JOURNAL OF APPLIED POLYMER SCIENCE VOL. 8, PP. 169–196 (1964)

A Medium-Speed Tensile Testing Machine and Some Dynamic Data Produced Thereby

A. G. H. ANDERSON, *U. S. Army Materials Research Agency, Watertown Arsenal, Watertown, Massachusetts*

Synopsis

A pneumatic tensile tester, recently designed and built at Watertown Arsenal Laboratories, has a load capacity of 15,000 lb. and an idling speed of about 300 in./sec. over a 3-in. stroke, at 500 psi nitrogen or one-third the allowable maximum pressure. Loads and strains may be recorded by oscillographs or oscilloscopes. The scope can be triggered through an electric circuit by an internal, automatic poppet valve in the main gasport. External, auxiliary diaphragm valves are actuated by solenoids. Excess energy of piston assembly, after a tensile rupture, is absorbed through rapidly damped oscillations between two air cushions at opposite ends of the cylinder. The machine is mounted on a carriage resting on springs and Barrymounts so that operation at full load transmits negligible vibrations to the floor. Weight of machine and carriage is 700 lb.; base, 600 lb.; and steel safety cabinet, 400 lb. Short descriptions and a number of illustrations are presented which show typical actions of the machine and results of various tests recently performed on structural materials.

INTRODUCTION

Dynamic testing of mechanical properties of materials began early in this century, and in recent years has become increasingly important to requirements of the modern U. S. Army. However, it is interesting to note that, as far back as 1936, Watertown Arsenal had constructed and applied one of the earlier dynamic testing machines.[1]

The advent of electric resistance strain gages and the development of oscilloscopes have advanced the state of the dynamic testing art significantly since World War II. The concept of a highly mobile striking force has likewise resulted in accelerating the developmental effort in this area through its demand for a better knowledge of the dynamic behavior of modern materials.

Numerous items of Army materiel: rocket motor cases, launching tubes, and shells, to mention a few, are subjected to service conditions corresponding to strain rates ranging from quasi-static up to about 100/sec. In general, this range of strain rates coincides with the capabilities of the so-called medium-speed testing machines; as opposed to the high-speed testing machines (operating up to 1000/sec.), and the highly dynamic methods used in wave propagation studies (such as the Hopkinson bar, etc.).

A number of different machines have been developed for medium-speed testing; however, few of these are available commercially. In order to provide the capabilities for determining dynamic stress-strain behavior of modern structural materials for application to the development of Army materiel, the Fast-Acting Tensile Tester was designed and built at Watertown Arsenal.

GENERAL CHARACTERISTICS OF THE TESTING MACHINE

The Fast-Acting Tensile Tester has components arranged essentially similar to those of the ordinary hydraulic tensile testing machines whereby a piston, connected to the upper crosshead, strains the specimen. However, this machine utilizes high-pressure gas for driving power. A diagram of the machine is shown in Figure 1.

Power is supplied according to a principle commonly used for dynamic

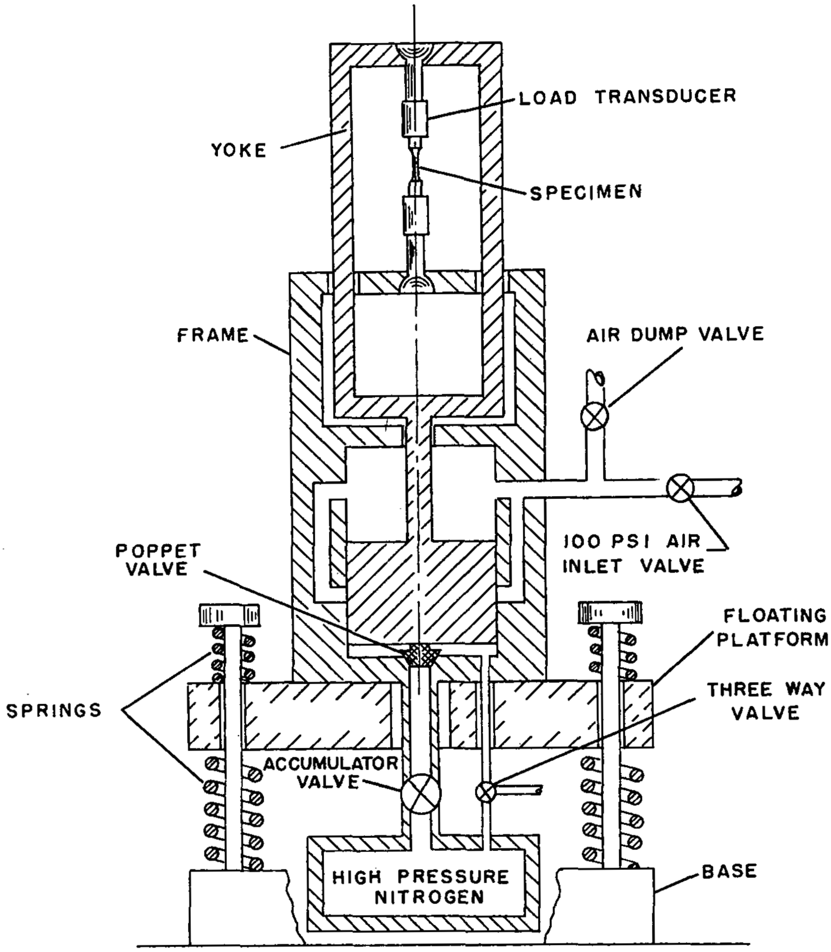


Fig. 1. Diagram of the Fast-Acting Tensile Tester.

piston-driven testing machines. The piston is held stationary by balancing pressures on its two sides; and made to move by unbalancing the pressures. The load capacity of the machine is 15,000 lb. in tension between crossheads. With specimens secured tightly in the grips, loading rates of 5 Klb/msec. have been achieved during rise times of 2 msec. More commonly, rise times of 3–8 msec. at loading rates of 1–2 Klb/msec. have been employed. The strain rates obtained on high strength, low modulus alloys with these loading rates were between 2 and 7 in./in./sec. These rates can be considerably increased when slack is allowed to occur between the crosshead and the specimen grips, thereby causing the moving components to acquire kinetic energy before engaging the specimen.

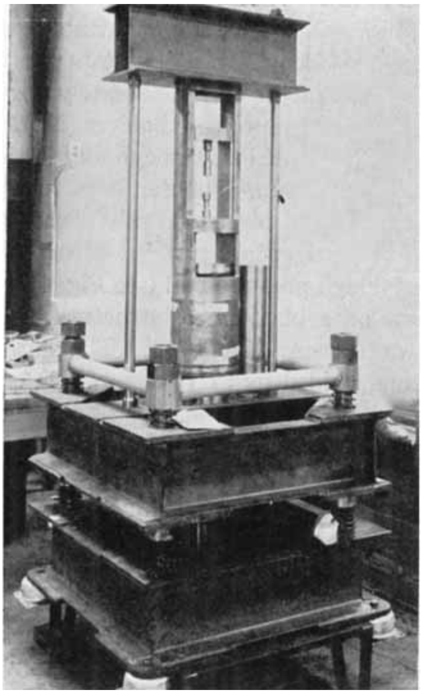


Fig. 2. Fast-Acting Tensile Machine.

Load, strain, and crosshead travel data can be photographically recorded on an oscilloscope, triggered through an electric circuit by an internal automatic poppet valve in the main gasport. External valves actuated by solenoids provide convenient control of the gas flow through the machine. The machine is mounted on a carriage flexibly supported by springs on a heavy base resting on Barrymounts so that operation at full load transmits negligible vibrations to the floor. Surplus energy of the moving components is absorbed by rapidly damped oscillations of the piston assembly between two air cushions forming at the extreme ends of the cylinder.

DESCRIPTION OF THE MACHINE

Assembly

The machine consists of a stanchion, including a cylinder, piston and attached mobile components, a base, a mounting platform, tie rods, a beam for securing the stanchion to the platform, Figure 2, and electric controls.

The stanchion assembly, (Fig. 3) contains a frame terminating in a cap in its upper end, (1B), and near its middle, the lower platen. The gasports are closed to the outside atmosphere by fittings not shown in Figure 3.

The piston is provided with a connecting rod (4A), having a bore which contains a spring with guide rod (4D). This bore also contains the stem of the poppet valve head (4I). The piston rod passes through a bushing in the cylinder head and is connected to a circular table carrying two posts (2) terminating in the upper platen (2E). The posts pass freely through slots in the lower platen. The platens carry accurately aligned ball and socket joints with stems to receive the specimen holders (2H).

At the lower end of the stanchion, the cylinder is closed by a block (5) and sealing rings (5H). A 1-in.-diameter bore runs through the block terminating in the electrically insulated valve seat (5C). This is connected to the oscilloscope trigger by a wire leading out through a narrow duct closed by a special high pressure seal (see Fig. 4)

The stanchion rests on a platform of structural steel (Fig. 2), and is secured thereto by two tie rods and a girder. The platform rests on springs carried by the base and guided by four posts, which extend from the base through holes in the platform. Springs are similarly provided above the platform, and are held in place by a railing attached to the posts.

As a safety measure, the cyclinder is covered by a $^1/_4$-in. steel shell (not shown in Fig. 2). All parts of the machine below the top level of the cylinder are located within a steel plate cabinet, the topside deck of which forms the work table of the machine. The plates are of various gages, from $^1/_8$ to $^1/_4$ in., according to safety considerations. The base and carriage are welded structures of steel plate and channels, as can be seen in Figure 2. The railing and spring stops, visible above the carriage, are welded aluminum tubes.

