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AIRSHIPS FOR TRANSPORTING HIGHLY VOLATILE COMMODITIES

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ABSTRACT: Large airships may prove feasible as carriers of commodities that move as gases or cryogenic liquids; buoyant gaseous cargo could be ballasted with liquid cargo. Airships are compact in shape, operate in a rarified medium, and hence can be fast and perhaps economic carriers of costly cryogenic tanks. The high-pressure gas pipeline has excessive surface area when carrying hydrogen and excessive fluid density when carrying natural gas, while the cryogenic ocean tanker runs in a dense medium and makes gravity waves. But the airship, despite its fluid dynamic advantages, faces problems of safety, weather, and altitude control.

A promising mission for airships is the long-distance, high-traffic-volume transportation of highly volatile commodities. Methane is presently the most important of the low-boiling-point commodities, but hydrogen, oxygen, and light hydrocarbons other than methane may achieve considerable volume in the future. (Consult [1] on thermochemical cycles for H_2-O_2 production, [2] on fusion energy and hydrogen, [3, 4] on handling of hydrogen, and [5] on cryogenic ocean transportation of methane.) It is conceivable that even nonfuel elements such as sulphur, phosphorus, and tin might be transported as gaseous hydrides blended with hydrogen to form slightly buoyant cargoes. In many cases the buoyancy of a gaseous cargo might conveniently be balanced by a quantity of the same commodity carried as a cryogenic liquid. Liquids having very low boiling points might be carried in spherical tanks, which are efficient for pressurization and in the utilization of

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thermal insulation. Two or three such tanks might be suspended low in the nonrigid envelope of a very large airship, their content balancing the buoyancy of the gaseous cargo, above which would be positioned a body of permanent lifting gas capable of floating the unladen aircraft.

COMPETING MODES

Gas pipelines and cryogenic tankers appear to be the major competitors of high-volatile-cargo airships. Other possible competitors are cryogenic liquid pipelines, inland barges, and integral trains, but these latter modes are not likely candidates for long-distance, high-volume routes. Liquid pipelines suffer from extended surface and internal friction. Insulated area and influx of ambient heat are excessive if diameter is large, while heat from flow friction is excessive if diameter is small; hence much heat must be refrigerated out even when diameter is optimum. The low speeds, circuitous routes, and seasonality of inland barge service lead to poor utilization of costly cryogenic tanks and allow significant boiloff. And tanks tall enough to allow full-draft loading with liquid hydrogen would exceed many bridge clearances. Railroad tank cars suffer from restrictive horizontal and vertical clearances, which result in a somewhat extended surface and severely limit payload for the lighter cryogenic liquids.

AIRSHIPS VERSUS GAS PIPELINES

Because a pipeline is a container that extends from origin to destination, it need not shuttle back and forth. Yet for a given volume, great container length implies small diameter; hence this mode lacks the substantial scale economies associated with the batch handling of gas in vessels of compact shape. For example, a pipeline 1000 miles long and of uniform diameter has 59 times the surface area of a 1000-foot-diameter sphere of like volume. The relatively small surface of the batch vessel tends to give it a higher economic speed, which in turn implies a larger required volume for the pipeline. Of course the surface advantage of the batch process is partially offset by the need for container streamlining, multi-vehicle fleets, shuttling, and terminal transfer and storage. Yet on long hauls and assuming equal speed and throughput for the airship fleet and the pipeline, the surface area of a pipeline would still exceed that of an optimum airship fleet by an order of magnitude.

The gas pipeline suffers not only from an extended surface area resulting from its uncompact shape, but also from surface-protection problems. For practical purposes the line must be buried; hence it faces electro-chemical attack and concentrations of external pressure to a far greater extent than does the envelope of an airship. Therefore the optimized pipeline operates at many atmospheres of absolute pressure, but the resulting reduction in surface area is gained only by acceptance of severe requirements for propulsion power and tensile material.

The reason that required propulsion power increases with a scaling down of pipeline diameter and a corresponding increase in pressure is as follows. Surface area $\underline{s}$ in a pipeline of given length varies as the square root of volume $\underline{V}$ (i.e., $s \propto V^{1/2}$, while the specific gravity $\underline{g}$ of a given tonnage of contained gas varies inversely with volume (i.e., $g \propto V^{-1}$). Now, the force $\underline{F}$ required to move the gas through the pipeline at a given velocity is approximately proportional to $\underline{gs}$, which is inversely proportional to the square root of volume (i.e., $F \propto gs = V^{-1/2}$).

