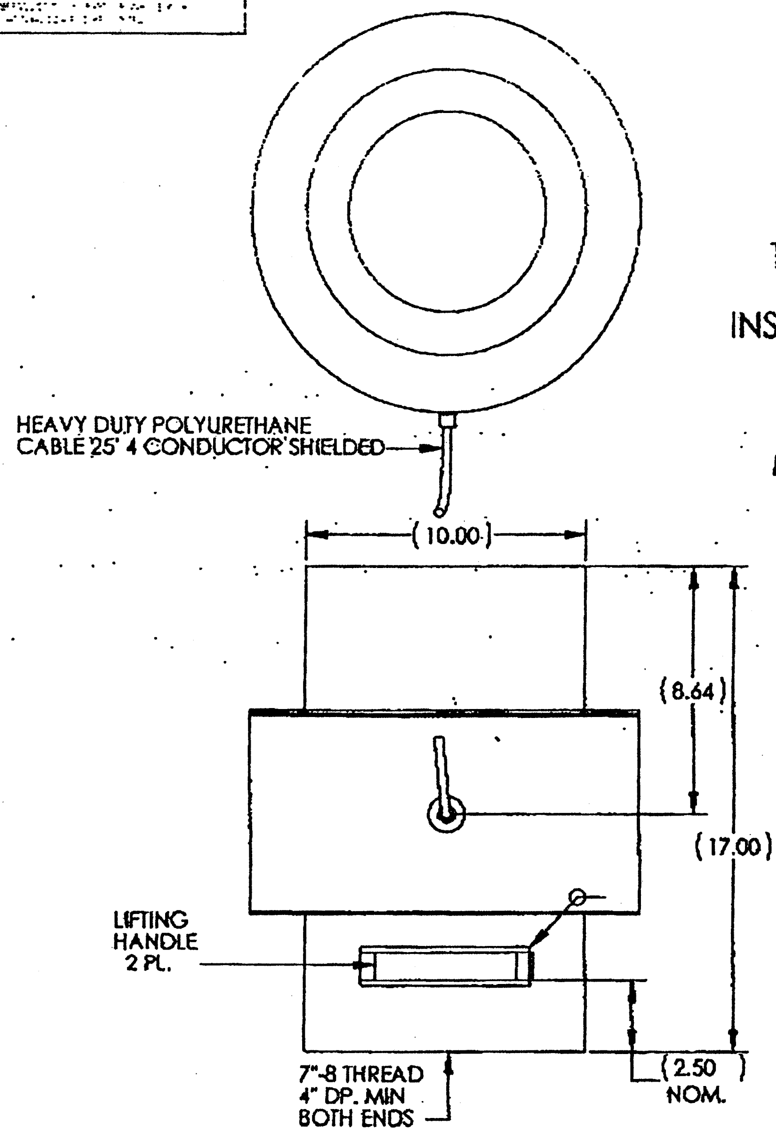


Electro-Hydraulic Volume Control Pressure Compensated Models

TYPICAL PERFORMANCE CURVES







CONSTRUCTION:STAINLESS STEEL HERMETIC
EXC. VOLTAGE:10-15 VDC or VAC
OUTPUT:1.5 mV/V NOM.
TEMPERATURE RANGE:10 to 110°F
BRIDGE RESISTANCE:350 OHMS NOM.
INSULATION RESISTANCE:5000 MEGOHMS MIN.
LINEARITY:.25% F.S.
REPEATABILITY:.1% F.S.
MAX. LOAD SAFE:150% OF RATED CAP.
MAX. LOAD ULTIMATE:200% OF RATED CAP.

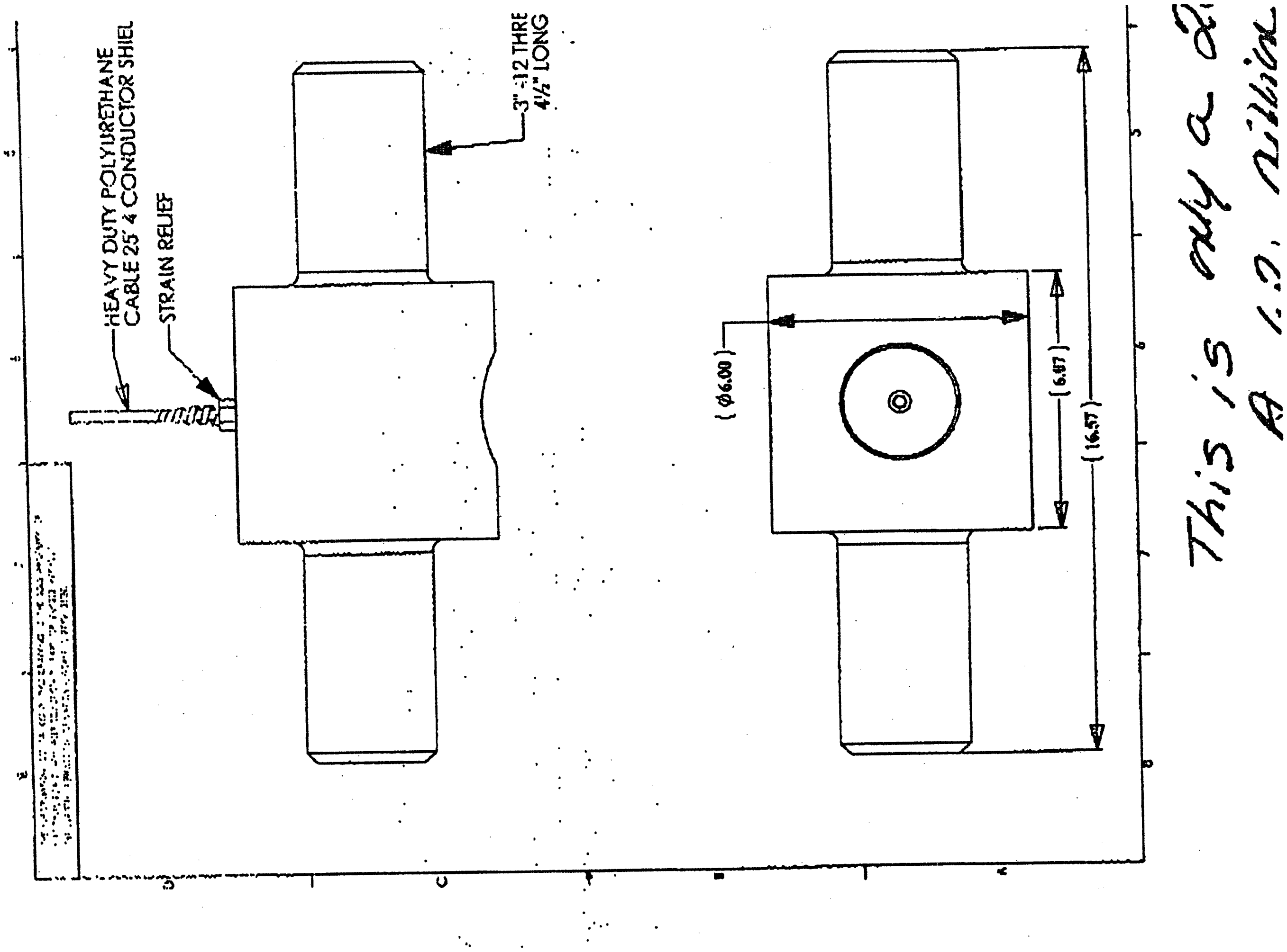
WIRE CODE
+EXC:GREEN
-EXC:BLACK
+SIG:WHITE
-SIG:RED

NATIONAL SCALE TECHNOLOGY
690 Discovery Dr. Huntsville Al. 35806

U2000 1.5 MILLION LB.
TENSION L.C. @1.5 mV/V

BI 6/20/01
JS 6/20/01
1200105
1200105
1200105
SHEET 3 of

DO NOT SCALE DRAWING


HEAVY DUTY POLYURETHANE CABLE 25' 4 CONDUCTOR SHIEL
STRAIN RELIEF
3"-12 THRE 4½" LONG
(Ø6.00)
(6.87)
(16.57)
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Fax 709-737-4042
Atn: David Bursey

QUOTATION NO.MULS030502WH
DATE: March 27, 2002

WE ARE PLEASED TO SUBMIT THE FOLLOWING FOR YOUR CONSIDERATION:

QUANTITY	DESCRIPTION	UNIT PRICE	EXTENSION
1	P/N XXXXXXX **Shear Web Universal Load Cell** 1,200,000 Lb. capacity, Stainless Steel.	$4,399.00	

**The above pricing does not include calibration fees.

DELIVERY:	F.O.B. Huntsville, AL	TERMS: Net 30 days WAC

IMPORTANT:
Prices good for acceptance and shipment in 30 days only, Unless such time is extended in writing. Quantities shown above are not guaranteed.

RESPECTFULLY SUBMITTED,

Lauriellen Stimpson
Sales Representative

DYNEX
High Pressure Hydraulics

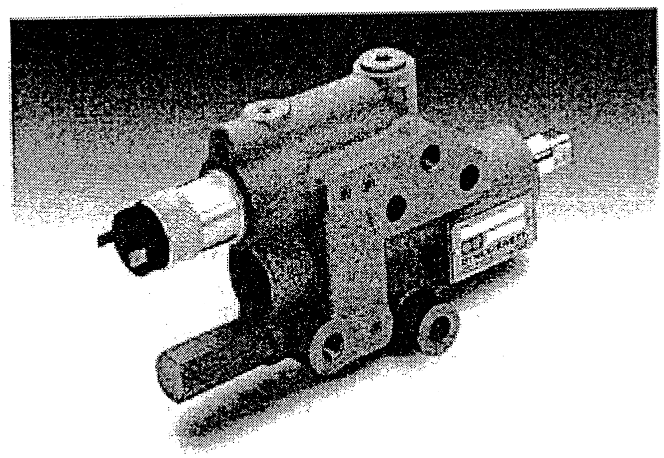
▲ ▲ ▲ ▲ ENGINEERING SPECIFICATIONS

Electro-hydraulic Remote Proportional Actuators

SA SERIES
1200 lbs. (5,33 kN) Output Force

Remote Proportional Actuators (RPA) produce output rod displacement proportional to an electrical input signal.

RPA's can be used to remotely control variable volume pumps and motors. They can also be used to stroke spools of large valves, throttle controls, clutches or brakes.



COMPACT DIRECT MOUNTING

These actuators are ideal where machine size or component location make it impossible to operate a component directly.

Compact size and direct mounting makes it easy to convert existing components for remote electro-hydraulic control.

ACCURATE REMOTE CONTROL

The RPA provides accurate control without additional electronic feedback. Movement of the rod is proportional to the electrical signal, with force determined by the supply pressure.

Complex tasks can be performed with high speed and accuracy, using position sensors or microprocessor input.

These actuators feature *Mechanical Position Feedback*. This patented design monitors and controls the position of the output rod.

ELECTRICAL DATA

Specifications	Actuator Model (Voltage)	
	12 Volts DC	10 Volts DC①
Rated Voltage	± 12 VDC	± 10 VDC
Full Stroke Voltage	± 9 VDC	± 9 VDC
Rated Input Current	± 490 ma	± 510 ma
Resistance	24,5 Ohms	19,7 Ohms
Wattage	5,9 Watts	5,1 Watts
Inductance at 1,0 KHz	± 60 MH	± 60 Mz
Recommended Dither②	± 2 V, 80 Hz Square Wave	± 2 V, 80 Hz Square Wave
Pulse Width Modulation Frequency②	100 to 120 Hz	100 to 120 Hz

① Certified by "Mine Safety and Health Administration" as Intrinsically Safe up to ±10 VDC.
② Dither not required except as noted: Actuators with 1,0 inch (25,4 mm) stroke when operated with a supply pressure below 1000 PSI (70 Bar), and all "High Response" models must have a dither signal superimposed on the input signal or be driven with a pulse-width modulated signal.

SPECIFICATIONS:

Maximum Stroke Options
Extend or retract 0.5 inch (12,7 mm), with change in polarity;
Extend 1.0 inch (25,4 mm) or retract 1.0 inch (25,4 mm), with current increase.

Supply Pressure
Minimum, 200 PSI (15 bar);
Maximum, 3000 PSI (210 bar)

Output Force
60 lbs. (0,27 kN) at 200 PSI (15 bar) supply pressure;
1200 lbs. (5,33 kN) at 3000 PSI (210 bar) supply pressure.

Required Flow
50 cu.in (820 cc) per minute at 200 PSI (15 bar). See performance curves on page 3.

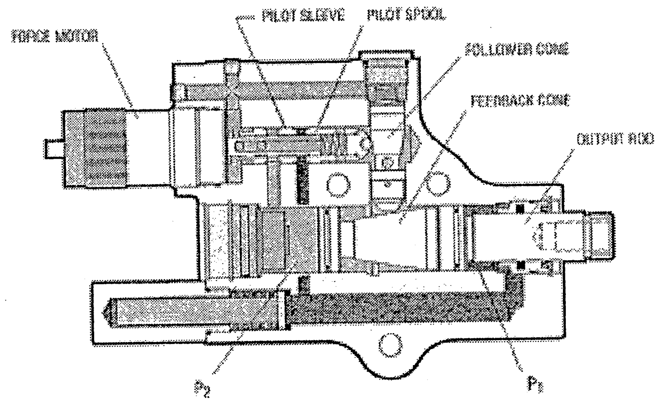
Maximum Return Pressure
10% of supply pressure.

Seals
Buna-N standard. Contact the Dynex sales department for information on optional Fluorocarbon (Viton® or Fluorel®) seals.

How the Actuator Works

The RPA consists of a force motor, a pilot stage (with a pilot spool and pilot sleeve) and an output rod.

Pilot supply passes through an internal filter and is routed directly to the pressure chamber (P_1) and through the pilot stage to the control chamber (P_2).



A FORCE BALANCE IS ACHIEVED

In the absence of an electrical signal, the pilot stage maintains the control pressure (P_2) at a level equal to one-half of the supply pressure (P_1).

Since the control chamber (P_2) has an effective area twice the effective area of the pressure chamber (P_1), a force balance is achieved by the pressures acting on the output rod.

MECHANICAL POSITION FEEDBACK

The pilot spool rides within the pilot sleeve and is held in contact with the force motor armature by a spring. The pilot sleeve is held in contact with the follower cone by a spring. Likewise the follower cone is held in contact with the feedback cone on the output rod.

As the rod moves back and forth, the follower cone moves up and down forcing the pilot sleeve to move through a proportional distance.

The force motor moves the pilot spool in reaction to the variable electrical signal.

METERED FLOW MOVES ROD

When the pilot spool is displaced relative to the pilot sleeve, it meters flow in or out of the control chamber (P_2) causing a change in pressure. Once the pressure between P_1 and P_2 becomes unequal, the output rod moves.

As the output rod moves, the follower cone rides along the feedback cone moving the pilot sleeve until it realigns itself with the pilot spool.

At this point, a null condition is achieved and movement of the output rod stops. The output rod will always seek an internal force balance.

The result is accurate rod movement proportional to the electrical signal.

Actuator Installation And Performance

Installation drawing dimensions are shown in millimeters and are nominal. Refer to the *Variable Dimensions* table on page 3 for dimension "A".

Typical Performance

See *"Typical Performance Curves"* on page 3 for step response;

Thermal null shift:
≤1% per 100°F. (40°C.);

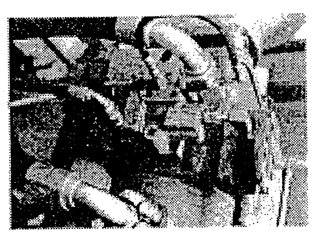
Pressure null shift:
≤3% per 1000 PSI (70 bar);

Hysteresis:
≤+3% with dither, ≤+4% without dither;

Threshold:
≤2% with dither, ≤3% without dither

Fluid Recommendations

High grade premium petroleum-based oil, with a combination of anti-wear, demulsibility, oxidation, rust protection and foam resistance properties.



An RPA can be direct mounted to control the delivery of a Sundstrand piston pump.

Guidelines for viscosity

Minimum, 45 SUS (6 cSt);
Maximum, 6000 SUS (1320 cSt)

Minimum Filtration Levels

10 microns nominal.

Mounting

To allow self-bleeding of air, the actuator must be mounted so the pressure port (P) is at the same level or below the return/tank port (T).

For more information on suppliers for controllers and electronics to be used with these actuators, contact your Dynex sales representative.

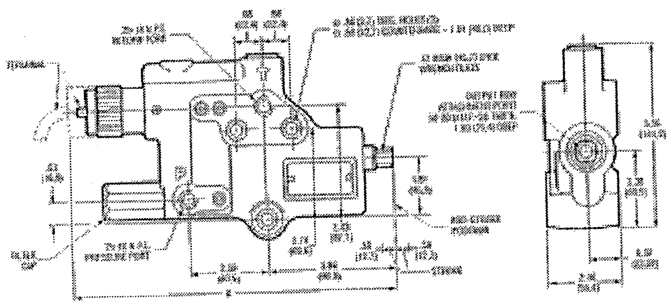
Hydro-static Transmission Applications

The actuator may be operated directly off the charge pump pressure of a hydrostatic transmission. No additional pressure supply is needed.