The piston (Fig. 3) is aluminum alloy except for the steel bushing in its topside. The yoke is of titanium alloy and weighs 25 lb. If it were made of steel of the same strength, its weight would amount to 42 lb. However, the higher rigidity of steel could possibly be beneficial.

Specimen Holders

Grips are provided for round specimens and for two types of flat test pieces, viz., with and without pin holes, respectively. An adjustable compression head and a pressure transducer are available. When used, these are mounted between the lower platen and the movable table. Adjustable buffers tipped with rubber are provided for use with the pressure-head, in

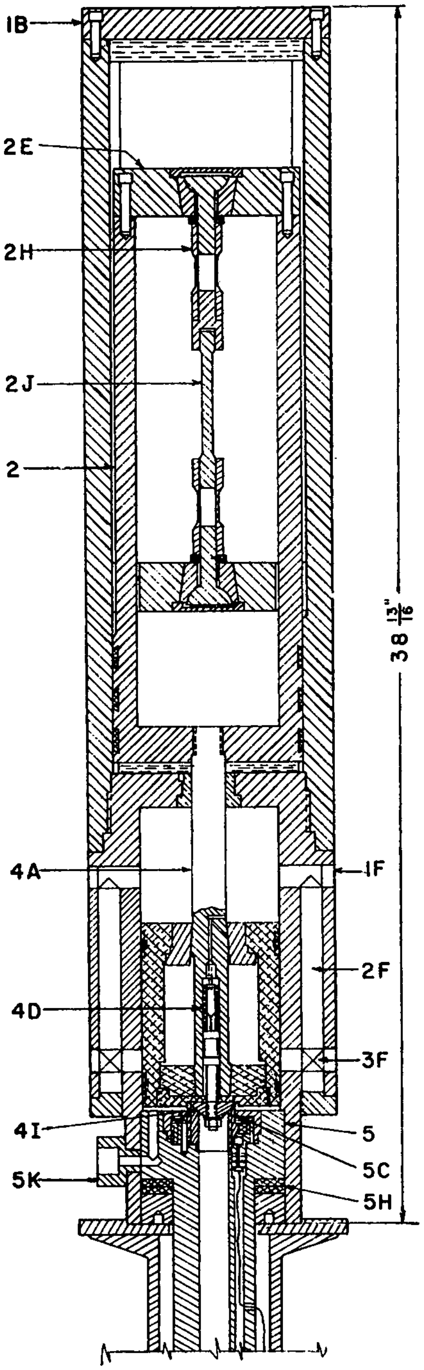


Fig. 3. Stanchion assembly.

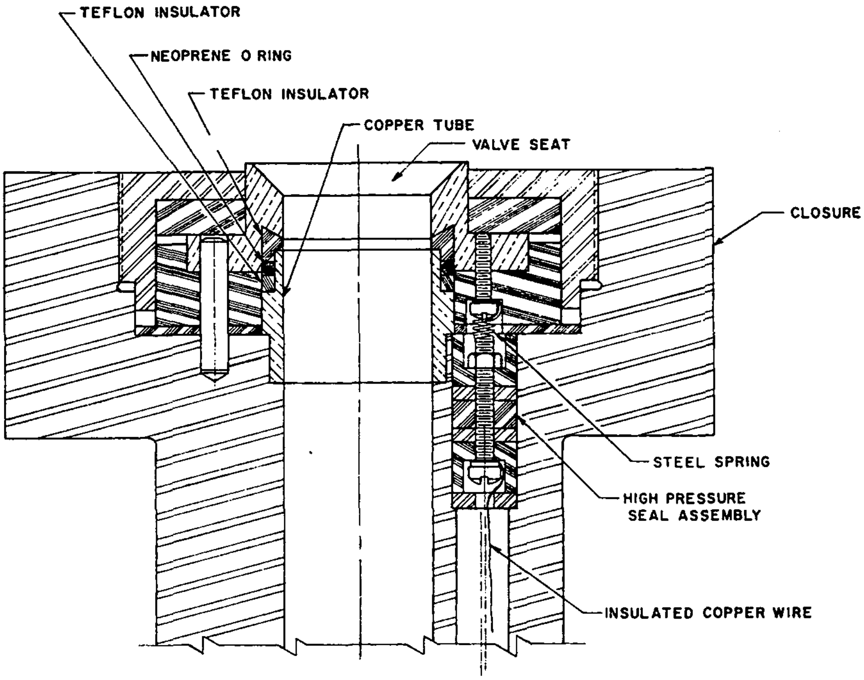


Fig. 4. High pressure seal and valve seat assembly in closure.

order to stop an excessive motion of the table and piston assembly in case a specimen should collapse. This arrangement is illustrated by Figure 5.

A fixture for conducting dynamic bend tests of brittle materials has been built for use with this machine. It consists of a four-support system of rollers, set between two plates, separated by an adjustable distance. The upper one is in contact with a suitable transducer that transmits the working pressure through the supporting rollers to the specimen. In operation, this assembly is located in the same space as the compression fixtures (Fig. 5).

Provision has also been made for hydrodynamic testing; intensifiers, with manifolds for pressure gages and tubular specimens, are available. When in use these are placed in the space occupied by the compression fixtures (Fig. 5).

OPERATION OF THE TESTING MACHINE

Activated by high-pressure gas, the piston and yoke will be impelled upward and the cylinder will recoil. In order to take this downward thrust, the cylinder is attached to a carriage which rests on springs fixed to a heavy base. The piston complex may, after the specimen is broken, possess high kinetic energy. -Its motion can be stopped and reversed by a cushion of trapped gas in the cylinder head and this action impels the

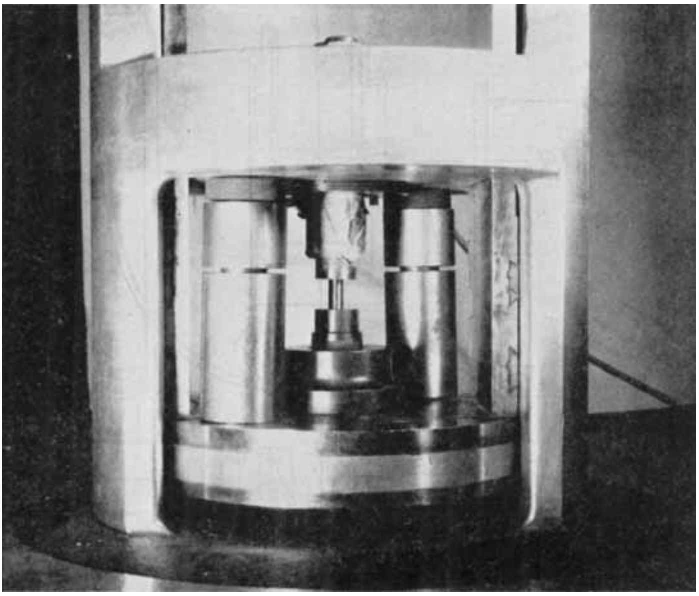


Fig. 5. Compression fixture showing position of pressure transducer and adjustable buffers.

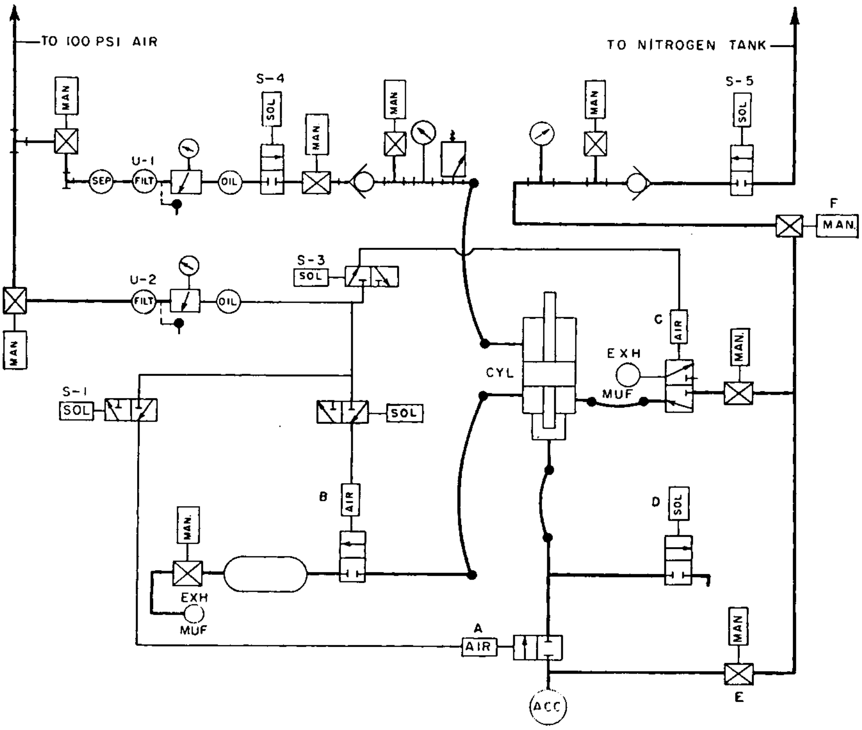


Fig. 6. Functional diagram.