Suppose, for example, that a perfect gas at one atmosphere absolute pressure in a pipeline eight yards in diameter were compressed to 64 atmospheres by reducing the pipeline diameter to one yard. Specific gravity g would increase by a factor of 64, surface s would decrease by a factor of 8, and gs--and propulsion power--would rise by a factor of eight. (Pipeline pressures of 64 atmospheres are roughly in line with natural gas pipeline practice.) Thus in terms of required propulsion power, the pipeline would appear to be worse off than the airship fleet--by two orders of magnitude. The assumption here is that average airship speed and average gas speed in the pipeline are equal and that at standard conditions the gas has the same density as air. In practice, gas would move faster via airship than via pipeline, so that the airship fleet would have a propulsion power advantage of one order of magnitude, along with a modest surface area advantage.

In the pipeline the absolute pressure of the gas is contained almost entirely by tensile material, while in the airship the absolute pressure of the gaseous cargo is contained almost entirely by the atmosphere. The quantity of tensile material required is proportional to the product of volume and gauge pressure, assuming a safety factor of unity. (Tensile material can be measured in pound-feet, the measure of a filament of such material being the product of its length and its maximum working strength. As shown in [6], three pound-feet are required to contain one cubic foot of gas at a gauge pressure of one pound per square foot.) The ratio R of required tensile material to a standard volume of contained gas is given by the equation:

$$R = 3\left(1 - \frac{p_o}{p_i}\right), \qquad (1)$$

where: p_o is the pressure of the atmosphere surrounding the container; p_i is the absolute pressure of the gas within the container; $p_i \geqq p_o$; and the contained gas obeys Boyle's law. In an airship, p_i is only slightly greater than p_o. In a pipeline, p_i is ordinarily many times as large as p_o. Hence, R is much greater for the pipeline. Suppose, for example, that p_o is one atmosphere, p_i is 64 atmospheres for a pipeline, and an airship operates on a maximum gauge pressure of 20.4 inches water column, i.e., has a p_i of 1.05 atmospheres. The ratio of required tensile material is then 20.67 in favor of the airship, where airship and pipeline each contain the same mass of gaseous cargo.

Thus an airship fleet would require less container-surface area, less propulsion power, and less tensile material than a competing long-distance, high-pressure gas pipeline. And in the last two of these three basic indicators of cost, the airship fleet leads by an order of magnitude. (See [7] for quantitative airship-pipeline comparisons in the context of natural gas and under rather specific assumptions.) Other considerations in the comparison are: (1) the possibility of applying laminar boundary layer control to airships; (2) air/gas density ratio and the resulting ratio of liquid to gaseous cargo; (3) the compressibility coefficient of the gas; (4) propulsion efficiency; (5) air/gas viscosity ratio; (6) parasitic volume; (7) wind and weather; and (8) the geographic versatility of the airship fleet. Either of the last two considerations could turn out to be important, but the degree of importance would vary from one situation to another; hence in the present preliminary analysis these considerations are in the nature of imponderables. Of the six remaining factors, only the first two--they will be discussed in the succeeding paragraph--could affect the airship-pipeline comparison by a factor much exceeding 1.5. Compressibility coefficients (which measure deviations from Boyle's law) show a volume reduction of some 15 percent for the high-pressure pipeline when methane is the cargo. Propulsion efficiency might be somewhat better for a centrifugal pipeline compressor than for airship propulsion, especially in view of the drag of airship control surfaces, but it is most unlikely that the propulsion power comparison would be affected by as much as a factor of 1.5. Hydrogen has an absolute viscosity about half that of air, but at best a doubling of the Reynolds number would cause a friction-factor reduction only of the order of 10 percent. Parasitic volume, which would be devoted largely to permanent lifting gas, inert shield gas, and cryogenic tanks, might run some 10 to 25 percent of total displacement, depending on aircraft type and size and on materials of construction.