DIMENSIONS

Installation drawing dimensions are shown in inches (mm in parentheses) and are nominal.

The table below shows variable dimensions for "A" for the three coil/terminal options.

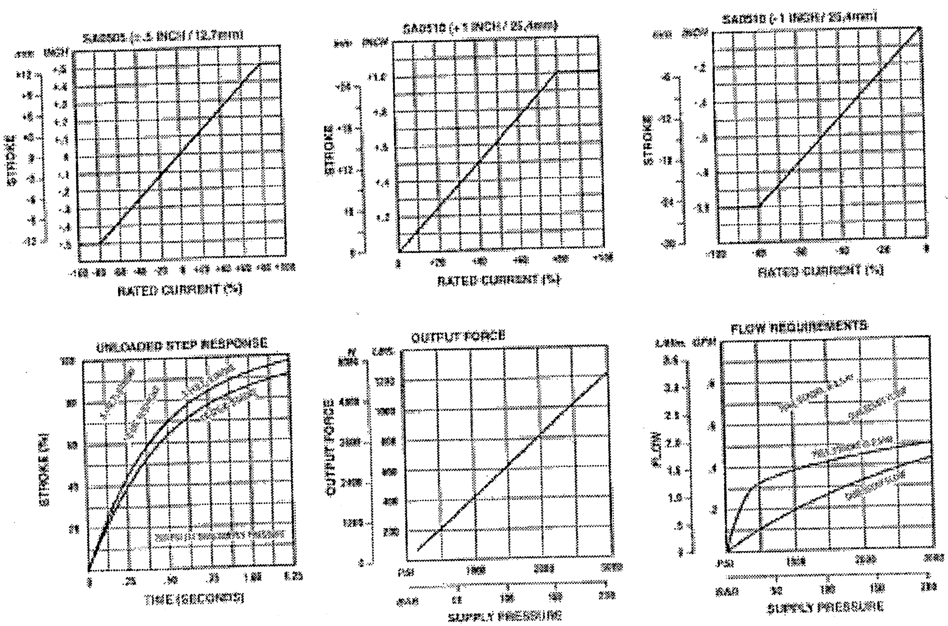


VARIABLE DIMENSIONS

Coil Option	Terminal Configuration	Dimension "A" Inches	Dimension "A" mm
10 VDC[®]	2-Wire Cable (18 gage x 91 cm)	10.25	260,4
12 VDC	2 Male Spades (6,4 wide x 0,8 thick)	10.00	254,0
12 VDC	2 Male No. 6 Terminals	9.70	246,4

® *Intrinsically Safe*

PERFORMANCE CURVES

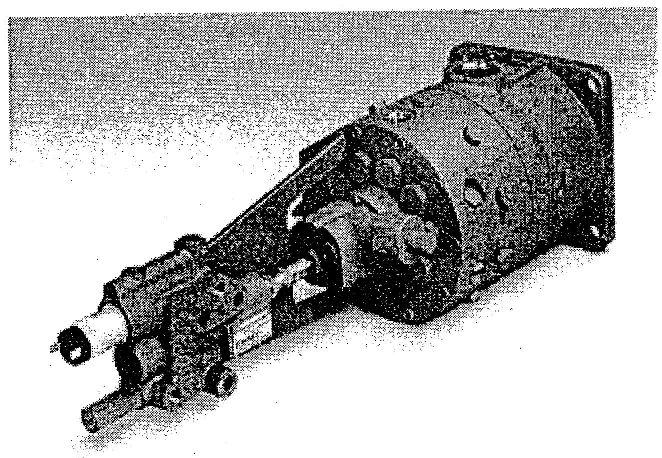


Performance curves for "High Response" models shown in gray.
Typical curves based on 100 SUS (20 cSt) petroleum-based fluids at 120° F. (50°C.).

Electro-hydraulic Pump Volume Control

The RPA can be used to control the output of Dynex variable delivery checkball pumps.

Kits, shown below, are available to mount the actuator to the pumps. These kits include a bracket and necessary hardware. The RPA must be ordered separately.



A Remote Proportional Actuator can control a Dynex variable delivery checkball pump. Output flow is controlled by stroking the spring-biased linear stem actuator at the back of the pump.

ACTUATOR MOUNTING KITS

Kit Number	Dynex Pump Series	Pump Type
KP4026-9047	PV4000	Variable Delivery
KP4030-9047	PV4000	Pressure Compensated
KP6046-9047	PV6000	Pressure Compensated

Typical Model Code

SA 05 05 — 03 00

Product Type
SA — Remote Proportional Actuator

Design
05 — Standard

Maximum Stroke
05 — ± 0.5 inch (12,7 mm)
10 — + 1.0 inch (25,4 mm); Extends with Voltage Increase
15 — − 1.0 inch (25,4 mm); Retracts with Voltage Increase

Rated Voltage
02 — 10 VDC, Intrinsically Safe, (Single Coil)
03 — 12 VDC (Single Coil, Spade Terminals)
04 — 12 VDC (Single Coil, Stud Terminals)

Response
00 — Standard
02 — High Response

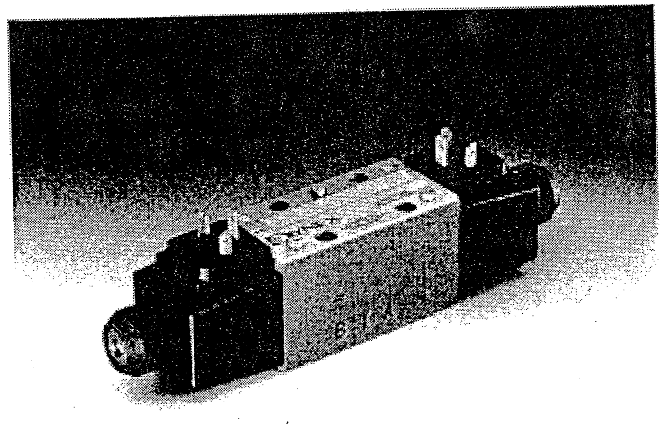
DYNEX

DYNEX/RIVETT INC.

USA Headquarters
770 Capitol Drive
Pewaukee, WI 53072
(414) 691-2222
FAX: 414-691-0312

Power Units & Systems
54 Nickerson Road
Ashland, MA 01721
(508) 881-5110
FAX: 508-881-6849

European Sales
Unit C5 Steel Close, Little End Road,
Eaton Socon, Huntingdon,
Cambs. PE19 3JH United Kingdom
Tel: (01480) 213980
FAX: 01480-405662



Compact Spool Valves Rated to 10 000 psi (700 bar)

HP03 valves are rated for 5 U.S. gpm (19 L/min) nominal flow at pressures to 10 000 psi (700 bar). Flows to 15 U.S. gpm (57 L/min) are possible with some models.

These high performance valves operate at pressures double that of conventional subplate mounted valves.

SMOOTH, PRECISE SHIFTING

The reliable sliding-spool valves provide true four-way control in a simple compact package.

A four-land spool design assures exceptionally smooth spool travel. Additional outboard lands provide greater support, eliminating spool imbalance. Balancing grooves reduce silt buildup, providing precise spool centering.

RANGE OF OPTIONS AVAILABLE

Select from manual, solenoid, hydraulic or air-pilot operation with a range of spools, internal operators and electrical options.

SPECIFICATIONS

Special Mounting
Although similar to standard N.F.P.A. D03 (CETOP 3) valves in size, HP03 valves require a special mounting pattern. Refer to drawing on page 21.

Rated Pressure
10 000 psi (700 bar)

Rated Flow
5 U.S. gpm (19 L/min) nominal; See *"Typical Valve Performance"* on page 19.

Maximum Tank Port Pressure
Manual Operated Models:
3000 psi (210 bar);
Solenoid Actuated Models:
Standard,
1000 psi (70 bar) dynamic,
3000 psi (210 bar) static;
High Pressure Option ("HPT"),
3000 psi (210 bar) dynamic,
5000 psi (350 bar) static;
Hydraulic and air actuated models:
Standard, 1500 psi (105 bar);

Response Time (Full Stroke)
Solenoid Energized:
A.C., 12 ms; D.C., 20 ms
Spring Returned:
A.C., 15 ms; D.C., 20 ms

Electrical Connections
Standard Wiring Box with leads;
Optional Terminal Strip, Cable Grip or Pin Connector (N.F.P.A. standard T3.5-29-1980; A.N.S.I. standard B93,55M-1981);
Optional Plug-in-Terminal Solenoids fit DIN Connector Standard 43650 (Hirschmann GDM 209)

Explosion Proof ("EPW" Option)
Solenoids with special enclosures are approved by *UL* and *CSA* for use in hazardous locations.
UL Classification:
Class I, Group C, D;
Class II, Group E, F, G

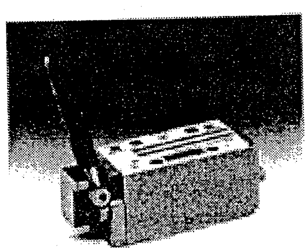
CSA/UL Recognized ("C" Option)
Solenoid coils are printed with the symbol:
c**RU** (*CSA* and *UL* Recognized)
Available with 115/DF coils only. For other voltages, contact the Dynex sales department.

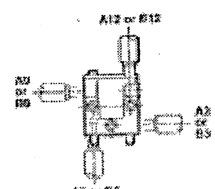
MANUAL OPERATED MODELS

Lever operated models offer handle position flexibility with four positions on either port "A" end or port "B" end of valve.

In-the-field changes are easy, by removing the bracket assembly and rotating the handle to the desired position.

To specify position, see *"Typical Model Code"* on page 24 and refer to the drawing at right.





Handle Position Viewed from Port "A" or Port "B" End of Valve

SOLENOIDS

Models are available with A.C. or D.C. solenoids. For detailed information on electrical options see pages 8-10.

The table shows electrical specifications for these valves.

SPOOL SELECTION

For a description of spools and operator functions, see pages 6-7.

Note that lever actuated models, with Code 1 or Code 2 internal operators, use *Type 0* or *Type 1* spools. All other models with Code 1 or Code 2 internal operators use *Type 20* or *Type 21* spools.

Type 0 and *Type 1* spools provide the same function, but are not interchangeable with *Type 20* or *Type 21* spools.

ELECTRICAL DATA

Solenoid Code[1]	Input Voltage (Volts)	Frequency (Hz)	Inrush Current (Amps)	Holding Current (Amps)	Holding Power (Watts)	Coil Resistance (Ohms ± 10%)
24/DF	24 A.C.	50	9.50	2.60	27	1.67
(Dual Frequency)	24 A.C.	60	6.60	1.75	22	1.67
115/DF	110 A.C.	50	1.65	.47	20	40.00
(Dual Frequency)	115 A.C.	60	1.55	.40	20	44.00
230/DF	220 A.C.	50	.80	.22	20	150.00
(Dual Frequency)	230 A.C.	60	.80	.18	20	150.00
460/DF	440 A.C.	50	.40	.13	22	600.00
(Dual Frequency)	460 A.C.	60	.41	.10	21	600.00
12 VDC	12 D.C.	—	—	—	28	5.10
24 VDC	24 D.C.	—	—	—	28	20.60
12VDC EPW	12 D.C.	—	—	—	33	4.36
24VDC EPW	24 D.C.	—	—	—	33	17.50
110/50 EPW	110 A.C.	50	1.80	.54	23	35.20
115/60 EPW	115 A.C.	60	1.90	.50	23	33.50

[1] *Ordering Codes shown are for standard wire leads with wiring box. "Plug-In-Terminal" solenoids (Hirschmann GDM 209) are also available; see "Typical Model Code" on page 17.*

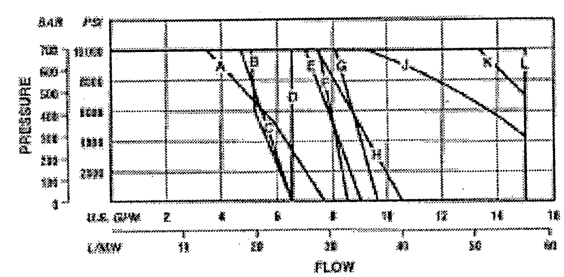
Typical Valve Performance

SOLENOID MODELS

The curves show typical flow capacity for each spool type. The letters in the *"Flow Curve Reference"* table identify the appropriate curve.

For example, in the table under spool Type 0, curve "L" is called out for models with Code 5 internal operators and D.C. solenoids. Looking at the curves, "L" indicates a maximum capacity of 15 U.S. gpm (57 L/min) at pressures to 10,000 psi (700 bar).

FLOW CAPACITY — SOLENOID MODELS



FLOW CURVE REFERENCE

Operator Code	Solenoid Type	Spool Type 0	20	1	21	3	4	011	2	2R	32	32R	36	03
1	All Types	—	K	—	L	—	—	—	—	—	—	—	—	—
2	All Types	—	K	—	L	—	—	—	—	—	—	—	—	—
3	All Types	B	—	L	—	—	—	—	—	—	—	—	—	—
4	A.C.	E	—	L	—	L	L	G	A	A	C	C	D	H
	D.C. & "EPW"	L	—	L	—	L	L	G	G	G	L	L	L	L
5	A.C.	E	—	L	—	L	L	G	A	A	C	C	D	H
	D.C. & "EPW"	L	—	L	—	L	L	G	G	G	L	L	L	L
6	All Types	L	—	L	—	L	L	F	F	F	L	L	L	J

LEVER OPERATED MODELS

Most manual models are rated for 15 U.S. gpm (57 L/min) maximum. Exceptions are models with operators and spool types shown below.

FLOW LIMITATIONS

Operator Code	Spool Type	Maximum Flow U.S. gpm	Maximum Flow L/min
1	0	7.0	26
	1	8.0①	30①
	03	7.0	26
2	0	7.0	26
	1	8.0①	30①
	03	7.0	26
3	1	8.0①	30①
	011	7.5	28
	2 or 2R	7.5	28
5	1	8.0①	30①
7	1	8.0①	30①

① 8 U.S. gpm (30 L/min) at 10,000 psi (700 bar). Flow capacity increases with reduced pressure; i.e., 11 U.S. gpm (41 L/min) at 2000 psi (140 bar).

PILOT OPERATED MODELS

The maximum flow for pilot operated models is dependent on pilot pressure. Generally, the maximum flow for most pilot operated valves is 8 U.S. gpm (30 L/min). When using a Type 011 spool (tandem center), the maximum flow rating is 6 U.S. gpm (23 L/min).

Minimum Pilot Pressure

The table shows the minimum pressure required to shift the spool at 5 U.S. gpm (19 L/min). These values are based on zero tank pressure. For hydraulic piloted models, as back pressure increases above zero, the minimum pilot pressure must be increased equally.

Maximum Pilot Pressure

Hydraulic: 3000 psi (210 bar);
Air: 200 psi (14 bar)

Maximum Volume

To shift spool full stroke:
Hydraulic, 0.014 in³ (0,23 cm³);
Air, 0.220 in³ (3,61 cm³)

MINIMUM PILOT PRESSURE

Series	Spool Type	Pilot Pressure at 5 U.S. gpm (19 L/min) psi	bar
6000 Series Hydraulic Piloted	0 or 20	215	14,8
	1 or 21	215	14,8
	3	215	14,8
	4	215	14,8
	011	360	24,8
	2 or 2R	360	24,8
	32 or 32R	260	17,9
	36	260	17,9
	03	215	14,8
6900 Series Air Piloted	0 or 20	35	2,4
	1 or 21	28	1,9
	3	35	2,4
	4	35	2,4
	011	50	3,4
	2 or 2R	50	3,4
	32 or 32R	40	2,8
	36	35	2,4
	03	35	2,4

Determining Valve Efficiency

PRESSURE DROP

The curves indicate pressure drop for all HP03 valves, except manual operated (see page 21 for those curves).

These curves show resistance to flow for specific flow paths and various spool types. The *"Flow Curve Reference"* table identifies the proper curve.

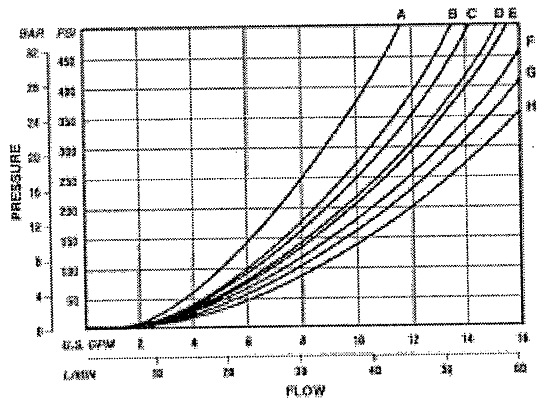
Maximum flow capacity depends on valve actuator, internal operator, spool type and other application factors. Refer to *"Typical Valve Performance"* on pages 19-20.

AN EXAMPLE

In the table under spool Type 1, curve "D" is called out to determine the pressure drop for P→A. Looking at the curves, "D" indicates a drop of about 65 psi at 5 U.S. gpm (4,5 bar at 19 L/min).

To determine total "loop" drop, the individual pressure drops for P→A and B→T (or P→B and A→T) must be added.

