The use of hydraulic drives to mechanize technological operations in the meat industry

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The authors studied design principles of the basic processing equipment used in the meat industry. Some advantages of the machines equipped with hydraulic drives are found, viz.,
- the maximum mechanization and automation of technological processes are made easier;
- the reliability and the durability of machines are increased;
- machine designs are simplified;
- the weight and the dimension of machines are diminished;
- costs are greatly reduced.

Hydrodrives ensure a smooth movement of the working elements of machines and their continuous speed control within a broad range using simple devices, e.g., a regulating throttle valve.
Important features of hydrodrives are simplicity of pressure control in a hydrosystem and of working element stresses, of reversal and overload protection.
In case of a discrete mode of machine operation hydrodrives allow to accumulate energy, transmitted with a pump electric motor and unused with machine working elements between technological operations, and to use it during the peak consumption periods. This is achieved due to accumulating an excess pressure fluid, forced into a hydrosystem during interoperational periods, in special containers, hydraulic accumulators filled with an inert gas under a certain pressure.
The use of a hydroaccumulator makes it possible to increase effective utilization of a machine drive throughout its working cycle up to about 100%. For many hydrodriven machines operating without accumulators or with an electromechanical drive, the utilization efficiency constitute only about 10-15%. This is confirmed with the analysis of the operation of a hydraulic sausage stuffer GSRU-I without an accumulator. Fig.1 is a graph of the utilization of the stuffer drive during its operation cycle, where ABCD is the total pressure fluid pumped to the hydrosystem; EFQD is the capacity of the cavity of a working stroke; ABJK is the capacity of the cavity of an idle stroke of the power cylinder.
The effective utilization ($\mathcal{E}'ef$) of the stuffer drive in relation to the pump efficiency can be in this case calculated as the ratio of the summary area EFQD and ABJK to the area ABCD.
The graph in Fig.2 characterizes the operation of the stuffer drive after an accumulator is inserted in its hydrosystem.
The total pressure fluid fed to the stuffer hydrosystem in this case corresponds to the area A'B'C'D' and at the same time to the summary capacity of the cavities of working and