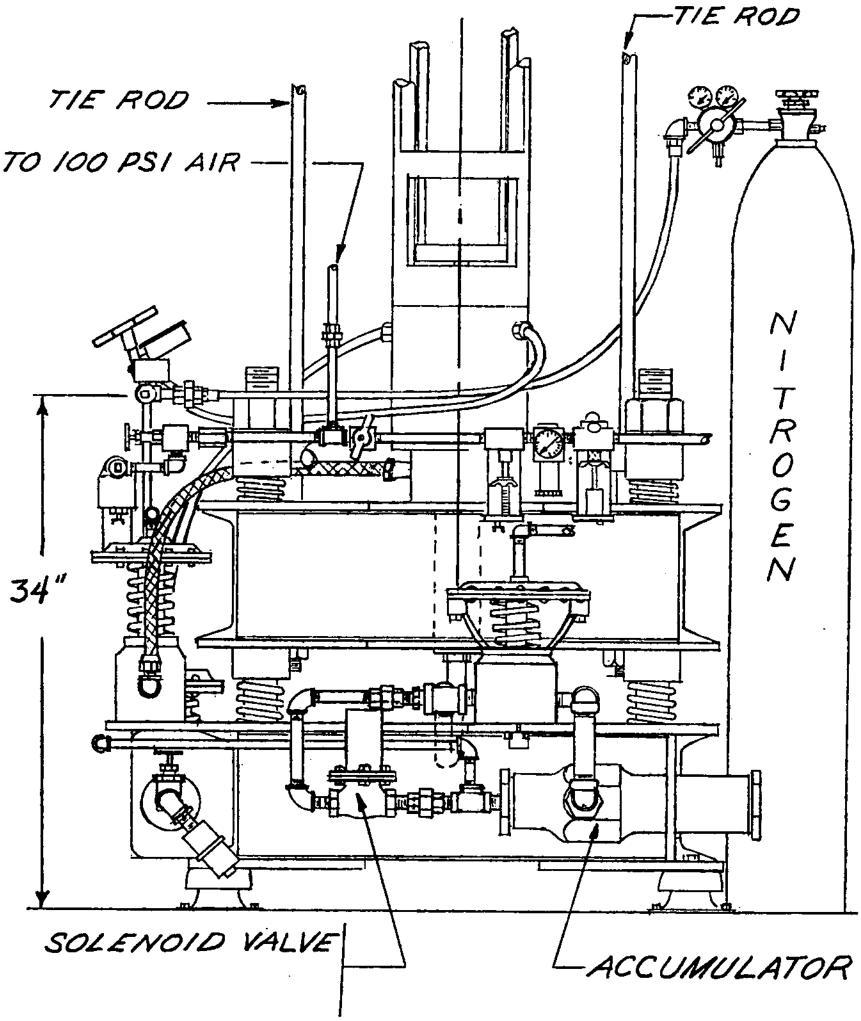


Fig. 7. Position of valves in the Fast-Acting Tensile Tester.

machine and carriage upwards. Hence, springs are provided above the carriage to take its upward thrust. The carriage thus "floats" between two sets of springs held in position by sturdy rods that pass with loose fit through holes in the carriage. The upward thrust, caused by the rebound of the piston complex, tends to force the cylinder and frame off the carriage. Therefore, these are secured in position between the carriage and an overhead girder by means of two tie rods. This arrangement is illustrated by Figure 2.

A sectional view is shown in Figure 3 from which the functioning of the machine may be understood. Dry nitrogen gas is lead into the cylindrical space beneath the poppet valve head, designated as (4I). This chamber is connected through a valve to an accumulator (Figs. 6 and 7), which can be safely charged with nitrogen up to 1500 psi.

Ordinarily, only a small pressure under the valve head would be required to lift the piston assembly enough to let the high-pressure gas escape past the valve into the space under the cylinder and thereby impel the piston upward. However, the slight motion of the poppet valve head required to initiate this event, is prevented by the admittance of low-pressure air through channels (1F) in Figure 3, into the space between the cylinder head and the piston's upper face. The ratio of the areas of the piston face and the valve opening is 20:1, so that an air pressure $^1/_{20}$ the nitrogen pressure is needed to balance the forces on the valve and piston. With a somewhat higher ratio of air pressure to nitrogen pressure, say $^1/_{15}$, the valve will remain securely seated. The 15:1 force seating the valve may be augmented by putting the specimen under some initial tension.

In time, however, wear and tear will cause gas to leak past the poppet valve. Therefore, an arrangement has been made to vent the space under the piston, above the valve, to the atmosphere through the fitting (5K) (Fig. 3), and a three-way valve connected thereto.

Upon "striking" a specimen, the accumulator valve A (Fig. 6) opens, admitting high pressure gas under the poppet and the air pressure above the piston is dumped through the dump valve B.

Thus, with the dump valve and the accumulator valves open, the force under the poppet valve increases and the force on the cylinder top decreases until the former exceeds the latter. With a tight specimen, the resisting force of the specimen may prevent the poppet valve from opening. Positive action is nevertheless assured, for now the vent of the three-way valve is automatically closed and a small stream of high pressure gas is let in under the piston, through this valve. The entrance of this gas causes the piston to move up slightly. The poppet valve stem which slides in the piston rod is depressed by a slight spring pressure (see Fig. 3), but pressed upwards by the difference in pressure acting on the upper and lower faces of the poppet valve head. The latter pressure exceeds the former and the poppet valve head moves up in unison with the piston, thus initiating admission of the main stream of high pressure gas through the poppet valve opening.

LOAD AND STRAIN GAGES

A tensile specimen to be tested (2J) (Fig. 3), is attached through tubular adaptors (2H) to ball and socket joints in the crossheads. One adaptor also serves as load transducer and is supplied with four SR-4 gages connected to form a complete bridge circuit. Small strains are measured by SR4 gages attached to the specimen. Crosshead travel can be measured by means of a linear potentiometer gage or a differential transformer gage, attached to the frame, and actuated through a wiper and rod attached to the upper crosshead.

The outputs of the gages are fed into an oscilloscope triggered by a battery current through the poppet valve head and the electrically insulated valve seat. When the valve head rises from the seat, it acts as a switch, breaking the circuit, thereby energizing a thyratron which triggers the scope.

THE PNEUMATIC SYSTEM

A functional diagram is shown schematically in Figure 6. All pressure lines, leading to and from the cylinder mounted on the floating carriage, are flexible extra-strong braid tubing. All other high-pressure lines are extra-strong steel pipe and fittings. The high-pressure valves are rated at 6000 psi hydraulic pressure, but their use has been limited to 1500 psi gas

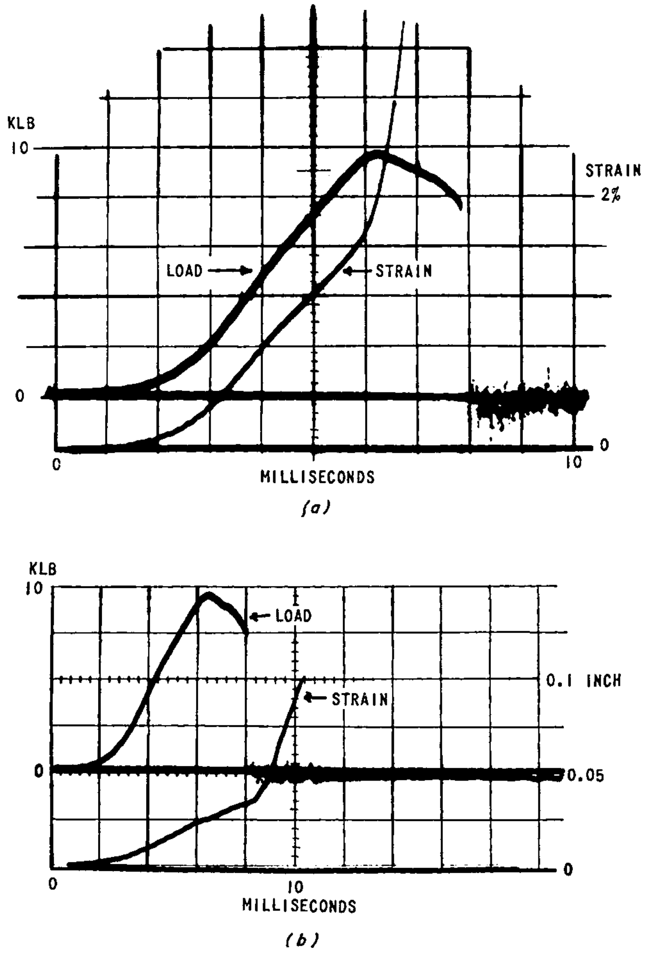


Fig. 8. Typical oscilloscope traces of uranium alloy (8% Mo, 0.5% Ti): (*a*) load and strain versus time; (*b*) load and head travel versus time.

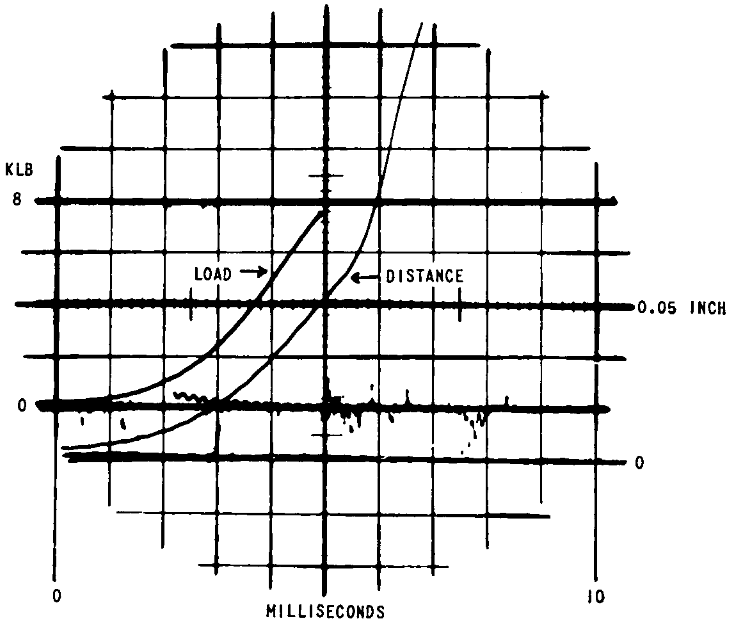
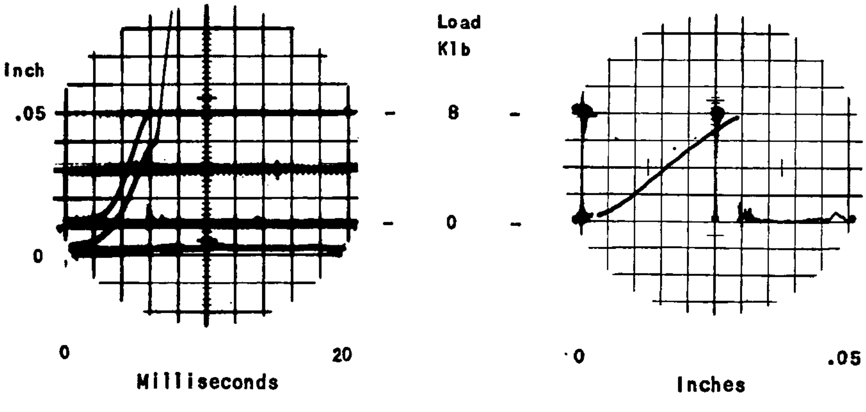


Fig. 9. Oscilloscope traces of notched specimen showing load and head travel versus time.