PRESSURE DROP (ΔP) — ALL MODELS EXCEPT LEVER ACTUATED



FLOW CURVE REFERENCE

Flow Path	0	20	1	21	3	4	011	2	2R	32	32R	36	03
P→A	B	B	D	E	B	D	C	C	C	B	B	B	B
P→B	B	B	D	E	B	D	C	C	C	B	B	B	B
A→T	E	E	G	G	H	E	E	E	E	E	E	E	—
B→T	E	E	G	G	H	E	E	E	E	E	E	E	—
P→T	—	—	D	D	—	—	A	A	A	—	—	—	—

LEVER ACTUATED MODELS

The curves indicate pressure drop for lever actuated HP03 valves.

These curves show resistance to flow for specific flow paths and various spool types. The *"Flow Curve Reference"* table identifies the proper curve.

Maximum flow capacity depends on valve actuator, internal operator, spool type and other application factors. Refer to the *"Flow Limitations"* table on page 20.

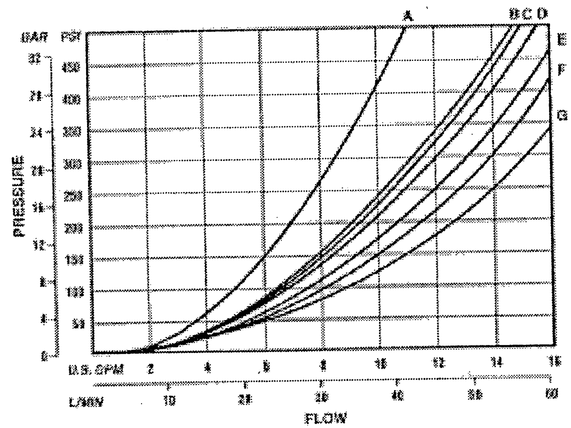
AN EXAMPLE

In the table under spool Type 1, curve "C" is called out to determine the pressure drop for P→A. Looking at the curves, "C" indicates a drop of about 60 psi at 5 U.S. gpm (4,1 bar at 19 L/min).

To determine total "loop" drop, the individual pressure drops for P→A and B→T (or P→B and A→T) must be added.

For example, curve "G" is used for the return flow B→T for spool Type 1. Curve "G" indicates a pressure drop of 30 psi at 5 U.S. gpm (2,1 bar at 19 L/min). Adding the individual pressure drops results in a "loop" drop through the valve in both directions of 60 + 30 = 90 psi (4,1 + 2,1 = 6,2 bar).

PRESSURE DROP (ΔP) — LEVER ACTUATED MODELS



FLOW CURVE REFERENCE

Flow Path	Spool Type 0	1	3	4	011	2	2R	32	32H	33	03
P→A	B	C	B	C	B	B	B	B	B	B	B
P→B	B	C	B	C	B	B	B	B	B	B	B
A→T	F	G	G	F	D	D	D	F	F	F	—
B→T	F	G	G	F	D	D	D	F	F	F	—
P→T	—	B	—	—	A	A	A	—	—	—	—

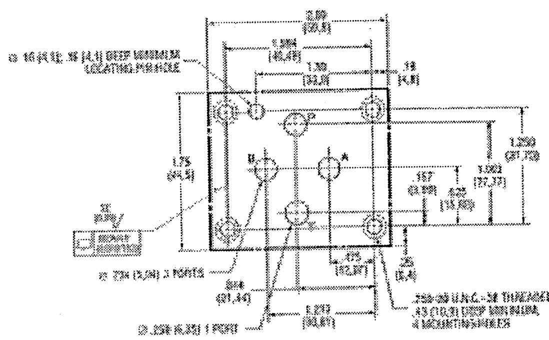
Installation and Dimensions

SPECIAL VALVE MOUNTING

The mounting surface drawing shows the minimum flush or raised surface required for this special pattern.

Mounting face must be flat within 0.0004 inch/4.0 inches (0,010 mm/102 mm) with a surface finish of 32 microinch (0,80 µm) AA.

Port o-rings are included with all valves. Mounting bolts must be ordered separately; .250-20 U.N.C. Threaded x 0.75 inch (19 mm). Grade 8 or better; four required. Recommended mounting torque is 12 lb·ft (16 N·m) maximum.



Minimum Mounting Surface, Special HP03 Pattern

SOLENOID MODEL DIMENSIONS

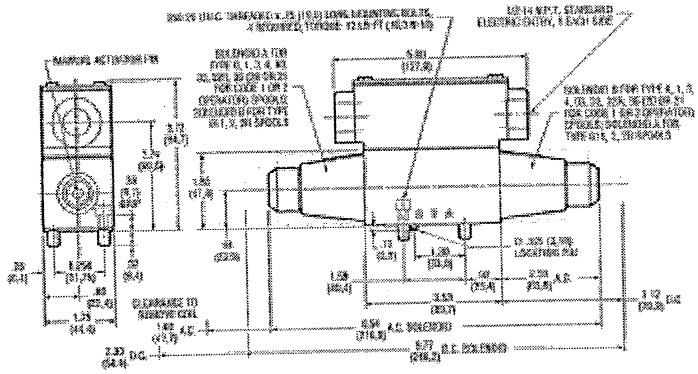
Dimensions are shown for both A.C. and D.C. solenoids; D.C. configuration is shown printed in gray.

Overall length of single solenoid configuration (not shown) is 6.78 inches (172,2 mm), A.C.; and 7.39 inches (187,7 mm), D.C.

Weight (Mass)

Single Solenoid:
- A.C., 3.4 lb (1,5 kg);
- D.C., 3.9 lb (1,8 kg)

Double Solenoid:
- A.C., 4.0 lb (1,8 kg);
- D.C., 5.3 lb (2,4 kg)



6500 Series, Double Solenoid Models

EXPLOSION PROOF SOLENOIDS

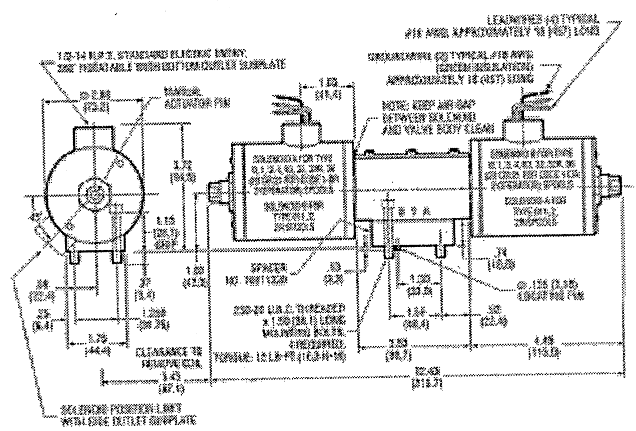
Solenoids with special enclosures are approved by *UL* and *CSA* for use in hazardous locations. Overall length of single solenoid model (not shown) is 8.23 inches (209,0 mm).

Note that spacer plate, 10811320, is required when valves are mounted on manifolds, side outlet subplates or when used as a pilot valve.

Valves can be mounted without removing nameplate. Openings in plate provide access to mounting holes in valve body.

Weight (Mass)

Single Solenoid: 8.3 lb (3,8 kg);
Double Solenoid: 14.0 lb (6,4 kg)



6500 Series, Double "EPW" Solenoid Models

HIGH PRESSURE HP03 PATTERN

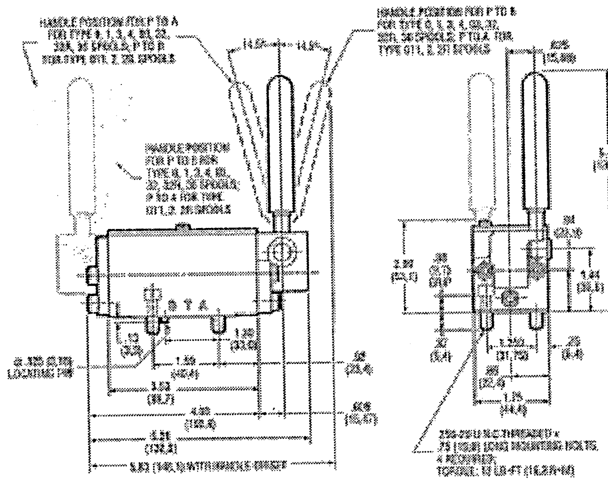
MANUAL OPERATED MODELS

Manual models are lever actuated, with handle located in a choice of four positions on either port "A" or port "B" end of valve.

Valves can be mounted without removing nameplate. Openings in nameplate provide access to mounting holes in valve body.

To specify handle position, see the drawing on page 18 and refer to *"Typical Model Code"* on page 24.

Weight (Mass)
3.2 lb (1,5 kg)



6100 Series, Manual Lever Operated Models

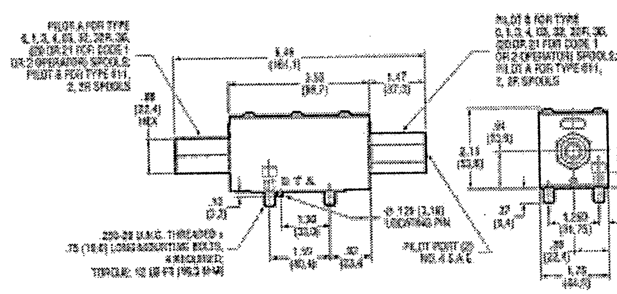
HYDRAULIC PILOTED MODELS

Single and double actuator models are available. Overall length of single actuator configuration (not shown) is 5.25 inches (133,4 mm).

Valves can be mounted without removing nameplate. Openings in nameplate provide access to mounting holes in valve body.

Refer to page 20 for required shifting pressure and volume.

Weight (Mass)
Single Actuator: 2.5 lb (1,1 kg);
Double Actuator: 2.8 lb (1,3 kg)



6800 Series, Double Hydraulic Piloted Models

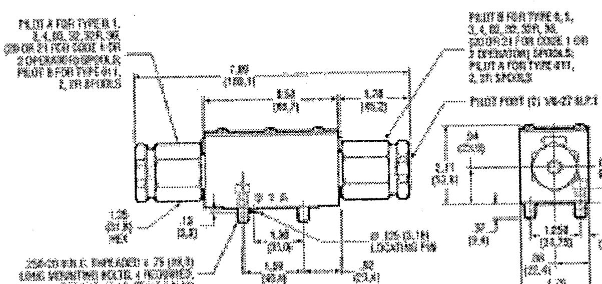
AIR PILOTED MODELS

Single and double actuator models are available. Overall length of single actuator configuration (not shown) is 5.56 inches (141,2 mm).

Valves can be mounted without removing nameplate. Openings in nameplate provide access to mounting holes in valve body.

Refer to page 20 for required shifting pressure and volume.

Weight (Mass)
Single Actuator: 2.3 lb (1,0 kg);
Double Actuator: 2.5 lb (1,1 kg)



6900 Series, Double Air Piloted Models

Typical Model Code

6 5 4 0 — HP03 — 115/DF — R — ✻ — SL — 2 0

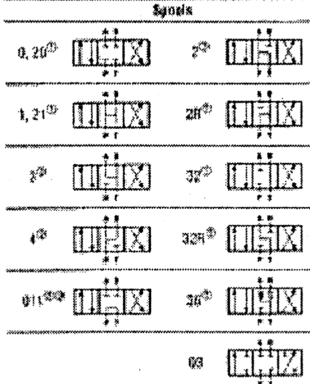
Valve Type
6 — Special Mounting Directional Control

Actuator
1 — Manual Lever
5 — Solenoid Operated
8 — Hydraulic Piloted
9 — Air Piloted

Internal Operator
1 — Two Position; Spring Offset (P→B), Actuator Offset (P→A)
2 — Two Position; Spring Offset (P→A), Actuator Offset (P→B)
3 — Two Position; Actuator Offset, Detented for Non-Manual Actuators[1]
Three Position; Detented for Manual Lever
4 — Two Position; Spring Centered, Actuator Offset[2]
5 — Three Position; Spring Centered, Actuator Offset
6 — Two Position; Spring Offset, Actuator Centered[2]
7 — Manual Lever Only: Two Position, Detented

[1] Only available with Type 0, Type 1 and Type 03 spools.
[2] Not available with Manual Lever Operated valves.

Spools



✻ Code 1 or Code 2 operators (non-lever actuated models) use Type 20 or Type 21 spools. These spools provide the same function, but are not interchangeable with Type 0 or 1 spools.
[2] Not available with Type 3 Internal Operators (except manual lever models).
[3] Open crossover

Valve Size
HP03 — High Pressure, Special Mounting Pattern

Reverse Flow Operator (Code 4 and 6 Only)
R — Code 4: Two Position; Spring Centered, Actuator Offset (Reverse Flow)
Code 6: Two Position; Spring Offset (Reverse Flow), Actuator Centered

Design Number

Modification Number

Lever Position (Manual Models Only)
A12 — 12 o'clock position, on port "A" end of valve
A9 — 9 o'clock position, on port "A" end of valve
A6 — 6 o'clock position, on port "A" end of valve
A3 — 3 o'clock position, on port "A" end of valve
B12 — 12 o'clock position, on port "B" end of valve
B9 — 9 o'clock position, on port "B" end of valve
B6 — 6 o'clock position, on port "B" end of valve
B3 — 3 o'clock position, on port "B" end of valve

Options (Solenoid Models Only)
C — CSA and UL Recognized Coils (Etched with Symbol)[1]
M — Hand Actuated Manual Override[2]
T — Terminal Strip[2][3]
CG — Cable Grip, for .38 to .44 inch (9,5 to 11,1 mm) O.D. machine tool cable[2][3]
SL — Solenoid Lights (Available 115/DF A.C. Only)[2][3]
HPT — High Pressure Tank Port
2300 psi (160 bar) maximum A.C. models
3000 psi (210 bar) maximum D.C. models
EH3A — 3-pin Connector (N.F.P.A. standard T3.539-1980), for single solenoid models, on port "A" end of valve[2][3][4]
EH3B — 3-pin Connector, for single solenoid models, on port "B" end of valve[2][3][4]
EH5A — 5-pin Connector, for single or double solenoid models, on port "A" end of valve[2][3][4]
EH5B — 5-pin Connector, for single or double solenoid models, on port "B" end of valve[2][3][4]

[1] Available with 115/DF solenoids only. For other voltages, consult the Dynex sales department.
[2] Option not available with "EPW" solenoid models.
[3] Option not available with "Plug-in Terminal" solenoid models.
[4] N.F.P.A. standard T3.539-1980; A.N.S.I. standard B93.55M-1982.

Electrical – Solenoid Options

STANDARD SOLENOIDS:
24/DF — Dual Frequency, 24/60, 24/50
115/DF — Dual Frequency, 115/60, 110/50
230/DF — Dual Frequency, 230/60, 220/50
460/DF — Dual Frequency, 460/60, 440/50
12VDC — Direct Current, 12 Volts
24VDC — Direct Current, 24 Volts
12VDC EPW — Explosion Proof Solenoids
24VDC EPW — Explosion Proof Solenoids
115/60 EPW — Explosion Proof Solenoids
110/50 EPW — Explosion Proof Solenoids
220/50 EPW — Explosion Proof Solenoids

PLUG-IN TERMINAL SOLENOIDS:[5]
115/HAC — Dual Frequency, 115/60, 110/50
230/HAC — Dual Frequency, 230/60, 220/50
12/HDC — Direct Current, 12 Volts
24/HDC — Direct Current, 24 Volts

For Other Voltages, Consult the Dynex Sales Department

[5] Fits DIN Connector Standard 43650 (Hirschmann GDM 209)

24

Internal Operators and Application Data

INTERNAL OPERATORS

The table shows available internal operators and the most common spools. For other spool options, contact the Dynex sales department.

To specify correct valve function, it is important to refer to the *"Typical Model Code"* for each specific model.

Function symbols show solenoid actuated models, as reference. Air, hydraulic or lever actuators are also available. Flow pattern in the center position or during crossover is determined by the spool selected.

FLOW ACTUATING PATTERN

Operating actuator "A" opens flow path to port "A" (P→A). Operating actuator "B" opens flow path to port "B" (P→B). Models with Code 6 operators, which are actuator centered, are the exception.

Spring-centered or spring-offset models are spring positioned unless actuated continuously.

Code 3 operators (two position detented) hold the spool in the last actuated position. These valves can be actuated momentarily (minimum electrical signal duration, 50 ms) to shift and hold the spool in that position.

APPLICATION NOTES

Mounting Position

Unrestricted for all models.

Standard Seals

All valves use Fluorocarbon (*Viton*® or *Fluorel*®) o-rings, providing greater fluid compatibility and improved temperature range performance.