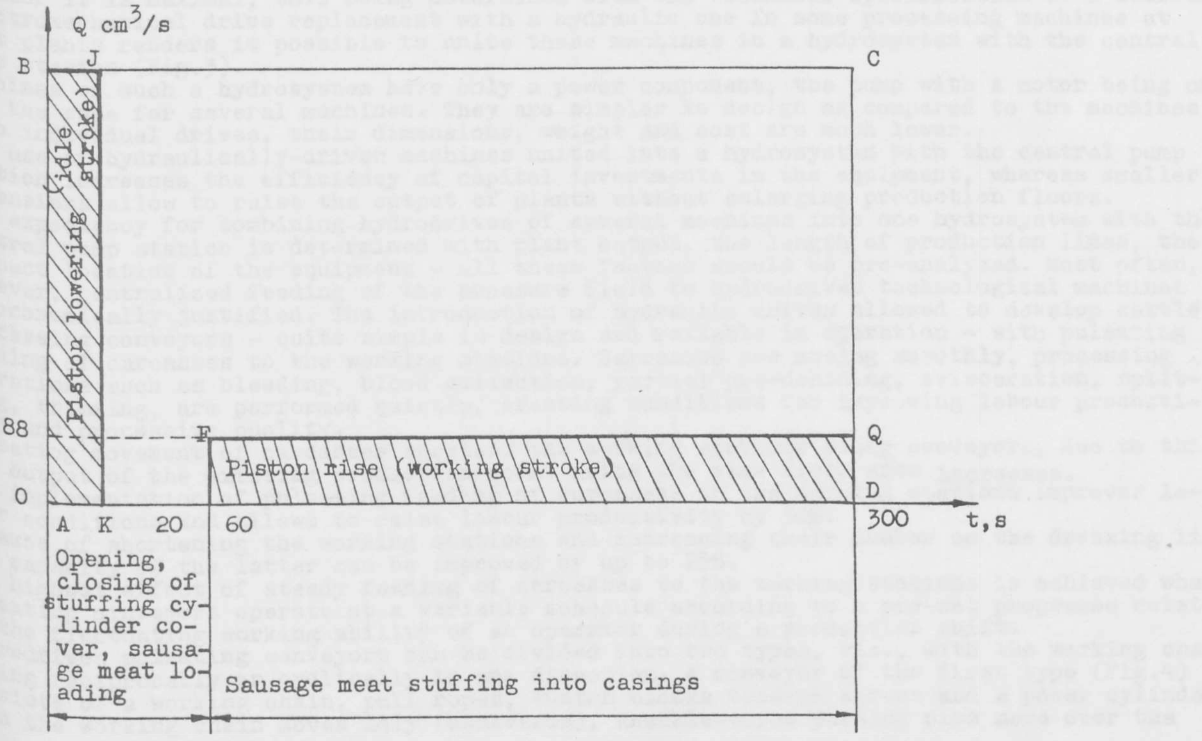

Fig.1 The utilization of stuffer drive during its operation cycle

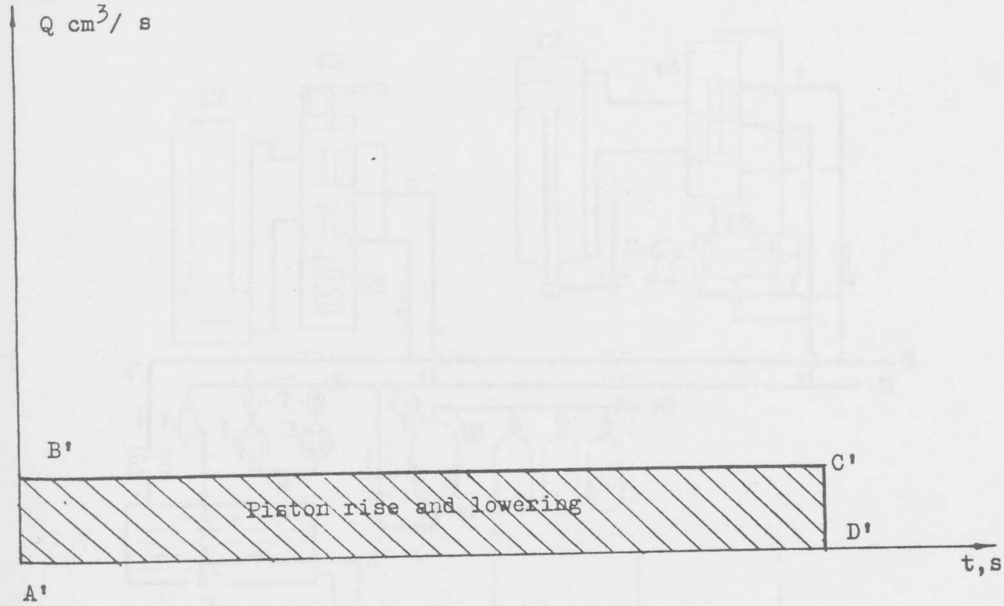

Fig.2 The operation of the drive of a stuffer with the accumulator included into its hydrosystem

idle strokes of the power cylinder. The effective utilization of the drive will be at its maximum, i.e. $\mathcal{E}'$ ef = 1 since the required pump power in this case is equal to 110 cm^3/s, not 583 cm^3/s as is observed in the first case, i.e. when an accumulator is included into the hydraulic system the required power of the pump equals the average pressure fluid consumption during a working cycle of the stuffer, whereas in a hydrosystem without an accumulator it is maximal, this being determined with the technical specification of a stuffer.
Electromechanical drive replacement with a hydraulic one in some processing machines at meat plants renders it possible to unite these machines in a hydrosystem with the central pump station (Fig.3).
Machines of such a hydrosystem have only a power component, the pump with a motor being one and the same for several machines. They are simpler in design as compared to the machines with individual drives, their dimensions, weight and cost are much lower.
The use of hydraulically-driven machines united into a hydrosystem with the central pump station increases the efficiency of capital investments in the equipment, whereas smaller dimensions allow to raise the output of plants without enlarging production floors.
The expediency for combining hydrodrives of several machines into one hydrosystem with the central pump station is determined with plant output, the length of production lines, the compact location of the equipment - all these factors should be pre-analyzed. Most often, however, centralized feeding of the pressure fluid to hydrodriven technological machines is economically justified. The introduction of hydraulic drives allowed to develop cattle processing conveyors - quite simple in design and reliable in operation - with pulsating feeding of carcasses to the working stations. Carcasses are moving smoothly, processing operations such as bleeding, blood collection, partial pre-dehiding, evisceration, splitting, trimming, are performed quietly, creating conditions for improving labour productivity and processive quality.
Pulsating movement of carcasses shortens the working stations along conveyors, due to this the output of the existing production rooms using the same floor area increases.
The implementation of pulsating feeding of carcasses to the working stations improves labour conditions and allows to raise labour productivity by 30%.
Because of shortening the working stations and increasing their number on the dressing line the capacity of the latter can be improved by up to 25%.
The highest effect of steady feeding of carcasses to the working stations is achieved when pulsating cinveyors operate at a variable schedule according to a pre-set programme related to the fluctuating working ability of an operator during a production shift.
Hydrodriven pulsating conveyors can be divided into two types, viz., with the working chain moving reciprocally or cyclically in one direction. A conveyor of the first type (Fig.4) consists of a working chain, pull ropes, snatch blocks tension screws and a power cylinder. When the working chain moves idly (backwards), knuckle-throw pushing pins move over the