(*a*) (*b*)

Fig. 10. Oscillscope traces of notched specimen (E3, L-11, N: −65°F.): (*a*) load and platen travel versus time; (*b*) load versus platen travel.

pressure. The positions of the valves can be seen in Figure 7. For the sake of convenience, the operating valves are electrically actuated from a central switchboard.

Referring to Figure 6, low-pressure air is charged into the cylinder above the piston from a 100 psi air main. The air passes through a cleaner-pressure regulator unit before it is admitted to the cylinder through a

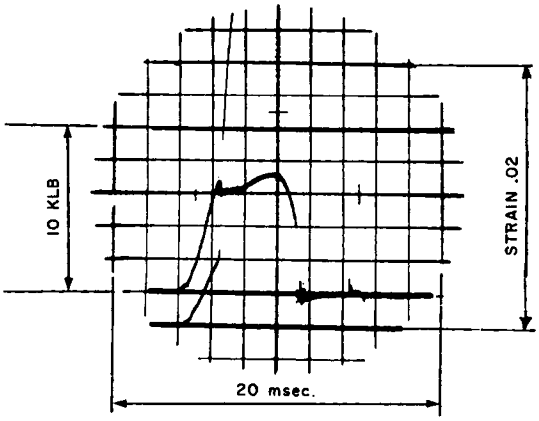


Fig. 11. Oscilloscope traces of a soft tempered 4340 steel.

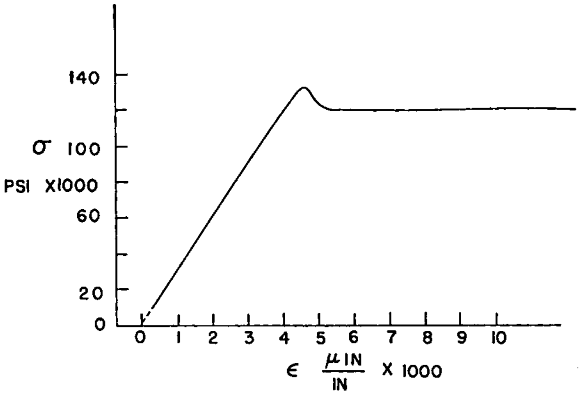


Fig. 12. Stress-strain curve of soft tempered 4340 steel.

$^1/_4$-in. pipe and solenoid valve. This air line contains a check valve, a blow-off valve, a safety valve, and a pressure gage.

The nitrogen gas is supplied from commercial tanks connected to a manifold, provided with a gage and regulator. The gas is charged into the accumulator through a $^1/_4$-in. pipe by means of a high-pressure solenoid valve; and this line also contains a check valve, blow-off valve, and pressure gage. When charging, the accumulator valve, (A), may be kept open and gas at any pressure up to about 800 psi can be introduced in the space under the poppet valve head. Valve (A) is then closed while the accumulator is being charged to any desired higher pressure, up to 1500 psi. The 800, psi or so, limit, stated above, is determined from time to time as the pressure at which the poppet valve might leak excessively.

The quantity of gas thus charged remains in the accumulator until released through the diaphragm valve (A) and the 1-in. flexible tubing leading to the space under the poppet valve.

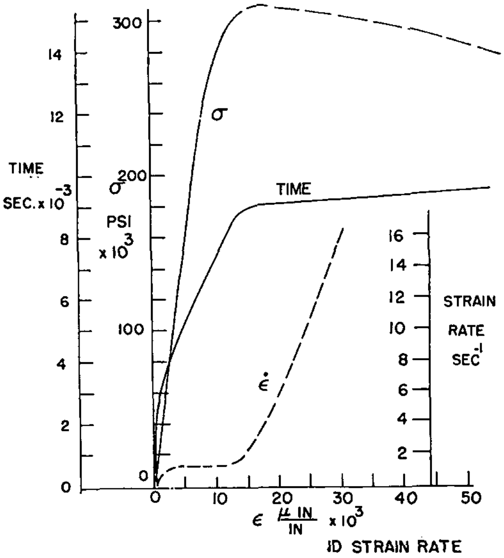


Fig. 13. Stress-strain curves of hard tempered 4340 steel possessing no definite yield point.

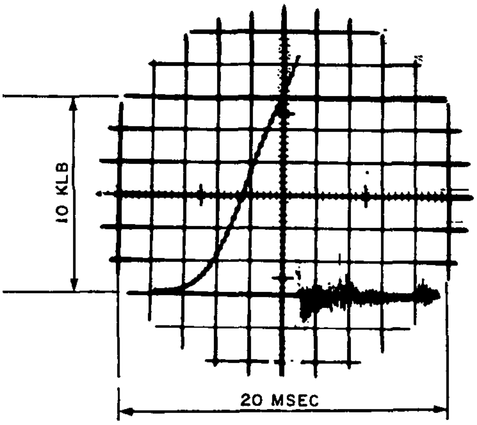


Fig. 14. Oscilloscope trace of notched 4340 steel in hard temper.

At the instant of striking, the air above the piston in the cylinder head is dumped through the $^1/_2$-in. valve (B) into the surge tank and then through a throttling valve and exhaust muffler to the atmosphere. The three-way valve, already referred to, which, before striking, vents the space in the cylinder under the piston and, during a strike, injects high-pressure gas into this space, is a $^1/_2$-in. diaphragm valve designated C. The valve D is a $^1/_2$-in. valve which is used mainly for quick pressure release when needed. All these valves are normally closed and will open and remain open only when their solenoids are energized. The three diaphragm valves are

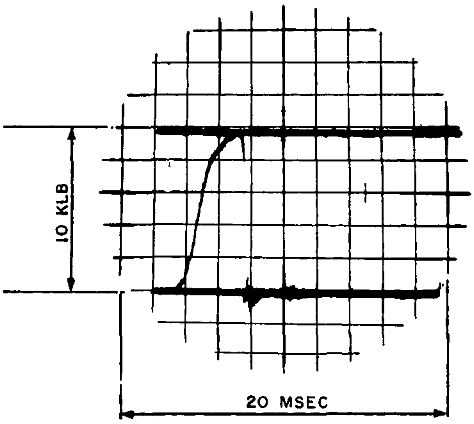


Fig. 15. Oscilloscope trace of notched 4340 steel in soft temper.

actuated by low-pressure air from the main. The auxiliary air line leads through a cleaner-regulator unit into three $^1/_4$-in. branch lines. Each branch contains a solenoid pilot valve which, upon opening, supplies air at 35 psi to activate its master diaphragm valve. It should be noted that valves A, B, and C are comparatively slow acting and that the actions of B and C can be adjustably delayed respecting opening of A. The fast action of the machine depends upon the poppet valve which functions suddenly, only after the slower valves have transmitted sufficient gas to create excess pressure under the piston. Thereafter, these valves sustain the pressure difference. The machine may be operated slowly by opening valve C while A remains closed. In this case no low pressure air is admitted to act on the cylinder head. The speed is then regulated by the needle valve, F, in the gas inlet line. The manual accumulator valve E is best kept closed during this operation.

DAMPING OF MACHINE VIBRATIONS

When the machine is used for tensile and for compressive testing, the lower platen is struck by a force reacting to the load on the specimen.

When a specimen is struck without being fractured, as is often the case in compression and in multiple blow tensile testing, the piston complex immediately comes to a stop while the kinetic energy is dissipated through the specimen and machine.

But, when rupture occurs in tension of specimens having high strength and low ductility, the piston may travel an additional $^3/_4$-in. or so under high gas pressure and thus acquire say, 250 ft. lb. of kinetic energy. This energy could deliver a disturbingly severe blow to vital components, if it were not dissipated gradually. This is done by rapidly damping the oscillations of the piston complex.

Some materials will collapse during compression; in such an event, the piston complex must immediately be prevented from proceeding under pressure and gaining excessive momentum. This is done by placing suitable buffers parallel with the compression fixture and the transducer attached to the lower platen as shown in Figure 5. The buffer consists merely of a $^3/_4$ in. rubber block attached to an adjustable iron coupling and serves to stop the piston in its travel. Excessive vibration to the machine after collapse of a compression specimen can be prevented both by use of these adjustable buffers and by carefully avoiding higher loads than necessary.