Fluid Recommendations

50 to 1500 SUS (7 to 323 cSt) viscosity; -20° to 200° F (-29° to +93° C) temperature range

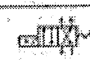
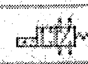
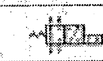
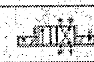
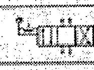
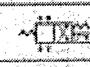
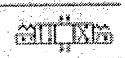
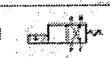
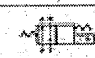
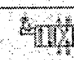
Recommended Filtration

Standard N.F.P.A. (CETOP) Patterns, 25 micron or better filtration;

HP03 and HP05 Patterns, 5 micron or better filtration;

VST Seated Valves, 25 micron or better filtration

INTERNAL OPERATORS

Operator Code	Actuator, Operation	Spool Types: D03, HP03, D05, HP05	Spool Types: D05H, D08, D08H	Operator Function: Non-Actuated	Operator Function: Actuated	Function Symbol[1]
1	Single Actuator, Two Position	0, 20[2] 1, 21[2]	5 or 6	P→B	P→A	
		03	—	P→B	P→A	
2	Single Actuator, Two Position	0, 20[2] 1, 21[2]	5 or 6	P→A	P→B	
		03	—	P→A	P→B	
3	Double Actuator, Two Position[3]	0 or 1	5 or 6	Detented in Actuated Positions	P→A or P→B	
	Lever Operated, Three Position[3]	All Types	All Types	Detented in Actuated Positions	P→A or P→B	
4	Single Actuator, Two Position[4]	0, 1, 3	5, 6, 8 or 9	Spring Centered	P→A	
		011	56 or 58	Spring Centered	P→B	
5	Double Actuator, Three Position	All Types	All Types	Spring Centered	P→A or P→B	
6[5]	Single Actuator, Two Position[4]	0, 1,3	—	P→B	Centered	
		011	—	P→A	Centered	
7	Lever Operated, Two Position[6]	0 or 1	—	Detented in Actuated Positions	P→A or P→B	

① *Symbols show solenoid actuated models, as reference. Air, hydraulic or lever actuators are also available.*
② *Type 20 and 21 spools are used for HP03 and HP05 model valves with Code 1 and Code 2 internal operators (except manual lever HP03 models which use Type 0 and 1 spools).*
③ *Code 3 operators with solenoid, hydraulic or air-piloted actuators provide two position operation. Manual lever operated models provide three position operation.*
④ *Flow can be reversed with "R" option (i.e., with "R" in model code, Code 4 operator with Type 0 spool will direct flow to port "B" (P→B) in the actuated position).*
⑤ *Code 6 operators not available with manual lever operated models.*
⑥ *Code 7 operators only available for manual lever operated D03, HP03 and D05 models.*

Fine filtration is critical for spool valves held in one position for long periods under pressure. Silting may cause spool sticking and improper shifting. Valves should also be cycled periodically to prevent this problem.

Pressure Surges

Consistent with standard practice, the system should be protected from pressure surges which can affect the shifting of any spool valve. In systems with multiple valves, a separate line to tank, or to another low pressure line, is recommended. This is especially critical with detented models.

Drain and Pilot Connections

On pilot operated models, valves are supplied with external drain and internal pilot as standard.

Internal drain and external pilot are optional. See *"Typical Model Code"* in the appropriate section for each valve model. Also refer to the installation drawings, which indicate plug locations for various drain and pilot configurations.

External drain is recommended for applications with high tank pressure, to assure proper spool shifting.

TRC hydraulics inc.

ron.brown@trchydraulics.com
Tel: (709)-364-9670
Fax: (709)-364-1084

To:	MUN FACULTY OF ENGINEERING	**From:**	Ron Brown
Attn:	DAVID BURSEY	**Pages:**	7
Phone:	(709)-737-8958	**Date:**	26/03/02
Fax:	(709)-737-4042	**Re:**	HIGH PRESSURE SYSTEM

☐ **Urgent** ☑ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **Please Recycle**

David,

As per your request we are pleased to quote the following for your consideration. Please see attached data sheets.

QTY

1- #R58510D, DOUBLE ACTING RAM

1- #RP100 , 10 GAL HYDRAULIC RESERVOIR

1- #PE554 HYDRAULIC POWER UNIT

2- #9762 (20') HOSE ASSEMBLY

2- #9798 MALE COUPLERS

2- #9795 QUICK COUPLER ASSEMBLY

TOTAL $ 20,186.00 + HST (NOTE: 50' HOSE ASS'Y $1109.00 EXTRA)

NOTE: DELIVERY ON RAM 10 WEEKS, ALL OTHER COMPONENTS 1-2 WEEKS

F.O.B.- ST-JOHN'S

Regards

Ron Brown – Projects Manager

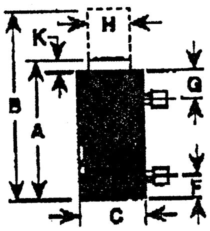
High-tonnage low cycle, hydraulic return, economy cylinders. (Similar to "Load Return" cylinders with hydraulically powered return.)

Hoses, Fittings & Gauges Pages 74-90

Cylinder/Pump Speed/Selection Chart Page 178

Cylinder Repair Kits Page 159

- Cylinders come standard with swivel caps to reduce the effects of off-center loading.
- Cylinders may be "dead-ended" without damage.
- Hard chrome plated, heat treated piston rod provides reduced wear on both piston and gland nut.
- Built-in safety relief valve prevents accidental over-pressurization of the retract circuit.
- Each cylinder has two 9796 ⅜" NPTF female half couplers.
- In full compliance with ASME B30.1 standard.
- Integral swivel cap is a standard component on this series of cylinder.



ORDERING INFORMATION

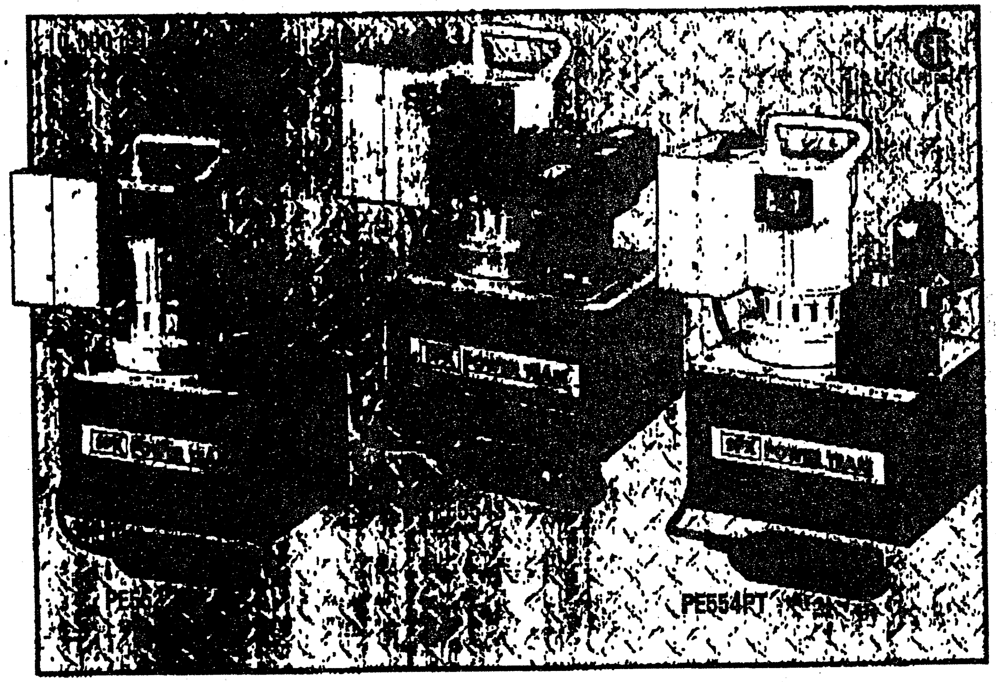
See current price list for shipping weights

Cyl. Cap. (tons)	Stroke (in.)	Order No.	Oil Capacity (cu. in.)		A Re-tracted Height (in.)	B Ex-tended Height (in.)	C Outside Dia. (in.)	F Base to Port (in.)	G Cylinder Top to Port (in.)	H Piston Rod Dia. (in.)	K Piston Rod Protrusion (in.)	Bore Dia. (in.)	Cylinder Effective Area (sq. in.)	Internal Press. at Cap.	Tons at 10,000 psi	Prod. Wt. (lbs.)
			Push	Return									Push	Push	Push	
100	2	R1002D	41.2	19.2	8⁹⁄₁₆	8¹¹⁄₁₆	6¾	1	2¹¹⁄₁₆	3¾	⁵⁄₁₆	5¼	20.60	9,695	103.0	54
100	6	R1006D	123.8	57.8	10¹¹⁄₁₆	16¹¹⁄₁₆	6¾	1	2¹¹⁄₁₆	3¾	⁵⁄₁₆	5¼	20.60	9,695	103.0	81
100	10	R10010D	206.0	96.0	14¹¹⁄₁₆	24¹¹⁄₁₆	6¾	1	2¹¹⁄₁₆	3¾	½	5¼	20.60	9.695	103.0	108
150	2	R1502D	61.4	29.6	7⅛	9⅝	8⅛	1¼	2¼	4½	¹¹⁄₁₆	6¼	30.70	9,778	153.4	95
150	6	R1506D	184.2	88.8	11⅛	17⅛	8⅛	1¼	2¼	4½	⁹⁄₁₆	6¼	30.70	9,778	153.4	136
150	10	R15010D	307.0	148.0	15⅛	25⅛	8⅛	1¼	2¼	4½	⁹⁄₁₆	6¼	30.70	9,778	153.4	177
200	2	R2002D	82.6	39.2	8⁹⁄₁₆	10⁹⁄₁₆	9¼	1⅜	2⁵⁄₁₆	5¼	1¹⁄₁₆	7¼	41.30	9,690	206.4	136
200	6	R2006D	247.8	117.6	12⁹⁄₁₆	18⁹⁄₁₆	9¼	1⅜	2⁵⁄₁₆	5¼	½	7¼	41.30	9,690	206.4	187
200	10	R20010D	413.0	196.0	16⁹⁄₁₆	26⁹⁄₁₆	9¼	1⅜	2⁵⁄₁₆	5¼	1½	7¼	41.30	9,690	206.4	239
280	2	R2802D	118.4	47.2	9¹⁵⁄₁₆	11¹⁵⁄₁₆	10⅞	1⅝	[illegible]	6¼	⅝	8½	56.70	9,870	283.7	219
280	6	R2806D	340.2	141.6	13¹⁵⁄₁₆	19¹⁵⁄₁₆	10⅞	1⅝	2¾	6¼	⅝	8½	56.70	9,870	283.7	297
280	10	R28010D	567.0	236.0	17¹⁵⁄₁₆	27¹⁵⁄₁₆	10⅞	1⅝	2¾	6¼	⅝	8½	56.70	9,870	283.7	378
355	2	R3552D	141.8	47.4	11⅜	13⅜	11⅜	2¼	2⅜	7¾	¾	9½	70.90	10,017	354.4	324
355	6	R3556D	425.4	142.2	15⅜	21⅜	11⅜	2¼	[illegible]	7¾	[illegible]	9½	70.90	10,017	354.4	421
355	10	R35510D	709.0	237.0	19⅜	29⅜	11⅜	2¼	2⅜	7¾	⅞	9½	70.90	10,017	354.4	517
439	2	R4302D	173.2	59.6	12⁵⁄₁₆	14⁵⁄₁₆	13	2¼	[illegible]	8¼	[illegible]	10½	86.60	9,932	433.0	439
439	6	R4306D	519.6	178.8	16⁵⁄₁₆	22⁵⁄₁₆	13	2¼	2¹³⁄₁₆	8¼	1¹⁄₁₆	10½	86.60	9,932	483.0	558
439	10	R43010D	[illegible]	298.0	20⁵⁄₁₆	30⁵⁄₁₆	13	[illegible]	[illegible]	[illegible]	[illegible]	10½	86.60	9,932	433.0	673
565	2	R5652D	226.2	76.8	13¹⁵⁄₃₂	15¹⁵⁄₃₂	14¼	2¾	3¹³⁄₁₆	9¾	¾	12	113.10	9,991	565.5	619
565	6	R5656D	678.6	230.4	17¹⁵⁄₃₂	23¹⁵⁄₃₂	14¼	[illegible]	[illegible]	9¾	[illegible]	12	113.10	9,991	565.5	772
565	10	R56510D	1131.0	384.0	21¹⁵⁄₃₂	31¹⁵⁄₃₂	14¼	2¾	3¹³⁄₁₆	9¾	¾	12	113.10	9,991	565.5	926

Electric Hydraulic Pumps

55 cu. in./min. — 1¼ hp

This is a proven pump for many of the toughest applications, and for starting under low voltage conditions. The PE55 pump has earned its place as the mainstay for heavy construction and the concrete stressing business world wide. Generally recommended for cylinders up to 200 tons.



Hoses, Fittings & Gauges Pages 74-80

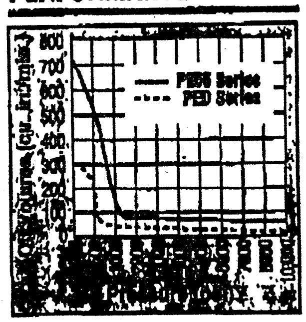
Pump Accessories Pages 161-165

Cylinder/Pump Speed/Selection Chart Page 178

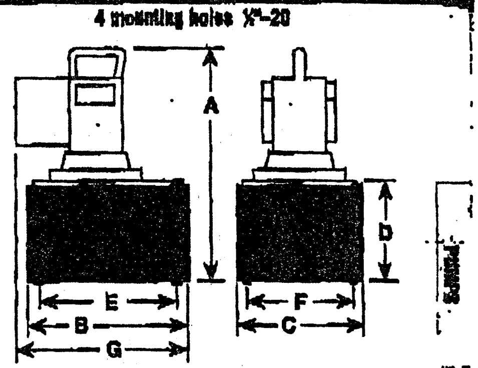
Choosing The Right Pump Pages 181-184

- Two-speed high performance. Forty years of reliability and constant improvement make Vanguard® pumps a mainstay worldwide. Some original pumps are still in service!
- Designed for operating pressures to 10,000 psi. CSA rated for intermittent duty. Noise level of 90 dBA.
- Has 1¼ hp, 12,000 rpm, 110/115 volt, 50/60 Hz universal motor; draws 25 amps at full load, starts at reduced voltage.
- Internal relief valve preset at 10,000 psi, 2¼ gallon metal reservoir.

PERFORMANCE



- All have 10 foot remote motor control except PE552S which has a 25 foot remote motor and valve control.
- True unloading valve achieves greater pump efficiency, allowing higher flows at maximum pressure.
- Reservoirs available in sizes up to 10 gallons. See accessories page 165.
- Light weight and portable. Best weight to performance ratio of all Power Team pumps.
- "Assemble to Order" System: There are times when a custom pump is required. Power Team's "Assemble to Order" system allows you to choose from a wide range of pre-engineered, off-the-shelf components to build a customized pump to fit specific requirements. By selecting standard components you get a "customized" pump without "customized" prices. All pumps come fully assembled, less oil and ready for work. See pages 70-73.



SPECIFICATIONS AND DIMENSIONS

Pump No.	rpm	Maximum Pressure Output	dBA at Idle and 10,000 psi	Amp Draw at 10,000 psi (115 V.)**	Oil Delivery (cu. in./min. @)				Dimensions (in.)								Product Weight With Oil (lbs.)
					100 psi	700 psi	5,000 psi	10,000 psi	A	B	C	D	E	F	G	H	
PE55 Series	12,000	10,000 psi	90/89*	25	704	440	74	56	18¼	11½	9½	7	10	8	14	–	65

* Noise level reading (dBA) measured at a 3 ft. distance, all sides.

** Amp draw at 10,000 psi, 230 Volts 50/60 Hz is 16 Amps.

ORDERING INFORMATION

See current price list for shipping weights.

SINGLE-ACTING

Description	Order No.***	Valve			Control Switch ††	Motor	Reservoir (Usable)
		Type	No.	Function			
Base model 1½ hp pump with 2½ gal. reservoir, remote motor control & 3-way valve.	PE552	3-Way	9582	Advance Return**	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	525 cu. in.
PE552, except also has solenoid operated remote valve.	PE552S	3-Way	9579	Advance Return	Remote Motor & Valve	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	[illegible]
PE552, except has "Auto Dump" valve.	PE552A▬	Auto/Dump	9610	Advance Hold Return	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	525 cu. in.
1½ hp pump with 2½ gal. reservoir. Valve has "Posi-check" feature.	PE553	3-Way †	9520	Advance Hold Return	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	[illegible]

DOUBLE-ACTING

Description	Order No.***	Valve			Control Switch ††	Motor	Reservoir (Usable)
		Type	No.	Function			
Base model 1½ hp pump with 2½ gal. res. and 4-way valve for double-acting systems.	PE554	4-Way †	9506	Advance Hold Return	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	525 cu. in.
[illegible] PE554, except has 9500 tandem center valve. [illegible]	PE554T	4-Way	9500	Advance Hold Return**	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	[illegible]
For use with single-acting Spring Seat, Stressing Jack or double-acting cylinder.	PE554P	4-Way	9500	Advance Hold Return	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	525 cu. in.
[illegible]	PE554PT	4-Way	9628	Advance Hold Sequenced Return	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	[illegible]
Pump suitable to run multiple spring return tools.	PE554C	4-Way	9511 †††	Advance Hold Return	Remote Motor	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	525 cu. in.
[illegible]	PE554S	4-Way	9592	Advance Hold Return	Remote Motor & Valve	1½ hp*, 110/115 VAC, 50/60 Hz, Single Phase	[illegible]

* Pumps available with 230 volt, 60/50 Hz motors. Specify voltage when ordering. See "Assemble to Order" pump options on pages 70-73.