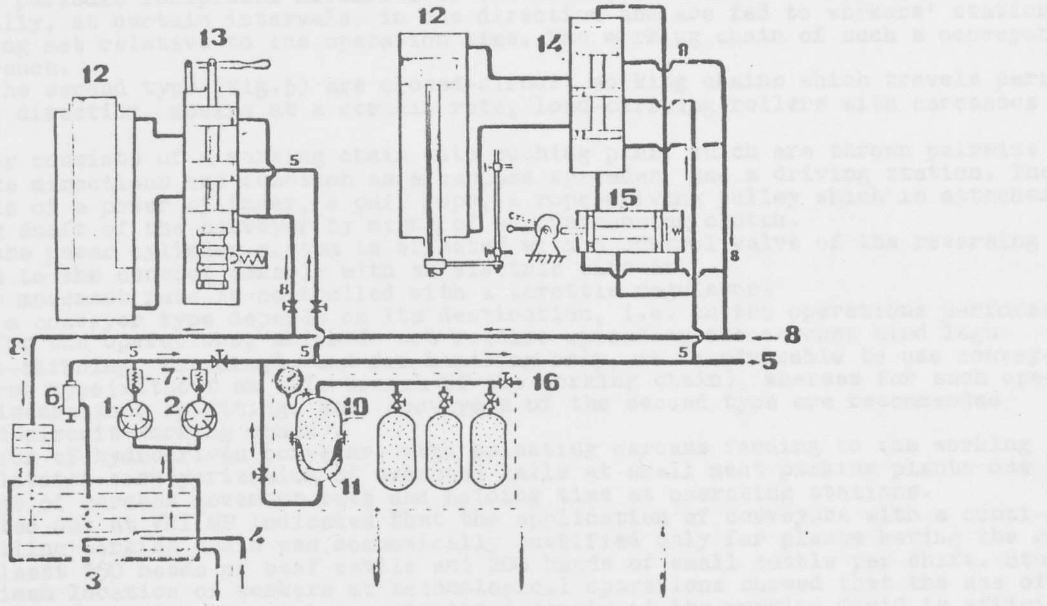

Fig.3 A schematic view of a centralized hydrodrive system:
1 - a normal vave pump; 2 - stand-by vave pump; 3 - a tank for pressure fluid (oil); 4 - a water cooling coil; 5 - a delivery pipeline, Ø 40 mm; 6 - a safety valve; 7 - check valves; 8 - a discharge pipeline, Ø 50mm; 9 - a filtering block; 10 - a pneumatic hydro-accumulator; 11 - a rubber diaphragm; 12 - power hydrocylinders of the machines; 13 - a hand-operated control valve of the reversing gear; 14 - a hydro-operated control valve of the reversing gear; 15 - a pilot control valve; 16 - a valve to charge the accumulator with compressed air.

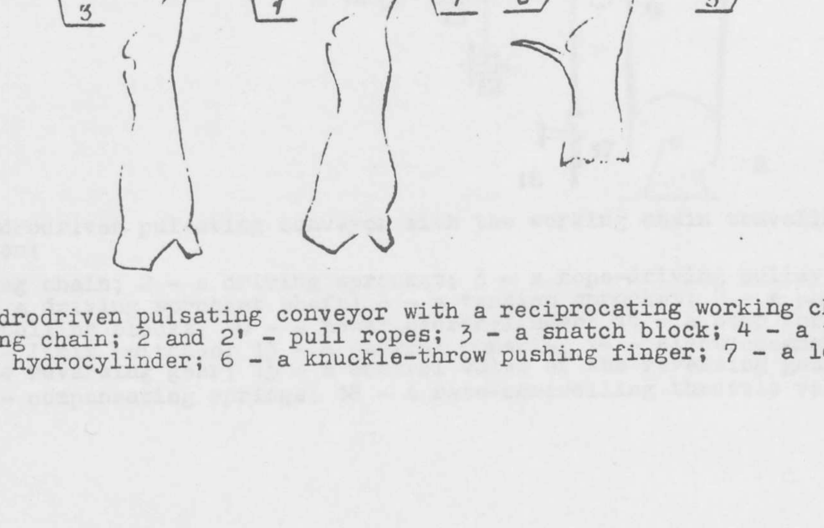

Fig.4 A hydrodriven pulsating conveyor with a reciprocating working chain:
1 - a working chain; 2 and 2' - pull ropes; 3 - a snatch block; 4 - a tension screw; 5 - a power hydrocylinder; 6 - a knuckle-throw pushing finger; 7 - a load-carrying roller.

clamps of load-carrying rollers which are in the state of rest. During the working stroke the pushing pins move the rollers for the distance of one chain stroke which is equal to the distance between the pins.