TEST DATA OBTAINED WITH THE MACHINE

The Fast-Acting Tensile Tester at U. S. Army Materials Research Agency has been used on development projects for dynamic tensile testing of alloys at temperatures ranging from −65 to +170°F., multiple strike tests have been made on notched specimens at room temperature; compression tests on metallic and on plastic specimens at room temperature have also been done.

Typical traces of tensile load and strain versus time in a uranium alloy (8% Mo, 0.5% Ti) can be seen in Figure 8; two scopes were used in tandem, (*a*) shows strain as in./in., while (*b*) shows crosshead distance. This distance can often be used to calculate an approximate strain before maximum load is reached, taking into consideration that the total extension of the whole specimen is involved. This, of course, contrasts with the strain measured over a 0.25-in. length at the middle of the specimen as shown in (*a*). It is noted in (*b*) that the crosshead speed is nearly uniform until after maximum load has been reached; this indicates that the speed is virtually unchanged during general and local extension of the specimen. Consequently, the actual strain takes off at the very high rate observable in (*a*) during localized extension. It is not until the specimen, in breaking, releases its load, that the crosshead speeds up; this is quite apparent in (*b*). Sometimes a specimen will break while the load is on the increase; this is shown for a notched specimen in Figure 9. The hash seen on the load base-lines indicates shaking of the transducer as its load is abruptly released during fracture of the specimen.

In order to obtain stress-strain curves from the load-strain-time diagrams, the films were put into a photo-enlarger and the traces projected onto suitable coordinate paper so that they could be traced off in pencil. The coordinates were supplied with scalars representing stress and strain. From these diagrams crossplots of stress versus strain were finally made.

When no special interest is attached to individual variations of stress and strain with time, x-y records of stress versus strain can be made. A comparison of the two types of records are shown in Figure 10 (*a*) and (*b*), which were obtained on a uranium alloy, at −65°F., using two scopes in tandem.

Figure 11 shows oscilloscope traces of a soft tempered 4340 steel. The trace displays upper and lower yield points. The stress-strain curve for a

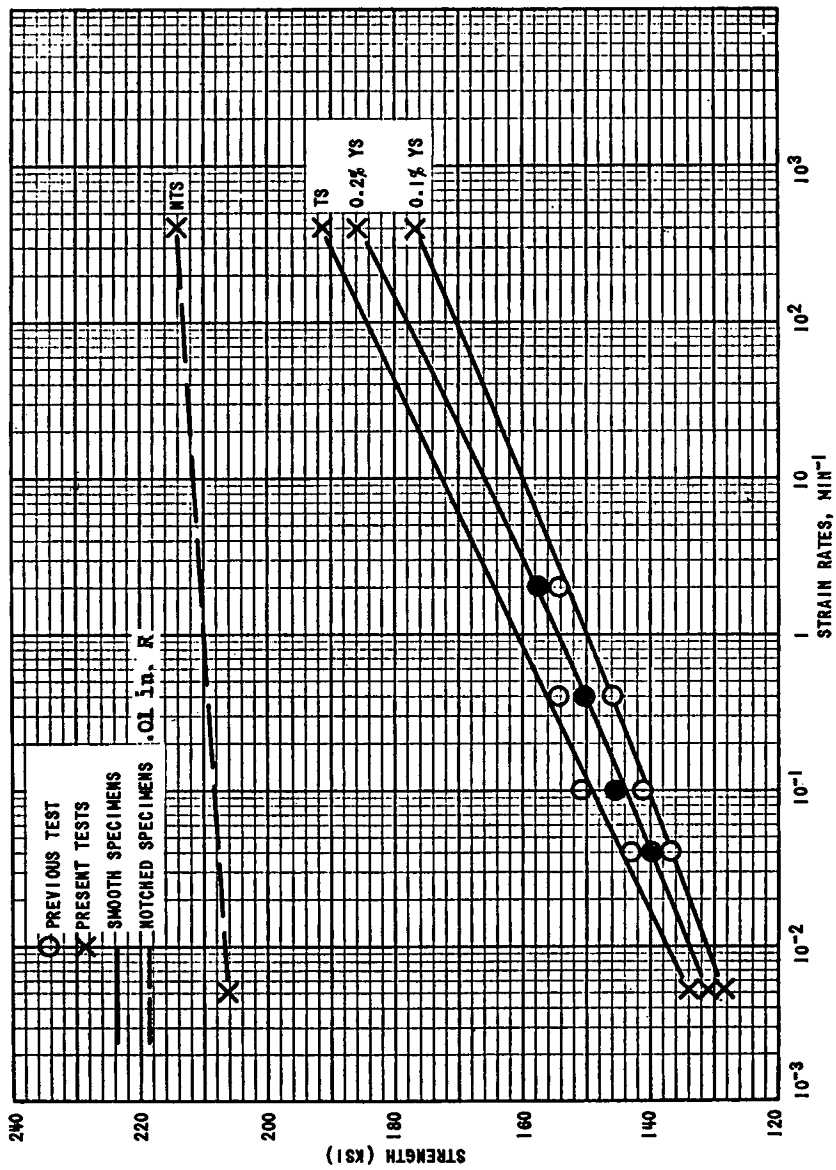


Fig. 16. Strengths versus strain-rates of 8% Mo, 0.5% Ti alloy of uranium at 70°F.

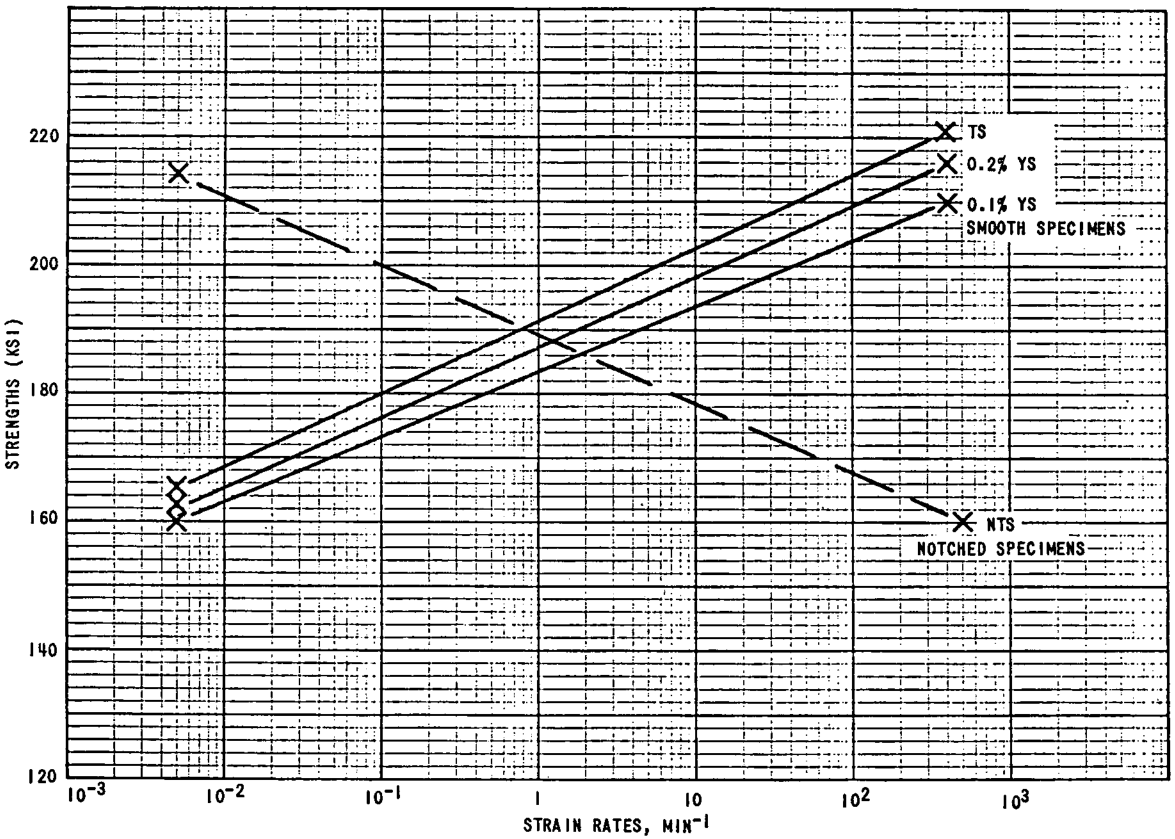


Fig. 17. Strengths versus strain-rates of 8% Mo, 0.5% Ti alloy of uranium at −20°F.