** Holds with motor shut off.

*** To order PE55 series pumps with CSA approval, add "-C" to the Order No.

† Valves have "Posi-Check®" feature.

†† Control switch wired with line voltage. All remotes are 10 ft. long except for PE552S which is 25 ft. long.

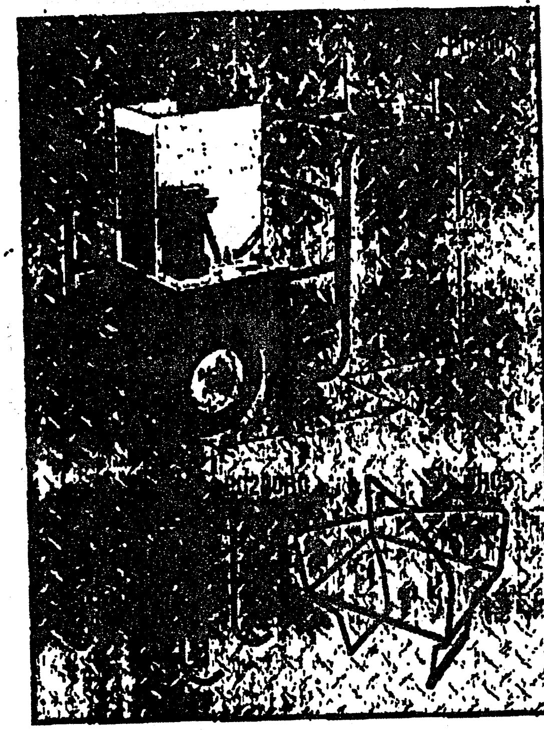
††† Valving allows alternate and independent operation of two different spring return tools. Valve holds pressure only while valve is in "A" or "B" port position with pump motor shut off.

▬ Not to be used for lifting.

Universal pump cart

Mobilize your hydraulic pumps with the PC200. The rugged tubular frame can easily handle pumps weighing up to 200 lbs. With 12" wheels, the cart rolls easily. Just load the pump onto the cart and wheel it right to the job. The universal mounting hole pattern lets you handle a wide variety of Power Team pumps.

No. PC200 – Universal pump cart with 12" wheels. Cart can be used with the following pumps: PA60, PA54 and PA554 air/hydraulic pumps; PE55 series, PE183-2 and PE184-2 electric/hydraulic pumps; PE21, PQ60 and PQ120 series "Quiet" pumps; PG55 series gas engine/hydraulic pumps; and pumps with optional 5- and 10-gallon reservoirs; Nos. RP50, RP51, RP101 and RP103. Wt., 27 (Shown with pump, pump not included)



Protective pump roll cage

Safeguards pump, gas engine and valves on the job site. Horizontal bars provide convenient hand holds for carrying pump, a pick-up point permits lifting unit with an overhead crane or other device. Standard equipment on PG1203 and PG1204. Can be ordered as an option with any other gas, air, or electrically driven hydraulic pump equipped with a 5-gallon reservoir.

Note: Refer to PG1203/PG1204 specification chart (pages 68-69) for dimensions of roll cage.

No. PC200RC – Roll cage for use with PC200. (Cannot be used on pumps with 10 gallon reservoirs.) Wt., 36 lbs.

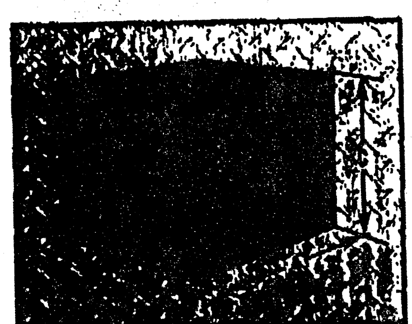
No. RC5 – Roll cage. Wt., 19.5 lbs.

Large capacity reservoirs

Capacity (gal.)	Order Number	Usable Oil (cu. in.)	Use With	Size (in.) A	B	C
2	RP20**	442	PA6, PA50 series (models A-E)	11½	8½	6½
2	RP20-F**	442	PA6 series (model F), PA 50 series (model F & G)	11½	9½	6½
2½	RP20M*	450	PA6, PA50 series (models A-E)	11½	9½	6½
2½	RP20M-F*	450	PA6 series (model F), PA50 series (model F & G)	11½	9½	6½
2½	RP21*	450	PE18 series	11½	9½	6½
2½	RP22†	442	PE55, PE90, PE120, PA55	11½	9½	6½
5	RP50	1150	PA46, PE46, PE21	15	12½	8½
5	RP51	1150	PE55, PE90, PE120, PA55	15	12½	[illegible]
10	RP100	2194	PE55, PE90, PE120, PA55	15	12½	14½
10	RP101	[illegible]	[illegible]	15	12½	[illegible]
10	RP10[illegible]*	2310	PQ60, PQ120	15¾	14¼	12¾
10	RP104	2194	PA46, PE46, PE21	15	12½	[illegible]

* Four mounting holes: ½"-20, for 2" diameter swivel casters (No. 10494)

** High density polyethylene reservoir. † Aluminum reservoir.



NOTE: All metal reservoirs are equipped with drain plugs and all necessary conversion items.

Hydraulic oil is not included with reservoir kits. Please order separately. See page 78.

Metal reservoir conversion kits for pumps *includes gaskets and fasteners.

Pump Number	Metal Res. Order Number	Metal Reservoir Capacity	Reservoir Weight (lbs.)
PA6	213896	105 cu. in.	3
PA50	213896	[illegible]	[illegible]
PA6D	213896	105 cu. in.	3
[illegible]	213895	578 cu. in.	[illegible]
PA5D2	213895	578 cu. in.	9

Pump Number	Metal Res. Order Number	Metal Reservoir Capacity	Reservoir Weight (lbs.)
PA50	213896	105 cu. in.	3
PA50R	213896	105 cu. in.	[illegible]
PA6R	213896	105 cu. in.	3
PA50R2	213895	578 cu. in.	9
PA172	213895	578 cu. in.	9

Pump Number	Metal Res. Order Number	Metal Reservoir Capacity	Reservoir Weight (lbs.)
PA174	213895	578 cu. in.	9
PE172[illegible]	213895	[illegible]	[illegible]
PE172A	213895	578 cu. in.	9
PE172[illegible]	213895	[illegible]	[illegible]
PE174	213895	578 cu. in.	9

Oil
Page 78

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Manifolds
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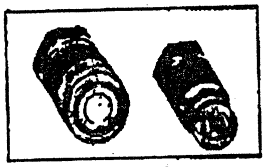
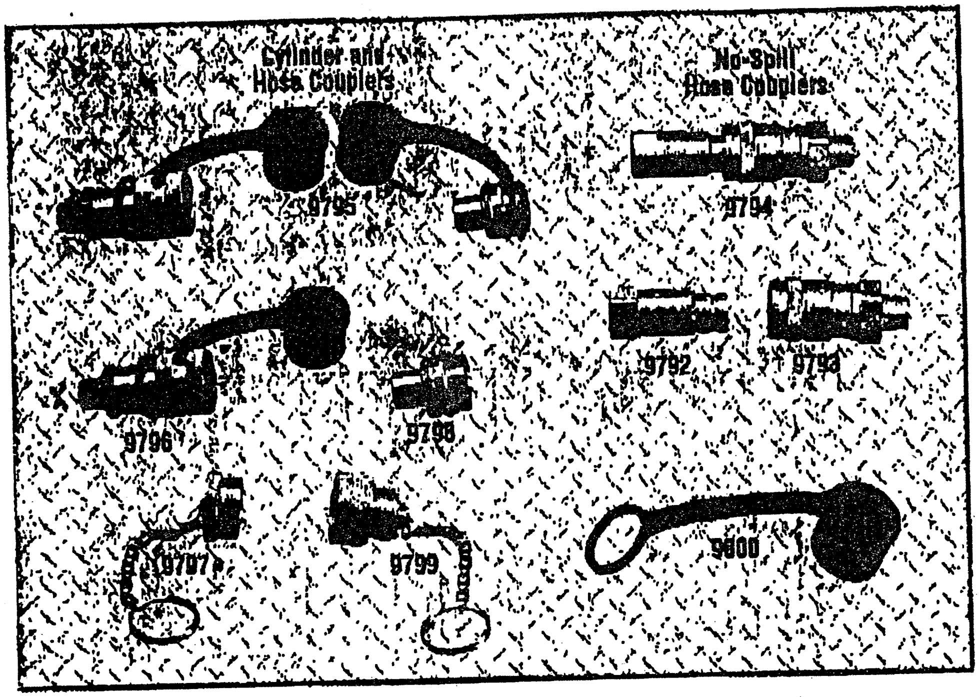
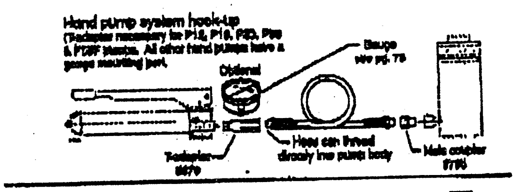
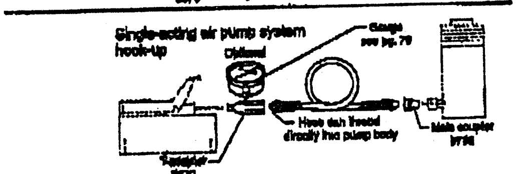
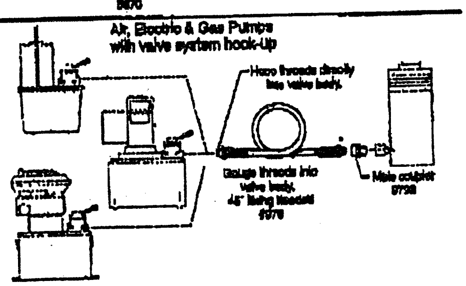


9794 Flush-Face couplers









■ **Cylinder and hose couplers**

Designed for use up to 10,000 psi with hydraulic jacks, cylinders, etc. They are the threaded union type for interchanging cylinders in seconds. Each half is valved with a precision ball for a tight shutoff when disconnected. These couplers also permit the separation of cylinders or hose from pump when at 0 psi with minimal oil loss.

No. 9795 – Complete quick coupler, 3/8" NPTF. (Includes two 9800 dust caps.)

No. 9798 – Male (hose) half coupler (less hose half dust cap), 3/8" NPTF.

No. 9796 – Female (cylinder) half coupler with No. 9800 dust cap, 3/8" NPTF.

No. 9796-V – Same as 9796, but with Viton seals.

No. 9796-E – Same as 9796, but with EPR seals.

No. 9799 – Optional metal dust cap (Hose half.)

No. 9797 – Optional metal dust cap (Cylinder half.)

■ **No-spill, push-to-connect hydraulic hose couplers**

High flow, no-spill, push-to-connect couplers with locking collar and flush face designed for high pressure applications. The flush-face concept makes it easy to clean both coupler ends before connecting. Our unique push-to-connect, "dry-break" design eliminates oil spillage. The locking collar makes accidental disconnects a thing of the past. For 10,000 psi operation. Designed to permit high oil flow.

No. 9792 – Female (cylinder) half quick coupler only. Wt., 0.3 lb.

No. 9793 – Male (hose) half quick coupler only. Wt., 0.3 lb.

No. 9794 – Complete quick coupler (male and female). Dust caps not included. Wt., 0.5 lb.

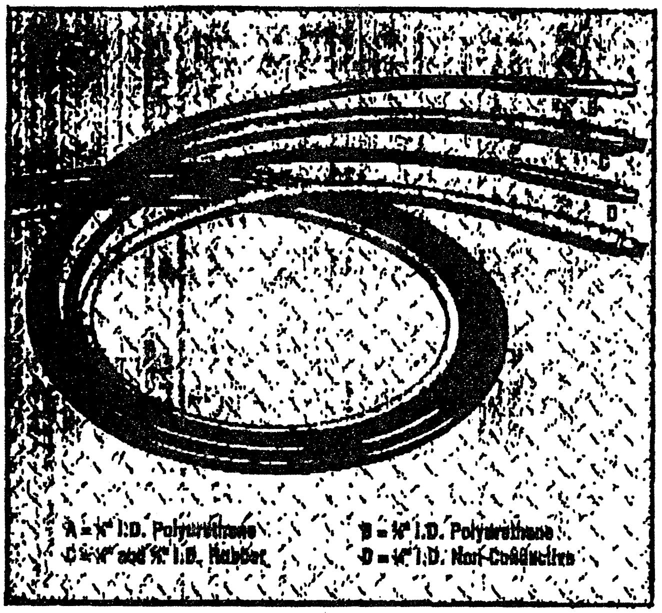
■ **Hydraulic coupler dust cap**

Dust cap fits either male or female half couplers.

No. 9800 – Dust cap. For male or female 3/8" NPTF half couplers. Wt., 0.3 lb.

Hoses

Polyurethane, rubber and non-conductive



A = ¼" I.D. Polyurethane B = ⅜" I.D. Polyurethane
C = ¼" and ⅜" I.D. Rubber D = ¼" I.D. Non-Conductive

- There are five styles in lengths from 2 to 100 ft. All have plastic hose guards except for the ¼" I.D. polyurethane hoses which have spring guards.
- All have ¼" NPTF fittings on both ends.
- Operating pressure is 10,000 psi. All comply with MHI standard IJ100.

■ Polyurethane hose

Made up of nylon core tube with polyester fiber reinforcement which will withstand the minimum SAE bend radius without shortening service life. These hoses last up to seven times longer than rubber hose, and are suitable for continuous service at temperatures from -40° to 150° F.

■ Rubber hose

2-ply rated hose reinforced with two braids of high tensile steel wire. The rubber covering is oil and weather resistant. These hoses are MSHA approved.

■ Non-conductive hose

For applications requiring electrical isolation by the hose, "non-conductive" hose has a leakage factor of less than 50 microamperes, considered a safe level on conductivity by SAE standards. The covering is polyurethane and colored orange for easy identification as non-conductive hose. The covering is not perforated, preventing moisture from entering the hose and affecting its overall conductivity. All non-conductive hoses have a minimum burst pressure of 40,000 psi.

■ Hydraulic hose assembly

No. 9764 – Hose assembly consisting of 9767 (6' hose), ¼" I.D. polyurethane with 9798 hose half coupler and 9800 dust cap assembled.

No. 9754 – Hose assembly consisting of 9756 (6' hose), ¼" I.D. rubber with 9798 hose half coupler and 9800 dust cap assembled.

CYLINDER RETURN TIME

The figures show the relative effect two styles of hose can have on return time. Actual times may vary.

Cylinder	No. 9769 10 Ft. Hose ¼" I.D.	No. 9781 10 Ft. Hose ⅜" I.D.
C2514C	51 sec.	14 sec.
C556C	1 min., 30 sec.	24 sec.
C5513C	4 min., 12 sec.	59 sec.
C10010C	6 min., 56 sec.	1 min., 8 sec.

ORDERING INFORMATION

Hose Type	Hose I.D.	Hose Length	Burst Rating	Order No.
Polyurethane	¼"	2 ft.	20,000 psi	9765
Polyurethane	¼"	3 ft.	20,000 psi	9766
Polyurethane	¼"	6 ft.	20,000 psi	9767
Polyurethane	¼"	6 ft.	20,000 psi	9764*
Polyurethane	¼"	8 ft.	20,000 psi	9768
Polyurethane	¼"	10 ft.	20,000 psi	9769
Polyurethane	¼"	12 ft.	20,000 psi	9770
Polyurethane	¼"	20 ft.	20,000 psi	9771
Polyurethane	¼"	50 ft.	20,000 psi	9772
Polyurethane	¼"	75 ft.	20,000 psi	9750
Polyurethane	¼"	100 ft.	20,000 psi	9751
Polyurethane	⅜" High Flow	6 ft.	30,000 psi	9780
Polyurethane	⅜" High Flow	10 ft.	30,000 psi	9781
Polyurethane	⅜" High Flow	20 ft.	30,000 psi	9782
Polyurethane	⅜" High Flow	50 ft.	30,000 psi	9783
Rubber, Wire-braid	[illegible]	[illegible]	20,000 psi	9755
Rubber, Wire-braid	¼"	6 ft.	20,000 psi	9756
Rubber, Wire-braid	¼"	6 ft.	20,000 psi	9754*

NOTE: Polyurethane hoses not recommended for use where heat or weld splatter conditions exist.

Hose Type	Hose I.D.	Hose Length	Burst Rating	Order No.
Rubber, Wire-braid	¼"	8 ft.	20,000 psi	9757
Rubber, Wire-braid	¼"	10 ft.	20,000 psi	9758
Rubber, Wire-braid	¼"	12 ft.	20,000 psi	9759
Rubber, Wire-braid	¼"	20 ft.	20,000 psi	9760
Rubber, Wire-braid	¼"	30 ft.	20,000 psi	9761
Rubber, Wire-braid	¼"	50 ft.	20,000 psi	9762
Rubber, Wire-braid	⅜" High Flow	3 ft.	20,000 psi	9733
Rubber, Wire-braid	⅜" High Flow	6 ft.	20,000 psi	9776
Rubber, Wire-braid	⅜" High Flow	10 ft.	20,000 psi	9777
Rubber, Wire-braid	⅜" High Flow	15 ft.	20,000 psi	9734
Rubber, Wire-braid	⅜" High Flow	20 ft.	20,000 psi	9778
Rubber, Wire-braid	⅜" High Flow	30 ft.	20,000 psi	9735
Rubber, Wire-braid	⅜" High Flow	40 ft.	20,000 psi	9736
Rubber, Wire-braid	⅜" High Flow	50 ft.	20,000 psi	9779
"Non-Conductive"	¼"	6 ft.	40,000 psi	9773
"Non-Conductive"	¼"	10 ft.	40,000 psi	9774
"Non-Conductive"	¼"	20 ft.	40,000 psi	9775

*Furnished with 9798 hose half coupler and 9800 dust cap.