As a result of periodic reciprocal movements of the chain, the carcass-carrying rollers move rhythmically, at certain intervals, in one direction and are fed to workers' stations the rhythm being set relative to the operation time. The working chain of such a conveyor has no idle branch.

Conveyors of the second type (Fig.5) are closed-circuit working chains which travels periodically in one direction, moving at a certain rate, load-carrying rollers with carcasses on them.

Such a conveyor consists of a working chain with pushing pins, which are thrown pairwise in the opposite directions and function as a carcass spreader, and a driving station. The latter consists of a power cylinder, a pull rope, a rope-driving pulley which is attached to the driving shaft of the conveyor by means of an overrunning clutch.

Reversing of the power cylinder piston is effected with a control valve of the reversing gear connected to the control console with an electric circuit.

Conveyor chain movement rate is controlled with a throttle regulator.

The choice of a conveyor type depends on its destination, i.e. on the operations performed on it. E.g., for the operations, which do not require spreading the carcass hind legs (bleeding, pre-skinning, trimming), and for handling only, it is advisable to use conveyors of the first type(without an idle branch of the working chain), whereas for such operations as evisceration, splitting, etc. conveyors of the second type are recommended (with a closed-circuit working chain).

The introduction of hydrodriven conveyors with pulsating carcass feeding to the working stations facilitates conveyorization of overhead rails at small meat packing plants due to a wide range of carcass movement rate and holding time at operating stations.

The work carried out at VNIIMP indicated that the application of conveyors with a continuously travelling working chain was economically justified only for plants having the capacity of at least 150 heads of beef cattle and 200 heads of small cattle per shift. Studying the optimum location of workers at technological operations showed that the use of hydrodriven pulsating conveyors with a centralized supply of the working fluid is efficient only for the plant with the shift capacity of at least 25 heads of beef cattle and 50 heads of small cattle and up to 800 heads of any livestock.

As result of research and designing work, a number of hydrodriven technological machines and devices was built which operate from the central pumping station, e.g., conveyors, head-splitters, hoof-pullers, horn-removing machines, carcass locks for dehiding machines, elevating platforms, etc.

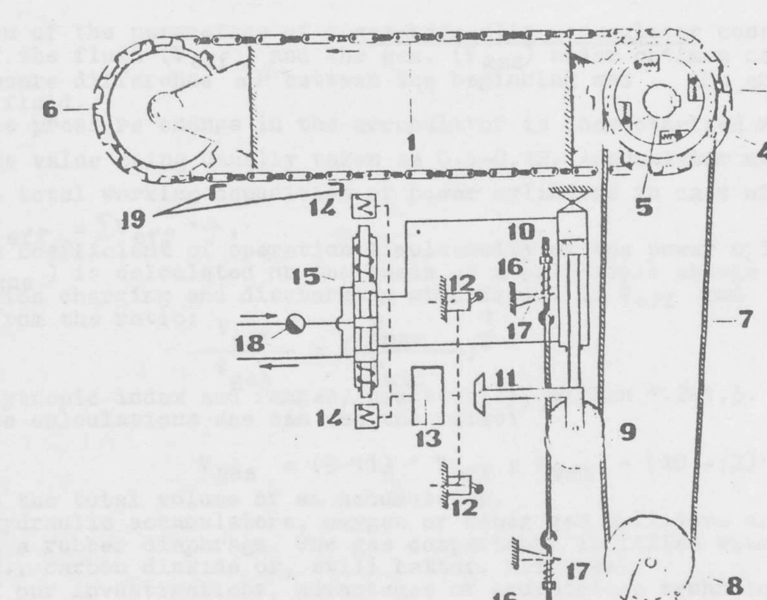

Fig.5 A hydrodriven pulsating conveyor with the working chain travelling periodically in one direction:

1 - a working chain; 2 - a driving sprocket; 3 - a rope-driving pulley; 4 - an overrunning clutch; 5 - a driving sprocket shaft; 6 - a tension sprocket; 7 - a pull rope; 8 - a snatch block; 9 - pulling blocks; 10 - a power hydrocylinder; 11 - a stop for switching the limit switch; 12 - limit switches; 13 - a control console; 14 - electromagnets of the control valve of the reversing gear; 15 - a control valve of the reversing gear; 16 - tension screws; 17 - compensating springs; 18 - a rate-controlling throttle valve; 19 - a pushing pin.