The successful application of laminar boundary layer control to airships could be a highly significant advantage for this mode, the theoretical power saving at high Reynolds numbers ranging up to some 85 percent [8], which would be equivalent to reducing propulsion power by a factor of some 6 2/3. The practical application of laminar boundary layer control to a pipeline would appear to be much more difficult if not entirely out of the question. Finally, a low gas/air density ratio could favor the pipeline in the propulsion power comparison, although it would simultaneously favor the airship in the surface area and tensile material comparisons. The difference in densities would be most pronounced if the highly volatile cargo were hydrogen, and the air would then be some 14 1/2 times as dense as the gas. If the volume of the airship were reduced by a factor of 14 1/2 (as compared with the original assumption that airship and pipeline volumes were equal), its surface area would fall by a factor of $(14\ 1/2)^{2/3}$, that is by a factor of about 6. The specific gravity of the air would, however, be 14 1/2 times that of the gas in the pipeline. The adjustment in the original airship-pipeline comparison would then call for a 14 1/2-fold increase of the airship's specific gravity $\underline{g}$ and a sixfold decrease in its surface area $\underline{s}$, with the result that $\underline{gs}$, and airship propulsion power, would rise by a factor of 2.4. The airship's relative economic gain by reason of the reduction of surface area would tend to be offset by the necessity of liquifying a large portion of the cargo.

The implicit assumption so far has been that airships operate at substantially the same altitude as pipelines. This may, at least for laden airships, be a reasonable working assumption in a comparison where concern is chiefly with order-of-magnitude differences. Yet an unladen airship might utilize the entire envelope volume--exclusive of that devoted to tanks and inert shield gas--to contain the permanent lifting gas at low absolute pressure and at a correspondingly high altitude. The empty return trip could then be made at higher speed--59 percent faster, on the assumptions that propulsion power is proportional to the cube of airspeed, normal power level is maintained at high altitude, and $\underline{g}$ is reduced by a factor of four.

AIRSHIPS VERSUS OCEAN TANKERS

The deep sea cryogenic tanker is a surface vessel, the airship a vessel submerged in a medium about 1/1000 as dense as sea water, assuming a standard atmosphere at an altitude of about 7000 feet. The airship largely avoids wave drag and encounters a viscous drag smaller by an order of magnitude than that encountered by the ship. The lower viscous drag stems from the nonproportional behavior of specific gravity $\underline{g}$ and surface area $\underline{s}$ as a vessel of fixed shape and weight displacement is scaled up in volume while the density of the flotation medium is reduced correspondingly. Although g falls in inverse proportion to volume displacement, s rises only as the two-thirds power of volume. Thus in the shift from sea water to air at 7000 feet, g falls by a factor of 1000 while s rises by a factor of 100, with a resulting 10-fold reduction in gs and almost that large a reduction in viscous drag.

Other factors in the airship-ocean tanker comparison include: (1) viscosity and fluid dynamic smoothness; (2) the volume-surface advantage of the surface vessel; (3) wave drag; (4) the possibility of high-altitude empty return flight for airships; (5) the portion of the cargo transported in gaseous form; and (6) wind and weather. Note that for airships and ocean vessels of like speed and tonnage displacement, Reynolds number does not differ greatly unless high altitudes or warm waters are involved; for 15° C and low airship altitudes the kinematic viscosity of air is some 12 to 15 times as great as that of water, but this difference is largely offset by the fact that the airship is about 10 times as long. Apparently the airship could be maintained in a relatively smoother condition, as it does not grow barnacles and has a thicker boundary layer within which to hide its roughness. A single-hull surface vessel has a volume-to-surface advantage over a submerged vessel, the reduction in wetted surface for a body symmetrical about a horizontal median plane which is also the water line being 20.63 percent, according to the "half-of-two-to-the-two-thirds law." Of course this saving may not be fully realized in practice, particularly if the surface vessel is to operate at sizable Froude numbers ($> \sim 0.20$) and will therefore need relatively small volumetric and prismatic coefficients in order to avoid excessive wave drag. Indeed, an ocean-going hydrogen tanker would have little if any volume-surface advantage by reason of operating at the interface; the low density of its cargo (1/15 that of sea water, 1/6 that of liquid methane) would dictate the use of a catamaran or of a rather broad, barge-like vessel.