Double acting →

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TO: M.U.N. ENGINEERING FROM: RON BROWN

ATTN: DAVID BUNSEF PAGES: 2

FAX: 737-4042 DATE: 01/24/02

RE: HYD CYLINDER APPLICATION

☐ Urgent ☐ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

DAVID As per our conversation concerning your application, we can supply a single acting hyd cylinder rated for 565 tons @ 10,000 PSI only your cost $9473.20 + HST

DEL'Y 4-6 weeks

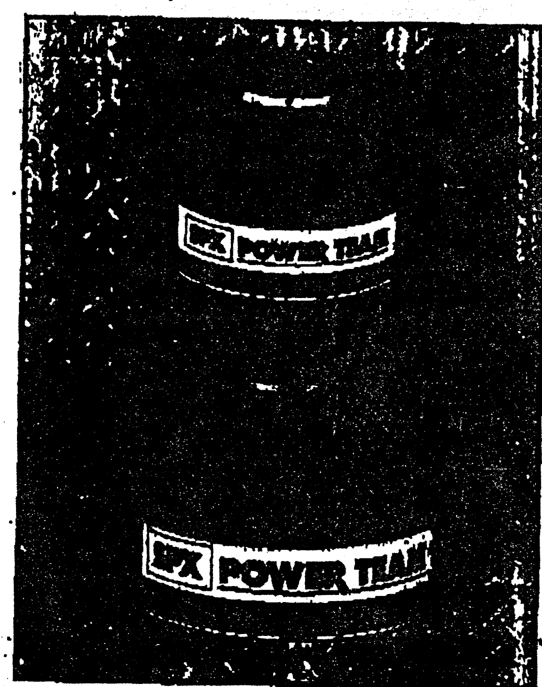
Regards

P.S. you will require a 10,000 PSI HPU.

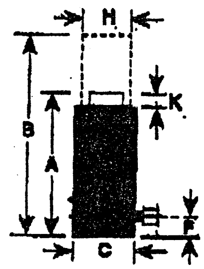
High Tonnage

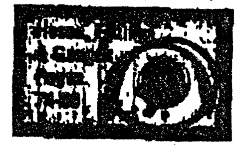
Single-Acting,

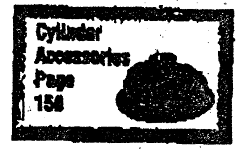
High-tonnage, low cycle, gravity return, economy cylinders.

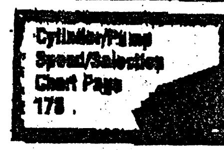


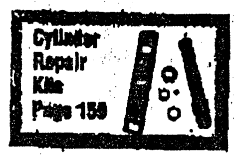
- Fully comply with ASME B30.1 standard.
- Visible indicator band alerts operator when stroke limit is reached; overflow port ("weep hole") stroke limiter prevents piston from being inadvertently overextended.
- Alloy heat treated piston and body for exceptional reliability and strength.
- Plated piston rods greatly increase corrosion resistance and give superior bearing qualities.

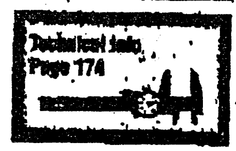












ORDERING INFORMATION

See current price list for shipping weights

Cyl. Cap. (tons)	Stroke (in.)	Order No.	Oil Cap. (cu. in.)	A Retracted Ht. (in.)	B Extended Ht. (in.)	C Outside Dia. (in.)	F Base to Port (in.)	H Piston Rod Dia. (in.)	K Piston Rod Protrusion (in.)	Saddle Dia. (in.)	Cylinder Effective Area (sq. in.)	Internal Pressure at Cap. (psi)	Tons at 10,000 psi	Product Wt. (lbs.)
55	2	R552C	22.1	4 11/16	6 11/16	5	1	3 3/4	1/4	3 3/4	11.04	9,960	55.2	27
55	[illegible]	R556C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55	10	R5510C	110.4	12 11/16	22 11/16	5	1	3 3/4	1/4	3 3/4	11.04	9,960	55.2	72
100	[illegible]	R1002C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
100	6	R1006C	123.8	9 1/4	15 1/4	6 1/4	1	5 1/4	1/4	5 1/4	20.63	9,695	108.2	89
100	[illegible]	R10010C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150	2	R1502C	61.4	6 3/4	8 3/4	8 1/16	1 1/4	6 1/4	1/4	6 1/4	30.68	9,778	153.4	92
150	[illegible]	R1506C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
150	10	R15010C	306.8	14 3/4	24 3/4	8 1/16	1 1/4	6 1/4	1/4	6 1/4	30.68	9,778	153.4	210
200	[illegible]	R2002C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
200	6	R2006C	247.7	11 1/4	17 1/4	9 3/4	1 1/4	7 1/4	1/4	7 1/4	41.28	9,690	206.4	221
200	[illegible]	R20010C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
280	2	R2802C	113.5	7 1/4	9 1/4	10 3/4	1 1/4	8 1/4	1/4	8 1/4	56.74	9,870	283.7	201
280	[illegible]	R2806C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
280	10	R28010C	567.4	15 1/4	25 1/4	10 3/4	1 1/4	8 1/4	1/4	8 1/4	56.74	9,870	283.7	401
355	[illegible]	R3552C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
355	6	R3556C	425.3	13 1/4	19 1/4	11 1/4	2 1/4	9 1/4	1/4	9 1/4	70.88	10,017	354.4	434
355	[illegible]	R35510C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
430	2	R4302C	173.2	10 1/4	12 1/4	13	2 1/4	10 1/4	1/4	10 1/4	86.69	9,932	483.0	440
430	[illegible]	R4306C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
430	10	R43010C	865.9	18 1/4	28 1/4	13	2 1/4	10 1/4	1/4	10 1/4	86.59	9,982	433.0	778
565	[illegible]	R5652C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
565	6	R5656C	678.8	15 1/4	21 1/4	14 1/4	2 1/4	12	1/4	12	118.10	9,991	585.5	858
565	[illegible]	R56510C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ROCTEST

Measuring up on **all scales**

To :	Mr. David Bursey	From :	Jean-Pierre Perron	
Company :	Memorial University of Newfoundland Fac. of Engineering & Applied Science	Date :	February 28, 2002	Page 1 of 3
Fax : Tel.:	709-737-4042 709-737-8958	Subject :	Tension/Compression load cell	

Dear Mr. Bursey,

Further to your request regarding the tension/compression load cell, we are pleased to send you the attached document regarding this instrument.

Let us know if one of these models will meet your specifications.

For more information, please do not hesitate to contact us.

Best regards,

Jean-Pierre Perron
Sales representative

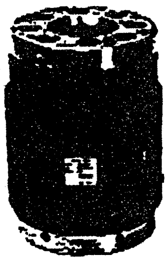
Roctest Ltd., 665 Pine Avenue, Saint-Lambert (Quebec) Canada J4P 2P4 • Tel: (450) 465-1113 • Fax: (450) 465-1938
E-mail : info@roctest.com - Web Site: http://www.roctest.com

GEOTECHNICAL AND STRUCTURAL INSTRUMENTATION SINCE 1967 • VIBRATING WIRE AND FIBER-OPTIC TECHNOLOGIES

ISO 9001

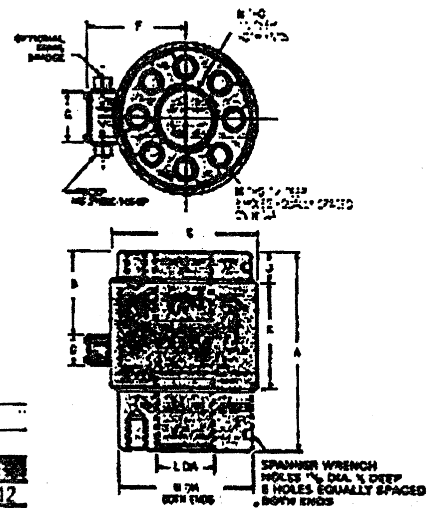
FATIGUE RESISTANT LOAD CELLS-continued

TENSION AND COMPRESSION 150,000 LBS. TO 2,000,000 LBS.

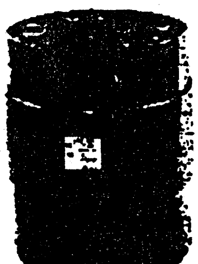


Model 3129-112 (English)
Capacities Available
150K, 200K and 300K lbs.

Model 3129-121 (Metric)
Capacities Available
750K, 1M and 1.5M Newtons



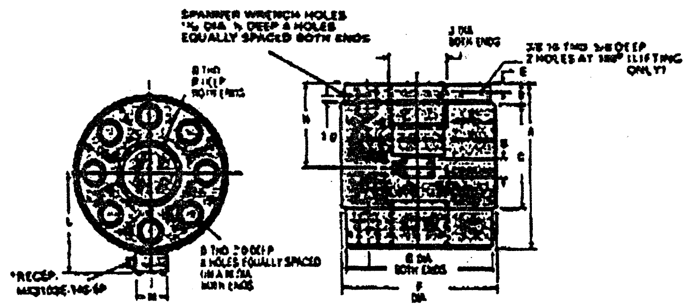
Model	A	B	C	D	E	F	G	H	J	K	L	M	N
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3129-112	10.0	7.0	1.5	4.25	7.5	5.0	2.5	5.0	1.5	5.5	3.31	1.0-8	3.0-12
3129-121	[illegible]	[illegible]	[illegible]	10.80	109.05	12.70	6.35	12.70	8.81	13.97	8.41	M27-2	[illegible]



Model 3130 (English)
Capacities Available
500K, 800K and 1,000K lbs.

Model 3130-131 (Metric)
Capacities Available
2M, 3.5M and 5M Newtons

*Optional Dual Bridge not shown

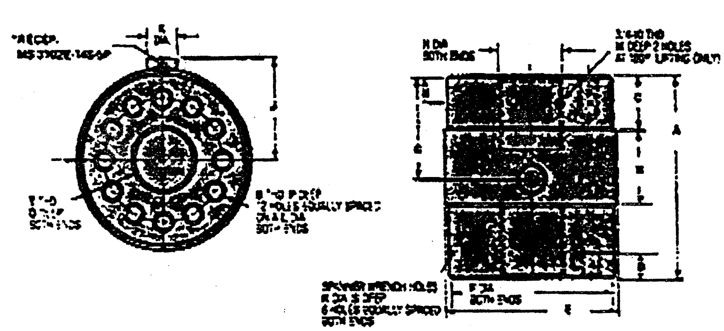


Model	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
	In.	In.	In.	In	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3130	12.5	7.0	1.5	2.0	.75	12.75	12.25	6.25	5.25	1.0	7.82	2.5	9.5	3.5	1.75-12	5.0-8
3130-131	[illegible]	[illegible]	[illegible]	5.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Model 3127 (English)
Capacity Available
2,000K lbs.

Model 3127-118 (Metric)
Capacity Available
10M Newtons

*Optional Dual Bridge not shown



Model	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3127	22.5	8	6.5	.5	17.63	17.0	11.25	6.5	9.75	3.0	12.0	1.5	2.5	3.5	8.25	.41	.5	6.0-8	1½-12
3127-118	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20.96	[illegible]	[illegible]	[illegible]	[illegible]

FEATURES

- resists fatigue failure
- low failure rate
- special structure designs
- capacities to 2,000,000 lbs.
- bending moment resistance up to 7,500,000 lb. inches
- up to 450,000 lbs. of shear force resistance

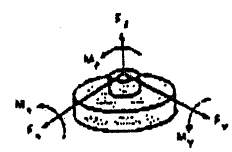
Lebow* fatigue-resistant load cells are the result of many years of design development. You will note from the specifications that these load cells are extremely resistant to extraneous bending and side loading forces. The structure virtually eliminates bending strains at the strain gage, minimizing the primary cause of load cell failure.

Load Cell Model No.	Nominal Load Limit Capacity F_z		Static Overload Capacity % of Nom. Capacity	Fatigue Capacity % of Nom. Capacity	Static Extraneous Load Limits			Deflection At Nom. Load Limit Inches	Ringing Frequency Hz
	Lbs.	[redacted]			Shear F_x or F_y Lbs.	Bending M_x or M_y Lb. Inches	Torque M_z Lb. Inches		
3129-112	150K	[redacted]	150	75	40K	625K	150K	.004	3000
	200K	[redacted]	150	75	55K	730K	260K	.004	3400
—	300K	[redacted]	150	75	65K	840K	236K	.004	4100
3130*	500K	[redacted]	150	50	94K	4530K	820K	.006	2500
	800K	[redacted]	150	50	180K	5450K	1050K	.006	3100
—	1000K	[redacted]	150	50	180K	6110K	1100K	.006	3600
3127*	2000K	[redacted]	100	50	450K	7500K	1500K	.007	1900

*Please note: models 3130 and 3127 can be calibrated to 600,000 lbs. compression only. Calibration in tension; consult factory.

Static extraneous load limits are calculated such that *only one* extraneous load (F_x or F_y or M_x or M_y or M_z) can be applied simultaneously with *half* the nominal load limit capacity. Also note that these values are for static application. Ringing frequency values are calculated or determined by test with no external force or load.

NOTE: Refer to pages 116 and 117 for Extraneous Load Coefficients



F_z—Force on load axis.
F_x, F_y—Side loads (shear force).
M_x, M_y, M_z—Bending moments.

Specifications:	3127	3129	3130
Output at rated capacity: millivolts per volt, nominal	±2	±2	±2
Nonlinearity: of rated output	±0.2%	±0.2%	±0.2%
Hysteresis: of rated output	±0.2%	±0.2%	±0.2%
Repeatability: of rated output	±0.05%	±0.05%	±0.05%
Zero balance: of rated output	±1.0%	±1.0%	±1.0%
Bridge resistance: ohms nominal	700	350	700
Temperature range, compensated: °F	+70 to +170	+70 to +170	+70 to +170
Temperature range, compensated: °C	+21 to +77	+21 to +77	+21 to +77
Temperature range, useable: °F	−65 to +200	−65 to +200	−65 to +200
Temperature range, useable: °C	−54 to +93	−54 to +93	−54 to +93
Temperature effect on output: of reading per °F	±0.003%	±0.003%	±0.003%
Temperature effect on output: of reading per °C	±0.0054%	±0.0054%	±0.0054%
Temperature effect on zero: of rated output per °F	±0.003%	±0.003%	±0.003%
Temperature effect on zero: of rated output per °C	±0.0054%	±0.0054%	±0.0054%
Excitation voltage, maximum: volts DC or AC rms	40	20	40
Insulation resistance, bridge/case: megohms at 50 VDC	>5000	>5000	>5000
Number of bridges	1 or 2	1 or 2	1 or 2
Fatigue life: 0 to full fatigue load (cycles × 10^6)	100	100	100
Fatigue life: full fatigue tension to full fatigue compression (cycles × 10^6)	50	50	50

ROCTEST
Measuring up on all scales

To : Mr. David Bursey B. Eng.	*From :* Jean-Pierre Perron Sales Representative		
Company : MEMORIAL UNIVERSTITY ST-JOHN'S NF Canada	*Date :* 2002/03/11	*Page :* 1 of 3	
Fax : 1-709-737-4042 *Tel :* 1-709-737-8958 *E-mail :* dbursey@engr. mun.ca	*Subject :* **Quotation No. JPP40097**		

Dear Mr. Bursey,

I am very sorry for the delay to response to your request.

Attached you will find our quotation no. JPP40097, confirming our prices regarding the tension and compression load cells.

We are hoping this will be to your satisfaction and for more information, please do not hesitate to contact us.