The estimation of the hydrosystem consists in calculating pump capacity, motor power, pipe sections, accumulator capacities. On the basis of the calculated data the necessary hydro-devices are selected which are batch-manufactured.

Pump capacity (Q_p) is determined as the total working fluid consumption of all the machines in the system:

$$Q_p = \sum q,$$

where q is working fluid consumption of each machine (cm^3/s):

$$q = \frac{V_c}{T \cdot \eta_o},$$

where V_c is the working capacity of the power cylinder; η_o is the volume efficiency of the power cylinder, its value depending on the piston seal type (in case of rubber seals $\eta_o = 1$, in case of metallic seals $\eta_o = 0.98$); T is the operating cycle time of a machine (s).

If the cavity of idle strokes of the power cylinder functions as an independent line (when there is an accumulator of idle strokes in a hydrosystem), the working capacity V_c will be equal to the cavity volume of working strokes ($V_c = V_w$); if the power cylinder is brought into circuit as usual, $V_c = V_w + V_i$; where V_i is the capacity of the idle stroke cavity of the cylinder.

Motor power (N_m) of the pump is derived from the equation:

$$N_m = \frac{P_w \cdot Q}{10^3 \cdot 10{,}2 \cdot \eta_e}, \text{ kW},$$

where P_w is the operating pressure in the hydrosystem (kg/cm^2); η_e is the net efficiency of the pump, $\eta_e = 0.8$-0.85.

The operating pressure (P_w) in the hydrosystem is established with account for the development of the necessary force (G,kg) on the power cylinder rod during working strokes and for pressure losses in pipes (ΔP_p) in installed hydrodevices (control valves, throttle valves, etc.) (ΔP_d):

$$P_w = \frac{G}{F \cdot \eta_m} + \Delta P_p \; \Delta + P_{dev}, \text{ kg/cm}^2,$$

where F is the piston area of the power cylinder on the working stroke cavity end (cm^2); η_m is the mechanical efficiency of the power cylinder, $\eta_m = 0.95$.

Pressure losses via friction in piping and pipe ID can be determined from the equation (in respective units):

$$\Delta P = \frac{128 \nu \cdot \rho \cdot l \cdot Q}{\pi \cdot d^4},$$

where Q is oil consumption; l is pipe length; d is pipe ID; ν is kinematic viscosity; ρ is fluid density.

The calculation of the parametres of a gas-hydraulic accumulator consists in determining the volumes of the fluid (V_{eff}) and the gas. (V_{gas}) under optimum conditions, i.e. under the least pressure difference ΔP between the beginning and the end of accumulator charging with the fluid.

The permissible pressure change in the accumulator is characterized with the coefficient $i = \frac{\Delta P}{P_{max}}$, its value being usually taken as 0.1-0.12. Accumulator net capacity can be calculated as the total working capacities of power cylinders in case of their simultaneous operation:

$$V_{eff} = \sum V_{eff} \cdot \alpha,$$

where α is the coefficient of operation simultaneity of the power cylinders.

Gas volume (V_{gas}) is calculated on the basis of a polytropic change in the gas state during accumulation charging and discharging with fluid. If V_{eff} and P are known, V_{gas} can be found from the ratio:

$$\frac{V_{eff}}{V_{gas}} = \left(\frac{P_{max}}{P_{min}}\right)^{\frac{1}{n}} - 1,$$

where n is polytropic index and ranges, practically, within 1.2-1.3.

For approximate calculations one can use the ratio:

$$V_{gas} = (9\text{-}11) \cdot V_{eff}\;;\; V_{tot} = (10\text{-}12) \cdot V_{eff},$$

where V_{tot} is the total volume of an accumulator.

To build gas-hydraulic accumulators, oxygen or other gas cylinders are used. Gas and oil are separated with a rubber diaphragm. The gas compartment is filled with compressed air or inert gas, e.g., carbon dioxide or, still better, nitrogen.

As a result of our investigations, advantages of hydrodriven technological equipment, operating from the centralized pumping station, have been found. Recommendations are given on designing and calculating hydrodriven pulsating conveyors and other pieces of equipment.

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