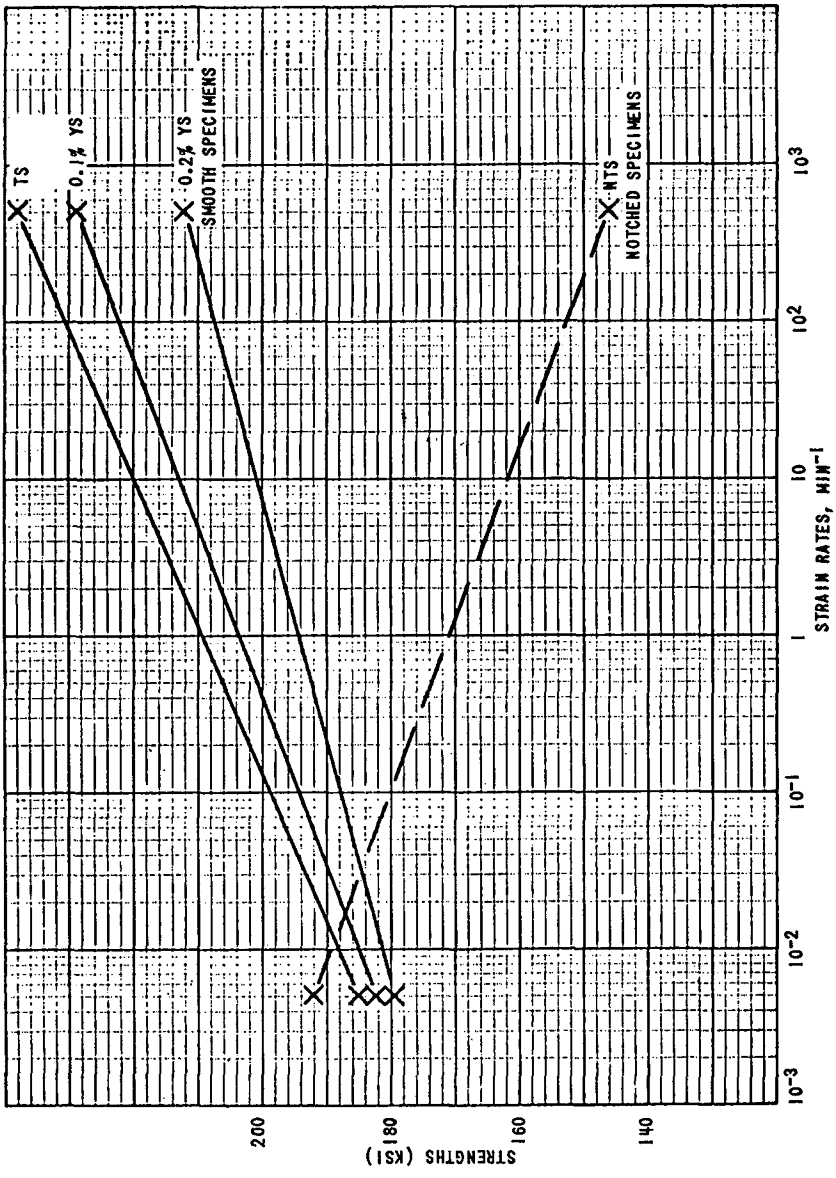


Fig. 18. Strengths versus strain-rates of 8% Mo, 0.5% Ti alloy of uranium at −65°F.

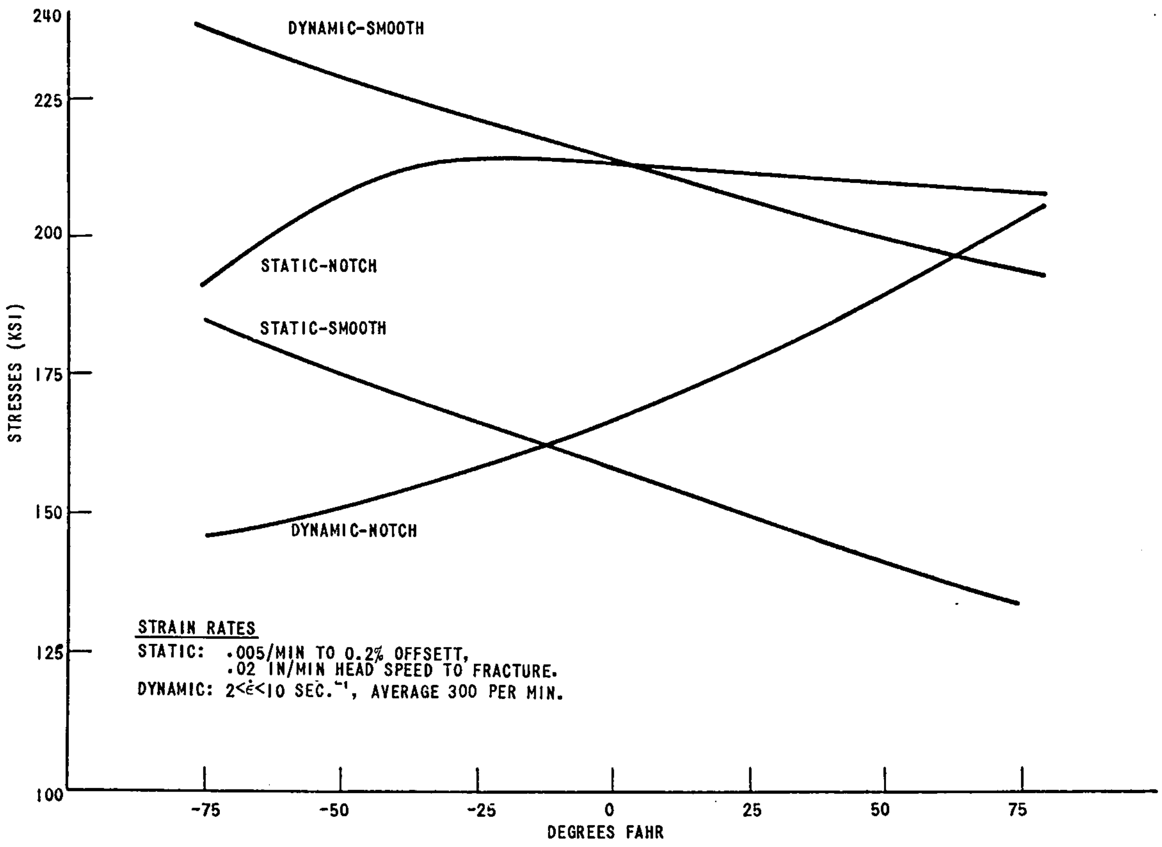
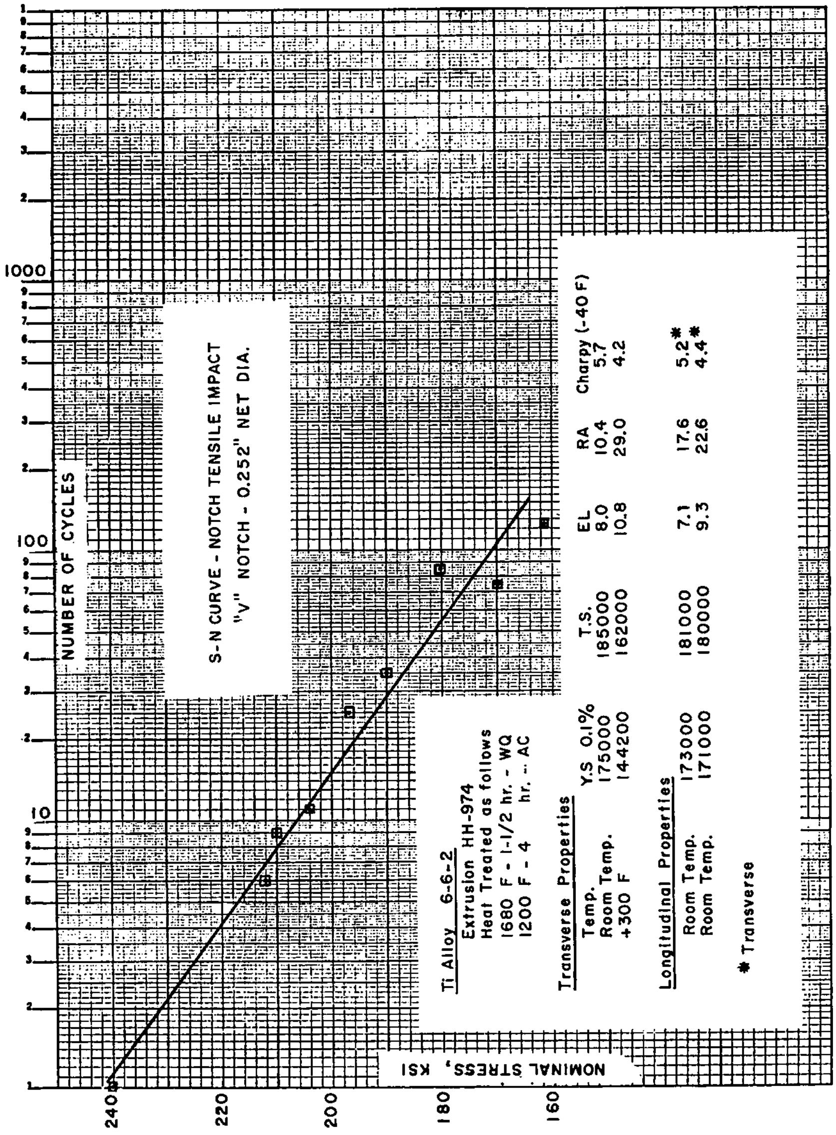


Fig. 19. Plots of tensile strength versus temperature for both dynamic and static tests on the 8% Mo, 0.5% Ti uranium alloy.



Ti Alloy 6-6-2
Extrusion HH-974
Heat Treated as follows
1680 F - 1-1/2 hr. - WQ
1200 F - 4 hr. - AC

Temp.	Y.S 0.1%	T.S.	EL	RA	Charpy (-40 F)
Transverse Properties					
Room Temp.	175000	185000	8.0	10.4	5.7
+300 F	144200	162000	10.8	29.0	4.2
Longitudinal Properties					
Room Temp.	173000	181000	7.1	17.6	5.2*
Room Temp.	171000	180000	9.3	22.6	4.4*

* Transverse

Fig. 20. Results of repeated tensile loading tests.