Resistance arising from the generation of gravity waves would be experienced by ocean tankers but not ordinarily to any appreciable degree by airships, except perhaps while operating partly submerged in a stable layer of cold air. A cryogenic tanker, by reason of costly tanks, insulation, and boiloff, has a higher economic speed than does a conventional tanker of like displacement. A liquid hydrogen tanker, in particular, would be under economic pressure to move along; its cargo would be relatively valuable and its insulation task relatively difficult, the ratio of volume to heat of vaporization being some seven times as large for liquid hydrogen as for liquid methane. Wave drag, which rises roughly as the third power of speed in the 0.3-0.4 Froude-number range [9], would impose a stronger barrier to really high speeds than would viscous drag, which rises roughly as the second power of speed. If the cryogenic ocean tankers were extremely large, however, they might perhaps reach economic speed without encountering high Froude numbers and the associated high wave making resistance.

The possibility of making empty return voyages at high altitudes and relatively high speeds is a significant potential advantage of the airship, as is the ability to reduce liquifaction cost by transporting in gaseous form a portion of the cargo--3/5 for natural gas, 1/15 for hydrogen, 2/3 of the hydrogen for a stoichiometric oxygen-hydrogen carrier. Another advantage of the airship is freedom from the effects of waves, spray, and relative wind-water velocities; the airship, including its cryogenic tanks, can be more delicately constructed, since it is not subjected to high accelerations. But it does face the problems of operating in a relatively mobile medium (winds being far more swift than ocean currents) and of maintaining a desired altitude.

THE VOLATILE-CARGO AIRSHIP

The airship designed for transporting highly volatile commodities on long hauls would be very large. A displacement of tens of thousands or even hundreds of thousands of tons would probably be typical, once the technique was developed. Great size would appear to call for a nonrigid airship with a framework of steel or fiberglass cables, fitted perhaps with a rigid, semibuoyant stern section that would provide propulsion and control. The nonrigid portion might be assembled out of doors, lifted by launch aerostats, and inflated in nonturbulent air at altitude. The rigid pusher section might be constructed indoors, lifted by an aerostat, and joined to the nonrigid section in midair.

In very large freight airships the forces of buoyancy and inertia would dominate. Wind gusts would be of little significance in ground handling. (Rosendahl [10] stated that even the 50-percent size increase from the Los Angeles to the Graf Zeppelin noticably reduced the effect of gusts.) Propulsion power requirements would be low in relation to airspeed. And pitch might be controlled less by aerodynamic forces than by buoyant trim. Although positive and negative aerodynamic lift would provide valuable short-term altitude control, altitude would be controlled primarily via the control of buoyancy, probably by means of superpressure and/or superheating. A one-percent decrease in heaviness could be had by decreasing the gauge pressure by about four inches water column or by increasing the gas temperature about five degree Fahrenheit.

Conceptually, there are two distinct types of volatile-cargo airships, the light-gas tanker and the heavy-gas "bagger." The light-gas tanker transports commercial hydrogen as a buoyant cargo gas whose lift supports a volatile liquid cargo, refriger ted and/or pressurized. The heavy-gas bagger carries a gas of unitary specific gravity, e.g., a blend of methane and propane or of hydrogen and vinylidene chloride, and therefore needs no nongaseous ballast. In between these extremes are various gradations--airships transporting commercial gases denser than hydrogen but not as dense as air and carrying some liquid ballast.

The light-gas tanker tends to have high optimum speed, large fineness ratio, relatively small optimum size, and high construction cost per ton of capacity. The heavy-gas bagger tends to have lower optimum speed, smaller fineness ratio, relatively large optimum size, and low construction cost [11]. Although there are a number of commodities that could be blended with hydrogen or methane to form mixtures of unitary specific gravity [12], with most commodities it might be desirable to maintain some buoyancy in the cargo gas, either via composition or superheating, to reduce the probability of accidentally spilling dangerous gases on the ground.

Perhaps the most serious problem of the volatile-gas airship is that of safety. Flammable or noxious gases should perhaps be surrounded by a pressurized blanket of inert gas and the blanket sectionalized and metered. Routing, scheduling, and weather prediction should be precise or ample safety margins provided. The cargo airships might be remotely controlled and on-board repair men provided with escape devices. In an emergency, cryogenic tanks could be exploded and cargo and lifting gas fired while a derelict airship was still in a relatively safe location. It is to be presumed that aerial cryogenic tankers would not be routed near cities, although heavy-gas baggers, slightly buoyant and ballasted with water, would be relatively safe. In any case, the pilot of a disabled volatile-cargo airship would have more time and a wider choice of ditching procedures than an airplane pilot has, and he would never have unprotected personnel aboard. Related problems are storm avoidance, wind regime utilization, and ground handling.