Best regards,

Jean-Pierre Perron
Sales representative

ROCTEST LTD.
665, Pine Avenue
St-Lambert, QC J4P 2P4
CANADA
Tel. : 1-877-ROCTEST
Tel. : (450) 465-1113
Fax : (450) 465-1938
E-mail : info@roctest.com
Web Site : www.roctest.com

ROCTEST INC.
P.O. Box 2907
Plattsburgh, NY 12901-0970 U.S.A.
Tel. : 1-877-ROCTEST
Tel. : (518) 561-3300
Fax : (518) 561-1192
E-mail : info@roctest.com
Web Site : www.roctest.com

ROCTEST BEIJING
7 DongDaMoChang Jie
ChongWen District, Office Tower 508
Beijing 100062
CHINA
Tel. : 86.10.67.08.29.80
Fax : 86.10.67.08.29.81
E-mail : beijing@roctest.com
Web Site : www.roctest.com

TELEMAC S.A.
10, Eiffel Avenue
77220 Gretz-Armainvilliers
FRANCE
Tel. : 33.1.64.06.40.80
Fax : 33.1.64.06.40.26
E-mail : info@ telemac.fr
Web Site : www.telemac.fr

ROCTEST

Measuring up on all scales

To : MEMORIAL UNIVERSTITY
COMPTROLLER'S OFFICE
ACCOUNTS PAYABLE
ST-JOHN'S NF A1C 5S7

Phone : 99999999999 **Fax :**

Contact : Mr. David Bursey B. Eng.
E-mail :
Quote Date : 11/03/2002
Representative : Jean-Pierre Perron

Item	Description	Unit Price	Qty	Net
01	TENSION AND COMPRESSION LOAD CELL . MODEL 3130-1000k. **CALIBRATION TO 500,000 POUNDS COMPRESSION AND 300,000 POUNDS TENSION, NO EXTRA CHARGE**	20 490,00	1	20 490,00
02	TENSION AND COMPRESSION LOAD CELL, MODEL 3127-2000k. **CALIBRATION TO 500,000 POUNDS COMPRESSION AND 300,000 POUNDS TENSION NO EXTRA CHARGE**	46 580,00	1	46 580,00
03	CALIBRATION TO FULL SCALE IN TENSION AND COMPRESSION FOR MODEL 3130-1000K	7 455,00	1	7 455,00
04	CALIBRATION TO FULL SCALE IN TENSION AND COMPRESSION FOR MODEL 3127-2000K	9 320,00	1	9 320,00

DELIVERY : *12-14 weeks*
F.O.B. : *St-Lambert,QC*
CURRENCY : *Canadian Dollars*

VALIDITY : *90 days*
TERMS : *Net 30 days*

SubTotal	**83 845,00**
G.S.T.	**5 869,15**
P.S.T.	**6 728,56**
TOTAL	**96 442,71**

Jean-Pierre Perron
Sales Representative

ROCTEST LTD.
666, Pine Avenue
St-Lambert, QC J4P 2P4
CANADA
Tel. : 1-877-ROCTEST
Tel. : (450) 465-1113
Fax : (450) 465-1938
E-mail : info@roctest.com
Web Site : www.roctest.com

ROCTEST INC.
P.O. Box 3568
Champlain, NY 12919-3568
U.S.A.
Tel. : 1-877-ROCTEST
Tel. : (450) 465-6311
Fax : (450) 465-1938
E-mail : info@roctest.com
Web Site : www.roctest.com

TELEMAC S.A.
10, Eiffel Avenue
77220 Gretz-Armainvilliers
FRANCE
Tel. : 33.1.64.06.40.80
Fax : 33.1.64.06.40.26
E-mail : info@telemac.fr
Web Site : www.telemac.fr

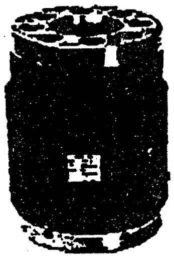
***QUOTE NO :* JPP40097**

Page 1 of 1

IN CASE OF ERROR, UNIT PRICE PREVAILS
SUBJECT TO ROCTEST SALES CONDITIONS

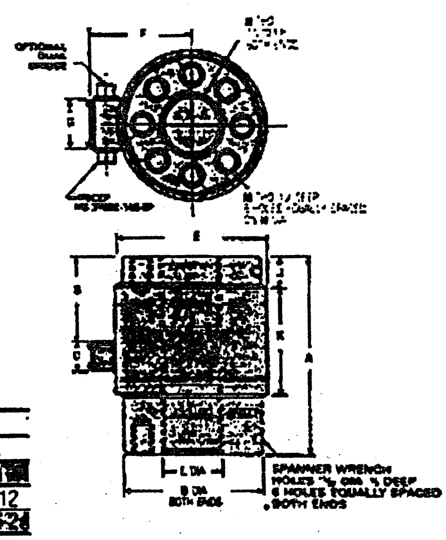
FATIGUE RESISTANT LOAD CELLS-continued

TENSION AND COMPRESSION 150,000 LBS. TO 2,000,000 LBS.

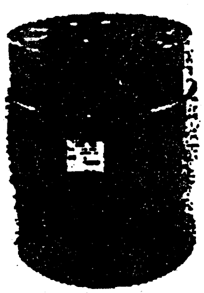


Model 3129-112 (English)
Capacities Available
150K, 200K and 300K lbs.

Model 3129-121 (Metric)
Capacities Available
750K, 1M and 1.5M Newtons



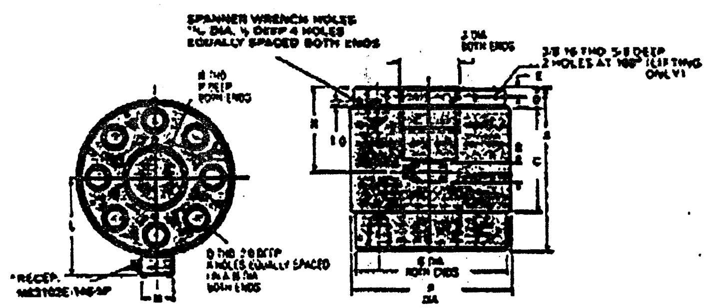
Model	A	B	C	D	E	F	G	H	J	K	L	M	N
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3129-112	10.0	7.0	1.5	4.25	7.5	5.0	2.5	5.0	1.5	5.5	3.31	1.0-8	3.0-12
3129-121	[illegible]	[illegible]	3.81	10.80	19.05	12.70	6.35	12.70	3.81	13.97	8.41	[illegible]	[illegible]



Model 3130 (English)
Capacities Available
500K, 800K and 1,000K lbs.

Model 3130-131 (Metric)
Capacities Available
2M, 3.5M and 5M Newtons

*Optional Dual Bridge not shown

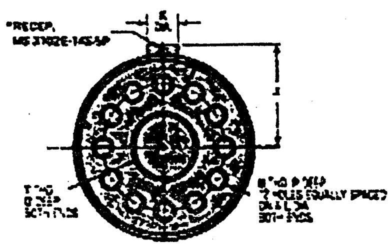


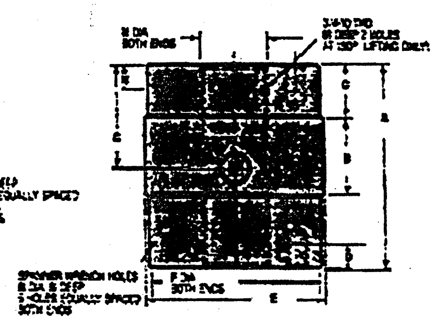
Model	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3130	12.5	7.0	1.5	2.0	.75	12.75	12.25	6.25	5.25	1.0	7.82	2.5	9.5	3.5	1.75-12	5.0-8
3130-131	[illegible]	[illegible]	3.81	5.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Model 3127 (English)
Capacity Available
2,000K lbs.

Model 3127-118 (Metric)
Capacity Available
10M Newtons

*Optional Dual Bridge not shown





Model	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	S	T	U
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3127	22.5	8	6.5	2.5	17.63	17.0	11.25	6.5	9.75	3.0	12.0	1.5	2.5	3.5	8.25	.41	.5	6.0-8	1-½-12
3127-118	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

WESTERN HYDRAULIC 2000 LTD.

10 SAGONA AVE. MT. PEARL NF. A1N 4R1
PH: 709-368-7800
FAX: 709-368-7811

FAX/ TRANSMITTAL No. of Pgs. 5 (inc. cover)

TO: David Busey COMPANY: MUN

FAX #: 737-3056 DATE: Jan 23/02

David,

Please inform what style of cylinder you would like. Please call when you recieve this fax.

Thanks,
Scott

FROM: SCOTT MERCER
TECHNICAL SALES

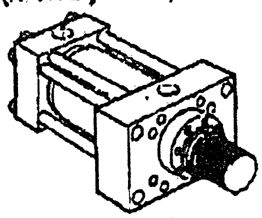
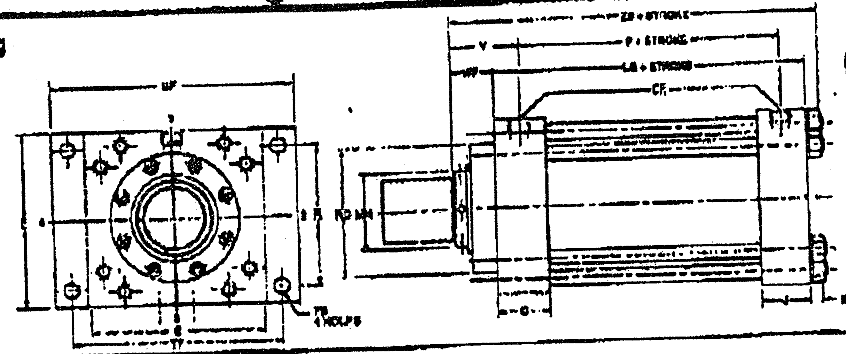
Head Office: Western Hydraulic & Mechanical Ltd.
P.O. Box 816, Maple Valley Ind. Park
Corner Brook, Nf. A2H 6H6
Phone: 709-634-5151
Fax: 709-634-1533

E-MAIL: westernhydraulic@nfld.net

WEBSITE: www.westernhydraulic.nf.net

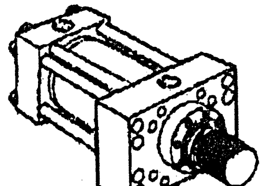
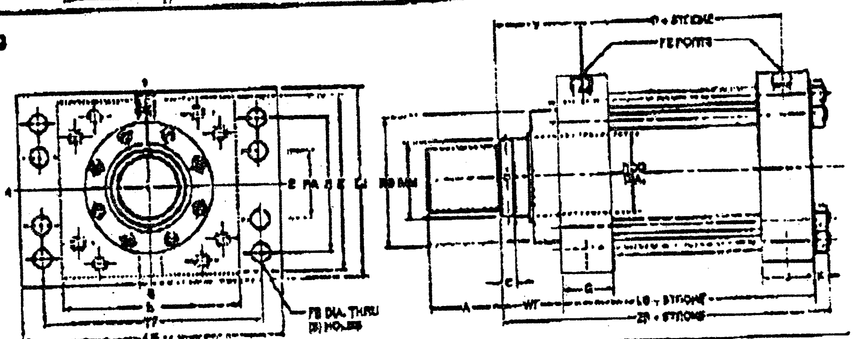
Series 3H Large Bore High Pressure Hydraulic Cylinders

Head Rectangular Mounting
Style JJ (10"-14" Bore)
(NFPA Style ME5)

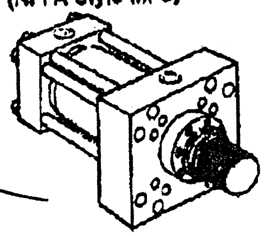
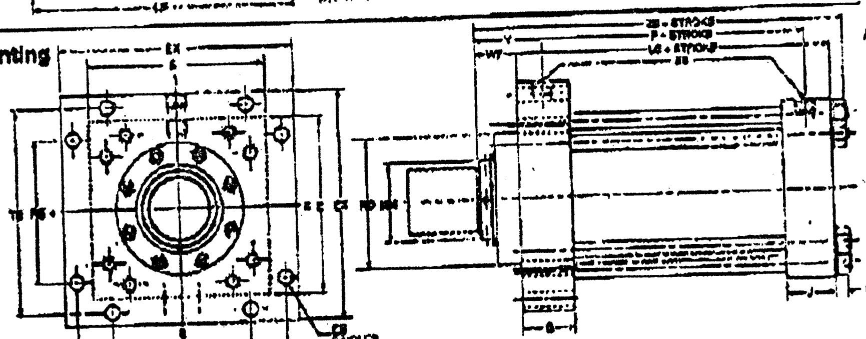
Jerry Pelly

Head Rectangular Mounting
Style JJ (16"-20" Bore)
(NFPA Style ME5)

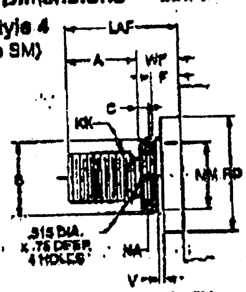
10,000 psi power unit whole package ≤ 40,000

Head Square Flange Mounting
Style JB
(NFPA Style MF5)

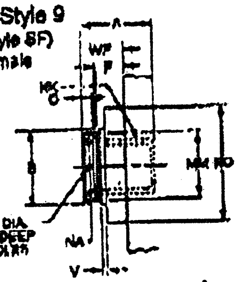
Rod End Dimensions — see table 2

Thread Style 4
(NFPA Style SM)
Small Male



If rod end is not specified, Style 4 will be furnished.

Thread Style 9
(NFPA Style SF)
Small Female



Use Style 9 for applications where female rod ends are required.

Special Thread Style 3
Special thread, extension, rod eye, blank, etc., are also available.
To order, specify "Style 3" and give desired dimensions for KK, A and LAF or WF. If otherwise special, furnish dimensional sketch.

For additional information – call your local Parker Fluidpower Motion & Control Distributor.

Western Hydraulic & Mechanical Ltd.

P.O. Box 816 Maple Valley Industrial Park
Corner Brook, Newfoundland A2H 6H7
Telephone: (709) 634-5151
Fax: (709) 634-1533

10 Sagona Avenue
Mount Pearl, Newfoundland A1N 4R1
Telephone: (709) 368-7800
Fax: (709) 368-7811

Email: westernhydraulic@nfld.net Website: www.westernhydraulic.nf.ca

January 24, 2002

Memorial University

Attn: David Bursey

Subject: Price Quotation

1/ PLR 60012 600 Ton ram - 12" stroke
single acting weight 1200lbs
Double Acting

PRICE: $11,840.00

1/ PES 5036 Power pack for above
Double Acting

OK PRICE: $ 6,850.00

We are able to quote on your original request if you desire but I would like to point out the cost may run as high as $80,000.00. The high cost is due to the limited pressure you have available.

The price quoted does not include freight or any changes we have to make to the ram.

I trust this meets your requirements. For further information please do not hesitate to call.

Regards,

John Pelley, Sr.
General Manager

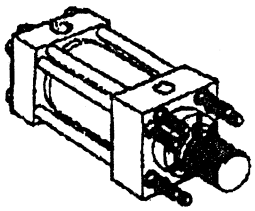
JP\kb

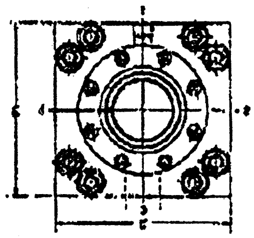
FEB-27-2002 WED 03:33 P. 01

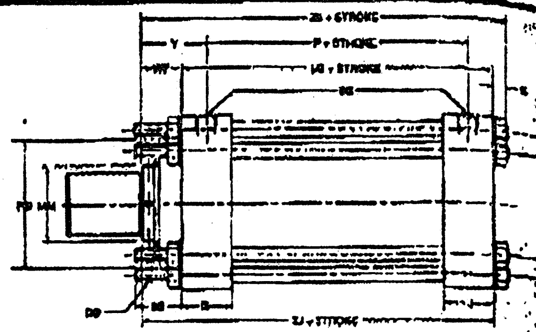
Tie Rod Mountings
Large Bore Sizes

Series 3H Large Bore High Pressure Hydraulic Cylinders

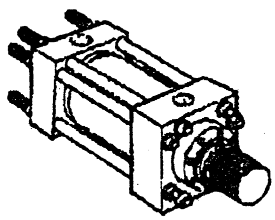
Tie Rods Extended Head End
Style TB
(NFPA Style MX3)

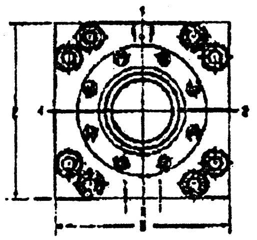


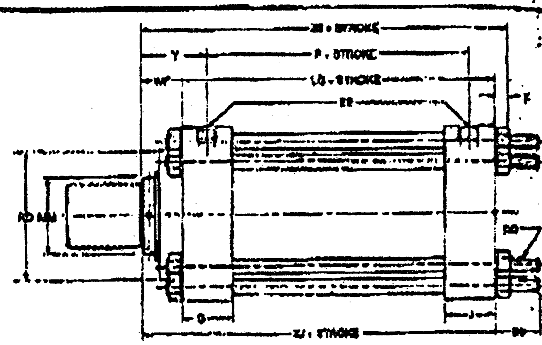




Tie Rods Extended Cap End
Style TC
(NFPA Style MX2)

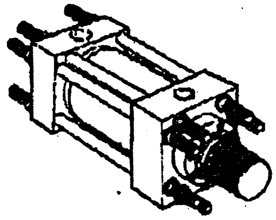


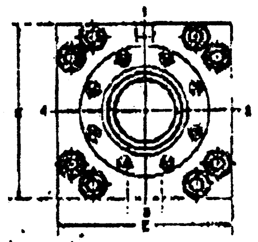


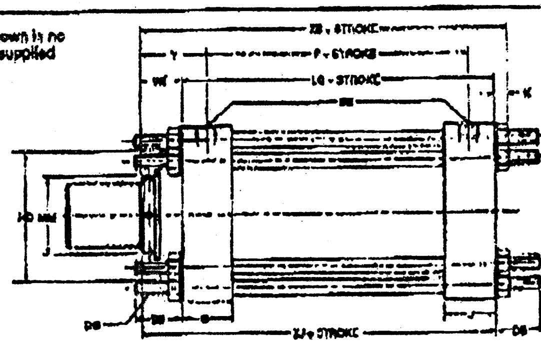


Tie Rods Extended Both Ends
Style TD
(NFPA Style MX1)

Basic Mounting (T) — Not shown is no tie rod extended and can be supplied upon request.