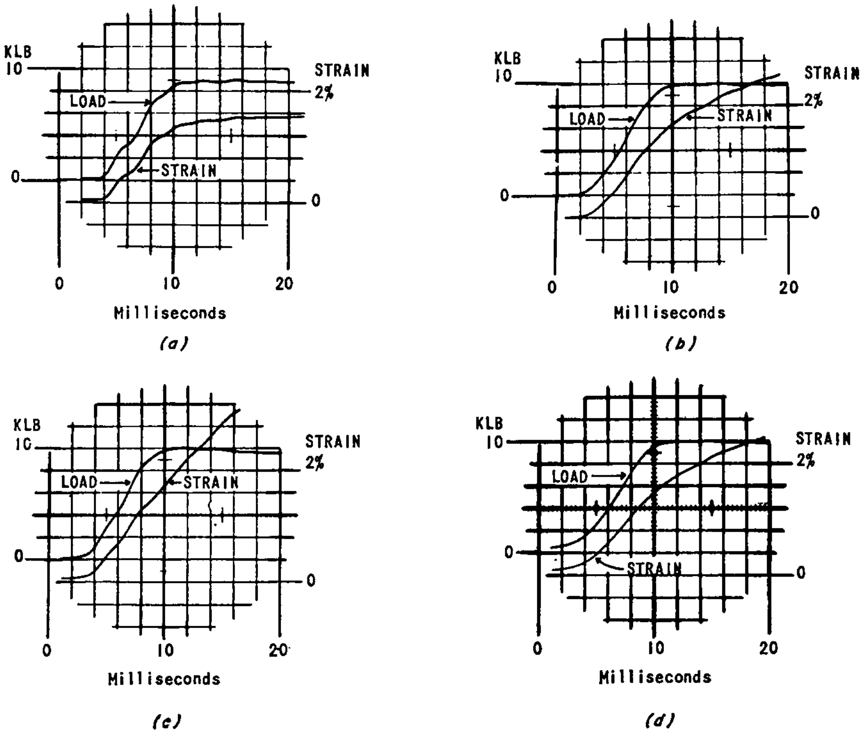


Fig. 21. Examples of the traces obtained on 8% Mo, 0.5% Ti alloy of uranium (*a*) specimen CL-3; (*b*) specimen CL-4; (*c*) specimen CL-5; (*d*) specimen CL-6.

similar specimen is shown in Figure 12. The stress-strain curve for a hard tempered 4340 steel possessing no definite yield point is shown in Figure 13. Here instantaneous strain rates and the time to reach a given stress and strain are also depicted. The former are fairly constant over a large part of the stress-strain curve, but increase rapidly after maximum load.

Traces of notched 4340 steel in hard and soft temper are shown in Figures 14 and 15, respectively. The differences in shape of the traces obtained at 72°F. also persist at −65°F.

Strength versus strain rate at 3 temperatures for an 8% Mo, 0.5% Ti alloy of uranium are shown in Figures 16–18. The data showing strain rates of 300 in./in./min. were obtained on the Fast-Acting Tensile Tester. For slower rates hydraulic and screw driven machines were used. All specimens were cut from hot extruded tubular stock $^3/_4$-in. thick. Tensile strength of notched specimens (45° angle with a 0.010 in. root radius) increases with temperature but decreases with strain rate at the lower temperatures, while at 70°F. there is a slight increase in strength with strain rate. The strength of the smooth specimens increase with strain rates and decrease with temperature.

Plots of tensile strength versus temperature are shown in Figure 19 for both dynamic and static tests. The static smooth tests lay on a lower strength level than the dynamic smooth tests. Both follow the same trend; i.e., lower strength at higher temperatures. The static notched tests lay on a higher strength level than the dynamic notched tests and the trend is to higher strength at higher temperatures with the exception that above 0°F. there is a slight drop in the static notch strength.

TENSILE FATIGUE

Results of repeated tensile loading tests are shown in Figure 20 in which stress is plotted versus number of cycles to failure on notched specimens of titanium alloy 6-6-2. The number of strikes required to break the specimen increases from 1 at 240,000 psi to 126 at 161,000 psi.

COMPRESSION TESTS

A number of compression tests have been made on various materials. Examples of the traces obtained on a uranium, 8% Mo, 0.5% Ti alloy are given in Figure 21. The dynamic stress-strain diagrams obtained from Figure 21 (*c*) and (*d*) are shown in Figure 22. Considerable creep is displayed in these illustrations.

Static and dynamic compression data on a uranium alloy (0.06 in.^{2} area) are compared with tensile data in Table I. This alloy is stronger in tension than in compression. The difference amounts to roughly 4% statically and 14% dynamically. In compression its dynamic strength exceeds its static strength by 27% while in tension the corresponding figure is 42%.

TABLE I

Comparison of Static and Dynamic Strengths in Compression and in Tension. Uranium (8% Mo, 0.5% Ti) Alloy at 75°F.[a]

	Offset Y.S., *KSI*			
	0.1%	0.2%	E, million psi	
Static	123	127	10.7	Compression
Dynamic	156	161	11.1	
Static	129	131	11.1	Tension
Dynamic	175	184	12.0	

[a] Longitudinal specimens only.

Three kinds of beryllia samples were tested: (*a*) 96% BeO $^1/_4$ in. diameter × $^1/_2$ in. long; (*b*) 100% BeO $^1/_4$ in. diameter × $^3/_8$ in. long; and (*c*) 98% BeO $^1/_4$ in. × $^3/_{16}$ in. × $^1/_2$ in. long.

Every test piece was provided with a pair of SR-4 strain gages, connected in series and bonded to the long sides, 180° apart. Both dynamic and quasi-static tests were made. The results are graphically summarized

TABLE II

Dynamic Load and Time Versus Strain of Glass Reinforced Plastics. Compression Tests at Room Temperature

Material	Specimen no.	Dimensions of specimen, in.		Time to fracture, msec.	Rate of loading, klb./msec.	Fracture strength, KSI	Average
		Dia.	Length				
Epoxy (fiber)	4	0.252	0.161	[a]	1.2	98,000	146,000
	5	0.252	0.161	7	1.4	140,000	
	6	0.252	0.160	5	3.1	140,000	
	7	0.248	0.172	8	1.8	140,000	
	8	0.252	1.235	5	1.5	150,000	
	9	0.248	0.021	14 < t	1.0	160,000	
Polycarbonate (cloth)	30-1	0.250	0.137	50 < t	1.4	80,000	80,000
	40-1	0.250	0.134	20 < t	1.5	60,000	60,000
Melamine (cloth)	1	0.253	0.128	5	1.9	80,000	99,000
	2	0.253	0.534	6	1.0	96,000	
	3	0.254	0.539	7	1.9	115,000	
	4	0.252	0.539	20 < t	1.7	104,000	
(Epoxy cloth)	1	0.252	0.153	200 < t	0.5	68,000	75,000
	2	0.252	0.131	200 < t	0.2	76,000	
	3	0.253	0.131	13	1.0	80,000	

[a] Fracture delayed a second or more.

TABLE III

Dynamic Compression Tests of Glass Reinforced Plastics at Room Temperature

Ident. index	No.	ply	Dimension of specimen, in. Dia. Length	msec. Rise-time	msec. Time to fracture	Rate of loading, klb./msec.	Strength levels, KSI 0.1%	Strength levels, KSI 0.2%	Strength levels, KSI F.S.	Modulus of elasticity, psi × 10⁻⁶
Epoxy (cloth)	1	3	0.277 × 0.75	6.0	10.0	1.2	84.5	88.0	120	1.58
	2	3	0.277 × 0.75	4.0	[b]	4.0	85.0	86.0	[b]	[b]
	3	3	0.277 × 0.75	4.0	[c]	2.0	72.0	74.0	[c]	1.36
	4	3	0.315 × 0.71	3.5	[d]	1.8	[b]	[b]	[b]	1.15–1.60
	5	3	0.277 × 0.60	6.0	[b]	1.8	[e]	[e]	110	[b]
Mean				4.7		2.0	80.5	82.7	115	1.44
Epoxy (fiber)	1	6	0.252 × 0.60	6.0	10.0	2.5	[a]	[a]	140	1.68
	2	6	0.252 × 0.60	8.0	12.5	1.8	[a]	[a]	150	1.40–1.70
	3	6	0.252 × 0.60	[b]	[b]	1.0	[b]	[b]	[b]	1.36–2.10
	4	6	0.252 × 0.60	6.0	6.0	1.2	[b]	[b]	150	
Mean				6.7	9.5	1.6			147	1.65
Polyester	1	1	0.252 × 0.94	4.0	9.0	0.7	77.0	79.0	83	0.90
	2	1	0.254 × 0.97	4.5	6.0	2.9	[a]	[a]	113	1.50
Mean				4.3	7.5	1.8	77.0	79.0	98	1.20
Melamine	5	1	0.252 × 0.50	3.0	4.0	1.1	[a]	[a]	75	1.35

[a] No observable yielding before fracture.

[b] Time to fracture exceeded scope of oscillogram, 20 msec., and/or gain exceeded load scale.

[c] Fracture delayed for a second or more.

[d] Loaded under fracture strength.

[e] No strain measured.

in Figure 23. The dynamically determined strength is, on the average, 33% higher than the static strength, while Young's modulus shows no significant change. Extensive dynamic bend tests indicate that the tensile strength (fiber stress) may be about 25 KSI or about $^1/_8$ the compressive strength.