SUMMARY AND CONCLUSIONS

For operation at equal speeds, propulsion power is greater by two orders of magnitude for the high-pressure gas pipeline and by one order of magnitude for the cryogenic ocean tanker than it is for the airship. When speeds are optimized mode by mode, the airship is faster, and an airship fleet would use roughly the same power as a comparable ocean tanker fleet and about one-tenth as much as a pipeline of comparable throughput capacity. The airship fleet has almost as much surface area and about one-tenth the tensile material of the gas pipeline. Being faster and more adaptable to direct routing, an airship might make three or four times as many round trips per year as an ocean tanker, utilizing well the substantial investment in cryogenic tanks and reliquefaction equipment.

In the three-way comparison between airship, ocean tanker, and gas pipeline, the first two benefit from the compact shape of the batch container. In principle, the airship and the gas pipeline both enjoy the propulsion power advantage associated with a low density flow medium, but in the conventional, high-pressure version the pipeline sacrifices this advantage to gain a much needed reduction in surface area and volume. The airship and tanker can be deployed far from the construction site and redeployed as desired. Compared with the ocean tanker, the airship can travel more directly and reach more destinations, and it can take to high altitudes on empty return voyages. Nevertheless, the airship faces problems of safety, altitude control, storm avoidance, and wind regime utilization. Of the three modes, the airship is the only one that has never been tried out in practical, multikiloton sizes.

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USING LIGHTER THAN AIR VEHICLES (DIRIGIBLES) IN HOUSING CONSTRUCTION

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ABSTRACT: This paper reports on the potential use of Lighter Than Air vehicles for the transport and erection of modular housing units. Comparisons are made between traditional methods of construction and the use of an airship. Data on LTA cost is based on an airship design study and the operation of a 12 meter model.

Lighter Than Air vehicles are capable of extended station-keeping with loads suspended from a cargo winch. This makes it possible to use dirigibles not only for the transport of housing modules but also for their erection at construction sites. This application has been investigated at the S. Lazo Politechnical Institute in Kishinev.

A transport-mounting dirigible, the TS.M-100, was designed by the K. E. Tsiolkovsky Dirigible Design Office in Leningrad for this purpose. The TS.M-100 is an unballasted dirigible 245 meters (789 ft.) long, with a fineness ratio of 6.67 (maximum diameter is 37 meters). Gross payload is 130 metric tons (143 short tons) and the useful load is 100 metric tons (110 short tons). The gondola is 60 x 5 x 5 meters (197 x 16.5 x 16.5 ft.). Cruising speed is 170 km/hr (106 mph). The vehicle is metal-clad and uses engine exhaust heat for aerostatic gas control. Tentative

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cost per ton-kilometer is 2.2 kopecks (4.3¢ per short ton-mile), which is considerably below the cost of normal air transportation.

A twelve meter model was tested and has shown good maneuverability. It easily moved up, down and sideways, and turned around while holding position. The design study and test results allow the projection of performance for a full size Lighter Than Air vehicle of similar design.

The TS.M-100 would be used for both transportation and mounting of housing modules. Five or six standard three dimensional modules can be assembled in one to one-and-one-half hours using the TS.M-100 as a transport/crane. The TS.M-100 could also carry 30 to 50 wall panels but vehicle utilization would be low because it would take an eight hour shift to assemble the load.

Modular construction is the most progressive technology in housing today. A five story apartment house with 60 dwelling units uses 1,300 to 1,400 components if constructed from large wall panels that can be trucked to the site. A similar building can be made from 206 to 240 one room modules or 100 to 120 two room modules by a team of half a dozen workers in ten days.

Despite its potential, modular housing construction has been limited by two factors: (1) the difficulty of transporting and positioning large modules, and (2) the slow curing rate of normal concretes, leading to low output from the complex machines used to produce three dimensional structures. The latter problem has been solved at the Politechnical Institute in Kishinev by developing techniques that use quick setting concretes. Special equipment has been designed and tested that yields six to eight times the productivity of the older methods.