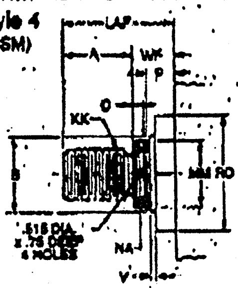






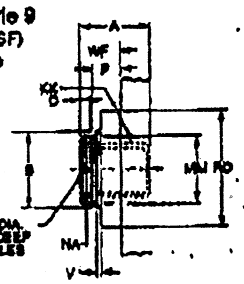
Rod End Dimensions — see table 2

Thread Style 4
(NFPA Style SM)
Small Male



If rod end is not specified, Style 4 will be furnished.

Thread Style 9
(NFPA Style SF)
Small Female



Use Style 9 for applications where female rod ends are required.

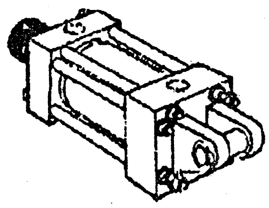
Special Thread Style 3
Special thread, extension, rod eye, blank, etc., are also available. To order, specify "Style 3" and give desired dimensions for KK, A and LAF or WF. If otherwise special, furnish dimensional sketch.

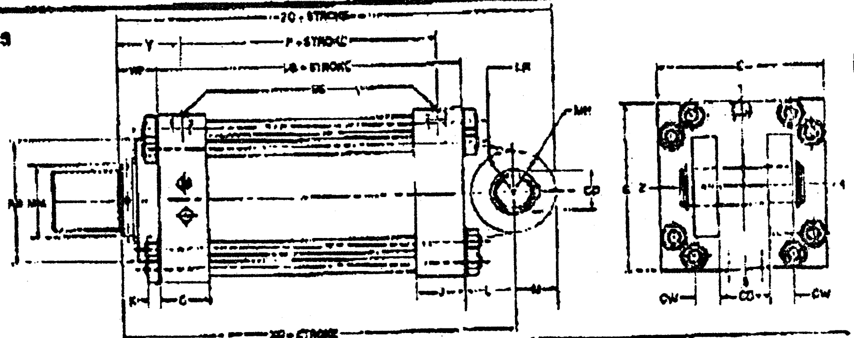
For additional information – call your local Parker Fluidpower Motion & Control Distributor.

Cap Fixed Clevis and Trunnion Mountings Large Bore Sizes

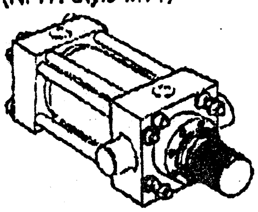
Series 3H Large Bore High Pressure Hydraulic Cylinders

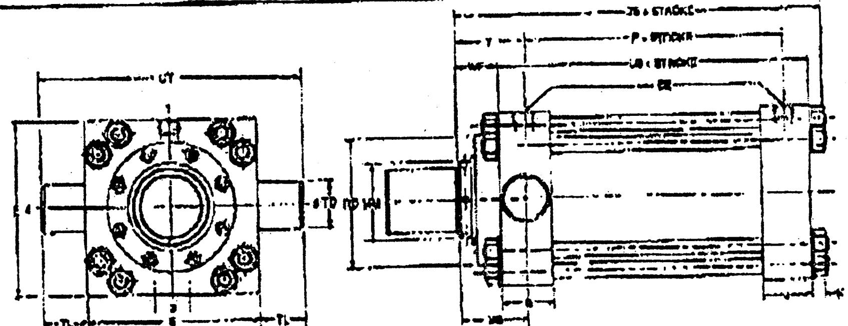
Cap Fixed Clevis Mountings
Style BB
(NFPA Style MP1)



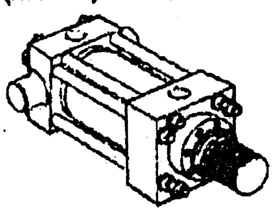


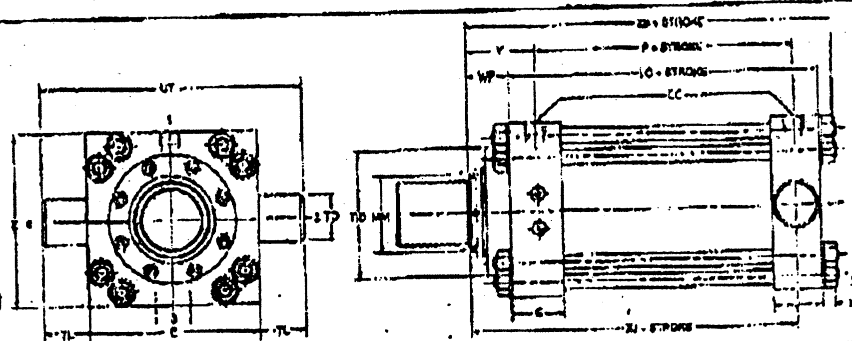
Head Trunnion Mounting
Style D
10"-14" Bore only
(NFPA Style MT1)



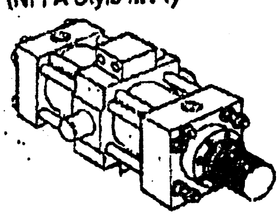


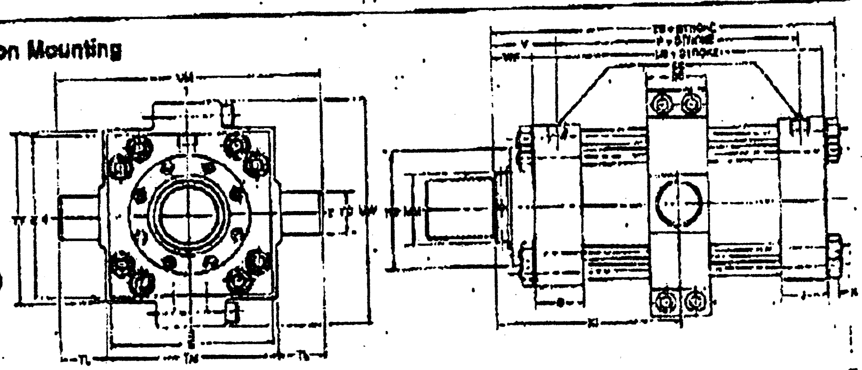
Cap Trunnion Mounting
Style DB
10"-14" Bore only
(NFPA Style MT2)





Intermediate Fixed Trunnion Mounting
Style DD
(NFPA Style MT4)





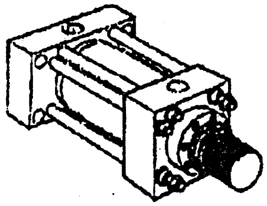
For additional information – call your local Parker Fluidpower Motion & Control Distributor.

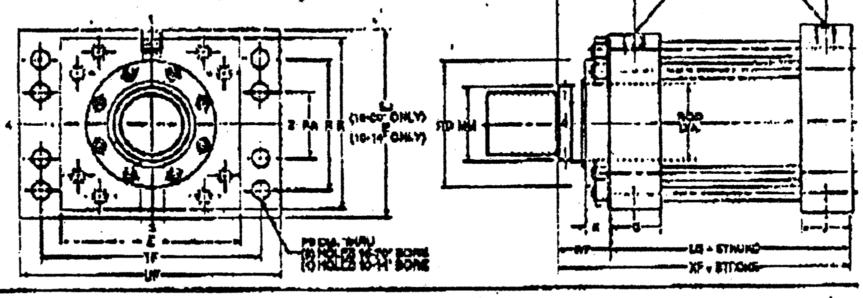
Cap Rectangular and Square, Side Lug and Centerline Lug Mountings Large Bore Sizes

Series 3H Large Bore High Pressure Hydraulic Cylinders

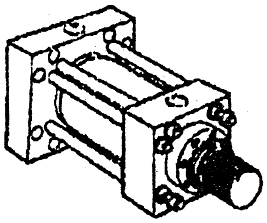
Cap Rectangular Mountings
Style HH
(NFPA Style ME6)

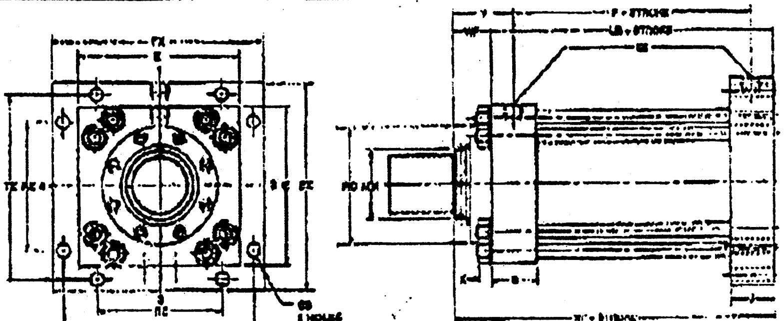
Note: 10"-14" Bores have (4) mounting holes, 16"-20" Bores have (8) mounting holes.





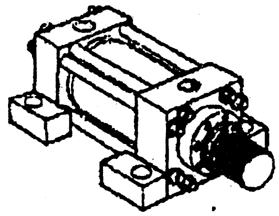
Cap Square Flange Mounting
Style HB
(NFPA Style MF6)

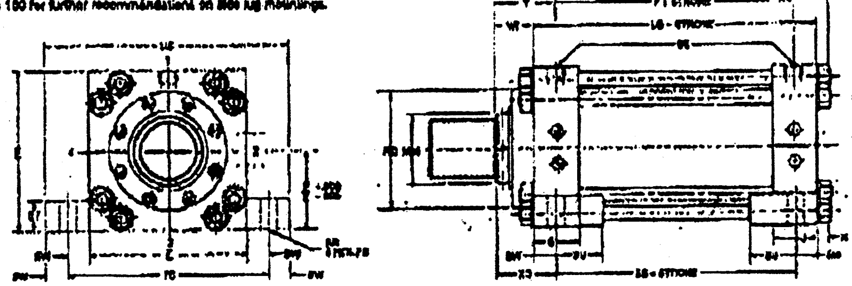




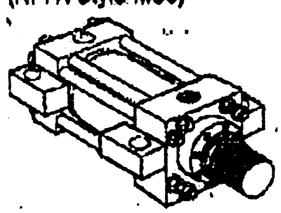
Side Lugs Mounting
Style C
10"-14" Bore only
(NFPA Style MS2)

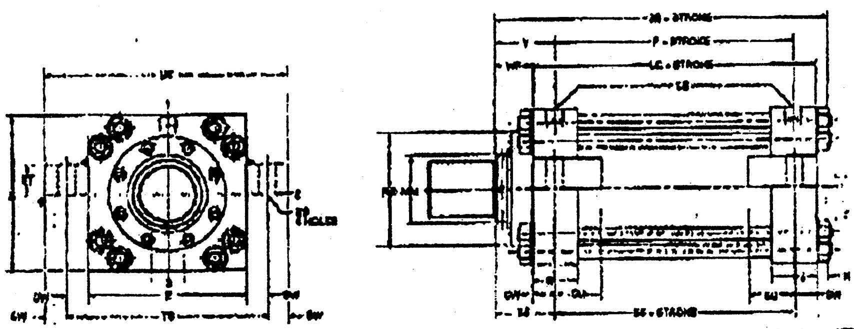
Note: Stroke lengths on lug mounted cylinders should not be shorter than the cylinder bore diameter. Consult factory for recommendations on shorter stroke lengths. See page 100 for further recommendations on side lug mountings.





Centerline Lugs Mounting
Style E
10"-14" Bore only
(NFPA Style MS3)





For additional information – call your local Parker Fluidpower Motion & Control Distributor.

STRAIN GAUGE LOAD CELLS

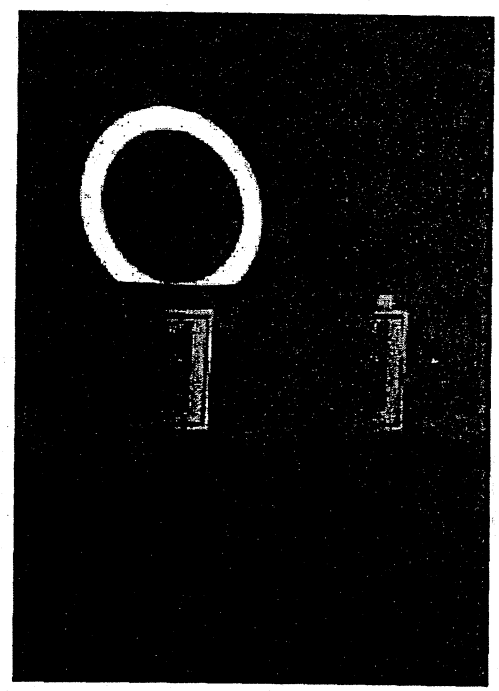
GENERAL DESCRIPTION:

A load cell incorporating from 8 to 16 high output electrical resistance strain gauges, in full bridge configuration bonded to a high strength steel or stainless steel spool. This arrangement compensates for both temperature effects and off center loading. Available in virtually any size, in both annular and solid styles. Gauge waterproofing is provided utilizing the latest application techniques and protective materials. The rugged design includes heavy duty protective cover, sealed construction, and low deflection under load.

Mounting surfaces should be flat and parallel for optimum performance. RST recommends the use of top & bottom loading platens for best performance with annular load cells.

FEATURES:

- Compatible with any conventional strain indicator instrument
- Options readout instrument in engineering units – Models IR-2840
- High resistance strain gauges to minimize cable effects
- High sensitivity
- Long term reliability
- Heat treated and stress relieved load element
- Available with either a plug connector, or with cable attached to load cells per client specified length
- Accommodates off center loading
- Custom manufactured to fit project requirements
- Matched calibration for readout in engineering units
- Temperature compensated



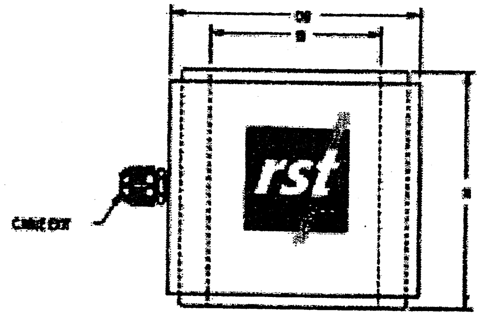
400 Kip Tie back cell with IR-2840 Intelligent Readout 50 Kip Tie back cell

OPTIONS:

- Armored cable
- Metal military, or plastic connectors (connectors not recommended in waterproof applications)

SPECIFICATIONS:

• Capacity	5,000 lbs to 2,400,000 lbs (22.5 kN to 10675 kN)
• Hole Size	5/8 in. to 14 in. (16mmto 356mm), as required
• Material	High strength steel or stainless elements
• Temperature Compensation	-40 F to + 107 F (-40 C to + 40 C)
• Overrange	100% FS
• Sensitivity	±2.0 mV/V



STANDARD DIMENSIONS:

MODEL	CAPACITY		I.D.		O.D.		HEIGHT	
	Kips	(kN)	In.	(mm)	In.	(mm)	In.	(mm)
SGA-50-1	50	(233)	1.0	(25)	4.0	(102)	3.0	(76)
SGA-100-1	100	(445)	1.0	(25)	4.0	(102)	3.0	(76)
SGA-136-1.4	136	(605)	1.4	(36)	4.5	(114)	3.5	(89)
SGA-200-1.75	200	(890)	1.75	(44)	5.0	(127)	5.0	(127)
SGA-255-2.0	255	(1135)	2.0	(51)	5.5	(140)	5.25	(133)
SGA-300-2.0	300	(1334)	2.0	(51)	5.5	(140)	5.25	(133)
SGA-300-3.0	300	(1334)	3.0	(76)	6.0	(152)	6.25	(159)
SGA-400-2.5	400	(1779)	2.5	2.5	(63)	(152)	6.25	(159)
SGA-400-3.5	400	(1779)	3.5	(89)	7.0	(178)	7.25	(184)
SGA-600-3.0	600	(2669)	3.0	(76)	7.0	(178)	7.5	(190)
SGA-600-4.0	600	(2669)	4.0	(102)	7.75	(197)	8.5	(216)

NOTE: These dimensions are typical only and may be modified to suit project requirements. The model number is determined as follows:

SGA – strain gauge annular cell.
200 – maximum capacity in Kips
1.5 – hole size in inches.

ORDERING INFORMATION:

1. Application
2. Annular or solid cell
3. Maximum capacity and smallest increment required
4. Environmental data
5. Size limitations
6. Cable connection and length
7. Loading Platens
8. Options

ANCILLARY EQUIPMENT:

- Digital strain indicator
- Cable
- Load and bearing plates
- Terminal stations
- Centralize bushings if required

LPB0005A

CANADA
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FAX: (1) 604-540-1005
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MALAYSIA
RST INSTRUMENTS (MALAYSIA) LTD.
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EMAIL: rst_malaysia@rst-inst.com