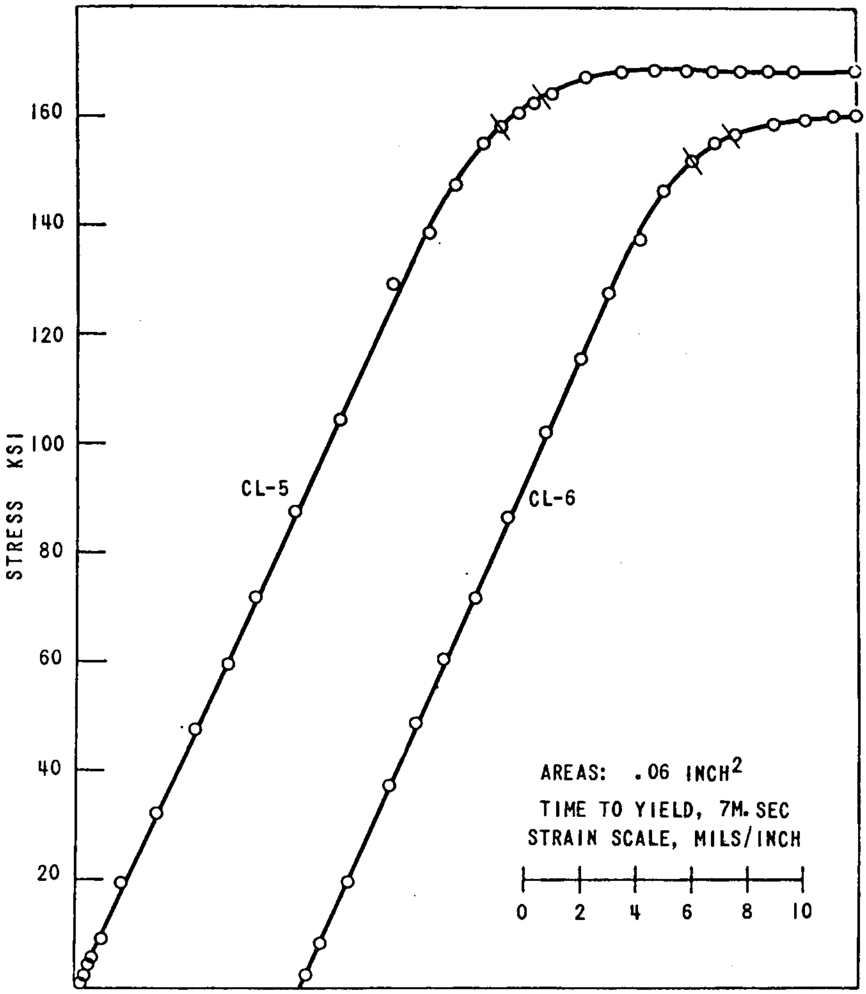


Fig. 22. Dynamic stress-strain diagrams of specimen CL-5 and specimen CL-6.

Tests on Plastic laminates are shown in Tables II and III and a comparison of static and dynamic data shown in Table IV. In every case the dynamic strength exceeds the static strength. There is no apparent relation between strength level and %-increase in strength on the limited number of materials evaluated.

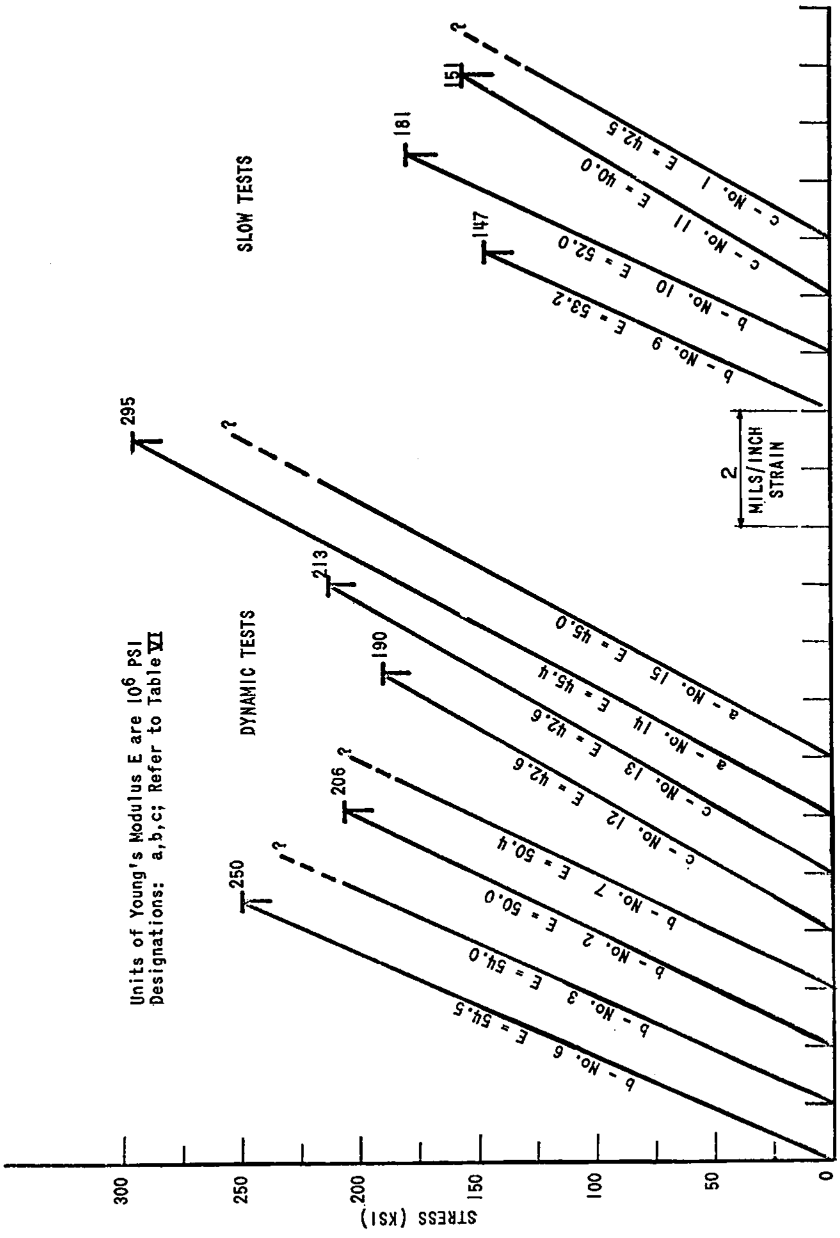


Fig. 23. Dynamic and quasi-static tests of beryllia samples.

TABLE IV

Comparison of Compressive Strengths of Glass Reinforced Plastics at Dynamic and Static Rates of Loading, Room Temperature

		Strength levels, psi × 10^{-3}			
Material	Condition	Y.S. 0.1%	Y.S. 0.2%	F.S.	E × 10^{-6}
Epoxy (cloth)	Static	56	61	65	1.1
	Dynamic	80	83	115	1.4
Polyester (cloth)	Static	73	73	74	1.2
	Dynamic	95	96	98	1.2
Melamine (cloth)	Static	50	54	83	1.4
	Dynamic	[a]	[a]	94	1.4
Epoxy (fiber)	Static	97	97	94	1.4
	Dynamic	[a]	[a]	147	1.7

[a] Fractured without yielding.

CONCLUSION

A medium speed testing machine is described for measuring properties of materials at strain rates between 2 and 7 in./in./sec. Data are given on uranium and titanium alloys, beryllia, 4340 steel and structural plastics, representing the results of routine and service testing for development projects. They show the kind of data obtained by the Fast Acting Tensile Tester at U. S. Army Materials Research Agency.

Reference

1. Mann, H. C., *ASTM Proc.*, **36**, 1936.

Résumé

Un appareil pneumatique d'essai de tension, récemment élaboré et construit aux laboratoires de l'Arsenal de Watertown, a une capacité de charge de 15.000 livres, une vitesse d'environ 300 pouces/seconde sur une plaque de 3 pouces, sous une pression d'azote de 500 psi, soit un tiers de la pression maximum tolérée. Les charges et les tensions peuvent être enrégistrées par des oscillographes ou oscilloscopes. Le champ d'action peut être délimité par un circuit électrique au moyan d'une petite valve automatique dans le circuit gazeux. Des valves externes d'un diaphragme auxiliaire sont rêglées par des solénoïdes. L'excès d'énergie du piston, après rupture à la tension, est absorbé par des oscillations rapidement amorties entre deux coussins d'air aux extrémités opposées du cylindre. La machine est montée sur un chariot reposant sur des ressorts, de sorte que les opérations a pleine charge ne transmettent pas de vibrations appréciables au plancher. Le poids de la machine et du chariot est de 700 livres; le sous-bassement 600 livres, et l'enceinte de sécurité en acier, 400 livres. On présente des descriptions brêves et de nombreuses illustrations d'enrégistrements typiques de cette machine, et les résultats de tests variés effectués récemment sur des matériaux structurés.

Zusammenfassung

Ein kürzlich in den Watertown-Arsenal-Laboratorien entwickelter pneumatischer Dehnungstester besitzt eine Belastungskapazität von 15.000 lb und eine Leergeschwindigkeit von etwa 300 in/sec über einen Hub von 3 in. bei 500 psi Stickstoff oder

einem Drittel des zulässigen Höchstdruckes. Belastung und Verformung kann oszillographisch oder oszilloskopisch aufgezeichnet werden. Der Oszillograph wird über einen Stromkreis durch ein automatisches Schnüffelventil im Gas ausgelöst. Äussere Menbranhilfsventile werden durch Solenoide betätigt. Die Uberschüssenergie der Kolbenvorrichtung nach einem Dehnungsbruch wird durch rasch gedämpfte Schwingungen zwischen zwei Luftpolstern an den entgegengestzten Enden des Zylinders absorbiert. Die Maschine ist auf einem Wagen auf Federn und Barrymounts montiert, sodass das Arbeiten bei voller Belstung nur unmerkliche Schwingungen auf den Boden überträgt. Das Gewicht von Maschine samt Wagen beträgt 700 lb, das der Basis 600 lb und der Sicherheitskammer aus Stahl 400 lb. Eine kurze Beschreibung wird gegeben sowie einige Bilder, die typische Arbeitsgänge der Maschine und Ergebnisse einiger Tests an Konstruktionsmaterialien zeigen.