As a result the bottleneck is now transportation and installation of the modules. Modern construction management coordinates manufacture, transportation and installation into a single production cycle. The use of dirigibles to transport and position building modules could smooth production flow by eliminating delays caused by poor roads or great distances between the module factory and the construction site.

The cost of dirigibles and traditional methods of transport and construction were compared for three different building configurations. One story, 10.8 x 3.8 meter (35.4 x 12.5 ft.) modules were used in each building, loaded into the TS.M-100 gondola or suspended from its cargo winch at the factory. The building configurations studied are outlined in Table 1.

For each building configuration, three transportation/construction techniques were investigated. The first used tracked, caterpillar-type cranes for construction. The second used other types of cranes. The road transport equipment was the same in both cases. Table 2 lists the equipment used in these cases. The third technique used the TS.M-100 for transport and construction.

Type of Unit	Number of Apartments	Floor Space Meters^2 (ft^2)	Modules per Unit	Total Weight Metric Tons (Short Tons)
2 Story	20	656 (7,050)	20	440 (485)
5 Story	50	3,280 (35,300)	100	2,200 (2,420)
9 Story	108	8,850 (95,200)	270	5,900 (6,500)

Table 1
Building Configuration Parameters

Type of Unit	Transportation		Construction	
	Truck Tractors	Truck Trailers	Case 1 Tracked Cranes	Case 2 Other Cranes
2 Story	1	2	1 (SKG-50)	1 Wheeled Crane
5 Story	2	4	1 (SKG-63)	1 Coach-Box Crane
9 Story	3	6	1 (SKG-100)	1 Tower Crane

Table 2
Conventional Transport and Construction Equipment Requirements

Tables 3,4 and 5 present the results of the economic analysis for each building type and construction/transport method. Assembly and capital investment costs are included as are the labor costs for the transport, assembly and operation of the construction equipment. All cost data is per square meter of floor space. Consistent assumptions were used in all cases.

The data shows that the dirigible method of construction is most efficient economically over distances of 50 kilometers or more. It is less labor intensive at all distances. This would indicate that modular housing construction is a very promising potential market for Lighter Than Air.

Transport Distance km. (miles)	Case 1		Case 2		Case 3	
	Cost[1]	Labor[2]	Cost[1]	Labor[2]	Cost[1]	Labor[2]
10 (6.2)	1.22 (0.15)	0.22	1.79 (0.22)	0.29	3.50 (0.44)	0.15
20 (12.4)	1.98 (0.25)	0.37	3.14 (0.39)	0.60	4.36 (0.54)	0.17
50 (31.1)	4.42 (0.55)	0.81	6.21 (0.78)	1.19	4.40 (0.55)	0.18
100 (62.1)	7.61 (0.95)	1.39	11.73 (1.47)	2.30	6.26 (0.78)	0.26

Table 3
Two Story Housing

Transport Distance km. (miles)	Case 1		Case 2		Case 3	
	Cost[1]	Labor[2]	Cost[1]	Labor[2]	Cost[1]	Labor[2]
10 (6.2)	2.40 (0.30)	0.33	3.75 (0.47)	0.47	3.48 (0.44)	0.15
20 (12.4)	4.23 (0.53)	0.59	5.83 (0.73)	0.72	4.35 (0.54)	0.18
50 (31.1)	9.00 (1.13)	1.25	11.95 (1.49)	1.76	4.56 (0.57)	0.20
100 (62.1)	15.50 (1.94)	2.14	21.68 (2.71)	4.15	6.09 (0.76)	0.26

Table 4
Five Story Housing

Transport Distance km. (miles)	Case 1		Case 2		Case 3	
	Cost[1]	Labor[2]	Cost[1]	Labor[2]	Cost[1]	Labor[2]
10 (6.2)	4.13 (0.51)	0.49	2.58 (0.32)	0.32	3.58 (0.44)	0.15
20 (12.4)	6.64 (0.83)	0.81	4.70 (0.59)	0.58	4.44 (0.55)	0.19
50 (31.1)	12.01 (1.50)	1.54	7.93 (0.99)	0.97	4.74 (0.59)	0.22
100 (62.1)	20.89 (2.62)	2.75	15.39 (1.93)	1.90	6.20 (0.78)	0.27

Table 5
Nine Story Housing

1. Rubles per square meter (Dollars per square foot based on a conversion rate of $1.345 per ruble)
2. Man hours per square meter